Types of Civil Aircrafts

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First Edition, 2012

ISBN 978-81-323-2911-4

Published by:
Orange Apple
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
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Agricultural Aircraft and Cargo Aircraft

Agricultural aircraft

The Antonov An-2 was the first purpose-built agricultural aircraft to be mass-produced.

Polish M-18 Dromader waterbomber used in Western Australia.

A Grumman Ag Cat applies a low-insecticide bait on a soybean field.

An **agricultural aircraft** is an aircraft that has been built or converted for agricultural use - usually aerial application of pesticides (crop dusting) or fertilizer (aerial topdressing); in these roles they are referred to as "crop dusters" or "top dressers". Agricultural aircraft are also used for hydroseeding.

The most common agricultural aircraft are fixed-wing, such as the Air Tractor, Cessna Ag-wagon, Gippsland GA200, Grumman Ag Cat, M-18 Dromader, PAC Fletcher, Piper PA-36 Pawnee Brave and Rockwell Thrush Commander but helicopters are also used.

Early use of aircraft in agriculture

Crop dusting with insecticides began in the 1920s in the United States. The first widely used agricultural aircraft were converted war-surplus biplanes, such as the De Havilland Tiger Moth and Stearman. After more effective insecticides and fungicides were developed in the 1940s, and aerial topdressing was developed by government research in New Zealand, purpose-built agricultural fixed-wing aircraft became common.

Agricultural aircraft designs

In the US and Europe they are typically small, simple, and rugged. Many have spraying systems built into their wings, and pumps are usually driven by wind turbines. In places where farms are larger, such as New Zealand, Australia, the former Warsaw pact nations and parts of the developing world, larger and more powerful aircraft have been used, including turboprop powered aircraft such as the PAC Cresco, twin engined types, such as the Lockheed Lodestar and varying from the versatile and utilitarian Antonov An-2 biplane to the bizarre turbofan powered biplane, the WSK-Mielec M-15 Belphegor- all however tend to be of simple rugged STOL design. In places where dedicated use as an agricultural aircraft is uneconomic, utility types such as the De Havilland Canada DHC-2 Beaver have been used.

In the case of helicopters, tanks are placed on or outside the body of the aircraft, while a spray rig, extending outward to the sides, is attached well below the main rotor blades. Hydroseeding is often done by helicopters using tanks and drop systems much like those used for aerial firefighting.

Techniques

To reduce drift of the sprayed materials, agricultural pilots attempt to fly as low as possible, usually just above the crops being treated (4.5 meters/15 feet). Fields are often surrounded by obstacles such as trees, telephone lines, and farm buildings, so pilots have to switch quickly from the task of dropping chemicals accurately and smoothly to the task of dodging obstacles. It is not unusual for pilots to fly *under* telephone and power lines at the end of their runs. Nonetheless, accidents are inevitable when airplanes routinely fly so near the ground. Purpose-built agricultural airplanes are designed to protect the pilot and cargo if they strike the ground.

Conflicting views on aerial spraying

Australian Commonwealth CA-28 Ceres crop spraying aircraft of the 1950s

Aerial spraying has been controversial since the 1960s, due to environmental concerns about pesticide drift (raised for example by Rachel Carson's book *Silent Spring*). It is now often subject to restrictions, for example spraying pesticide is generally banned in Sweden, although exceptions can be made such as for an area plagued by mosquitoes during summer. Even the spread of fertilizer has raised concerns, for example in New Zealand fertilizer entering streams has been found to disproportionately promoted growth of species more able to exploit the increased nutrients, so leading to restrictions on topdressing near waterways. Even putting out forest fires has been criticized in the U.S.A. as preventing natural consumption of flammable material, and increasing long term risk.

Cargo aircraft

Antonov An-225: the largest cargo aircraft.

Lockheed C-5 Galaxy

A large military transport aircraft: the Boeing C-17A Globemaster III

A Bristol Freighter from the 1960s, with front opening clamshell doors and flight deck bulge

The Boeing 747 Large Cargo Freighter 'Dreamlifter'

A **cargo aircraft** (also known as **freight aircraft** or **freighter**) is a fixed-wing aircraft designed or converted for the carriage of goods, rather than passengers. They are usually devoid of passenger amenities, and generally feature one or more large doors for the loading and unloading of cargo. Freighters may be operated by civil passenger or cargo airlines, by private individuals or by the armed forces of individual countries. However most air freight is carried in special ULD containers in the cargo holds of passenger aircraft.

Aircraft designed for cargo flight use have a number of features that distinguish them from conventional passenger aircraft: a "fat" looking fuselage, a high-wing to allow the cargo area to sit near the ground, a large number of wheels to allow it to land at unprepared locations, and a high-mounted tail to allow cargo to be driven directly into and off the aircraft.

History

Aircraft were put to use carrying cargo in the form of air mail as early as 1911. Although the earliest aircraft were not designed primarily as cargo carriers, by the mid 1920s aircraft manufacturers were designing and building dedicated cargo aircraft.

The earliest "true" cargo aircraft is arguably the World War II German design, the Arado Ar 232. The Ar 232 was intended to supplant the earlier Junkers Ju 52 freighter conversions, but only small numbers were built. Most other forces used freighter versions of airliners in the cargo role as well, most notably the C-47 Skytrain version of the Douglas DC-3, which served with practically every allied nation. Post war Europe also served to play a major role in the development of the modern air cargo and air freight industry during what became known as the "Cold War." It is during the Berlin Airlift at the height of this "Cold War," when a massive mobilization of aircraft was undertaken by the "free world," to supply West Berlin residents with food and supplies, in a virtual around the clock air bridge; after the Soviet Union closed and blockaded Berlin's borders, and land links to the west.

In the years following the war era a number of new custom-built cargo aircraft were introduced, often including some "experimental" features. For instance, the US's C-82 Packet featured a removable cargo area, while the C-123 Provider introduced the now-common upswept tail with a drop-down loading and unloading ramp. But it was the introduction of the turboprop that allowed the class to mature, and even one of its earliest examples, the C-130 Hercules, is still the yardstick against which newer military transport aircraft designs are measured.

Today

Most conversions are carried out on older aircraft no longer suitable for passenger use, often due to changing safety or noise requirements, or when the aircraft type is considered to have become uncompetitive in passenger airline service, but there is also a market for new-build freighter designs. Freighter aircraft normally have strengthened cabin floors and the inclusion of a broad top-hinged door on the port fuselage in addition to an absence of passenger cabin windows which are "plugged."

The Boeing 747 can be ordered in a freighter version with a large nose door which could be raised above the cockpit for loading. The bulged top deck housing the cockpit was originally designed to allow an unobstructed main deck, and to keep cargo from crushing the pilots in the case of an accident. The interior size of the fuselage is matched to the size of a standard shipping container, stacked two high and two wide.

Other types of specialized civilian cargo aircraft configurations, include the swing-tail Canadair CL-44 and Boeing 747 Large Cargo Freighter, and the clamshell tail CASA CN-235.

Examples

Early Air mail and airlift logistics aircraft

The Type 158 York

Important "airlift and logistics;" "cargo-liners," "mail-liners," and "mail aircraft."

- Avro Lancastrian (Transatlantic mail)
- Avro York (Berlin Airlift)
- Boeing C-7000
- Curtiss JN-4
- Douglas M-2

Civilian cargo/freight aircraft

Air India Airbus A310-304

Cargolux Boeing 747-400F

Aeroflot Il-76TD

- Aero Spacelines Super Guppy
- Airbus A300
- Airbus A310
- Airbus A320 (Conversions)
- Airbus A330
- Airbus A380F
- Airbus Beluga
- Antonov An-124
- Antonov An-225 (the largest and heaviest aircraft in the world)
- Boeing 727
- Boeing 737 (Conversions)
- Boeing 757
- Boeing 767
- Boeing 747 Freighter
- Boeing 747 Large Cargo Freighter (Dreamlifter)
- Boeing 777 Freighter
- Douglas DC-3
- Douglas DC-9
- Ilyushin Il-76
- Ilyushin Il-96
- McDonnell Douglas DC-10
- McDonnell Douglas MD-11
- Tupolev Tu-204

Light aircraft

- Cessna Caravan - freight door and belly pod equipped
- Shorts 330 - drop ramp and twin tailed vertical stabilizer
- LET 410

Military cargo aircraft

A turboprop twin-engined transport aircraft: the Antonov An-32

Experimental cargo aircraft

- Hughes H-4 Hercules ("Spruce Goose")
- Lockheed R6V Constitution
- LTV XC-142

Comparisons

Aircraft	Cargo Volume	Cargo Mass	Cruise Speed	Maximum Range	Aircraft Category
Airbus A400M	-	37,000 kg (82,000 lb)	780 km/h (420 kn; 480 mph)	6,390 km (3,450 nm)	Military
Airbus 330-200F	475 m3	-	871 km/h (537 mph)	7,400 km (4,000 nm, 4,600 mi)	Commercial
Airbus Beluga	1210 m3	47,000 kg	-	4,632 km (2500 nm)	Commercial
Antonov 124	-	150,000 kg	800 km/h	5,400 km (2,900	Military &

		(330,000 lb)	(430 kn, 490 mph)	nm, 3,360 mi)	Commercial
Antonov 225	1,300 m3 (46,000 cu ft))	250,000 kg (550,000 lb)	800 km/h (430 kn, 500 mph)	15,400 km (9,570 mi)	Commercial
Boeing 747-8F	854.5 m3 (30,177 cu ft)	134,200 kg (295,800 lb)	908 km/h (490 kn, 564 mph)	-	Commercial
Lockheed C-5 (Galaxy)	-	122,470 kg (270,000 lb)	919 km/h	4,440 km (2,400 nmi; 2,760 mi)	Military
Lockheed C-130H (Hercules)	-	33,000 kg (72,000 lb)	540 km/h (292 kn, 336 mph)	3,800 km (2,050 nm, 2,360 mi)	Military

Chapter- 2

Airliner

Boeing 747-400, one of the most recognizable airliners in history.

The Airbus A320 narrow-body is a popular short-medium distance aircraft.

An **airliner** is a large fixed-wing aircraft for transporting passengers and cargo. Such planes are owned by airlines. Although the definition of an airliner can vary from country to country, an airliner is typically defined as a plane intended for carrying multiple passengers in commercial service, and the Russian Sikorsky Ilya Muromets was the first official passenger aircraft by this definition. This airliner made its first flight in 1913, and thus began the industry of commercial airlines. The industry would slowly develop for the next several decades and would begin to expand at an incredible rate after World War II.

History

A United Airlines DC-6 at Stapleton Airport, Denver, in September 1966

When Wilbur and Orville Wright made the world's first flight in Kitty Hawk, North Carolina, they not only made history but also were laying the foundation for what would become a major transportation and industrial industry. This flight in Kitty Hawk, North Carolina in 1903 was just 11 years before what is often defined as the world's first airliner. These airliners would change the world socially, economically, and politically in a way that had never been done before.

If an airliner is defined as a plane intended for carrying multiple passengers in commercial service, the Russian Sikorsky Ilya Muromets was the first official passenger aircraft. The Ilya Muromets was a luxurious aircraft with an isolated passenger saloon, wicker chairs, bedroom, lounge and a bathroom. The aircraft also had heating and electrical lighting. The Ilya Muromets first flew on December 10, 1913. On February 25, 1914, it took off for its first demonstration flight with 16 passengers aboard. From June 21 – June 23, it made a round-trip from Saint Petersburg to Kiev in 14 hours and 38 minutes with one intermediate landing. If it had not been for World War I, the Ilya Muromets would have probably started passenger flights that same year.

The second airliner was the Farman F.60 Goliath from 1919, which could seat up to 14 passengers, approximately 60 were built.

The Ford Trimotor was an important early airliner. With two engines mounted on the wings and one in the nose and a slabsided body, it carried eight passengers and was produced from 1925 to 1933. It was used by the predecessor to TWA as well as other airlines long after production ceased. In 1932 the 14-passenger Douglas DC-2 flew and in 1935 the more powerful, faster, 21–32 passenger Douglas DC-3. DC-3s were produced in quantity for WWII and sold as surplus afterward.The Douglas DC-3 was a particularly important airplane because it was the first airliner to be profitable without a government subsidy.

The first jet airliners came in the immediate post war era. Turbojet engines were trialled on piston engine airframes such as the Avro Lancastrian and the Vickers VC.1 Viking the latter becoming the first jet engined passenger aircraft in April 1948. The first purpose built jet airliners were the de Havilland Comet (UK) and the Avro Jetliner (Canada). The former entered production and service while the latter did not. The Comet was unfortunate in that metal fatigue caused crashes.

Jets did not immediately replace piston engines and many designs used the turboprop rather than the turbojet or the later turbofan engines.

Postwar Airliner History in the United States

The United States gained a huge advantage in design and production in the airline industry in the years leading up to the war, but many of the developments would be put off until after the war as the manufacturing efforts were placed on the war effort. The advancements that the United States would make in this industry were in large due to the cooperation of the airlines discussing what they desired with the airliner manufacturers. Soon after the war though Douglas made a large advancement with the DC-4, although this could not cross the Atlantic at every point, it was able to make a nonstop flight from New York to the United Kingdom. Due to the war going on, the first batch of these planes went to the US Army and Air Forces, and was named the C-54 Skymaster. Some of these that were used in the war would later be converted for the airline industry, along with the passenger and cargo versions that were placed on the market once the war ended. Douglas would later develop a version of this plane that was pressurized and 5 feet longer; this redesigned plane would become the DC-6. These DC-6s would be grounded for 6 months to rectify a few safety issues that were causing in-flight fires.

Soon after the DC-4, Lockheed developed the Constellation; this was a major development because it was the first airliner to have pressurization. This pressurization was very important because it allowed the planes to fly higher, and therefore further and faster than ever before. This had a fuselage that was about 127 inches wider than that of the DC-4. Like the DC-4 this plane also had a late entry to the civilian airline industry because they were used in the war and later converted for the airline industry. The constellation did experience some safety concerns soon after it entered service, requiring it to be grounded for 6 months while the problems were investigated and repaired.

In 1947, an airliner from third company made its maiden voyage. The Boeing 377 Stratocruiser entered the industry with a completely different design than the planes from Douglas and Lockheed. This plane was based on the C-97 military transport plane, and had a double deck, and pressurized fuselage. This plane was known for the luxury that it had to offer as well as its ability to hold 100 passengers. There were only 55 Stratocrusiers produced, but this plane was still incredibly important as nearly 900 of the C-97s were produced for the military.

The American companies had done a great job of advancing the status of transcontinental travel, but there was also the aging fleet of DC-3s that had to be addressed. Convair decided that they were going to address this market, and would begin producing the Convair 240 which was a 40 person fully pressurized plane. There were 566 of these planes that would fly, including 2 that were equipped with jet-assisted take off units. Convair would later develop the Convair 340, which was slightly larger and could accommodate between 44 and 52 passengers, and there were 311 of this model plane were produced. Finally Convair would create a Convair 440, which had small modifications including much better soundproofing than the previous models. Convair would experience a little bit of competition from the Martin 2-0-2 and Martin 4-0-4, but in general Convair was able to control this market, as the 2-0-2 had safety concerns and was unpressurized, and the 4-0-4 only sold around 100 units.

The United States was dominant in this industry for several reasons including a large domestic market for these planes. The market would also work in the United States favor as the American companies began to build pressurized airliners. During the postwar years engines became much larger and more powerful, and safety features such as deicing, navigation, and weather were added to the planes. Lastly, the planes produced in the United States were more comfortable and had superior flight decks than those produced in Europe.

Postwar Airliner History in Great Britain

Great Britain was in a very different position after the war than the United States. Unlike the United States, Great Britain had a small domestic market and almost all of the airplane construction that had take place domestically was for war. In December 1942 the British government had a committee put in place to set classifications for airplanes ranging from Non-Stop North Atlantic airplanes to Small Piston-engine airplanes for light traffic. These classifications were set up to encourage development of airliners of all types. In order to recover from the difficulties that this caused many of the postwar airliners were bombers that were converted to allow for commercial air travel, but this was not very economical as the planes could hold very few people. The first postwar program that was attempted in Great Britain was the Tudor airliner, however this was regarded as a failure due to safety concerns and few sales. The first successful British Airliner was a Vickers Armstrongs Viking. These were unpressurized and could hold between 21 and 27 people depending on the model. On April 6, 1948 one of these Viking airliners became the first jet-airliner to fly. The previous engines were now replaced with Rolls-Royce Nene Turbojets. In 1946 the Bristol 170 was the first transport aircraft to receive a Certificate of Airworthiness from the British government. This plane remained in production for 12 years with 214 of the aircraft built. The British would also produce several smaller aircraft such as the Airspeed AS.57 Ambassador in 1947 and the Miles

M.57 Aerovan in 1945. Most of the British planes produced in the postwar era were smaller planes that could hold less than 30 passengers, and did not sell as well as some of the planes produced in the United States, but these planes were enough to help the British airline industry from the lack of commercial production during the war.

