Handbook of
Glider Aircrafts

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Glider Aircraft

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

Glider aircraft are heavier-than-air craft that are supported in flight by the dynamic reaction of the air against their lifting surfaces, and whose free flight does not depend on an engine. Mostly these types of aircraft are intended for routine operation without engines, though engine failure can force other types of aircraft to glide. Some gliders have engines for extending their flights and some have engines powerful enough to launch.

There are a wide variety of types differing in the construction of their wings, aerodynamic efficiency, location of the pilot and controls. Some may have power-plants to take off and/or extend flight. Some are designed simply to descend, but the most common varieties exploit meteorological phenomena to maintain or even gain height. Gliders are principally used for the air sports of gliding, hang gliding and paragliding but are also used for recovering spacecraft. Perhaps the most familiar type is the paper plane.

History of gliders

Early attempts

Early pre-modern accounts of flight are in most cases sketchy and it is unclear whether each craft was a glider, kite or parachute and to what degree they were truly controllable. Often the event is only recorded at a great time interval after it allegedly took place. A 17th century account reports an attempt at flight by the 9th century poet Abbas Ibn Firnas near Cordoba, Spain which ended in heavy back injuries. The monk Eilmer of Malmesbury is reported by William of Malmesbury (c. 1080-1143), a fellow monk and historian, to have flown off the roof of his Abbey in Malmesbury, England, sometime between 1000 and 1010 AD, gliding about 200 metres (220 yd) before crashing and breaking his legs. Going by the sketchy reports, both used a set of (feathery) wings, and both blamed their crash on the lack of a tail.

19th century

Otto Lilienthal in flight

The first heavier-than-air (i.e. non-balloon) man-carrying aircraft that were based on published scientific principles were Sir George Cayley's series of gliders which achieved brief wing-borne hops from around 1849. Thereafter gliders were built by pioneers such as Jean Marie Le Bris, John J. Montgomery, Otto Lilienthal, Percy Pilcher, Octave Chanute and Augustus Moore Herring to develop aviation. Lilienthal was the first to make repeated successful flights (eventually totaling over 2,000) and was the first to use rising air to prolong his flight.

The Wright Brothers developed a series of three manned gliders after preliminary tests with a kite as they worked towards achieving powered flight. They returned to glider testing in 1911 by removing the motor from one of their later designs.

Development of gliders

After World War I recreational gliders were built in Germany and in the United States (Schweizer brothers). 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 to fly cross-country and now regularly fly hundreds or even thousands of kilometers in a day, if the weather is suitable.

Military gliders were developed during World War II by a number of countries for landing troops. A glider - the Colditz Cock - was even built secretly by POWs as a potential escape method at Oflag IV-C near the end of the war in 1944.

Development of flexible-wing hang gliders

Foot-launched aircraft had been flown by Lilienthal and at the meetings at Wasserkuppe in the 1920s. However the innovation that led to modern hang gliders was in 1951 when Francis Rogallo and Gertrude Rogallo applied for a patent for a fully flexible wing with a stiffening structure. The American space agency NASA began testing in various flexible and semi-rigid configurations of this Rogallo wing in 1957 in order to use it as a recovery system for the Gemini space capsules. Charles Richards and Paul Bikle developed the concept producing a wing that was simple to build which was capable of slow flight and as gentle landing. Between 1960-1962 Barry Hill Palmer used this concept to make foot-launched hang gliders, followed in 1963 by Mike Burns who built a kite-hang glider called Skiplane. In 1963, John W. Dickenson began commercial production.

Development of paragliders

January 10, 1963 American Domina Jalbert filed a patent US Patent 3131894 on the Parafoil which had sectioned cells in an aerofoil shape; an open leading edge and a closed trailing edge, inflated by passage through the air – the *ram-air* design. The 'Sail Wing' was developed further for recovery of NASA space capsules by David Barish. Testing was done by using ridge lift. After tests on Hunter Mountain, New York in September 1965, he went on to promote ‘slope soaring’ as a summer activity for ski resorts (apparently without great success). NASA originated the term ‘paraglider’ in the early 1960s, and ‘paragliding’ was first used in the early 1970s to describe foot-launching of gliding parachutes.

Rocket gliders

Although the sail wing was not used for spacecraft, based on German research on the Antipodal bomber going back to World War II, the Space Age in the 60s saw more interest in rocket gliders. Some research was done on gliding lifting bodies, and there was the X-20 Dyna-Soar project, but after cancellation this research eventually lead to the Space Shuttle.

On April 12, 1981, the Space Shuttle orbiter first flew. The Shuttle reenters at Mach 25 at the end of each spaceflight, and lands entirely as a glider. As with Buran these represent by far the fastest type of gliders of all time.