Postwar Airliner History in France

In the postwar years France developed a few significant airliners, some of these being planes that could land on water, part of the reason that the French companies were so focused on these flying boats is that in 1936 the French Air Ministry requested transatlantic flying boats that could hold at least 40 passengers. Only one model from this request would ever be put into service. The first set of these was 3 Latecoere 631's that Air France purchased and put into service in July 1947. However, two of these planes crashed, and the third plane was soon removed because of these safety concerns. There would later be a SNCASE SE.161 Languedoc build, which was a much more successful plane, and over 100 of these were built, with 40 of them being placed into service through Air-France. The French also developed the Breguet 763 Deux Ponts, which first flew in February 1949 . This was a double-decker transport airliner that would end up being used for both people and cargo. This four-engine airliner would end up being used to hold massive amounts of cargo or 97 passengers.

Postwar Airliner History in the USSR

Soon after the war most of the Soviet fleet of airliners consisted of DC-3s or the Lisunov Li-2. These planes were in desperate need of replacement, and in 1946 the Ilyushin Il-12 made its first flight. The Il-12 was very similar in design to American Convair 240, except was unpressurized. In 1953 the Ilyushin Il-14 would make its first flight, and this version was equipped with much more powerful engines.The main contribution that the Soviets made in regards to Airliners was the Antonov An-2. This plane is a bi-plane unlike most of the other airliners and sold more units than any other transport plane.

Types

The Airbus A330 is a wide-body airliner

Wide-body airliners

The largest airliners are *wide-body* jets. These aircraft are frequently called *twin-aisle aircraft* because they generally have two separate aisles running from the front to the back of the passenger cabin. Aircraft in this category are the Boeing 747, Boeing 767, Boeing 777, Airbus A300/A310, Airbus A330, Airbus A340, Airbus A380, Lockheed L-1011 TriStar, McDonnell Douglas DC-10, McDonnell Douglas MD-11, Ilyushin Il-86 and Ilyushin Il-96. These aircraft are usually used for long-haul flights between airline hubs and major cities with many passengers. Future wide-body models include the Boeing 787 and Airbus A350.

Narrow-body airliners

The Boeing 757 is a narrow-body airliner

A smaller, more common class of airliners is the *narrow-body* or *single aisle* aircraft. These smaller airliners are generally used for medium-distance flights with fewer passengers than their wide-body counterparts.

Examples include the Boeing 717, 737, 757, McDonnell Douglas DC-9 and MD-80/MD-90 series, Airbus A320 family, Tupolev Tu-204, Tu-214, Embraer E-Jets 190&195 and Tu-334. Older airliners like the Boeing 707, 727, Douglas DC-8, Fokker F70/F100, VC10, Tupolev, and Yakovlev jets also fit into this category.

Small airliners

Short haul airliners used by airlines and regional airlines

A JetBlue Airways Embraer 190 short haul airliner.

A PLUNA Bombardier CRJ900 short haul (regional) airliner taxiing.

Regional airliners - Small (Regional) short haul airliners typically seat fewer than 100 passengers and may be powered by turbofans or turboprops.

Direktflyg Jetstream 32 at Kristiansund Airport, Kvernberget

These airliners, though smaller than aircraft operated by most major carriers, legacy carriers, flag carriers, frequently serve customers who expect service, similar to that offered by the far larger airlines with their longer ranged larger jetliners. Therefore, these short haul airliners are usually equipped with lavatories, stand up cabins, pressurization, overhead storage bins, reclining seats, and have a flight attendant to look after the in-flight needs of the passengers upon point-to-point routes. Among some of earliest regional short haul airliners were the pre-airline deregulation Jetstream 31 aircraft.

Feederliner aircraft used by regional airlines

The Bombardier CRJ200

A Compass Airlines (North America) Embraer ERJ-170-200LR in the feederliner colors of Northwest Airlink

Regional airliners - (Regional) Feederliners typically seat fewer than 100 passengers and may be powered by turbofans or turboprops. These airliners, are the non mainline counterparts to the larger aircraft operated by the; major carriers, legacy carriers, and flag carriers and are used to feed traffic into the large airline hubs or focus cities. These particular routes may need the size of a smaller aircraft to meet the frequency needs and service levels, customers expect in the marketed product that is offered by larger airlines and their modern narrow and widebody aircraft. Therefore, most regional airliners are equipped with lavatories and have a flight attendant to look after the in-flight needs of the passengers, along with the features of a short haul regional airliner.

Typical aircraft in this category include the Bombardier CRJ and Embraer ERJ regional jets along with the "Q" (DASH-8) series, ATR 42/72 and Saab 340/2000 turboprop airliners. Airlines and their partners sometimes use these for flights between small hubs, or for bringing passengers to hub cities where they may board larger aircraft. Typically, these regional feederliners, are painted in the aircraft liveries and color schemes of the much larger airline partners so the regional airlines may offer and market a seamless transition between the larger airline to smaller airline.

Commuterliner aircraft used by regional airlines and air taxi charter operators

The Beechcraft 1900 short range commuter aircraft

The lightest (light aircraft, list of light transport aircraft) of short haul regional feeder airliner type aircraft that carry 19 or fewer passenger seats are called *commuter aircraft, commuterliners, feederliners,* and *air taxis*, depending on their size, engines, how they are marketed, region of the world, and seating configurations. The Beechcraft 1900, for example, has only 19 seats. Depending on local and national regulations, a commuter aircraft may not qualify as an airliner and may not be subject to the regulations applied to larger aircraft. Members of this class of aircraft normally lack such amenities as lavatories and galleys and typically do not carry a flight attendant as an aircrew member.

Other aircraft that may fall into this category are the Fairchild Metro, Jetstream 31, and Embraer EMB 110 Bandeirante. The Cessna Caravan and Pilatus PC-12, are single-engine turboprops, sometimes used as a small airliner, although many countries stipulate a minimum requirement of two engines for aircraft to be used as airliners.

Twin piston-engined aircraft made by Cessna, Piper, Britten-Norman, and Beechcraft are also in use as short haul, short range commuter type aircraft.

Engines

Until the beginning of the Jet Age, piston engines were common on propliners like the Douglas DC-3. Nearly all modern airliners are now powered by turbine engines, either turbofans or turboprops. Gas turbine engines operate efficiently at much higher altitudes, are more reliable than piston engines, and produce less vibration and noise. Prior to the Jet Age, it was common for the same or very similar engines to be used in civilian airliners as in military aircraft. In recent years, divergence has occurred so that it is now unusual for the same engine to be used on a military type as a civilian type. Usually military aircraft which share engine technology with airliners are transports or tanker types.

Airliner variants

Some variants of airliners have been developed for carrying freight or for luxury corporate use. Many airliners have also been modified for government use as VIP transports and for military functions such as airborne tankers (for example, the Vickers VC10, Lockheed L1011, Boeing 707), air ambulance (USAF/USN McDonnell Douglas DC-9), reconnaissance (Embraer ERJ 145, Saab 340, Boeing 737), as well as for troop-carrying roles.

Layout

Modern airliners are usually low-wing designs with engines mounted in underwing pods (usually two of them). For airliners, multi-engine design is mandated by some national regulations so that aircraft can continue to climb even in the worst case of power loss in one engine right after take-off. Another regulatory demand is that aircraft are able to fly a minimum specified amount of time after one engine fails in flight.

Mounting the engines underneath and to the fore of the wing moves weight from the fuselage to the wings, imposing less bending moment on them and allowing for a lighter wing structure. After this feature proved successful in military jets, Boeing introduced it to its 707 airliner design and it has been increasingly adopted since.

Mounting the engines in underwing pods also makes physical access for maintenance quicker and easier compared to tail-mounted engines.

Additionally, low wing design helps keep the engine nacelles and refueling valves closer to the ground to simplify access and the wing's surface acts as a barrier to prevent the engines' noise from reaching the fuselage in-flight.

Both Airbus and Boeing use this common layout for all of their current passenger aircraft and emerging manufacturers (e.g. Embraer and Sukhoi Superjet) follow the same scheme.

In a few special cases, where engine proximity to ground is detrimental (e.g. rural airfields with risk of foreign object damage or dirt), airliners will feature tail-mounted engines (e.g. MD-80 or Tu-334) or high-wing designs with underhung nacelles (e.g. BAe 146). These planes become rarer as almost all newly built airliners have underwing nacelles. Tail-engined designs are mostly used by business jet manufacturers.

Future airliners may feature innovative delta wing or lifting body outlines.

Manufacturers

Assembly of a Boeing 767 airliner nose section

These include:

- Asia
    - China
        - Comac (includes Shanghai Aircraft Manufacturing Factory)
        - Shenyang Aircraft Corporation
        - Xi'an Aircraft Industrial Corporation

- Europe
    -
        - Airbus S.A.S. (formerly a multinational conglomeration of the largest European aerospace companies of France, Germany, Spain and the UK)
    - Czech Republic
        - Let Kunovice
    - France/Italy
        - ATR
    - Netherlands
        - Fokker (now defunct)
    - Russian companies (formerly Soviet-controlled)
        - Ilyushin
        - Sukhoi
        - Tupolev
        - Yakovlev
    - Sweden
        - Saab (no longer manufactures civilian aircraft)
    - Ukraine (formerly Soviet-controlled)
        - Antonov
    - United Kingdom
        - BAE Systems (formerly British Aerospace, no longer manufactures civilian aircraft)
        - Britten-Norman

- North America
    - Canada
        - Bombardier (includes the former De Havilland Canada and Canadair)
    - United States
        - Boeing (includes the former McDonnell Douglas company which itself included the Douglas Aircraft Company)
        - Lockheed Corporation (now part of Lockheed Martin, and no longer involved in civil aviation)

- South America
    - Brazil
        - Embraer

The international market for middle-sized and large-sized airliners is now divided between Airbus and Boeing, although Russian/former Soviet manufacturers still sell significant numbers of airliners to their traditional markets. Smaller-sized aircraft manufacturers include, in addition to these two, ATR, Embraer and Bombardier.

Notable airliners

Notable airliners – a Boeing 747-400 "jumbo jet" of Qantas takes off

Notable airliners – an Airbus A380 "superjumbo" of Singapore Airlines takes off

- Boeing 247 – the first design to incorporate modern features such as all-metal construction and retractable landing gear
- Douglas DC-3 – still in service more than 70 years after its debut, it is generally regarded as one of the most significant transport aircraft ever made
- Douglas DC-6 – originally developed as a military transport, it was reworked for passenger service after World War II, a role it continues to perform today
- Boeing 377- Developed soon after World War 2, from the C-97 Stratofreighter, this was a luxurious double-decker airliner.
- Vickers Viscount – the first turboprop airliner to enter service
- Lockheed Constellation – a distinctive triple-tailed piston-engined airliner of the 1950s, it was one of the last large propeller-driven airliners
- De Havilland Comet – the world's first jetliner to reach mass production, its reputation was marred by a series of crashes due to structural failure
- Antonov An-2- Best selling transport airliner up to the point it was built.
- Sud Aviation Caravelle – one of the more successful European first-generation turbojet airliners
- Tupolev Tu-104 – the first turbojet airliner to provide sustained service, and the sole jetliner operating in the world between 1956 and 1958
- Boeing 707 – the first United States-built jetliner to enter production

- Douglas DC-8 – launched after the Boeing 707, it nevertheless established Douglas in the airliner market, and continues to serve as a cargo aircraft to this day
- Tupolev Tu-114 - long-range turbo-prop airliner and the world's largest and fastest passenger plane until 1968
- Tupolev Tu-154 - standard medium-range airliner for Russia (and others), carried half of all Soviet traffic since 1972 with 1015 built and the fastest airliner in service
- Ilyushin Il-62 - standard long-range airliner for Russia (and others) for three decades, first flight 1963 and still in service
- Boeing 727 – was the most produced commercial jet airliner in the world for over a decade, with 1,831 aircraft produced
- Douglas DC-9 – production of it and successive variants nearly reached 2,500
- Boeing 737 – currently the best selling civilian jet airliner
- Tupolev Tu-144 – the first supersonic transport aircraft constructed in Soviet Union
- Concorde – an Anglo-French supersonic transport, it remains the only supersonic aircraft to sustain a regular passenger service
- Boeing 747 "jumbo jet" – an iconic aircraft, it was the world's largest airliner between 1968 and 2005
- McDonnell Douglas DC-10 – a trijet competitor to the widebody 747
- Lockheed L-1011 TriStar – shared a similar configuration to the DC-10, but not its success, with only 250 produced
- Airbus A300 – the world's first twinjet widebody
- Airbus A320 – pioneered the use of fly-by-wire technology
- Airbus A340-600 - longest commercial airplane
- Boeing 777 – the first airliner designed entirely by computer, without physical mockups
- Airbus A380 "superjumbo" – the world's largest airliner from 2005 onwards
- Boeing 787 - the world's first jet airliner to make use of composite materials for most of its construction

Airliner recycling

As airliners are very expensive, most are leased out for times typically from 20 to 40 years. Very few go back into service after a long lease is up because evolving aerospace technology leaves older airliners unable to compete against newer machines that can be operated at a lower cost. Many end-of-service airliners end up in the Mojave Desert, at the Mojave Air and Space Port (also known as "The Boneyard"). From this, the term "Mojave" has come to refer to the temporary storage of aircraft, e.g. during decreased demand for air travel and between short-term leases. Another airliner retirement location is Marana, Arizona.

While almost every airliner will be reduced to scrap (the exceptions end up as museum pieces or flown by collector groups) they may pass through many owners before they are retired. A well-maintained airliner can operate safely for decades, depending on how often it is flown, its operating environment, and whether damage and wear and tear is properly repaired.

What may end an airliner's working life is a lack of spare parts, as the original manufacturer and third manufacturers may no longer provide or support them. Corrosion and metal fatigue are other issues that become more expensive to deal with as time goes on. Eventually, these factors and advances in aircraft technology lead to older airliners becoming too expensive or inefficient to operate.

To protect the environment, the Airbus company has set up a centre in France to decommission and recycle older aircraft. More than 200 airliners will finish active life each year, and will be dismantled and recycled under the newly established PAMELA Project.

Cabin configurations and features

Interior of a Qatar Airways Airbus. Video systems (the vertical white panels) are visible above the very centre seats of the aircraft

Boarding an Airbus A380 at the Farnborough Airshow, 2006

An airliner will usually have several classes of seating: first class, business class, and/or economy class (which may be referred to as coach class or tourist class, and sometimes has a separate "premium" economy section with more legroom and amenities). The seats in more expensive classes are wider, more comfortable, and have more amenities such as "lie flat" seats for more comfortable sleeping on long flights. Generally, the more expensive the class, the better the beverage and meal service.

Domestic flights generally have a two-class configuration, usually first or business class and coach class, although many airlines instead offer all-economy seating. International flights generally have either a two-class configuration or a three-class configuration, depending on the airline, route and aircraft type. Many airliners offer movies or audio/video on demand (this is standard in first and business class on many international flights and may be available on economy). Cabins of any class are provided with lavatory facilities.

Seats

The types of seats that are provided and how much legroom is given to each passenger are decisions made by the individual airlines, not the aircraft manufacturers. Seats are mounted in "tracks" on the floor of the cabin and can be moved back and forth by the maintenance staff or removed altogether. Naturally the airline tries to maximize the number of seats available in every aircraft to carry the largest possible (and therefore most profitable) number of passengers.

Passengers seated in an **exit row** (the row of seats adjacent to an emergency exit) usually have substantially more legroom than those seated in the remainder of the cabin, while the seats directly in front of the exit row may have less legroom and may not even recline (for evacuation safety reasons). However, passengers seated in an exit row may be required to assist cabin crew during an emergency evacuation of the aircraft opening the emergency exit and assisting fellow passengers to the exit. As a precaution, many airlines prohibit young people under the age of 15 from being seated in the exit row .

The seats are designed to withstand strong forces so as not to break or come loose from their floor tracks during turbulence or accidents. The backs of seats are often equipped with a fold-down tray for eating, writing, or as a place to set up a portable computer, or a music or video player. Seats without another row of seats in front of them have a tray that is either folded into the armrest or that clips into brackets on the underside of the armrests. However, seats in premium cabins generally have trays in the armrests or clip-on trays, regardless of whether there is another row of seats in front of them. Seatbacks now often feature small color LCD screens for videos, television and video games. Controls for this display as well as an outlet to plug in audio headsets are normally found in the armrest of each seat.

Overhead bins

The overhead bins are used for stowing carry-on baggage and other items. While the airliner manufacturer will normally supply a standard product, airlines may choose to have bins of differing size, shape, or color installed. Over time, these bins evolved out of what were originally overhead shelves used for little more than coat and briefcase storage. As concerns about falling debris during turbulence or in accidents increased, enclosed bins became the norm. Bins have increased in size in order to accommodate the larger carry-on baggage passengers may bring onto the aircraft. New bin designs may include a handrail, useful when moving through the cabin.

Passenger service units

Above the passenger seats are Passenger Service Units (PSU). These typically contain reading lights, air vents, and a flight attendant call light. On most narrowbody aircraft (and some Airbus A300s and A310s), the flight attendant call button and the buttons to control the reading lights are located directly on the PSU, while on most widebody aircraft, the flight attendant call button and the reading light control buttons are usually part of the in-flight entertainment system. The units frequently have small "Fasten Seat Belt" and "No Smoking" illuminated signage and may also contain a speaker for the cabin public address system.

The PSU will also normally contain the drop-down oxygen masks which are activated if there is a sudden drop in cabin pressure. These are supplied with oxygen by means of a chemical oxygen generator. By using a chemical reaction rather than a connection to an oxygen tank, these devices supply breathing oxygen for long enough for the airliner to descend to thicker, more breathable air. Oxygen generators do generate considerable heat in the process. Because of this, the oxygen generators are thermally shielded and are only allowed in commercial airliners when properly installed – they are not permitted to be loaded as freight on passenger-carrying flights. ValuJet Flight 592 crashed on May 11, 1996 as a result of improperly loaded chemical oxygen generators.

Cabin pressurization

Airliners developed since the 1940s have had pressurized cabins (or more accurately, pressurized hulls including baggage holds) to enable them to carry passengers safely at high altitudes where low oxygen levels and air pressure would otherwise cause sickness or death. High altitude flight enabled airliners to fly above most weather systems that cause turbulent or dangerous flying conditions, and also to fly faster and further as there is less drag due to the lower air density. Pressurisation is applied using compressed air, in most cases bled from the engines, and is managed by a environmental control system which draws in clean air, and vents stale air out through a valve.

Pressurization presents design and construction challenges to maintain the structural integrity and sealing of the cabin and hull and to prevent rapid decompression. Some of the consequences include small round windows, doors that open inwards and are larger than the door hole, and an emergency oxygen system.

To maintain a pressure in the cabin equivalent to an altitude close to sea level would, at a cruising altitude around 10,000 m (33,000 feet), create a pressure difference between inside the aircraft and outside the aircraft that would require greater hull strength and weight. Most people do not suffer ill effects up to an altitude of 1800–2500 m (6000–8000 feet), and maintaining cabin pressure at this equivalent altitude significantly reduces the pressure difference and therefore the required hull strength and weight. A side effect is that passengers experience some discomfort as the cabin pressure changes during ascent and descent to the majority of airports, which are at low altitudes.

Cabin climate control

The air bled from the engines is hot and requires cooling by air conditioning units. It is also extremely dry at cruising altitude, and this causes sore eyes, dry skin and mucosa on long flights. Although humidification technology could raise its relative humidity to comfortable middle levels, this is not done since humidity promotes corrosion to the inside of the hull and risks condensation which could short electrical systems, so for safety reasons it is deliberately kept to a low value, around 10%.

Baggage holds

An Airbus A320 baggage hold

Loading luggage onto a Boeing 747 at Boston Logan Airport, during a closure due to heavy snow

Boeing 747 front lower compartment. Note the rollers for ULDs on the floor and the partition labeled "Caution: Do Not Hit -- Potable Water Tank Inside".

Airliners must have space on board to store baggage that will not safely fit in the passenger cabin.

Designed to hold baggage as well as freight, these compartments are called "cargo bins", "holds", or occasionally "pits". Occasionally baggage holds may be referred to as **cargo decks** on the largest of aircraft. These compartments can be accessed through doors on the outside of the aircraft. Despite what is seen in many movies, access doors between passenger cabins and baggage holds are rare in modern airliners.

Depending on the aircraft, baggage holds are normally inside the hull and are therefore pressurized just like the passenger cabin although they may not be heated. While lighting is normally installed for use by the loading crew, typically the compartment is unlit when the door is closed.

Baggage holds on modern airliners are equipped with fire detection equipment and larger aircraft have automated or remotely activated fire-fighting devices installed.

Narrow-body airliners

Most "narrow-body" airliners with more than 100 seats have space below the cabin floor, while smaller aircraft often have a special compartment separate from the passenger area but on the same level.

Baggage is normally stacked within the bin by hand, sorted by destination category. Netting that fits across the width of the bin is secured to limit movement of the bags. Airliners often carry items of freight and mail. These may be loaded separately from the baggage or mixed in if they are bound for the same destination. For securing bulky items "hold down" rings are provided to tie items into place.

Wide-body airliners

"Wide-body" airliners frequently have a compartment like the ones described above, typically called a "bulk bin". It is normally used for late arriving luggage or bags which may have been checked at the gate.

However, most baggage and loose freight items are loaded into containers called Unit Load Devices (ULDs), often referred to as "cans". ULDs come in a variety of sizes and shapes, but the most common model is the LD3. This particular container has approximately the same height as the cargo compartment and fits across half of its width.

ULDs are loaded with baggage and are transported to the aircraft on dolly carts and loaded into the baggage hold by a loader designed for the task. By means of belts and rollers an operator can maneuver the ULD from the dolly cart, up to the aircraft baggage hold door, and into the aircraft. Inside the hold, the floor is also equipped with drive wheels and rollers that an operator inside can use to move the ULD properly into place. Locks in the floor are used to hold the ULD in place during flight.

For consolidated freight loads, like a pallet of boxes or an item too oddly shaped to fit into a container, flat metal pallets that resemble large baking sheets that are compatible with the loading equipment are used.

Chapter- 3

Business Jet

Gulfstream IV business jet.

Bombardier Global 5000 business jet takes off

Business jet, **private jet** or, colloquially, **bizjet** is a term describing a jet aircraft, usually of smaller size, designed for transporting groups of up to 19 business people or wealthy individuals. Business jets may be adapted for other roles, such as the evacuation of casualties or express parcel deliveries, and a few may be used by public bodies, governments or the armed forces. The more formal terms of *corporate jet*, *executive jet*, *VIP transport* or *business jet* tend to be used by the firms that build, sell, buy and charter these aircraft.

Background

Almost all production business jets, such as General Dynamics' Gulfstream and the Gates Lear Jet (now built by Bombardier), have had two or three engines, though the Jetstar, an early business jet, had four. Advances in engine reliability and power have rendered four-engine designs obsolete, and only Dassault Aviation still builds three-engine models (in the Falcon line). The emerging market for so-called "very light jets" and "personal jets", has seen the introduction (at least on paper) of several single-engine designs as well.

Almost all business jets have rear-mounted engines, because the wing (mounted low for performance reasons) is too near the ground for engines to be slung underneath it.

Airliners are sometimes converted into luxury business jets. Such converted aircraft are often used by celebrities with a large entourage or press corps, or by sports teams, but airliners often face operational restrictions based on runway length or local noise restrictions.

Private Boeing 737-800 lands at London Luton Airport, England

Cessna 525 CitationJet

A focus of development is at the low end of the market with small models, many far cheaper than existing business jets. Many of these fall into the very light jet (VLJ) category and are used by the air taxi industry. Cessna has developed the Mustang, a six-place twinjet (2 crew + 4 passengers) available for $2.55 million USD. A number of smaller manufacturers have planned even cheaper jets; the first was the Eclipse 500 from the now defunct Eclipse Aviation which was available at around 1.5 million USD. It remains to be seen whether the new jet manufacturers will complete their designs, or find the market required to sell their jets at the low prices planned.

There are approximately 11,000 business jets in the worldwide fleet with the vast majority of them based in the United States or owned by US companies. The European market is the next largest, with growing activity in the Middle East, Asia, and Central America.

Since 1996 the term "fractional jet" has been used in connection with business aircraft owned by a consortium of companies. Costly overheads such as flight crew, hangarage and maintenance can be shared through such arrangements.

Because of their low-volume productions and long lead times, new aircraft orders can take two to three years for delivery. This peculiarity fuels a large pre-owned marketplace, with aircraft for immediate availability.

Classes

The business jet industry groups the jets into five loosely-defined classes:

Heavy jets

The most expensive type of private jet is the heavy jet type, which is designed for the ultimate in large capacity luxury air travel. These aircraft, sometimes referred to as *Bizliners* (contraction of *Business Airliners*), are based on or converted from airliner types. Aircraft of this class include:

- Airbus
    - Airbus A318 Elite
    - Airbus A319CJ
    - Airbus A380 Flying Palace

- Boeing
    - Boeing Business Jet

- Embraer
    - Lineage 1000

Large Cabin jets

- Bombardier Aerospace
  - Bombardier Global 5000
  - Bombardier Global 7000
  - Bombardier Global 8000
  - Bombardier Global Express
  - Bombardier Challenger 850

- Dassault
  - Dassault Falcon 7X

- Gulfstream Aerospace
  - Gulfstream G500
  - Gulfstream G550
  - Gulfstream G650

Super mid-size jets

The elite class of the business and private jet aircraft are the super mid-size jets that feature wide body cabin space, high altitude, speed, and ultra long range capabilities. These ultra luxurious private jets combine the long range transatlantic capability with the speed and comfort of a wide body, high altitude aircraft. Aircraft of this class include:

- Bombardier Aerospace
  - Bombardier Challenger 300
  - Challenger 605

- Cessna
  - Citation X

- Dassault
  - Dassault Falcon 900DX
  - Dassault Falcon 900EX
  - Dassault Falcon 2000DX
  - Dassault Falcon 2000EX

- Embraer
  - Legacy 600

- Gulfstream
  - Gulfstream G350
  - Gulfstream G450

- Hawker Beechcraft
  - Hawker 4000

Mid-size jets

These aircraft are suitable for longer range travel such as transcontinental flights and for travel with larger passenger capacity requirements. Aircraft of this class include:

- Bombardier Aerospace
  - Learjet 60 XR
  - Learjet 85

- Cessna
  - Citation Columbus
  - Citation XLS
  - Citation Sovereign

- Dassault
  - Dassault Falcon 50EX

- Embraer
  - Embraer Legacy 450
  - Embraer Legacy 500

- Gulfstream
  - Gulfstream 150
  - Gulfstream 250

- Hawker Beechcraft
  - Hawker 750
  - Hawker 850 XP
  - Hawker 900XP

Light jets

The light jets have been a staple of the business jet industry since the advent of the Learjet 23 in the early 1960s. The light jets provide access to small airports and the speed to be an effective air travel tool. Aircraft of this class include:

- Bombardier Aerospace
  - Learjet 40
  - Learjet 40 XR
  - Learjet 45
  - Learjet 45 XR

- Cessna
  - Citation CJ1
  - Citation CJ2
  - Citation CJ3

- Citation CJ4
- Citation Bravo
- Citation Encore

- Embraer
  - Phenom 300

- Grob
  - Grob SPn

- Hawker Beechcraft
  - Beechcraft Premier I
  - Hawker 400

- Sino Swearingen
  - SJ30-2

Very light jets

Very light jets, also known as Microjets or VLJs, are designed to provide air travel, for example, to the more than 5,000 small community airports in the United States. VLJs have a maximum take off weight of not more than 10,000 lb. Aircraft of this class include:

- Adam Aircraft Industries
  - Adam A700

- Cessna
  - Citation Mustang

- Cirrus Design
  - Cirrus Vision SF50

- Comp Air
  - Comp Air Jet

- Diamond Aircraft Industries
  - D-Jet

- Eclipse Aviation
  - Eclipse 500
  - Eclipse 400

- Embraer
  - Phenom 100

- Epic Aircraft
    - Epic Elite
    - Epic Victory

- Honda
    - HondaJet

- Piper
    - PiperJet

- Spectrum Aeronautical
    - Spectrum S-33 Independence

Operators

There are three basic types of operators who own, manage and operate private jets.

Flight Departments

Flight departments are traditionally corporate owned operators who manage the aircraft of a specific company. i.e. Ford Motor Company, Chrysler, Altria are all example of companies that own, maintain and operate their own fleet of private aircraft for the exclusive use of their executives. Flight Departments handle all aspects of aircraft operation and maintenance. These aircraft are managed under the FAA rules (FAR's) Part 91.

Charter Companies

Charter operators are traditionally operators who own or simply manage private jets for multiple clients. Like traditional flight departments, charter companies handle all aspects of aircraft operation and maintenance. However, they are not aligned with just one corporation. They manage aircraft for a private owner or corporation and also handle the sales of available flight time on the aircraft they own or manage. These aircraft are usually operated under Part 135 of the FAA regulations.

Fractional Ownership

This is commonly known in the industry as "time share". An individual or corporation pays an up front equity share for the cost of an aircraft, Say 1/4 of the aircraft price, known in the industry as a "quarter share". The individual or corporation is now an equity owner in that aircraft and can sell their equity position if necessary. This entitles the new owner to 100 hours of flight time on that aircraft, or any comparable aircraft in the fleet. Additional fees include monthly management fees and incidentals like catering and ground transportation. These aircraft may operate under part 91 or part 135 of the FAA regulations, depending on the passengers using the aircraft.

Chapter- 4

Homebuilt Aircraft

A Rutan Long-EZ homebuilt in 1984 in England

Also known as *amateur-built aircraft* or *kit planes*, **homebuilt aircraft** are constructed by persons for whom this is not a professional activity. These aircraft may be constructed from "scratch," from plans, or from assembly kits.

Overview

In the United States, Australia and New Zealand, homebuilt aircraft may be licensed Experimental under FAA or similar local regulations. Provided that the owner has done at least 51% of the construction work themselves they can also apply for a repairman's certificate for that airframe. The repairman's certificate allows the holder to perform and sign off on most of the maintenance, repairs, and inspections themselves.

Alberto Santos-Dumont was the first to offer for free construction plans, publishing drawings of its Demoiselle in the June 1910 edition of Popular Mechanics. The first aircraft to be offered for sale as plans, rather than a completed airframe, was the Baby Ace in the late 1920s.

Canada's first homebuilt aircraft, Stitts SA-3A Playboy CF-RAD, first flown in 1955, seen in the Canada Aviation and Space Museum.

Homebuilt aircraft gained in popularity in the US in 1924 with the start of the National Air Races, held in Dayton, Ohio. These races required aircraft with useful loads of 150 lb (68 kg) and engines of 80 cubic inches or less and as a consequence of the class limitations most were amateur-built. The years after Lindberg's transatlantic flight brought a peak of interest between 1929-33. During this period many aircraft designers, builders and pilots were self taught and the high accident rate brought public condemnation and increasing regulation to amateur-building. The resulting federal standards on design, engineering, stress analysis, use of aircraft-quality hardware and testing of aircraft brought an end to amateur building except in some specialized areas, such as racing. In 1946 Goodyear restarted the National Air Races, including a class for aircraft powered by 200 cubic inch and smaller engines. The midget racer class spread nationally in the US and this led to calls for acceptable standards to allow recreational use of amateur-built aircraft. By the mid-1950s both the US and Canada once again allowed amateur-built aircraft to specified standards and limitations.

Homebuilt aircraft are generally small, one to four-seat sportsplanes which employ simple methods of construction. Fabric-covered wood or metal frames and plywood are common in the aircraft structure, but increasingly, fiberglass and other composites as well as full aluminum construction techniques are being used. Engines are most often the same as, or similar to, the engines used in certified aircraft (such as Lycoming, Continental, Rotax, and Jabiru). A minority of homebuilts use converted automobile engines, with Volkswagen air-cooled flat-4s, Subaru-based liquid-cooled engines, Mazda Wankel and Chevrolet Corvair six-cylinder engines being common. The use of automotive engines helps to reduce costs, but many builders prefer dedicated aircraft engines, which are perceived to have better performance and reliability. Other engines that have been used include chainsaw and motorcycle engines.

A combination of cost and litigation, especially in the mid-1980s era, which has discouraged general aviation manufacturers from introducing new designs, has led to homebuilts outselling factory types by five to one. In 2003, the number of homebuilts produced in the USA exceeded the number produced by any single certified manufacturer.

History

The history of amateur-built aircraft can be traced to the beginning of aviation. Even if the Wright brothers, Clément Ader, and their successors had commercial objectives in mind, the first aircraft were constructed by passionate enthusiasts whose goal was to fly.

Early years

Aviation took a leap forward with the industrialization that accompanied World War I. In the post-war period, manufacturers needed to find new markets and introduced models designed for tourism. However, these machines were affordable only by the very rich.

Many U.S. aircraft designed and registered in the 1920s onward were considered "experimental" by the (then) CAA, the same registration under which modern homebuilts are issued Special Airworthiness Certificates. Many of these were prototypes, but designs such as Bernard Pietenpol's first 1923 design were some of the first homebuilt aircraft. In 1928, Henri Mignet published plans for his HM-8, as did Pietenpol for his Air Camper. Pietenpol later constructed a factory, and in 1933 began creating and selling partially-constructed aircraft kits.

In 1936, an association of amateur aviation enthusiasts was created in France. Many types of amateur aircraft began to make an appearance, and in 1938 legislation was amended to provide for a *Certificat de navigabilité restreint d'aéronef* (*CNRA*, "restricted operating certificate for aircraft"). 1946 saw the birth of the Ultralight Aircraft Association which in 1952 became the Popular Flying Association in the United Kingdom, followed in 1953 by the Experimental Aircraft Association in the United States and the Sport Aircraft Association in Australia.

Technology and innovation

The Questair Venture set new standards for speed in kit-built aircraft design

Until the late 1950s, builders had mainly kept to wood-and-cloth and steel tube-and-cloth design. Without the regulatory restrictions faced by production aircraft manufacturers, homebuilders introduced innovative designs and construction techniques. Burt Rutan introduced the canard design to the homebuilding world and pioneered the use of composite construction. Metal construction in kitplanes was taken to a new level by Richard VanGrunsven in his RV series. As the sophistication of the kits improved, components such as autopilots and more advanced navigation instruments became common.

Litigation during the 1970s and 1980s caused stagnation in the small aircraft market, forcing the surviving companies to retain older, proven designs. In recent years, the less restrictive regulations for homebuilts allowed a number of manufacturers to develop new and innovative designs; many can outperform certified production aircraft in their class.