Other gliding rocket launched aircraft such as Spaceship One and XCOR aerospace's EZ-rocket were produced in the early 21st century.

Recreational types

The main application today of glider aircraft is sport and recreation.

Glider (sailplane)

A typical training glider, Schleicher ASK 21 just before landing

Gliders were developed from the 1920s for recreational purposes. As pilots began to understand how to use rising air, gliders were developed with a high lift-to-drag ratio. These allowed longer glides to the next source of 'lift', and so increase their chances of flying long distances. This gave rise to the popular sport known as gliding although the term can also be used to refer to merely descending flight.

Gliders were mainly built of wood and metal but the majority now have composite materials using glass, carbon fibre and aramid fibres. To minimise drag, these types have a fuselage and long narrow wings, i.e. a high aspect ratio. Both single-seat and two-seat gliders are available.

Initially training was done by short 'hops' in primary gliders which are very basic aircraft with no cockpit and minimal instruments. Since shortly after World War II training has always been done in two-seat dual control gliders, but high performance two-seaters are also used to share the workload and the enjoyment of long flights. Originally skids were used for landing, but the majority now land on wheels, often retractable. Some gliders, known as motor gliders, are designed for unpowered flight, but can deploy piston, rotary, jet or electric engines. Gliders are classified by in the FAI for competitions into glider competition classes mainly on the basis of span and flaps.

Ultralight "airchair" Goat 1 glider

A class of ultralight sailplanes, including some known as microlift gliders and some as 'airchairs', has been defined by the FAI based on a maximum weight. They are light enough to be transported easily, and can be flown without licensing in some countries. Ultralight gliders have performance similar to hang gliders, but offer some additional crash safety as the pilot can be strapped in an upright seat within a deformable structure. Landing is usually on one or two wheels which distinguishes these craft from hang gliders. Several commercial ultralight gliders have come and gone, but most current development is done by individual designers and home builders.

Hang gliders

Modern 'flexible wing' hang glider.

Unlike a sailplane, a hang glider is capable of being carried, foot launched and landed solely by the use of the pilot’s legs.

- In the original and still most common designs, Class 1, the pilot is suspended from the center of the flexible wing and controls the aircraft by shifting his/her weight.
- Class 2 (designated by the FAI as Sub-Class O-2) have a rigid primary structure with movable aerodynamic surfaces, such as spoilers, as the primary method of control. The pilot is often enclosed by means of a fairing. These offer the best performance and are the most expensive.
- Class 4 hang gliders are unable to demonstrate consistent ability to safely take-off and/or land in nil-wind conditions, but otherwise are capable of being launched and landed by the use of the pilot's legs.
- Class 5 hang gliders have a rigid primary structure with movable aerodynamic surfaces as the primary method of control and can safely take-off and land in nil-wind conditions. No pilot fairings are permitted.

In a hang glider the shape of the wing is determined by a structure, and it is this that distinguishes them from the other main type of foot-launched aircraft, paragliders, technically Class 3. Some hang gliders have engines, and are known as powered hang gliders. Due to their commonality of parts, construction and design, they are usually considered by aviation authorities to be hang gliders, even though they may use the engine for the entire flight. Some flexible wing powered aircraft, Ultralight trikes, have a wheeled undercarriage, and so are not hang gliders.

Paragliders

A paraglider taking off in Brazil

A **paraglider** is a free-flying, foot-launched aircraft. The pilot sits in a harness suspended below a fabric wing. Unlike a hang glider whose wings have frames, shape of a paraglider's wing is formed by its suspension lines and the pressure of air entering vents in the front of the wing. The concept of ram-air inflated wings has been refined so that the best of these have a glide ratio of 10 at 45 km/h. Like sailplanes and hang gliders, paragliders use rising air to gain height and this process is the basis for most recreational flights and competitions, though aerobatics and 'spot landing competitions' also occur. Launching is often by stepping from a slope, but winch launches are also used. Paramotors are attached to some types which are known as powered paragliders. These in turn have spawned paraplanes, which are wheeled and motorized but which still use ram-air wings.

Military gliders

Waco CG-4A of the USAF

Military gliders were used mainly during the Second World War for carrying troops and heavy equipment to a combat zone. These aircraft were towed into the air and most of the way to their target by military transport planes, e.g. C-47 Dakota, or by bombers that had been relegated to secondary activities, e.g. Short Stirling. Once released from the tow near the target, they landed on as close to target as possible. The advantage over paratroopers were that heavy equipment could be landed and that the troops were quickly assembled rather than being dispersed over a drop zone. The gliders were treated as disposable leading to construction from common and inexpensive materials such as wood, though a few were retrieved and re-used. By the time of the Korean War, transport aircraft had also become larger and more efficient so that even light tanks could be dropped by parachute, causing gliders to fall out of favor.

Research aircraft

Horten Ho IV flying wing sailplane recumbent glider

Even after the development of powered aircraft, gliders have been built for research. The NASA Parasev Rogallo flexible wing is an example that was built to investigate alternative methods of recovering spacecraft. Although this application was abandoned, publicity inspired hobbyists to adapt the flexible wing airfoil for modern hang gliders.

Unpowered flying wings are another type of aircraft that have been built for aerodynamic research. Examples are the Horten flying wings, Armstrong Whitworth A.W.52G and the Baynes Bat.

In contrast to the flying wings, lifting bodies have been also developed using unpowered prototypes. Although the idea can be dated to Vincent Justus Burnelli in 1921, interest increased as an alternative for returning spacecraft. Traditional space capsules have very little control over where they land, whereas a steerable craft using wings would have more options. The lifting bodies use the fuselage itself to generate lift without employing the usual thin and flat wing. The objective of the lifting body is to minimize the drag and structure of a wing for very high supersonic or hypersonic flight as might be experienced during the re-entry of a spacecraft. This can be compared with a flying wing that seeks to minimise drag at subsonic speeds by eliminating non-lifting surfaces. Examples of type are the Northrop HL-10 and Martin-Marietta X-24.

Rocket gliders

Me 163B on display at the National Museum of the USAF

Rocket powered aircraft consume their fuel quickly and so most must land unpowered, unless there is another type of engine. The first was the Lippisch Ente. Later examples include the Messerschmitt Me 163 rocket-powered interceptor and the Messerschmitt Me 323 military glider which was tested with rocket engines to assist take-off. The American series of research aircraft starting with the Bell X-1 in 1946 up to the North American X-15 spent more time flying unpowered than under power. The Space Shuttle orbiters and the Russian Buran are the culmination of these types and are by far the fastest type of aircraft of all to date. The latest examples of rocket glider are the privately-funded SpaceshipOne which is intended for sub-orbital flight and the XCOR EZ-Rocket which is being used to test engines.

Rotary wing

Most unpowered rotary-wing aircraft are kites rather than gliders, i.e. they are usually towed behind a car or boat rather than being capable of free flight. These are known as rotor kites. However rotary-winged gliders, 'gyrogliders', were investigated that could descend like an autogyro or helicopter, using the lift from rotors to reduce the vertical speed. These were evaluated as a method of dropping people or equipment from other aircraft.

Unmanned gliders

Model gliders

A paper aeroplane, also known as a 'paper plane' or 'paper dart', is an example of a model glider, other types are made of balsa or plastic.

Radio controlled model gliders

A 'radio-controlled glider' is a type of radio-controlled airplane that normally does not have any form of propulsion. Like piloted gliders they can remain airborne for extended periods by using the lift produced by slopes and thermals. They are controlled remotely from the ground with a transmitter.

Flying bombs

Glide bombs are bombs with aerodynamic surfaces to allow a gliding flightpath rather than a ballistic one. This increases the protection of the carrying aircraft that is attacking a heavily defended target. Remote control systems allow the carrying aircraft to direct the bomb to the target. These were developed in Germany from as early as 1915. In World War Two they were most successful as anti-shipping weapons. Some air forces today are equipped with gliding devices that can remotely attack airbases with a cluster bomb warhead.

Chapter- 2

Glider (sailplane)

Glider

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

Part of a series on **Categories of aircraft**	
Supported by lighter-than-air gases (aerostats)	
Unpowered	Powered
• Balloon	• Airship
Supported by LTA gases + aerodynamic lift	
Unpowered	Powered
• Hybrid moored balloon	• Hybrid airship

Supported by aerodynamic lift (aerodynes)	
Unpowered	Powered
Unpowered fixed-wing	Powered fixed-wing
• **Glider** • hang gliders • Paraglider • Kite	• Powered airplane (aeroplane) • powered hang gliders • Powered paraglider • Flettner airplane • Ground-effect vehicle
	Powered hybrid fixed/rotary wing
	• Tiltwing • Tiltrotor • Coleopter
Unpowered rotary-wing	Powered rotary-wing
• Rotor kite	• Autogyro • Gyrodyne ("Heliplane") • Helicopter
	Powered aircraft driven by flapping
	• Ornithopter
Other means of lift	
Unpowered	Powered
	• Hovercraft • Flying Bedstead • Avrocar