An example of high-end homebuilt design is Lancair, which has developed a number of high-performance kits. The most powerful is the Lancair Propjet, a four-place kit with cabin pressurization and a turboprop engine, cruising at 24,000 feet (7,300 m) and 370 knots (425 mph, 685 km/h). Although aircraft such as this are considered "home-built" for legal reasons, they are typically built in the factory with the assistance of the buyer. This allows the company which sells the kit to avoid the long and expensive process of certification, because they remain owner-built according to the regulations. One of the terms applied to this concept is commonly referred to as "The 51% Rule", which requires that builders perform the majority of the fabrication and assembly to be issued a Certificate of Airworthiness as an Amateur Built aircraft.

A small number of jet kitplanes have been built since the 1970s, including the tiny Bede Aircraft BD-5J.

Building materials

Homebuilt aircraft can be constructed out of any material that is light and strong enough for flight. Several common construction methods are detailed below.

Wood and fabric

A typical wood and fabric construction amateur-built, the Bowers Fly Baby.

A Pietenpol Air Camper under construction, showing the wooden frame structure that will be covered with aircraft fabric.

This is the oldest construction, seen in the first aircraft and hence the best known. For that reason, amateur-built aircraft associations will have more specialists for this type of craft than other kinds.

The most commonly-used woods are Sitka spruce and Douglas fir, which offer excellent strength-to-weight ratios. Wooden structural members are joined with adhesive, usually epoxy. Unlike the wood construction techniques used in other applications, virtually all wooden joints in aircraft are simple butt joints, with plywood gussets. Joints are designed to be stronger than the members. After the structure has been completed, the aircraft is covered in aircraft fabric (usually aircraft-grade polyester). The advantage of this type of construction is that it does not require complex tools and equipment, but commonplace items such as saw, planer, file, sandpaper, and clamps.

Examples of amateur-built wood and fabric designs include:

- The classic Pietenpol Air Camper, a homebuilt that has been built since the 1920s.
- The Bowers Fly Baby, a low-wing monoplane which has been popular since the 1960s.
- Fisher Flying Products (built with geodetic cross-bracing).
- The Ison miniMAX

- the Jodel models, including the *bébé* D-9, D-112, and the more recent D-18, D-19, and D-20
- the Piel CP-30 *Émeraude*
- the VP-1 and VP-2, designed by Bud Evans in the late 1960s and commonly called Volksplanes

Wood/composite mixture

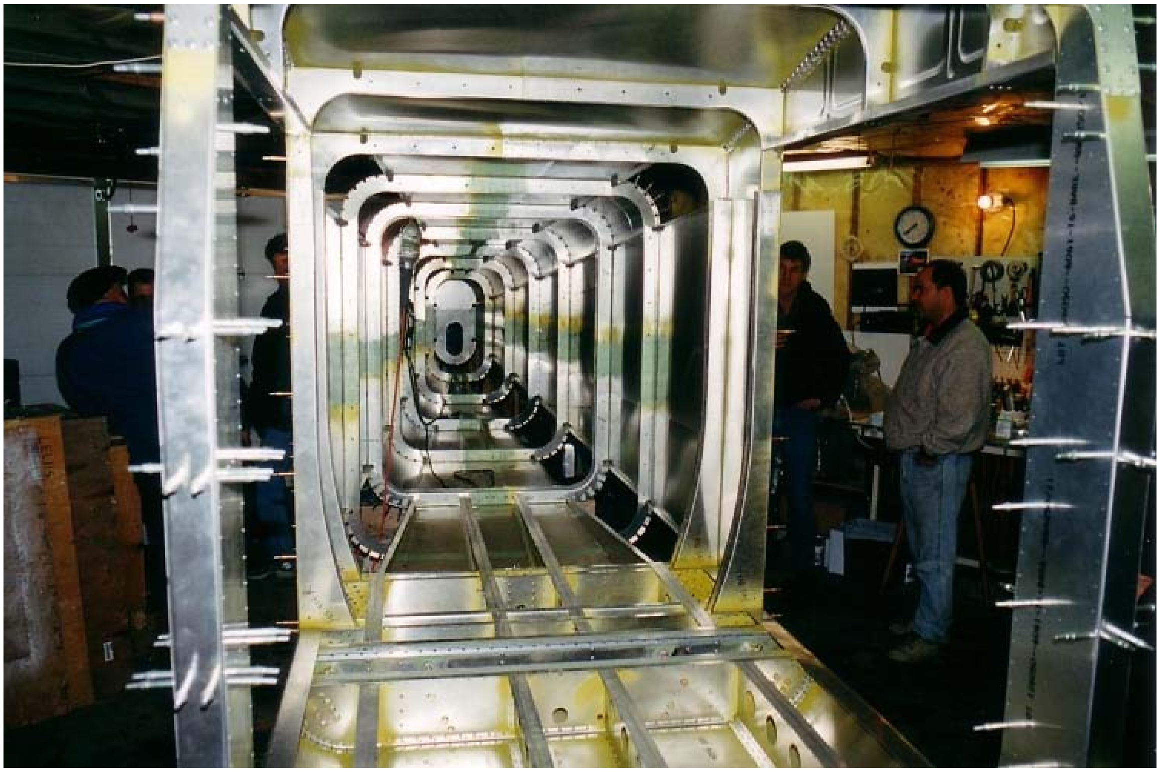
A recent trend is toward wood-composite aircraft. The basic load carrying material is still wood, but it is combined with foam (for instance to increase buckling resistance of load carrying plywood skins) and other synthetic materials like glass- and carbon fibre (to locally increase the modulus of load carrying structures like spar caps, etc.).

Examples of wood-composite designs include:

- Ibis experimental aircraft project, designed by Roger Junqua
- KR series of homebuilts designed by Ken Rand
- PIK-26 designed by Kai Mellen

Metal

Van's Aircraft like this RV-4 are the most common metal homebuilt type.



Inside of the tail cone of a Murphy Moose under construction, showing the all-metal semi-monocoque design

Planes built from metal use similar techniques to more conventional factory-built aircraft. They can be more challenging to build, requiring metal-cutting, metal-shaping, and riveting if building from plans. "Quick-build" kits are available which have the cutting, shaping and hole-drilling mostly done, requiring only finishing and assembly. Such kits are also available for the other types of aircraft construction, especially composite.

There are three main types of metal construction: sheet aluminum, tube aluminum, and welded steel tube. The tube structures are covered in aircraft fabric, much like wooden aircraft.

Examples of metal-based amateur aircraft include:

- The Murphy Aircraft SR3500 Moose, Rebel and Super Rebel, Maverick, Elite, JDM-8, and Yukon. Murphy Aircraft is a Canadian manufacturer that offers kits for self construction.
- The Vans RV-4, RV-8, RV-10 and other models produced by Van's Aircraft, are the most popular metal homebuilt aircraft.
- Chris Heintz's Zenith CH601 Zodiac and Zenith STOL CH701
- Sonex Aircraft's Sonex, Waiex, and Xenos kit planes

Composite

A fiberglass/foam Quickie Q2.

A composite construction Cirrus VK-30.

Composite material structures are made of cloth with a high tensile strength (usually fiberglass or carbon fiber, or occasionally Kevlar) combined with a structural plastic (usually epoxy, although vinylester is used in some aircraft). The fabric is saturated with the structural plastic in a liquid form; when the plastic cures and hardens, the part will hold its shape while possessing the strength characteristics of the fabric.

The two primary types of composite planes are molded composite, where major structures like wing skins and fuselage halves are prepared and cured in molds, and moldless, where shapes are carved out of foam and then covered with fiberglass or carbon fiber.

The advantages of this type of construction include smooth surfaces (without the drag of rivets), the ability to do compound curves, and the ability to place fiberglass or carbon fiber in optimal positions, orientations, and quantities. Drawbacks include the need to work with chemical products as well as low strength in directions perpendicular to fiber. Composites provide superb strength to weight. Material stiffness dependent upon direction (as opposed to equal in all directions, as with metals) allows for advanced "elastic tailoring" of composite parts.

Examples of amateur craft made of composite materials include:

- Canard designs such as the VariEze and Long EZ designed by Burt Rutan.
- The Jabiru range.
- All Lancair designs
- The pusher propeller Cirrus VK-30.
- The Europa Aircraft range.

Safety

The safety record of homebuilts is not as good as certified general aviation aircraft. In the United States, in 2003, amateur-built aircraft experienced a rate of 21.6 accidents per 100,000 flight hours; the overall general aviation accident rate for that year was 6.75 per 100,000 flight hours.

The accident rate for homebuilt aircraft in the USA has long been a concern to the Federal Aviation Administration. At Sun 'n Fun 2010 FAA Administrator Randy Babbitt said that homebuilts "account for 10 percent of the GA fleet, but 27 percent of accidents. It's not the builders [getting into accidents], but the second owners. We need better transition training."

Chapter- 5

3I Sky Arrow

A Sky Arrow 650 TCN (*VH-IOI*)

Role	Recreational aircraft
Manufacturer	3I, also for homebuilding
First flight	13 July 1992

The **Sky Arrow** is a tandem seat, pusher configuration, high wing and carbon fibre light aircraft manufactured by 3I (Iniziative Industriali Italiane). With only 16½ inches of hip room, the aircraft is considered open due to a large amount of unobstructed view from the large canopy, rear engine, and seating positions ahead of the wing.

Variants

The rear of the Sky Arrow 650 TCN (VH-IOI), sporting its rear propeller.

The seating of the Sky Arrow 650 TCN (VH-IOI)

General aviation - out of production

- Sky Arrow 650 TC
- Sky Arrow 650 TCN
- Sky Arrow 650 TCNS

General aviation - in production

- Sky Arrow 650TCS:

  (100 hp engine), VFR and Sky Arrow 650 TCNS for VFR Night - Maximum Take-Off Weight (MTOW) of 650 kg (1,433 lb)

- Sky Arrow 710RG:

  100 hp engine, C for VFR and CN for VFR Night with an increased MTOW of 710 kg (1,565 lb) and retractable landing gear

- Sky Arrow 710 PLUS:

  100 hp engine, C and CN with an increased MTOW of 710 kg (1,565 lb) and the fixed landing gear

- Sky Arrow 650 ERA:

  fitted with RAWAS instrumentation by the Atmospheric Turbulence Diffusion Division of the National Oceanic Atmospheric Administration and Iniziative Industriali Italiane, for use in territory control environmental monitoring and for scientific research purposes.

Light aircraft

- Sky Arrow 450TS (100 hp)
- Sky Arrow 480TS (100 hp)
- Sky Arrow 500TF (80 hp)

Light sport - in production

- Sky Arrow Sport (100 hp)

  Meets ATSM requirements for the FAA Light-Sport category of aircraft.

Self assembly kit

- Sky Arrow 1450L (100 hp/115 hp)

  Hombuilt package consists of 10 subkits. Meets the FAA 51 percent builder rule.

Specifications (650)

General characteristics

- **Crew:** 2
- **Length:** 7.60 m (24 ft 11 in)
- **Wingspan:** 9.68 m (31 ft 9 in)
- **Height:** 2.56 m (8 ft 5 in)
- **Wing area:** 13.5 m^2 (145 sq ft)
- **Gross weight:** 650 kg (1,433 lb)
- **Useful load:** 250kg (556 lbs)
- **Powerplant:** 1 × Rotax 912 F2 , 73.5 kW (98.6 hp)

Performance

- **Maximum speed:** 194 km/h (121 mph; 105 kn)
- **Cruising speed:** 187 km/h (116 mph; 101 kn)
- **Service ceiling:** 4,100 m (13,451 ft)
- **Rate of climb:** 4.3 m/s (850 ft/min)

Chapter- 6

Glider (Sailplane)

Single-seat high performance fiberglass Glaser-Dirks DG-808 over the Lac de Serre Ponçon in the French Alps

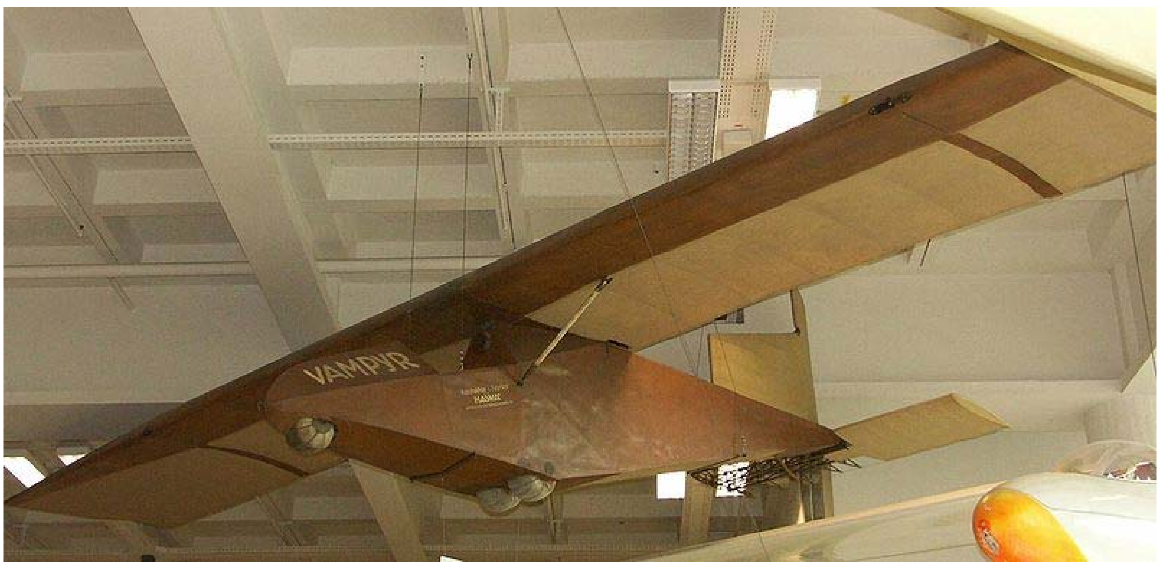
A **glider** or **sailplane** is a type of glider aircraft used in the sport of gliding. Some gliders, known as motor gliders are used for gliding and soaring as well, but have engines which can, in some cases, be used for take-off or for extending a flight. Foot-launched aircraft (such as hang gliders and paragliders) are described in separate articles, though their differences from sailplanes are covered below. Gliders have also been used for purposes other than recreation, for example for military purposes and for research.

Sports gliders benefit from creating the least drag for any given amount of lift, and this is best achieved with long, thin wings and a fully faired narrow cockpit. Aircraft with these features are able to climb efficiently in rising air and can glide long distances at high speed with a minimum loss of height in between.

Use of engines

Although most gliders do not have engines, there are a few that do. The manufacturers of high-performance gliders will list an optional engine with a retractable propeller that can be used to sustain flight, if required; these are known as 'self-sustaining' gliders. Some have enough thrust to launch themselves before the engine is retracted and are known as 'self-launching' gliders. There are also 'touring motor gliders' which can self launch and switch off the engine in flight without retracting their propellers.

History



HAWA Vampyr 1921

Sir George Cayley's gliders achieved brief wing-borne hops from around 1849. Otto Lilienthal built (barely) controllable gliders in the 1890s using weight shift with which he could ridge soar. Wright Brothers achieved full control in the early 1900s using movable surfaces, to which they successfully added an engine.

After World War I gliders were built for sporting purposes in Germany and in the United States (Schweizer brothers). Germany's strong links (continuing today) to gliding were to a large degree due to Post-WWI regulations forbidding the construction and flight of motorised planes in Germany, so the country's aircraft enthusiasts often turned to gliders and were actively encouraged by the German government.

The sporting use of gliders rapidly evolved in the 1930s and is now the main application. As their performance improved, gliders began to be used for cross-country flying and now regularly fly hundreds or even thousands of kilometers in a day if the weather is suitable.

Glider 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 gliders to soar more effectively than primary gliders, the designs minimized drag. Gliders now have very smooth, narrow fuselages and very long, narrow wings with a high aspect ratio and winglets.

Cockpit of a typical modern glider (Glaser-Dirks DG-101G ELAN).

A glider releasing its water ballast

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, fiber glass 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 FS-24 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 minimized by more aerodynamic shapes and retractable undercarriages. Flaps are fitted to the trailing edges of the wings on some gliders to minimise the drag from the tailplane at all speeds.

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 30:1 means that in smooth air a glider can travel forward 30 meters while losing only 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 modern flapped 18 meter gliders such as the ASG29 have a glide ratio of over 50:1. The largest open-class glider, the eta, has a span of 30.9 meters and has a glide ratio over 70:1. Compare this to the infamous Gimli Glider, a Boeing 767 which ran out of fuel mid-flight and was found to have a glide ratio of only 12:1, or to the Space Shuttle with a glide ratio of 4.5:1.

Due to the critical role that aerodynamic efficiency plays in the performance of a glider, gliders often have aerodynamic features seldom found in other aircraft. The wings of a modern racing glider have a specially designed low-drag laminar flow airfoil. After the wings' surfaces have been shaped by a mold to great accuracy, they are then highly polished. 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 span-wise 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 are disturbing the smooth flow of air over the wing.