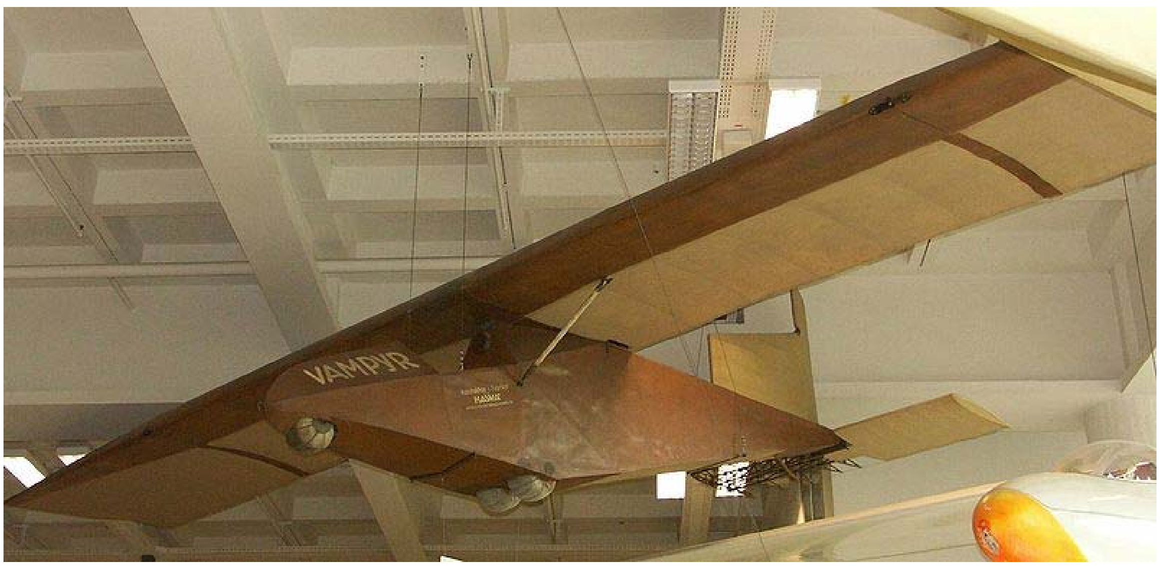
A **glider** or **sailplane** is a type of glider aircraft used in the sport of gliding. Some gliders, known as motor gliders are used for gliding and soaring as well, but have engines which can, in some cases, be used for take-off or for extending a flight. Foot-launched aircraft (such as hang gliders 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.

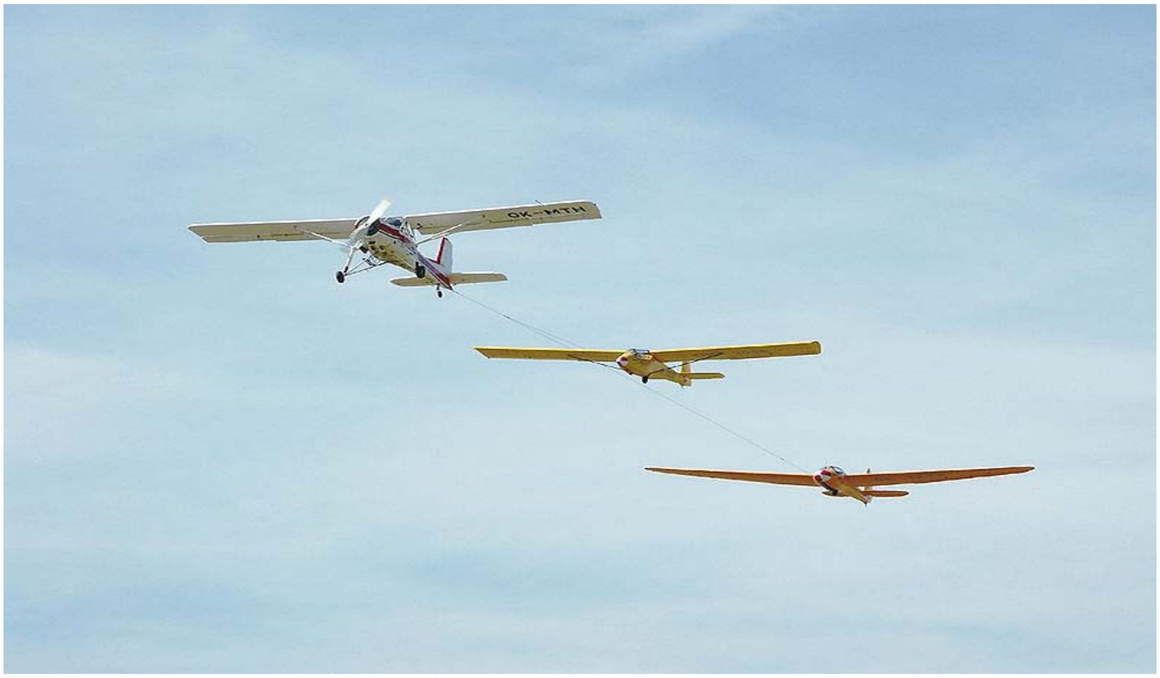
With each generation of materials and with the improvements in aerodynamics, the performance of gliders has increased. One measure of performance is the glide ratio. A ratio of 30:1 means that in smooth air a glider can travel forward 30 meters while losing only 1 meter of altitude. Comparing some typical 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.