Modern competition gliders carry jettisonable water ballast (in the wings and sometimes in the vertical stabilizer). The extra weight provided by the water ballast is advantageous if the lift is likely to be strong, and may also be used to adjust the glider's center of mass. Moving the center of mass toward the rear by carrying water in the vertical stabilizer reduces the required down-force from the horizontal stabilizer and the resultant drag from that down-force. Although heavier gliders have a slight disadvantage when climbing in rising air, they achieve a higher speed at any given glide angle. 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 in weaker thermal conditions. Another use of water ballast is to dampen air turbulence such as might be encountered during ridge soaring. To avoid undue stress on the airframe, gliders must jettison any water ballast before landing.

Most gliders are built in Europe and are designed to EASA Certification Specification CS-22 (previously Joint Aviation Requirements-22). These define minimum standards for safety in a wide range of characteristics such as controllability and strength. For example, gliders must have design features to minimize the possibility of incorrect assembly (gliders are often stowed in disassembled configuration, with at least the wings being detached). Automatic connection of the controls during rigging is the common method of achieving this.

Launch and flight

Double aerotow

The two most common methods of launching sailplanes are by aerotow and by winch. When aerotowed, the glider is towed behind a powered aircraft using a rope about 60 meters (about 200 ft) long. The glider pilot releases the rope after reaching the desired altitude. However, the rope can be released by the towplane also. 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 (about 2,500-4,000 ft) of cable and the winch rapidly winds it in. The glider can gain about 1200-2000 feet of height with a winch launch (about 400 - 600 metres), depending on the head wind. Less often, automobiles are used to pull gliders into the air, by pulling them directly or through the use of a reverse pulley in a similar manner to the winch launch. Elastic ropes (known as bungees) are occasionally used at some sites to launch gliders from slopes, if there is sufficient wind blowing up the hill. Bungee launching was the predominant method of launching early gliders. Some modern sailplanes can self-launch with the use of retractable engines and/or propellers, which can also be used to sustain flight once airborne.

Once launched sailplanes try to gain height using thermals, ridge lift or lee waves and can remain airborne for hours. This is known as 'soaring'. By finding lift sufficiently often experienced pilots fly cross-country, often on pre-declared tasks of hundreds of kilometers, usually back to the original launch site. Cross-country flying and aerobatics are the two forms of competitive gliding. For information about the forces in gliding flight.

Glide slope control

Pilots need some form of control over the glide slope to land the glider. In powered aircraft, this is done by reducing engine thrust. In gliders, other methods are used to either reduce the lift generated by the wing, increase the drag of the entire glider, or both. Glide slope is the distance traveled for each unit of height lost. In a steady wings-level glide with no wind, glide slope is the same as the lift/drag ratio (L/D) of the glider, called "L-over-D". Reducing lift from the wings and/or increasing drag will reduce the L/D allowing the glider to descend at a steeper angle with no increase in airspeed. Simply pointing the nose downwards only converts altitude into a higher airspeed with a minimal initial reduction in total energy. Gliders, because of their long low wings, create a high ground effect which can significantly increase the glide angle and make it difficult bring the glider to Earth in a short distance.

- Side Slipping - A slip is performed by crossing the controls (rudder to right with ailerons to left, for example) so that the glider is no longer flying aligned with the air flow. This will present one side of the fuselage to the air-flow significantly increased drag. Early gliders primarily used slipping for glide slope control.

- Spoilers - Spoilers are movable control surfaces in the top of the wing, usually located mid-chord or near the spar which are raised into the air-flow to eliminate (spoil) the lift from the wing area behind the spoiler, disrupting the spanwise distribution of lift and increasing lift-induced drag. Spoilers significantly increase drag and serve as air brakes.

- Air brakes - Air brakes, also known as dive brakes, are devices whose primary purpose is to increase drag. On gliders, the spoilers act as air brakes. They are positioned on top of the wing and, on some types, below the wing also. When slightly opened the upper brakes will spoil the lift, but when fully opened will present a large surface and so can provide significant drag. Some older gliders have *terminal velocity dive brakes*, which provide enough drag to keep its speed below maximum permitted speed, even if the glider were pointing straight down. This capability is considered a safer way to descend without instruments through cloud (or to descend vertically in confined terrain), than the only alternative, an intentional spin.

- Flaps - Flaps are movable surfaces on the trailing edge of the wing. The primary purpose of flaps is to change the camber of the wing and so change the lift-to-drag ratio of the wing. This reduces the stall speed and so allows reduced landing speeds. It was possible to lower the flaps on some older gliders by up to 90 degrees to increase drag significantly as well as increasing lift coefficient when landing. Another feature that flapped gliders possess are *negative flaps* that are also able to deflect the trailing edge upward. This feature is included on some competition sailplanes in order to reduce the pitching moment on the wing and allowing better glide ratios at higher speeds (a particularly desirable characteristic for racing sailplanes).

- Parachute - Some high performance gliders from the 1960s and 1970s were designed to carry a small drogue parachute because their air brakes are not particularly effective. This is stored in the tail-cone of the glider during flight. When deployed, a parachute causes a large increase in drag, but has a significant disadvantage over the other methods of controlling the glide slope. This is because a parachute does not allow the pilot to finely adjust the glide slope. Consequently a pilot may have to jettison the parachute entirely, if the glider is not going to reach the desired landing area.

Landing

A typical training glider, Schleicher ASK 21 just before landing

Early glider designs used skids for landing, but modern types generally land on wheels. Some of the earliest gliders used a dolly with wheels for taking off and the dolly was jettisoned as the glider left the ground, leaving just the skid for landing. A glider may be designed so the center of gravity (CG) is behind the main wheel so the glider sits nose high on the ground. Other designs may have the CG forward of the main wheel so the nose rests on a nose-wheel or skid when stopped. Skids are now mainly used only on training gliders such as the Schweizer SGS 2-33. Skids are around 100mm (3 inches) wide by 900mm (3 feet) long and run from the nose to the main wheel. Skids help with braking after landing by allowing the pilot to put forward pressure on the control stick, thus creating friction between the skid and the ground. The wing tips also have small skids or wheels to protect the wing tips from ground contact.

In most high performance gliders the undercarriage can be raised to reduce drag in flight and lowered for landing. Wheel brakes are provided to allow stopping once on the ground. These may be engaged by fully extending the spoilers/air-brakes or by using a separate control. Although there is only a single main wheel, the glider's wing can be kept level by using the flight controls until it is almost stationary.

Pilots usually land back at the airfield from which they took off, but a landing is possible in any flat field about 250 metres long. Ideally, should circumstances permit, a glider would fly a standard pattern, or circuit, in preparation for landing, typically starting at a height of 300 metres (1,000 feet). Glide slope control devices are then used to adjust the height to assure landing at the desired point. The ideal landing pattern positions the glider on final approach so that a deployment of 30-60% of the spoilers/dive brakes/flaps brings it to the desired touchdown point. In this way the pilot has the option of opening or closing the spoilers/air-brakes to extend or steepen the descent to reach the touchdown point. This gives the pilot wide safety margins should unexpected events occur.

Instrumentation and other technical aids

Schempp-Hirth Janus-C in flight, showing instrument panel configured in the basic-T, with airspeed, turn and bank and altitude displays across the top row; below a GPS-driven computer, with wind and glide information, drives two electronic variometer displays to the right. The yaw string and compass are above the glare shield

In addition to an altimeter, compass, and an airspeed indicator, gliders are often equipped with a variometer, turn and bank indicator and an airband radio (transceiver), each of which may be required in some countries. An Emergency Position-Indicating Radio Beacon (ELT) may also be fitted into the glider to reduce search and rescue time in case of an accident.

Much more than in other types of aviation, glider pilots depend on the variometer, which is a very sensitive vertical speed indicator, to measure the climb or sink rate of the plane. This enables the pilot to detect minute changes caused when the glider enters rising or sinking air masses. Both mechanical and electronic 'varios' are usually fitted to a glider. The electronic variometers produce a modulated sound of varying amplitude and frequency depending on the strength of the lift or sink, so that the pilot can concentrate on centering a thermal, watching for other traffic, on navigation, and weather conditions. Rising air is announced to the pilot as a rising tone, with increasing pitch as the lift increases. Conversely, descending air is announced with a lowering tone, which advises the pilot to escape the sink area as soon as possible. (Refer to the *variometer* article for more information).

Gliders' variometers are sometimes fitted with mechanical devices such as a "MacCready Ring" to indicate the optimal speed to fly for given conditions. These devices are based on the mathematical theory attributed to Paul MacCready though it was first described by Wolfgang Späte in 1938. MacCready theory solves the problem of how fast a pilot should cruise 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. Electronic variometers make the same calculations automatically, after allowing for factors such as the glider's theoretical performance, water ballast, headwinds/tailwinds and insects on the leading edges of the wings.

Soaring flight computers, often used in combination with PDAs running specialized soaring software, have been designed for use in gliders. Using GPS technology in conjunction with a barometric device these tools can:

- Provide the glider's position in 3 dimensions by a moving map display
- Alert the pilot to nearby airspace restrictions
- Indicate position along track and remaining distance and course direction
- Show airports within theoretical gliding distance
- Determine wind direction and speed at current altitude
- Show historical lift information
- Create a GPS log of the flight to provide proof for contests and gliding badges
- Provide "final" glide information (i.e. showing if the glider can reach the finish without additional lift).
- Indicate the best speed to fly under current conditions

After the flight the GPS data may be replayed on computer software for analysis and to follow the trace of one or more gliders against a backdrop of a map, an aerial photograph or the airspace.

Because collision with other gliders is a risk, the anti-collision device FLARM is becoming increasingly common in Europe and Australia. In the longer term, gliders may eventually be required in some European countries to fit transponders once devices with low power requirements become available.

Swift S-1 of the UK Swift Aerobatic Display Team at Kemble 2009

Markings

To distinguish gliders in flight, very large numbers/letters are sometimes displayed on the fin and wings. Registrations on narrow fuselages are difficult to read. These numbers were first added for use by ground-based observers in competitions, and are therefore known as "competition numbers" or "contest IDs". They are unrelated to the glider's registration number, and are assigned by national gliding associations. They are useful in radio communications between gliders, so glider pilots often use their competition number as their call-signs.

Fibreglass gliders are white in color after manufacture. Since fibreglass resin softens at high temperatures, white is used almost universally to reduce temperature rise due to solar heating. Color is not used except for a few small bright patches on the wing tips; these patches (typically bright red) improve gliders' visibility to other aircraft while in flight (and are a requirement for mountain flying in France). Non-fibreglass gliders (those made of aluminum and wood) are not subject to the temperature-weakening problem of fibreglass, and can be painted any color at the owner's choosing; they are often quite brightly painted.

Comparison of gliders with hang gliders and paragliders

There is sometimes confusion about gliders, hang gliders and paragliders. In particular paragliders and hang gliders are both foot-launched. The main differences between the types are:

	Paragliders	**Hang gliders**	**Gliders/Sailplanes**
Undercarriage:	Pilot's legs used for take-off and landing	Pilot's legs used for take-off and landing	Aircraft takes off and lands using a wheeled undercarriage or skids
Wing structure:	entirely flexible, with shape maintained purely by the pressure of air flowing into the wing in flight and the tension of the lines. prone to collapse in turbulence.	generally flexible but supported on a rigid frame which determines its shape and thus does not collapse in turbulence, but note that rigid wing hang gliders also exist	rigid surface to wings that totally encases structure
Pilot position:	sitting ‘supine’ in a seated harness.	usually lying ‘prone’ in a cocoon-like harness suspended from the wing. Seated, and 'supine' are also possible.	sitting in a seat with a harness surrounded by a crash-resistant structure.
Speed range (stall speed – max speed):	slower – hence easier to launch and fly in light winds, can get into trouble when winds pick up, poor wind penetration and no pitch control, cannot dive for speed, although some pitch variation can be achieved with speed bar.	faster – much faster, up to 145 km/h (90+ mph), hence easier to launch and fly in stronger conditions with better wind penetration, and can outrun bad weather, full pitch control	even faster - maximum speed up to about 280 km/h (170 mph); stall speed typically 65 km/h (40mph). Able to fly in windier turbulent conditions and can outrun bad weather. Exceptional penetration into the wind. Semi- or fully aerobatic.
Maximum glide ratio:	about 12, relatively poor glide performance makes long-distances more difficult. The current world record is just	about 17 for flexible wings, though up to 20 for rigid wings. Glide performance enables longer-	Open class sailplanes typically around 60:1 but in more common 15-18 meter span aircraft, glide ratios are between 38:1 and 52:1. , high glide performance

	above 500km (310 miles)	distance flying, 700km (430+ mile) record	enabling long distances, 3000km (1800+ mile record)
Turn radius:	tighter turn radius, allowing circling in the rapidly rising center of thermals	somewhat larger turn radius, not allowing such a high rate of climb in thermals	even greater turn radius but still able to circle tightly in thermals
Landing-out:	smaller space needed to land, offering more landing options from cross-country flights. Also easier to carry back to the nearest road	longer approach & landing area required, but can reach more landing areas due superior glide range	can land in less than 200 metres and can often reach another airfield. Specialised trailer needed to retrieve by road
Learning:			teaching is done in a two seat glider with dual controls
Convenience:	pack smaller (easier to transport and store); lighter (easier to carry); quicker to rig & de-rig; transported in the trunk of a car	more awkward to transport & store; longer to rig and de-rig; transported on the roof of a car	trailers are typically 10 m (30 ft) long. Rigging & de-rigging takes about 20 minutes
Cost:			Cost of new gliders very high but long lasting (several decades), so active second hand market typically from €2000 to €145,000 . Often shared ownership

Competition classes of glider

DG Flugzeugbau DG-1000 of the Two Seater Class

Eight competition classes of glider have been defined by the FAI. They are:

- Standard Class (No flaps, 15 m wing-span, water ballast allowed)
- 15 metre Class (Flaps allowed, 15 m wing-span, water ballast allowed)
- 18 metre Class (Flaps allowed, 18 m wing-span, water ballast allowed)
- Open Class (No restrictions except a limit of 850 kg for the maximum all-up weight)
- Two Seater Class (maximum wing-span of 20 m), also known by the German name "Doppelsitzer"
- 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 FAI 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 glider, 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 to be run with only one type of glider.
- Ultralight Class, for gliders with a maximum mass less than 220 kg.

Major manufacturers of gliders

The full list of gliders and manufacturers, past and present, shows that a large proportion have been and are still made in Germany, the birthplace of the sport. The principal German manufacturers are:

- DG Flugzeugbau GmbH
- Schempp-Hirth GmbH
- Alexander Schleicher GmbH & Co

though there are other specialist manufacturers in Germany, Poland and in other eastern European countries.

Chapter- 7

Aerobatics

The UK Utterly Butterly display team perform an aerobatic maneuver with their Boeing Stearmans

Red Arrows BAE Hawks in Apollo formation. (2010).

Patrouille de France producing colored smoke during an air show

Aerobatics is the practice of flying maneuvers involving aircraft attitudes that are not used in normal flight. Aerobatics are performed in airplanes and gliders for training, recreation, entertainment and sport. Some helicopters, such as the MBB Bo 105, are capable of limited aerobatic maneuvers.

Most aerobatic maneuvers involve rotation of the aircraft about its longitudinal (roll) axis or lateral (pitch) axis. Other maneuvers, such as a spin, displace the aircraft about its vertical (yaw) axis. Maneuvers are often combined to form a complete aerobatic sequence for entertainment or competition.

Aerobatic flying requires a broader set of piloting skills and exposes the aircraft to greater structural stress than for normal flight. In some countries, the pilot must wear a parachute when performing aerobatics.

While many pilots fly aerobatics for recreation, some choose to fly in aerobatic competitions, a judged sport.

Overview

In the early days of flying, some pilots used their aircraft as part of a flying circus to entertain. Maneuvers 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 dogfights between fighter aircraft.

Aerobatic aircraft 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, such as the Cessna 152 Aerobat model, can be dual purpose—equipped to carrying passengers and luggage, as well as being capable of basic aerobatic figures.

Flight formation aerobatics are flown by teams of up to sixteen aircraft, although most teams 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.

Teams often fly V-formations (otherwise known as echelon formation)— they will not fly directly behind another aircraft because of danger from wake vortices or engine exhaust. Aircraft will always fly slightly below the aircraft in front, if they have to follow in line (the "trail formation").

The UK Swift Aerobatic Display Team at Kemble Battle of Britain Weekend 2009. A Swift glider is performing continuous full rolls while towed by a Piper Pawnee

Aerobatic maneuvers flown in a jet powered aircraft are limited in scope as they cannot take advantage of the gyroscopic forces that a propeller 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.

To enhance the effect of aerobatic maneuveres smoke is sometimes generated; the smoke allows viewers to see the path travelled by the aircraft. Due to safety concerns, the smoke is not a result of combustion but is produced by the vaporization of fog oil into a fine aerosol, achieved either by injecting the oil into the hot engine exhaust or by the use of a dedicated device that can be fitted in any position on the aircraft. The first military aerobatic team to use smoke at will during displays was Fleet Air Arm 702 Squadron "The Black Cats" at the Farnborough Air show in September 1957.

Training

Aerobatics are taught to military fighter pilots as a means of developing flying skills and for tactical use in combat. Aerobatics and formation flying is not limited solely to fixed wing aircraft, helicopters are also used—the British Army, Royal Navy, Spanish Air Force and the Indian Air Force, among others, have helicopter display teams. All aerobatic maneuvers demand training and practice to avoid accidents. 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.