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.

- Sideslipping - 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	about 17 for flexible wings,	Open class sailplanes typically around 60:1 but in

	performance makes long-distances more difficult. The current world record is just above 500km (310 miles)	though up to 20 for rigid wings. Glide performance enables longer-distance flying, 700km (430+ mile) record	more common 15-18 meter span aircraft, glide ratios are between 38:1 and 52:1. , high glide performance 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.

Chapter- 3

Radio-controlled Glider

A traditionally built '100S' class thermal soaring glider

A **radio-controlled glider** is a type of radio-controlled aircraft that normally does not have any form of propulsion. They are able to sustain continuous flight by exploiting the lift produced by slopes and thermals, controlled remotely from the ground with a transmitter. They can be constructed from a variety of materials, including wood, plastic, polymer foams, and composites, and can vary in wing loading from very light to relatively heavy, depending on their intended use.

International radio-controlled glider competitions are regulated by the Fédération Aéronautique Internationale (FAI) although many countries have their own national classes.

Launching methods

Hand launch

Hand launching is the simplest way to get a model into the air. All the pilot needs to do is throw it horizontally, giving it sufficient speed. This method is usually combined with slope soaring, so the glider can gain altitude.

Towline launch

In this method another person runs along the ground, pulling a long (50 - 100m) line with the glider attached to the end, while the pilot steers it. It can be performed on any flat piece of terrain, as the glider is given sufficient altitude during the launch. A variation of this method uses a pulley staked to the ground with the tower moving toward the pilot.

Bungee/Hi-start launch

This launch is a variant of the towline launch performed alone. The running person is replaced by a combined length of elastic cord or rubber tubing and line which is attached to the ground, often using a 'corkscrew' dog stake.

'Piggyback' launch

A second, powered radio-controlled powered aircraft lifts the model glider into the air, attached to a special cradle which is, in turn, mounted to either the top or the bottom of the carrier aircraft. Although this method is spectacular, it requires an experienced pilot to steer the carrier aircraft as the addition of the glider can significantly affect the handling of the carrier aircraft. Special care must be also taken by the pilots of both models to avoid a collision after the release of the glider.

Discus launch

This method of launching can be performed only on a special type of glider - a Discus Launch Glider. To launch the model into the air, the pilot holds the model by the tip of a wing, spins 360°, rotating the model around his/her body and then releases hold of the model allowing it to launch at high speed . Although DLGs are a fairly new type of gliders, they are gaining popularity due to their ease of launching and efficient flight characteristics. DLG models are used in the F3K contest class, as defined by FAI.

Aerotow launch

As full-size aerotowing using a radio-controlled tug, often used for launching larger scale gliders.

Winch launch

As full-size winch launching but using a small electric motor and a reverse pulley staked to the ground. The launch speed is controlled by the pilot using a foot pedal.

Forms of flight

Slope soaring

Slope soaring uses the lift produced by wind blowing up the face of a steep slope on hills, mountains, and cliffs. Dynamic soaring, utilizing the leeward or "backside" of a hill, has recently become very popular.

Disciplines

Combat

Combat is usually flown with expanded polypropylene (EPP) foam models due to their impact resistance. Each pilot tries to knock the other's aircraft physically out of the air. A "kill" is scored only when the opponents aircraft hits the ground. If a hit occurs and each aircraft recovers and remains airborne, the hits generally do not count. Often this activity includes extreme maneuvers and aerobatics.

This particular class of slope glider is extremely popular, as novices can learn to fly with a model that is practically indestructible. There is also a wide appeal in owning an inexpensive glider that is also a stand-off scale model, particularly of favorite World War II fighters, e.g. the Spitfire/Seafire, P-51 Mustang and P-47 Thunderbolt.

Ridge racing

Ridge racing (or pylon racing where markers are present) is essentially using the slope lift to race along the "lift zone" -- generally parallel to the slope. This can be MoM (man-on-man) racing, in which 2 to 4 gliders compete against each other on the same course. Scoring is similar to match racing in the sport of sailing - the first pilot to complete the course receives one point, the second two points and so on. At the end of the competition, the pilot with the fewest points wins. Another form of slope r/c glider racing is called F3F. F3F is one of many competition categories for model and full scale aircraft that are defined by the Fédération Aéronautique Internationale (FAI). In F3F racing, the pilot is timed on the course for 10 legs of 100 meters for a total distance of 1 kilometer. All pilots fly a timed run for each round. The fastest pilot receives 1000 points for the round and all others are given a percentage which is determined by the ratio of their time to the fast time for the round. At the end of the competition, the pilot with the most points wins.

PSS

PSS, or Power Scale Soaring, is all about building and flying scale model gliders of full sized jet, rocket or piston powered aircraft. World War II prop planes such as the P-51, Supermarine Spitfire and Me 109 are common subjects for PSS planes, however PSS aircraft produced to date have ranged from the early bi-planes through to modern jet fighters and even commercial airliners.

The challenge with Power Scale Soaring is to build a model as close to scale as possible whilst at the same time ensuring the model has good flying characteristics.

Model EPP jet fighter slope soarers have become extremely popular, usually either 1950s and some 1960s designs e.g. the MiG-15, the P-80 Shooting Star, and the F-86 Sabre, and the Northrop F-5 and F-20. More ambitious modellers are experimenting with more recent jet fighters such as the F-16, F-15, MiG-29 and Su-27.

Equally popular are models of military trainers, such as the Pilatus PC-9, BAe Hawk, and Aermacchi MB 326 and MB 339.

More information about Power Scale Soaring can be found under Power Scale Soaring Association and the website of the Power Scale Soaring Association (PSSA)

Dynamic soaring

Dynamic soaring is a relatively new style of flying model gliders whereby the windshear just downwind of certain slopes can be used to create high speeds. It involves gaining altitude, then soaring into a patch of dead air, then back to the lift to gain speed.

Thermal soaring

Thermal soaring uses columns of warm, rising air called thermals to provide lift for a glider. Thermal soaring gliders are normally launched with a bungee cord catapult, a winch or towed by a powered plane. A discus launch glider (DLG) is simply catapulted into the air with a spinning motion much like a discus throw.

Discus launching is often combined with slope soaring. Thermals from elsewhere can drift in over the hill to combine with the hill lift or they can be formed by the hill itself, if the slope is angled to the sun causing the slope to heat up faster than in the surrounding areas. The resulting warm air will then flow upwards pulling in air from the valley below, causing a wind up the slope. The lift is thus a combination of ridge lift and thermal. This has produced a new term, "slermal", to describe the mixture of both slope lift and thermal activity coming up the hill face.

Types

Two foam wings

Flying wings

Expanded polypropylene foam (EPP) foam flying wings have become very popular recently, primarily due to their crash damage resistance and low cost. They are often used for slope combat, where pilots try to knock other pilots' gliders out of the sky with their own. A "kill" is *only* scored when the opponent's plane actually hits the ground. A popular airfoil used on some flying wing type gliders is the KF airfoil or one of the variants of the family of the Kline Fogleman airfoil. This airfoil has been proven to show an increase in performance by providing greater stability on the wing at lower speeds.

Scale gliders

Scale gliders are models of full-size gliders. Scale gliders are generally larger models (2 m wingspan or greater) and made from composite materials. Scale Gliders are sometimes modified slightly to obtain the best flying characteristics, such as less drag and more aerobatic potential. This is achieved by changing the size of the control surfaces or the wing airfoil. Some scale gliders are very close in appearance to their full scale counterparts, and this makes them a beautiful sight at any flying field. A model often "scaled" because of its clean looks and great aerobatic potential is the MDM-1 Fox. The ASW series (mostly ASW-26 and ASW-28) are also popular scale gliders.

Powered gliders

Powered gliders use electric motors, internal combustion engines or even jet turbines to provide propulsion for a glider to get in the air. They are normally used to get thermal soarers in the air. Some electric gliders have propellers which fold inwards when the power source is cut of during flight. This provides the glider with lower air resistance and reduces overall drag which may be present if the propeller was to remain in its open or natural state.

Competition classes

International

International radio-controlled glider competitions are regulated by the Fédération Aéronautique Internationale (FAI). The classes are:

- **F3B** - Multi-task soaring, no model limitations.
- **F3F** - Slope speed (pylon racing), no model limitations.
- **F3H** - Cross country soaring racing
- **F3J** - Thermal duration soaring, no model limitations. 150 m towline maximum length.
- **F3K** - Handlaunched glider
- **F5B** - Electric soaring, wing loading and maximum battery weight limitations apply.

United Kingdom

British national radio-controlled glider classes are:

- **Mini-glider** - Maximum wingspan 60 inches, maximum weight 22 ounces.
- **Two metre** - Maximum wingspan two metres, 150 m towline maximum length.
- **100S** or **Standard Class** Maximum wingspan 100 inches (thermal soaring). 150 m towline maximum length.
- **BARCS Open Class** - No model limitations, 150 m hand towline only.
- **Sixty inch slope** - Pylon racing, maximum wingspan 60 inches
- **Slope cross country** - No model limitations, pilot walks around a course while controlling the model.
- **PSS and Scale** - The model must be a recognisable replica of a full-size powered aircraft or glider.