There are aerobatic training schools in the U.S. and other countries.

Patty Wagstaff show at JeffCo Airport

"Blue Impulse" (JASDF)

Competition

Competitions start at Primary, or Graduate level and proceed in complexity through Sportsman, Intermediate and Advanced, with Unlimited being the top competition level. Experienced aerobatic pilots have been measured to pull +/-5g for short periods while unlimited pilots can perform more extreme maneuvers and experience higher g levels - possibly up to +8/-6g. The limits for positive g are higher than for negative g and this is due to the ability to limit blood pooling for positive g maneuvers, but it is generally accepted that +9 g for more than a few seconds will lead to loss of consciousness (also known as GLOC).

Performance

The Australian Roulettes

Aerobatics are most likely to be seen at a public airshows. Famous teams include:

- Asas de Portugal (Portuguese Air Force)
- August 1st (People's Liberation Army Air Force)
- Black Cats (Royal Navy Fleet Air Arm - United Kingdom)
- Black Eagle (Republic of Korea Air Force)
- Black Knights (Republic of Singapore Air Force)
- Blue Angels (United States Navy)
- Blue Diamonds (Philippine Air Force)
- Blue Eagles (Army Air Corps—United Kingdom)
- Blue Impulse (Japan Air Self-Defense Force)
- Breitling Jet Team (private (Breitling))
- Cartouche doré (French Air Force)
- Cruz del Sur ("Southern Cross"—Argentine Air Force)
- Diables Rouges (Belgian Air Force)
- Elang Biru (Indonesian Air Force)
- Esquadrilha da Fumaça (Smoke Squadron - Brazilian Air Force)
- Frecce Tricolori (Italian Air Force)
- Halcones (Falcons-Chilean Air Force)
- Hungarian Sky Hussars (Imitated Dogfight with MIG-21 bis - Hungarian Air Force)

- Green Hawk (Bureau of Royal Rainmaking and Agricultural Aviation, Thailand)
- Midnight Hawks (Finnish Air Force)
- Orlik Aerobatic Team, White-Red Sparks (known also as Team Iskry), Scorpion (aerobatic team) (Polish Air Forces)
- Patrouille de France (French Air Force)
- Patrouille Suisse (Swiss Air Force)
- Patrulla Aguila, Patrulla Aspa (Eagle Patrol; Blade Patrol—Spanish Air Force)
- Red Arrows (Royal Air Force—United Kingdom)
- Red Checkers (Royal New Zealand Air Force)
- Red Pelicans, Rothmans, Silver Falcons (South African Air Force)
- Rotores de Portugal (Portuguese Air Force—Helicopters)
- Roulettes (Royal Australian Air Force)
- Royal Jordanian Falcons (Royal Jordanian Air Force)
- Russian Knights, Strizhi (Swifts), Rus (Russian Air Force)
- Sagar Pawan (Indian Navy)
- Sanmueang (Royal Thai Air Force)
- Sarang (Indian Air Force)
- Saudi Hawks, (Royal Saudi Air Force)
- Sherdils (Pakistan Air Force)
- Silver Falcons (South African Air Force)
- Silver Swallows Irish Air Corps
- Snowbirds (Canadian Forces)
- Surya Kiran (Indian Air Force)
- Team Jupiter (Indonesian Air Force)
- Team 60 (Swedish Air Force)
- Team RV Formation Demontration Team
- The Flying Bulls (civilian, Austria)
- Thunder Tiger (Republic of China Air Force)
- Thunderbirds (United States Air Force)
- Turkish Stars (Türk Yıldızları) (Turkish Air Force)
- Ukrainian Falcons (Ukrainian Air Force)
- Wings of Storm (Croatian Air Force)

Former teams

Stunt flyer flying low in a Curtiss Pusher plane, California, circa 1927

Martin B-57B-MA Serial 52-1560 of the 71st Light Bomber Squadron - 1957. This aircraft was also one of the "Black Knights" aerial acrobatic team. After its withdrawal from France in 1958, this aircraft was eventually assigned to the 8th Tactical Bomb Squadron at Phan Rang Air Base South Vietnam and flew combat bombing missions into the late 1960s.

- Akrobatika (a particular Squadron from Ubatuba, São Paulo, Brazil)

- Yellowjacks (UK, RAF)
- Black Arrows (No. 111 Squadron RAF, 1950s)
- Blue Herons (UK, Royal Navy, FRADU)
- Simon's Sircus (UK, Royal Navy, Fleet Air Arm)
- Fred's Five (UK, Royal Navy, 892 Naval Air Squadron)
- The Sharks (UK, Royal Navy, 705 Naval Air Squadron)
- Blue Diamonds (No. 92 Squadron RAF)
- The Tigers (No. 74 Squadron RAF)
- The Firebirds (No. 56 Squadron RAF)
- The Red Pelicans (UK, RAF)
- The Red Knight (Royal Canadian Air Force)
- Golden Hawks (Royal Canadian Air Force)
- Golden Centennaires (Royal Canadian Air Force)
- Acrojets (USAF Fighter School at Williams Air Force Base, Arizona 1949-1950)
- Acrojets (USAFE at Fürstenfeldbruck AB, Germany in the mid-1950s)
- Skyblazers (USAFE at Fürstenfeldbruck AB, Germany from late 1940s to 1962)
- The Black Knights (38th Tactical Bombardment Wing, USAFE, 1950s)
- Flying Jokers (Squadron 332, Royal Norwegian Air Force)
- Golden Sabres (Philippine Air Force)
- *Silver Birds* (Austrian Armed Forces)
- Karo Ass (Diamonds Ace) (1975-1984 - Austrian Armed Forces)
- *Cavallino Rampante* (Prancing Horse) (1950-52 and 1956-57 - Italian Air Force)
- *Getti Tonanti* (Thundering Jets) (1953-55 and 1959-60 - Italian Air Force)
- *Tigri Bianche* (White Tigers) (1955-56 - Italian Air Force)
- *Diavoli Rossi* (Red Devils) (1957-59 - Italian Air Force)
- *Lancieri Neri* (Black Lancers) (1960- Italian Air Force)
- *Taj-Talaee* (Golden Crown) (1955-1979 -Imperial Iranian Air Force)

Chapter- 8

Ultralight Aviation

Huntair Pathfinder Mark 1 ultralight.

The term "**ultralight aviation**" refers to light-weight, 1- or 2-person airplanes. During the late 1970s and early 1980s, many people sought to fly affordably. As a result, many aviation authorities set up definitions of lightweight, slow-flying aeroplanes that could be subject to minimum regulation. The resulting aeroplanes are commonly called **ultralight** or **microlight**, although the weight and speed limits differ from country to country.

There is also an allowance of another 10% on Maximum Take Off Weight for seaplanes and amphibians, and some countries (such as Germany and France) also allow another 5% for installation of a ballistic parachute.

The safety regulations used to approve microlights vary between countries, the strictest being in the United Kingdom, Italy, Sweden and Germany, while they are almost non-existent in France and the United States. The disparity between regulations can be a barrier to international trade and overflight in strict regions, as is the fact that these regulations are invariably sub-ICAO, which means that they are not internationally recognised.

In most affluent countries, microlights or ultralights now account for a significant portion of the civil aircraft fleet. For instance in Canada in October 2010, the ultralight fleet made up 19% of the total civil aircraft registered. In other countries that do not register ultralights, like the United States, it is unknown what proportion of the total fleet they make up.

In countries where there is no specific extra regulation, ultralights are considered regular aircraft and subject to certification requirements for both aircraft and pilot.

Ultralight aircraft are generally called *microlight aircraft* in the UK, India and New Zealand, and *ULMs* in France and Italy. Some countries differentiate between weight shift and 3-axis aircraft, calling the former *microlight* and the latter *ultralight*.

The U.S. light-sport aircraft is similar to the UK and NZ *Microlight* in definition and licensing requirement, the U.S. 'Ultralight' being in a class of its own.

Definitions

Pegasus Quantum 145-912 ultralight trike

Flight Design CTSW

A powered paraglider

A US-made Pterodactyl Ascender ultralight on a camping flight

Canadian Lazair ultralight covered in clear Mylar

Aeroprakt A-22 Foxbat 3-axis ultralight

Ikarus C42, a German ultralight

A weight-shift ultralight, the Air Creation Tanarg

Phantom – MKI

FM250 Vampire

K-10 Swift - MKI

Quicksilver MXII

A foot-launched powered hang glider

Weight Shift Ultralight ("Trike")

P and M Aviation Quik GT450 ultralight

Pipistrel Sinus 912

Rans S-6 Coyote II, classified as an ultralight aircraft in Belgium

Australian Ultralight Industries Bunyip, 3-axis ultralight

Australia

In Australia Recreational Aircraft fall under many categories, but the most common category imposes:

- a maximum take off weight (MTOW) of 544 kg (1,199 lb) or less (614 kg (1,354 lb) for a seaplane);
- a stalling speed under 45 knots in landing configuration and
- a maximum of two seats.

A new certification category for Light Sport Aircraft came into effect on 7 January 2006. This category does not replace the previous categories, but creates a new category with the following characteristics:

- A maximum takeoff weight of 600 kg (1,323 lb) or 650 kg (1,433 lb) for an aircraft intended and configured for operation on water or 560 kg (1,235 lb) for a lighter-than-air aircraft.
- A maximum stall speed in the landing configuration (Vso) of 45 kn (83 km/h) CAS.
- Maximum of two occupants, including the pilot.

- A fixed landing gear. A glider may have retractable landing gear. (For an aircraft intended for operation on water, a fixed or repositionable landing gear)
- A single, non-turbine engine fitted with a propeller.
- A non-pressurised cabin.
- If the aircraft is a glider a maximum never exceed speed (Vne) of 135 kn (250 km/h) CAS

In either of the above categories, there are distinctions between factory manufactured and home built aircraft.

In Australia, microlight aircraft are defined as one or two seat weight-shift aircraft, with a maximum takeoff weight of 450 kg (992 lb), as set out by the Civil Aviation Safety Authority. In Australia microlights are also referred to as trikes and are distinguished from three-axis aircraft, of which the smallest are known as ultralights.

In Australia, microlight aircraft and their pilots can either be registered with the Hang Gliding Federation of Australia (HGFA) or Recreational Aviation Australia (RA Aus). In all cases, except for privately built single-place ultralight aeroplanes, microlight aircraft or trikes are regulated by the Civil Aviation Regulations.

Brazil

The Brazilian Aviation Regulation (RBHA 103A) defines an ultralight plane as: a very light manned experimental aircraft used mainly, or intended for, sports or recreation, during daylight, in visual conditions, with a maximum capacity of 2 people and with the following characteristics:

- Single internal combustion engine and one propeller;
- Maximum take-off weight equal or less than 750 kg (1,653 lb); and
- Calibrated stall speed (CAS), power off, in landing configuration (Vso) equal or less than 45 kn (83 km/h).

Canada

The Canadian Aviation Regulations define two types of ultralight aeroplanes: basic ultra-light aeroplanes (BULA), and advanced ultra-light aeroplanes (AULA). The US light sport aircraft is similar to, and was based upon, the Canadian AULA. AULAs may operate at a controlled airport without prior arrangement. Operating either class of ultralight in Canada requires an Ultralight Pilot Permit which requires both ground school, dual and solo supervised flights. The ultralight may be operated from land or water, but may only carry a passenger if the pilot has an Ultralight Aeroplane Passenger Carrying Rating and the aircraft is an AULA.

Europe

The definition of a microlight according to the Joint Aviation Authorities document JAR-1 is an aeroplane having no more than two seats, maximum stall speed (V_{S0}) of 35 knots (65 km/h) CAS, and a maximum take-off mass of no more than:

- 300 kg (661 lb) for a landplane, single seater; or
- 450 kg (992 lb) for a landplane, two-seater; or
- 330 kg (728 lb) for an amphibian or floatplane, single seater; or
- 495 kg (1,091 lb) for an amphibian or floatplane, two-seater, provided that a microlight capable of operating as both a floatplane and a landplane falls below both MTOM limits, as appropriate.

India

In India a microlight is an aircraft that has the following characteristics:

- two seater aircraft having an all up weight of not more than 450 kg (992 lb) without parachute and 472 kg (1,041 lb) with parachute
- a stall speed of less than 80 km/h (43 kn)
- a maximum level speed of less than 220 km/h (119 kn)
- 1 or 2 seats
- a single engine, reciprocating, rotary or diesel
- a fixed or ground adjustable propeller
- un-pressurized cabin
- wing area more than 10 square metres
- a fixed landing gear, except for operation on water or as a glider

Indian ultralights require aircraft registration, periodic condition inspections and a current permit to fly which has to be renewed annually.

Italy

In Italy, the category for this class of aircraft is Microlight.

- Requires flying with a helmet.
- Maximum weight requirements excludes seat belts, parachute and instruments.
- Single-seat maximum weight of 300 kg (661 lb), and 330 kg (728 lb) for amphibious, stall speed must not exceed 65 km/h (35 kn).
- Two-seat maximum weight of 450 kg (992 lb), and 500 kg (1,102 lb) for amphibious, stall speed must not exceed 65 km/h (35 kn). Aircraft may be used for instruction or flown by pilots with a valid private license, and at least 30 hours flight time.
- Intended for use at private fields. Use at civil airports requires prior permission.
- Airspace restrictions - Must remain within the territory of the state (the flight limit of 4 km (2.2 nmi) from the border of another state was abolished by the law 24

April 1998, n. 128 "Disposizioni per l'adempimento di obblighi derivanti dall'appartenenza dell'Italia alle Comunità Europee" - communitary law 1995/97- art.22 comma 20-, published on the Gazzetta Ufficiale n.88/L of May 7, 1998). It is forbidden to fly over cities.

- All aircraft must have a metal plate with the identification number issued by the AeCI (Aero Club Italia). The same number must be fixed onto the underneath of the wing with letters that measure a minimum of 30×15 cm (12 X 6 inches), in contrasting colour.
- From dawn till sunset, flight must be below 500 ft (152 m)
- On Saturday and holidays flight must be below 1,000 ft (305 m) with 5 km (2.7 nmi) separation from airports not located within ATZ .
- Microlight operation requires a certificate exam, insurance and a medical examination.

New Zealand

In New Zealand microlight aircraft are separated into two classes, basically single and two seat aircraft. All microlights are required to have a prescribed endurance testing period when they are first flown, and all microlights must have a minimum set of instrumentation to show airspeed (except powered parachutes), altitude and magnetic heading.

NZ Class 1

Single seat aircraft with a design gross weight of 544 kg (1,199 lb) (landplanes) or 579 kg (1,276 lb) (seaplanes or amphibians), or less, and a stall speed in the landing configuration of 45 knots (83 km/h) or less. Requires aircraft registration, and annual condition inspections, but does not require a permit to fly.

NZ Class 2

Two seat aircraft with a design gross weight of 544 kg (1,199 lb) (landplanes) or 614 kg (1,354 lb) (seaplanes or amphibians), or less, and a stall speed of 45 knots (83 km/h) or less in the landing configuration. Must meet minimum type acceptance standards which may be foreign standards which have been deemed acceptable, or via a temporary permit to fly and flight testing regime. Requires aircraft registration, annual condition inspections, and a current permit to fly.

Philippines

The Civil Aviation Regulations define "non-type certified aircraft", under which ultralights and microlights fall, as:

An aircraft that does not possess an aircraft type certificate issued by any country/state. It is, of simple design and constriction, either a homebuilt or a kit built variety and for recreational and sport use, day VFR condition only.

A class of non-type certificated aircraft is applicable to all classifications, including powered parachutes, gyrocopter, fixed wing aircraft and helicopters.

United Kingdom

The UK regulations describe a microlight aeroplane as limited to two people, with a Maximum Total Weight Authorised (MTWA) not exceeding:

- 300 kg (661 lb) for a single seat landplane.
- 390 kg (860 lb) for a single seat landplane for which a UK Permit to Fly or Certificate of Airworthiness was in force prior to 1 January 2003
- 450 kg (992 lb) for a two seat landplane
- 330 kg (728 lb) for a single seat amphibian or floatplane
- 495 kg (1,091 lb) for a two seat amphibian or floatplane

A microlight must also have either a wing loading at the maximum weight authorised not exceeding 25 kg per square metre or a stalling speed at the maximum weight authorised not exceeding 35 kn (65 km/h) calibrated speed. All UK registered aeroplanes (3-axis or flex-wing) falling within these parameters are Microlight aircraft.

A sub-category of microlights (SSDR) was introduced which allows owners more freedom to modify and experiment with their aircraft. Single Seat De-Regulated microlights must weigh less than 115 kg (254 lb) without fuel and pilot and the wing loading must not be more than 10 kg per sq m. There is no airworthiness requirement or annual inspection regime for SSDR microlights although pilots who fly them must have a normal microlight licence, and must observe the rules of the air.

A license is required to fly a microlight in the UK.

United States

The United States FAA's definition of an ultralight is significantly different from that in most other countries and can lead to some confusion when discussing the topic. The governing regulation in the United States is FAR 103 Ultralight Vehicles, which specifies a powered "ultralight" as a single seat vehicle of less than 5 US gallons (19 L) fuel capacity, empty weight of less than 254 pounds (115 kg), a top speed of 55 knots (102 km/h or 64 mph), and a maximum stall speed not exceeding 24 knots (45 km/h or 27.6 mph). Restrictions include flying only during daylight hours and over unpopulated areas. Unpowered "ultralights" (hang gliders, paragliders, etc.) are limited to a weight of 155 lb (70 kg) with extra weight allowed for amphibious landing gear and ballistic parachute systems.