- **Slope aerobatics** - No model limitations.
- **E-slot** - Maximum seven-cell battery pack
- **Electroslot E400** Motor must be standard 'Speed 400' type.

Chapter- 4

Airspeed Horsa

AS.51 and AS.58 Horsa

Role	Troop and cargo military glider
National origin	United Kingdom
Manufacturer	Airspeed Ltd
First flight	12 September 1941
Introduced	1941
Primary users	Royal Air Force United States Army Air Forces
Number built	3,799

The **Airspeed AS.51 Horsa** was a British World War II troop-carrying glider built by Airspeed Limited and subcontractors and used for air assault by British and Allied armed forces. It was named after Horsa, the legendary 5th century conqueror of southern Britain.

Development

The German military was one of the pioneers of the use of airborne operations, conducting several successful operations during the Battle of France in 1940, including the Battle of Fort Eben-Emael. Impressed by the success of German airborne operations, the Allied governments decided to form their own airborne formations. This decision would eventually lead to the creation of two British airborne divisions, as well as a number of smaller units. The British airborne establishment began development on 22 June 1940, when the Prime Minister, Winston Churchill, directed the War Office in a memorandum to investigate the possibility of creating a corps of 5,000 parachute troops. In 1941, the United States embarked on a similar program.

When the equipment for the airborne forces was under development, it was decided by War Office officials that gliders would be an integral component of such a force; these would be used to transport troops and heavy equipment. The first glider to be designed and produced was the General Aircraft Hotspur, the first prototype of which flew on 5 November 1940. However, several problems were found with the Hotspur's design, the primary one being that the glider did not carry sufficient troops. Tactically it was believed that airborne troops should be landed in groups far larger than the eight the Hotspur could transport, and also the number of aircraft required to tow the gliders needed to carry larger groups would be impractical. There were also concerns that the gliders would have to be towed in tandem if used operationally, which would be extremely difficult during nighttime and through cloud formations. So it was decided to use the Hotspur as a training glider, and continue with the development of several other types of glider, including a 25-seater assault glider which became the *Airspeed Horsa*.

Paratroops leaving an Airspeed Horsa Glider, a training aircraft of No 21 Heavy Glider Conversion Unit at Brize Norton, 4 June 1943.

The Horsa, given the designation of **AS 51**, was produced to meet Specification **X.26/40** issued on 12 October 1940. Initially it was planned that the Horsa would be used to transport paratroopers who would jump from doors installed on either side of the fuselage, and that the actual landing would be a secondary role; however the idea was soon dropped, and it was decided to simply have the glider land airborne troops. An initial order was placed for 400 of the gliders in February 1941, and it was estimated that Airspeed should be able to complete the order by July 1942. Enquiries were made into the possibility of a further 400 being produced in India for use by an Indian airborne forces, but this was abandoned when it was discovered the required wood would have to be imported into India at a prohibitive cost. Five prototypes were ordered with Fairey Aircraft producing the first two prototypes for flight testing while Airspeed completed the remaining prototypes to be used in equipment and loading tests. The first prototype (DG597) towed by an Armstrong Whitworth Whitley took flight on 12 September 1941 with George Errington at the controls, 11 months after the specification had been issued.

As specified in Specification **X3/41**, 200 **AS 52** Horsas were also to be constructed to carry bombs. A central fuselage bomb bay holding four 2,000 lb or two 4,000 lb bombs was fitted into the standard Horsa fuselage. The concept of towing bombs was dropped as other bombers became available, with the order for the AS 52 cancelled.

Production of the Horsa commenced in early 1942, and by May some 2,345 had been ordered by the Army for use in future airborne operations. The glider was designed from the outset to be built in components with a series of 30 sub-assemblies required to complete the manufacturing process. Manufacturing was intended primarily to use woodcrafting facilities not needed for more urgent aviation production, and as a result production was spread across separate factories, which consequently limited the likely loss in case of German attack. The designer A. H. Tiltman said that the Horsa "went from the drawing board to the air in ten months, which was not too bad considering the drawings had to be made suitable for the furniture trade who were responsible for all production."

Because the subcontractors did not possess airfields to fly the gliders from to their intended destinations, they were delivered in their 30 separate sub-assemblies to RAF Maintenance Units, where they would then be assembled. An initial production run of 695 gliders was undertaken by Airspeed at their factory in Christchurch, Hants, but the remainder were then produced by a number of subcontractors. These included Austin Motors and the furniture manufacturers Harris Lebus. A total of between 3,799 and approximately 5,000 Horsas were built when production came to an end.

Design

Airspeed Horsa Cockpit

Airspeed Horsa interior, complete with folding bike

The Horsa Mark I had a wingspan of 88 feet (27 m) and a length of 67 feet (20 m), and when fully-loaded weighed 15,250 pounds (6,920 kg).