In 2004 the FAA introduced the "Light-sport aircraft" category, which resembles some other countries' microlight categories.

In the United States no license or training is required by law for ultralights, but training is highly advisable. For light-sport aircraft a sport pilot certificate is required.

Ultralight aviation is represented by the United States Ultralight Association (USUA), which represents the US portion of the sport to the world through its affiliation with the FAI.

Types of aircraft

While ultralight-type planes date back to the early 1900s (such as the Santos-Dumont Demoiselle), there have been three generations of modern, fixed-wing ultralight aircraft designs, which are generally classed by the type of structure.

The first generation of modern ultralights were actually hang gliders with small engines added to them, to create powered hang gliders. The wings on these were flexible, braced by wires, and steered by shifting the pilot's weight under the wing.

The second generation ultralights began to arrive in the mid-1970s. These were designed as powered aircraft, but still used wire bracing and usually single-surface wings. Most of these have "2-Axis" control systems, operated by stick or yoke, which control the elevators (pitch) and the rudder (yaw) -- there are no ailerons, so may be no direct control of banking (roll). A few 2-Axis designs use spoilers on the top of the wings, and pedals for rudder control. Examples of 2-Axis ultralights are the "Pterodactyl" and the "Quicksilver MX".

The third generation ultralights, arriving in the early 1980s, have strut-braced wings and airframe structure. Nearly all use 3-Axis control systems, as used on standard airplanes, and these are the most popular. Third generation designs include the CGS Hawk, Kolb Ultrastar and Quad City Challenger.

There are several types of aircraft which qualify as ultralights, but which do not have fixed-wing designs. These include:

- **Weight-shift control trike** - while the first generation ultralights were also controlled by weight shift, most of the current weight shift ultralights use a hang glider-style wing, below which is suspended a three wheeled carriage which carries the engine and aviators. These aircraft are controlled by pushing against a horizontal control bar in roughly the same way as a hang glider pilot flies. Trikes generally have impressive climb rates and are ideal for rough field operation, but are slower than other types of fixed-wing ultralights.

- **Powered parachutes** - cart mounted engines with parafoil wings, which are wheeled aircraft.

- **Powered paragliding** - backpack engines with parafoil wings, which are foot-launched.

- **Powered hang glider** - motorized foot-launched hang glider harness.

- **Autogyro** - rotary wing with cart mounted engine, a gyrocopter is different from a helicopter in that the rotating wing is not powered, the engine provides forward thrust and the airflow through the rotary blades causes them to *autorotate* or "spin up" to create lift. Most of these use a design based on the Bensen B-8 gyrocopter.

- **Helicopter** - there are a number of single-seat and two-place helicopters which fall under the microlight categories in countries such as New Zealand. However, few helicopter designs fall within the more restrictive ultralight category defined in the United States of America. One example that does is the experimental Martin Jetpack.

- **Hot air balloon** - there are numerous ultralight hot air balloons in the US, and several more have been built and flown in France and Australia in recent years. Some ultralight hot air balloons are hopper balloons, while others are regular hot air balloons that carry passengers in a basket.

Electric powered ultralights

Research has been conducted in recent years to replace gasoline engines in ultralights with electric motors powered by batteries to produce electric aircraft. This has now resulted in practical production electric power systems for some ultralight applications. These developments have been motivated by cost as well as environmental concerns. In many ways ultralights are a good application for electric power as some models are capable of flying with low power, which allows longer duration flights on battery power.

In 2007 ElectraFlyer began offering engine kits to convert ultralight weight shift trikes to electric power. The 18 hp motor weighs 26 lb (12 kg) and an efficiency of 90% is claimed by designer Randall Fishman. The battery consists of a lithium-polymer battery pack of 5.6kwh which provides 1.5 hours of flying in the trike application. The power system for a trike costs USD $8285. to $11285. The company claims a flight recharge cost of 60 cents.

Safety

Historically, ultralights have had a poor safety reputation. Most of the early designs were fragile or unstable, and this resulted in a number of accidents.

As designs matured, pilot error was shown to be the cause of the vast majority of incidents involving ultralights. As a result, most countries now require an Ultralight Pilot's license/certificate, often regulated by one or more officially-delegated pilots' organizations. The United States does not require any training for ultralight pilots; however, experienced ultralighters are nearly unanimous in recommending that no one solo before receiving dual training. Instruction may be given in two-place light-sport versions of the ultralight. An instructor must be certified by the FAA to give dual instruction in a light-sport aircraft.

The build quality and airworthiness of ultralight aircraft (and homebuilt light-sport aircraft in the USA) can now equal that of Certified light aircraft. Some types satisfy both sets of requirements and are available for registration to either Ultralight or Certified status. When registered as an ultralight (or Experimental), the pilot is permitted to do more of the simple maintenance tasks, resulting in a lower cost of operation, although this comes at the cost of restrictions such as avoiding densely populated urban areas, bad weather, or night. Many older pilots are willing to trade these operational restrictions for a lower drain on their retirement incomes, and as a result many ultralights are now flown by experienced General Aviation (GA) pilots or ex-commercial pilots. One other reason for this increase in acceptance is that any pilot is "only one medical away from being an ultralight pilot" -- a reference to the requirement that most other pilots must pass periodic physical examinations, but not to fly ultralights.

The future

Ultralight/microlight aircraft were once regarded as "flying clotheslines", since early aircraft were typically completely open, wire, tube and rag aircraft – these aircraft were seldom used for anything more than local area flying.

However, ultralights are rapidly transforming into high performance aircraft, capable of very respectable speed and range. In recent years there has been a dramatic rise in the number of General Aviation pilots flying high performance ultralights due to the cost benefits.

These aircraft are now often referred to as recreational aircraft.

A rapidly growing area of the class is scale-replica "warbirds", such as the offerings from Titan Aircraft and Loehle Aircraft.

Chapter- 9

Ultralight Trike

An **ultralight trike**, also known as a **flex-wing trike**, **weight-shift control aircraft**, **microlight trike** or **Motorized Deltaplane**, is a type of powered hang glider using a high performance Rogallo wing coupled to a propeller-powered three-wheeled undercarriage. While most powered aircraft have three-wheeled landing gear, the term "trike" refers specifically to the form of aircraft described here. The principles of this page can generally be applied to the single place ultralight trike and the two place weight-shift control light-sport aircraft.

Trike in the Top End of the Northern Territory in Australia

Control

Flight control in a trike is by weight-shift . This is similar to controlling a hang glider, in which the aviator or pilot is suspended from the wing made from high-strength aluminium and fabric. The pilot controls the attitude of the wing by holding onto and operating a triangular control bar (or triangular control frame) (TCF) that is rigidly attached to the wing. Pushing, pulling, and turning the TCF causes a corresponding shift in the aircraft's center of gravity.

For instance, pushing the TCF's basebar forward causes the center of gravity to shift back. This, in turn, causes the nose of the aircraft to pitch up, causing the angle of attack to increase which causes the aircraft to fly more slowly. In contrast, pushing forward on the control stick of a traditional aircraft would cause that aircraft to dive.

Detail of a Mainair Blade ultralight trike (in 2009)

Turns are accomplished by rolling the wing in the direction of the intended turn. This is accomplished by moving the control bar to the left in order to enter a right hand turn. This causes the center of gravity--represented primarily by the weight of the undercarriage and pilot--to shift in the direction of the intended turn. This in itself does not cause the aircraft to turn, but it does cause the aircraft to bank, or tip, to the side. Some adverse yaw is also initially produced, which is soon damped by the natural yaw stability of the wing.

A banking maneuver becomes a turn because of the natural yaw stability of the wing. When a roll is applied, the aircraft begins to side slip towards the lower wing. Since the wing is yaw stable, a yaw is set up in the direction of the bank, thus coordinating the turn. A small anhedral effect may be built into the wing to aid roll response, where the side slip causes increased banking.

This is similar to the way in which a hang glider is controlled. In fact, trikes are essentially propeller-powered hang gliders with seats and wheels. Trikes have often employed wings designed for hang gliding; the Rogallo-winged trike Paresev 1B of NASA's 1960s experiments and Barry Hill Palmer's trike (Fleep inspired) modeled the wing that has evolved to contemporary trike wings. As weight and performance goals have increased purpose-built wings have become more commonplace. They are now long distance cross country machines as shown by record-breaking flights that echo the exploits of fixed-wing aviators in the 1920s and 1930s, e.g., the circumnavigation of the world.

Stability and equilibrium

Varadero, Cuba.

Because trikes are most often used for recreational flying by part time pilots, a premium is placed on gentle behavior especially at the stall, natural pitch stability, and ease-of-operation.

Unlike a traditional aircraft with an extended fuselage and empennage for maintaining stability, trikes rely on the natural stability of their wings to return to equilibrium in yaw and pitch. Roll stability is generally set up to be near neutral. In calm air, a properly designed wing will maintain balanced trimmed flight though a slow spiral may build up in either direction.

In roll most trikes are set up with near-neutral roll due to side slip (some slightly negative, some slightly positive) and also near neutral spiral stability, often mildly unstable. Moderate negative roll due to side slip (anhedral effect) can be built in to improve roll response by weight shift.

The yaw axis, which represents the direction that the aircraft is facing relative to the wind, is stabilized through the sweep of the wings. Instead of having wings that extend almost straight out side-to-side as in many types of traditional light aircraft, trikes are provided with a swept back wing planform. The swept planform, when yawed out of the relative wind, creates more lift on the advancing wing and also more drag. The differential drag stabilizes the wing in yaw. The differential lift causes positive roll due to sideslip like dihedral would. Too much dihedral effect is undesirable because it opposes weight shift roll response; the aircraft will be too stable and won't manouever. The lateral and directional stability of the swept wing is proportional to angle of attack - at high speed, yaw and roll instability can become unacceptable, giving dutch roll or wing walking oscillations. This is the primary reason for over sized rear undercarriage spats and wing lets on recent high performance machines.

Thus, if one wing advances ahead of the other it presents more area to the wind and causes more drag on that side. This causes the advancing wing to go slower and to fall back. The wing is at equilibrium when the aircraft is traveling straight and both wings present the same amount of area to the wind.

The third axis, represented by pitch, is also stabilized by the sweep of the wings. A combination of high lift airfoils with moderate pitching moment such as the UI 1720 and washout (tip trailing edge upwards twist) caused by loading of the sail produces a positive pitching tendency in the wing where increasing airspeed causes increasing pitch-up. The wing centre of gravity is close to the trike hang point and is located forward of the mean aerodynamic center of the wing at a distance known as the static margin. Therefore at some speed, called the trim speed, the positive pitching of the wing is balanced by the nose down moment caused by the aircraft weight times the static margin. At the trim speed the wing will fly hands off and return to trim when disturbed. The weight shift control system only works when the wing is positively loaded. A combination of very steep nose-up pitch attitude and very low airspeed is very hazardous because of the probability of a tail slide and violent nose down pitch rotation into an irrecoverable tumble. This is the primary area of the flight envelope trike pilots must always avoid.

Pegasus Quantum 145-912 ultralight trike

When the lift load is removed from the sail the washout disappears and the aircraft would not recover from a vertical dive or may even tuck upside down. To maintain a minimum safe amount of washout when the wing is unloaded or even negatively loaded, positive pitching devices such as reflex lines or washout rods are employed. These systems are normally tested by a truck based aerodynamic test.

There is no "pendulum" wing stabilizing effect of the trike at the trim speed because the trike is freely suspended in the pitch and roll axes. To fly at other speeds, the pilot applies a pitching moment to the wing by levering the trike mass around using the control bar connected directly to the wing. The bar is pushed on to rotate the wing more nose-up and so fly slower, vice-versa for high speed. A properly designed trike will always require increasing pilot force to be applied each side of the trim speed.

The free suspension of the trike means that the center of gravity (CG) position of the trike only affects the trike attitude and control range, not the hands off trim speed. From the pilot's point of view only the load carried has to remain within the aircraft limitations, no complicated CG calculations are required and it is nearly impossible to mis-load the aircraft, adding to the simplicity of operation. One great advantage of weight shift pitch apart from simplicity is that the wing lifting performance is not compromised by up elevon deflection as required for an aerodynamically controlled tailless machine, hence a lower landing speed can be achieved. Additionally, with a pitch stable wing it is also nearly impossible to overspeed the aircraft because it will simply trim in pitch at a limited speed with the bar held fully back.

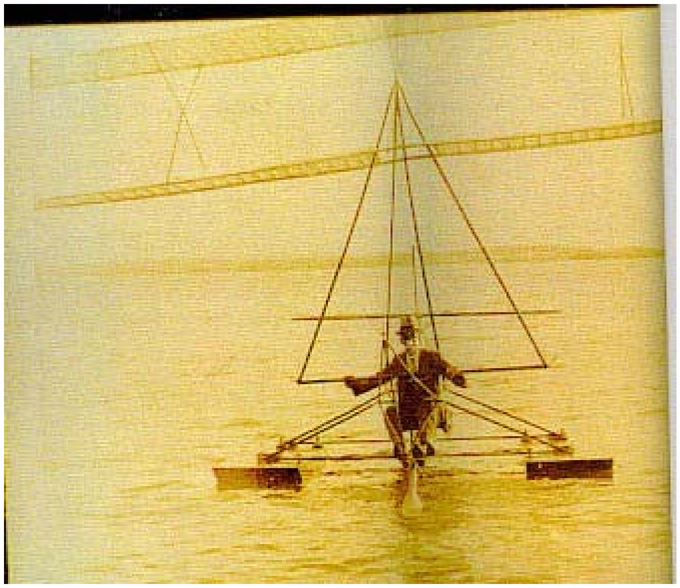
Pitch control response is very direct, but satisfactory weight shift roll response becomes more difficult to achieve as the sail is tightened to improve performance. In the roll axis, the pilot, using the wing control bar and reacting his input by the mass of the trike, applies a rolling moment directly to the wing. The wing is built to flex differentially across the span in response to the pilot applied roll moment. For example, under a right roll input, the right wing trailing edge flexes up more than the left, allowing the right wing to drop. Special features are built in such as a floating keel, four-bar control frame linkage to get a longer effective control frame height, keel pocket - all to ease roll response. Judicious use of anhedral improves roll response by converting the adverse yaw generated by the roll input into a pro-roll bank. Too much anhedral can cause instability in roll at high speeds.

Furthermore, the fact that the wing is designed to bend and flex in the wind provides favorable dynamics analogous to a spring suspension. This allows the wing to be less susceptible to turbulence and provides a gentler flying experience than a similarly sized rigid-winged aircraft.

Engine placement

Because trikes do not require an empennage, the space directly behind the pilot is used to mount the engine and propeller. Engines range from between 25-40 hp for single-seaters and 50-100 hp for two-seaters. An aft engine placement allows exhaust to stay behind the pilot and enhances visibility. It also means that the turbulent vortex of air behind the propeller is not coming in contact with the wing.

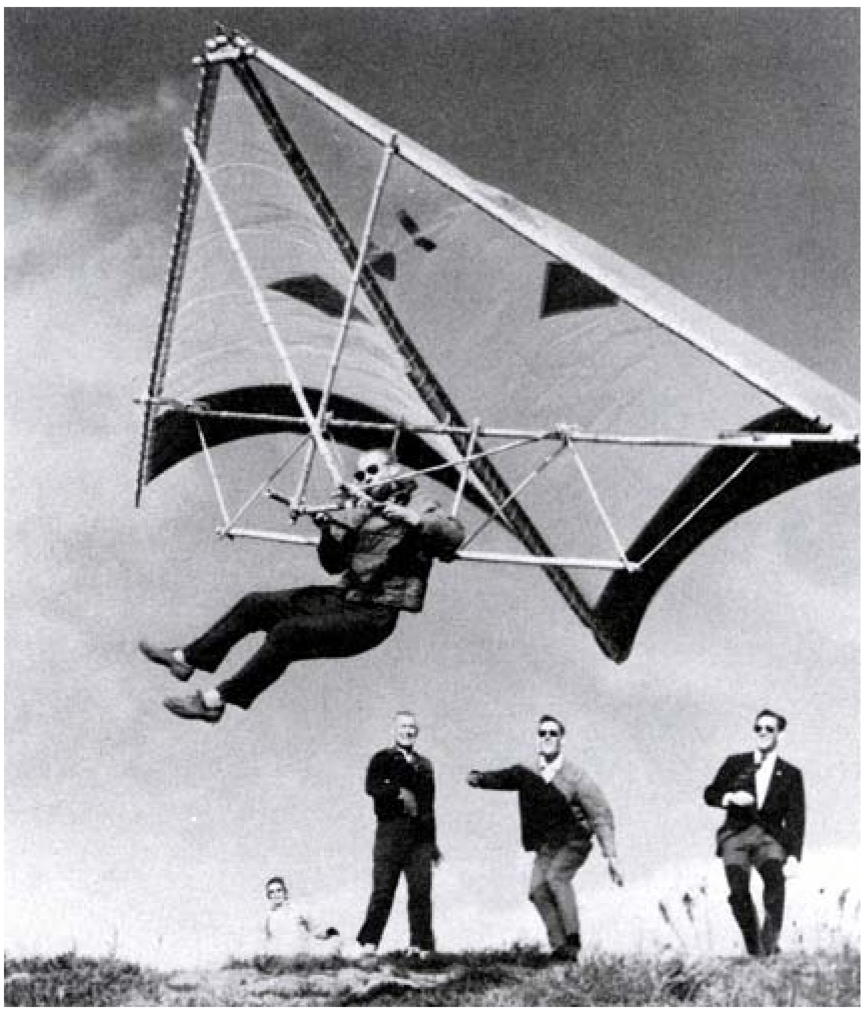
History



Dr. George A. Spratt towed his hang glider on floats using a motorboat. USA, 1929

First towing tests of NASA's Paresev glider (Para Wing Research Vehicle), March 1962.

Barry Hill Palmer, 1961. First hang glider based on Rogallo's flexible wing.



Richard Miller flying his 'Bamboo Butterfly' hang glider. Vista Del Mar. California, 1966.

'Standard' flexible wing hang glider, based on variants of the Rogallo wing aircraft, 1975.

Trikes are referred to as "microlights" in Europe and have been extremely popular since the 1980s. The history of the trike is traced back to the invention by Francis Rogallo's flexible wing and subsequent development by the Paresev engineering team's innovations and then others. On 1948, engineer Francis Rogallo invented a self-inflating wing which he patented on March 20, 1951 as the Flexible wing. It was on October 4, 1957 when the Russian satellite Sputnik shocked the United States and the space race caught the imagination of its government, causing major increases in U.S. government spending on scientific research, education and on the immediate creation of NASA. Rogallo was in position to seize the opportunity and released his patent to the government and with his help at the wind tunnels, NASA began a series of experiments testing Rogallo's wing - which was renamed **Para Wing**- in order to evaluate it as a recovery system for the Gemini space capsules and recovery of used Saturn rocket stages. F. Rogallo's team adapted and extended the totally flexible principle into semi-rigid variants. This mainly involved stabilizing the leading edges with compressed air beams or rigid structures like aluminum tubes. By 1960 NASA had already made test flights of a heavily framed cargo powered aircraft called the Ryan XV-8 or *Fleep* (short for 'Flying Jeep') and by March 1962, of a weight-shift experimental glider called Paresev. By 1967 all Para Wing projects were dropped by NASA in favor of using round parachutes without officially considering development of personal ultralight gliders, but the airfoil's simplicity of design and ease of construction, along with its capability of slow flight and its gentle landing characteristics, did not go unnoticed by hang glider enthusiasts. The challenge then, was to modify and fit a Rogallo flexible wing with an appropriate frame to allow it to be used as a hang glider.

Some modern Rogallo flexible winged aircraft

A crucial development toward the trike was the severe mechanical innovations developed by the Paresev and the Fleep engineers; they proved the Rogallo wing for free-flight gliding, powered and unpowered, for safe landing.

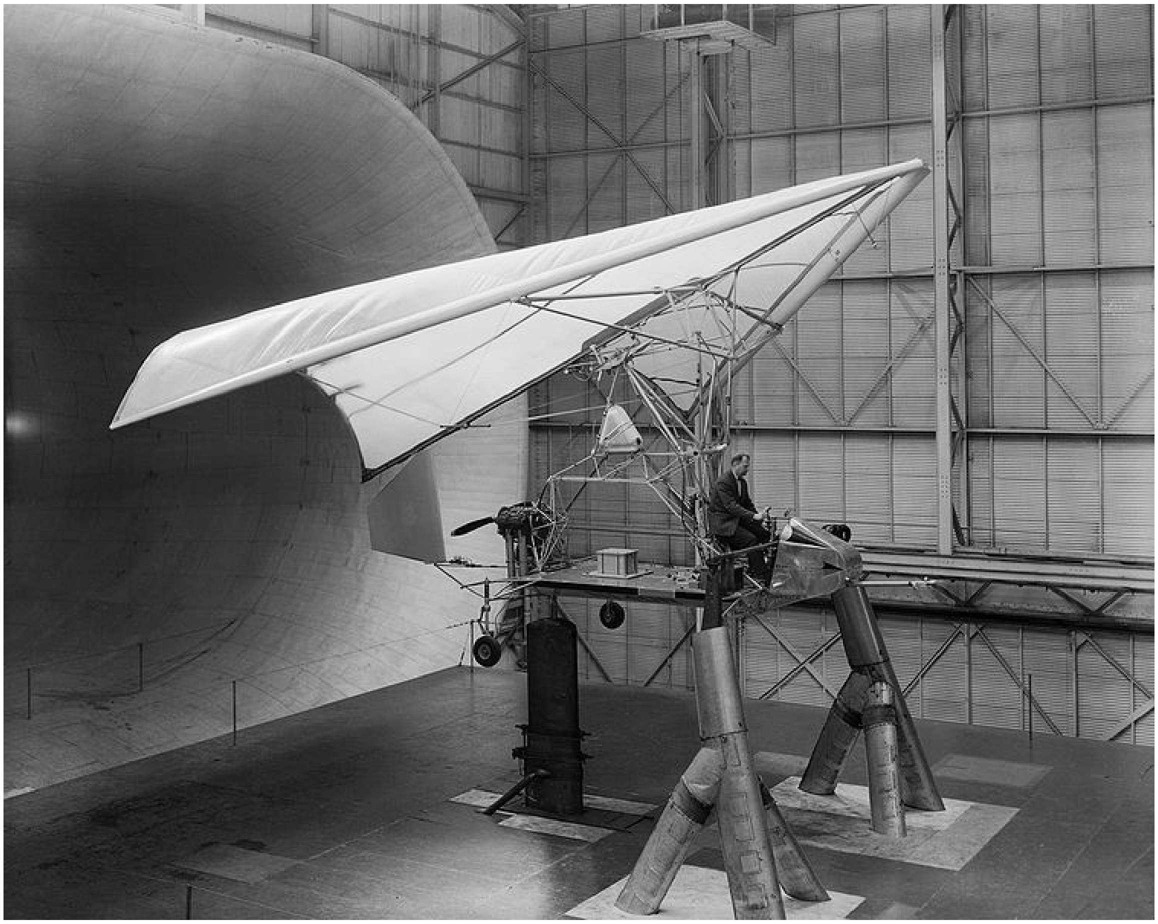
Publicity from the Fleep and the Paresev tests sparked interest in the design among several tinkerers, first through Barry Palmer. An engineer, Mike Burns of Australia, developed and used the boat-towed Rogallo airfoiled SkiPlane from 1962 through the 1960s. A fellow countryman of Mike Burns, John W. Dickenson, made ski-kites and eventually partnered with Mike Burns to improve the ski-kite; he formatted a ski-kite that used what could be found in the 1929 George A. Spratt simple triangle control bar or A-frame with single-point pendulum weight-shift control.

An influence through John Dickenson's duplication of his device, who named his flexible wing ski-kite the **Ski Wing**. Dickenson fashioned a water ski kite airframe to fit on a Rogallo airfoil where the pilot sat on a swinging seat while the control frame and wire bracing distributes the load to the wing as well as giving a frame to push/pull for weight-shift control. Dickenson's Ski Wing turned out to be stable and controllable under tow, unlike the flat manned kites used at water ski shows. The Ski Wing kite was first kited in public at the 'Grafton Jacaranda Festival' in September 1963 by **Rod Fuller** while towed behind a motorboat. Australian manufacturers like **Bill Bennett** and **Bill Moyes**, actively developed and marketed Dickenson's innovations to the world, which significantly fueled the hang glider revolution.

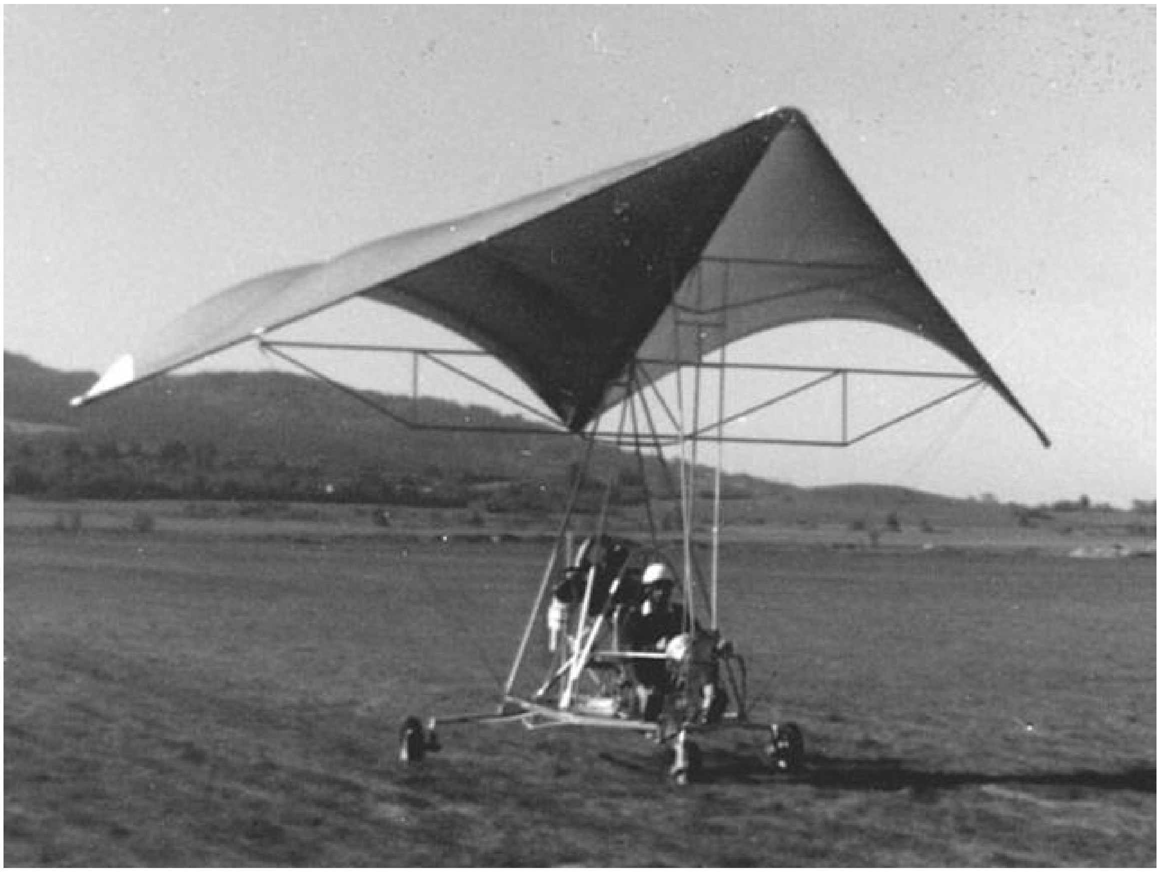
Although by the early 1970s many rigid wings were developed, none sold well, while dozens of flexible wing hang glider companies were springing up world-wide, building variants of Dickenson's Ski Wing. In 1972, Popular Mechanics and Popular Science magazines published articles on hang gliding which further increased its popularity, as the *Sky Raiders* hang gliding movie released in 1975.

Francis Rogallo, Barry Palmer, John Dickenson, and others never made any money out of their innovations. Profit to manufacturers of hang gliders and Rogallo winged hang gliders came once organized and insured sporting events grew in popularity. Dickenson's adaptation and innovations eventually produced a foldable hang glider that dramatically reduced difficulty in control, storage, transport, assembly and repair. In addition, the flexible wing lends itself open to design changes for possible improvements. The crucial developments put together by the Paresev engineers, Barry Palmer, John Dickenson, Bill Bennett, Bill Moyes, Richard Miller, and then hundreds of other innovators gave success to the flexible wing hang glider.

First trikes



Ryan XV-8 'Fleep' flown in the Full Scale Tunnel at Langley, 1962



Pierre Aubert, Switzerland, 1964

In 1961, Engineer **Thomas Purcell** built a towable Rogallo wing glider with an aluminum frame, wheels, a seat and basic control rods; soon he replaced the wheels for floats and motorized the aircraft. In 1964, Swiss inventor **Pierre Aubert** saw a photo of NASA's Fleep and completed construction of a similar trike. Like with the Fleep, his Rogallo wing was fixed and did not allow for pendulum weight-shift control.

In March 1967 aeronautical engineer Barry Palmer completed the earliest example of a true weight-shift powered trike: the **Paraplane**; it was controlled by a single vertical control bar as the Paresev experimental glider that inspired him. The Paraplane used two *West Bend-Chrysler* 820 engines of 8hp at 6000rpm, reduced to 4700rpm for about 6.5hp each, for a total of 13hp. Each engine had a direct drive to a 27in diameter two-blade propeller made of polyester and fiberglass. On March 24, 1967 Palmer registered the trike at the American FAA as the *Palmer Parawing D-6*, serial 1A, N7144; no restrictions were noted. The second Palmer trike, **Skyhook** (FAA registered N4411) in spite of its early date of origin, had most of the attributes of a modern ultralight, except it used a single cylinder snowmobile engine, as the two-stroke twin cylinders were not available yet. It was powered by a 17hp at 5000rpm single cylinder JLO L297 two stroke engine, driving a composite propeller designed and built by Palmer himself and driven by a 2.1/1 reduction gearbox. The engine had electric start and the craft had fiberglass composite spring landing gear. Airframe construction was bolted 6061-T6 aluminum thin wall tube, with 6061 T-6 extruded angle. The craft took off, flew, and landed at around 30mph. Palmer's trikes were not developed further and remained in obscurity.

The commercial availability of Dikenson's hang glider made the Rogallo wing very popular, and prompted several builders during the 1970s to attempt motorization of their flexible wing aircraft but unlike Barry Palmer -who placed the center of gravity well below the keel- most builders were mounting the engine to the wing, where a fine balance existed between applying too much power, causing the aircraft to overtake the pilot or not enough power for flight. It was not until **Roland Magallon** took a long look at the *Motodelta* ultralight (a hybrid Rogallo wing designed by Jean-Marc Geiser had a 'fuselage' and rudder) and Magallon decided replace the Motodelta's 'fuselage' with a simple tubular framework pendulum and dispensing with the rudder. Magallon is thus generally thought to have invented the trike because it was he who first marketed it. He called the first version 'Mosquito' and marketed it from October 1979 through 1981. The prototype had flown with a McCulloch MC-101A motor of 125 cc, delivering 10 hp at 8000 rpm to a direct-drive prop with ground adjustable pitch. Later he offered it with a Solo 210 engine which produced 15 hp (11 kW) at much less frantic RPM.

The "trike", as it soon became known, quickly became popular in the UK and France where it had been reborn. Trike technology still shows its hang gliding origins, though the wings are no longer converted hang gliders, but are designed for power. In fact, none of the commercially available trike wings can be used as foot-launched hang gliders as they are too heavy and too fast.

Regulation

In the United States, trikes are often referred to as "ultralight trikes" and are designed to operate under the designation of the Federal Aviation Regulations (FAR 103) that define an ultralight as a single seat vehicle with under 5 US gallons (19 L) of fuel capacity, an empty weight of less than 254 pounds (115 kg), a top speed of 55 knots (102 km/h), and a maximum stall speed that does not exceed 24 knots (45 km/h). Ultralights are only allowed to operate during daylight hours. FAR 103 makes further weight allowances for two-seat trainers(in which both persons are able to control the craft and thus definable as pilots), amphibious landing gear, and ballistic parachute systems.

A light sport aircraft (LSA) certification code has been produced for heavier and higher performance machines. This is an airworthiness code based on a consensus of industry experts, drawing from many years experience including the British BCAR-S requirements. The LSA initiative also includes similar consensus-based pilot licencing and maintenance requirements. It is proving popular, enabling more people to fly modern designs safely. Trike pilots may also obtain the private pilot certificate which permits them to fly at night, above 10,000 feet, and in other venues not permissible for ultralight or sport pilots.

Popularity

Due to their relatively low cost, low fuel consumption, light weight, ability to take off and land in very short distances, and ability to fly in somewhat turbulent conditions, trikes have become popular with recreational pilots. In particular, trikes have been used to fly across oceans, frozen tundra, barren deserts, and even into backyard landing strips. As with all types of aviation, regulations in the United States dictate where and how these aircraft are allowed to fly, especially with regard to avoiding other air traffic and populated areas. Notwithstanding, trikes continue to grow in popularity with those living in urban areas due to their portable nature and rapid assembly time. Most trikes may be transported on a very small trailer, stored in a standard garage, and assembled for flight in less than thirty minutes.

Manufacturers

There are around 56 manufacturers world-wide that build trikes. Some started out making hang glider wings and now provide both wing and undercarriage. Many produce only the undercarriage and procure their wings elsewhere. The majority of these companies are found in Europe with a number appearing in the United States. Manufacturers can also be found in India, South Africa, Australia, and elsewhere. Manufacturers often sell their ultralight trikes at a price of around $5000-10000.

Records

On January 19, 2008 Mark Jackson from Altrincham, UK, flew over Kilimanjaro. In doing so he broke the record for the highest altitude attained in a microlight (24,262 feet) and the fastest climb to 20,000 feet (25 minutes). He also broke the British record for the fastest climb to 10,000 feet (19 minutes). He did the flight with Eve Jackson.