The Horsa was considered sturdy and very manoeuvrable for a glider. Its design was based on a high-wing cantilever monoplane with wooden wings and a wooden semi-monocoque fuselage. The fuselage was built in three sections bolted together, the front section held the pilot's compartment and main freight loading door, the middle section was accommodation for troops or freight, the rear section supported the tail unit. It had a fixed tricycle landing gear and it was one of the first gliders equipped with a tricycle undercarriage for take off. On operational flights the main gear could be jettisoned and landing was then made on the castoring nose wheel and a sprung skid under the fuselage.

The wing carried large "barn door" flaps which, when lowered, made a steep, high rate-of-descent landing possible — allowing the pilots to land in constricted spaces. The pilot's compartment had two side-by-side seats and dual controls. Aft of the pilot's compartment was the freight loading door on the port side. The hinged door could also be used as a loading ramp. The main compartment could accommodate 15 troops on benches along the sides with another access door on the starboard side. The fuselage joint at the rear end of the main section could be broken on landing to assist in rapid unloading of troops and equipment on landing. Supply containers could also be fitted under the centre-section of the wing, three on each side. The later **AS 58 Horsa II** had a hinged nose section, reinforced floor and double nose wheels to support the extra weight of vehicles. The tow cable was attached to the nose wheel strut, rather than the dual wing points of the Horsa I.

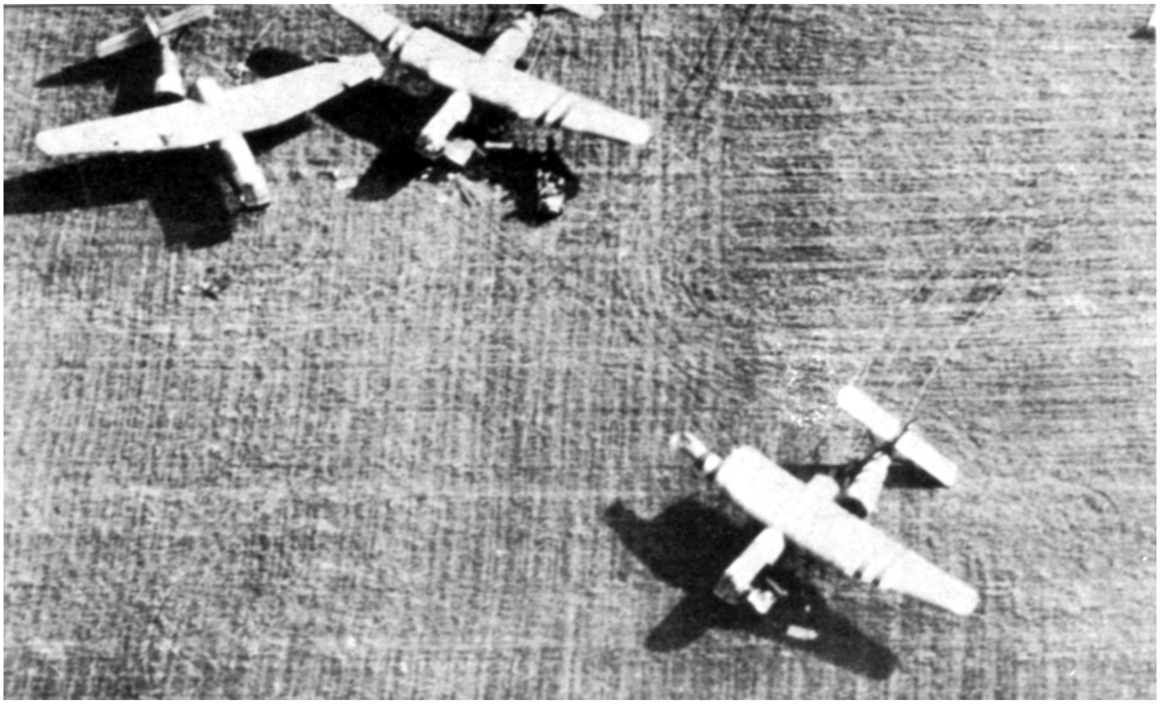
The Airborne Forces Experimental Establishment and 1st Airlanding Brigade began loading trials with the prototypes in March but immediately ran into problems. Staff attempted to fit a jeep into a prototype, only to be told by Airspeed personnel present that to do so would break the glider's loading ramp, as it had only been designed to hold a single motorbike. With this lesson learnt, 1st Airlanding Brigade subsequently began sending samples of all equipment required to go into Horsas to Airspeed, and a number of weeks were spent ascertaining the methods and modifications required to fit the equipment into a Horsa.

Operational history

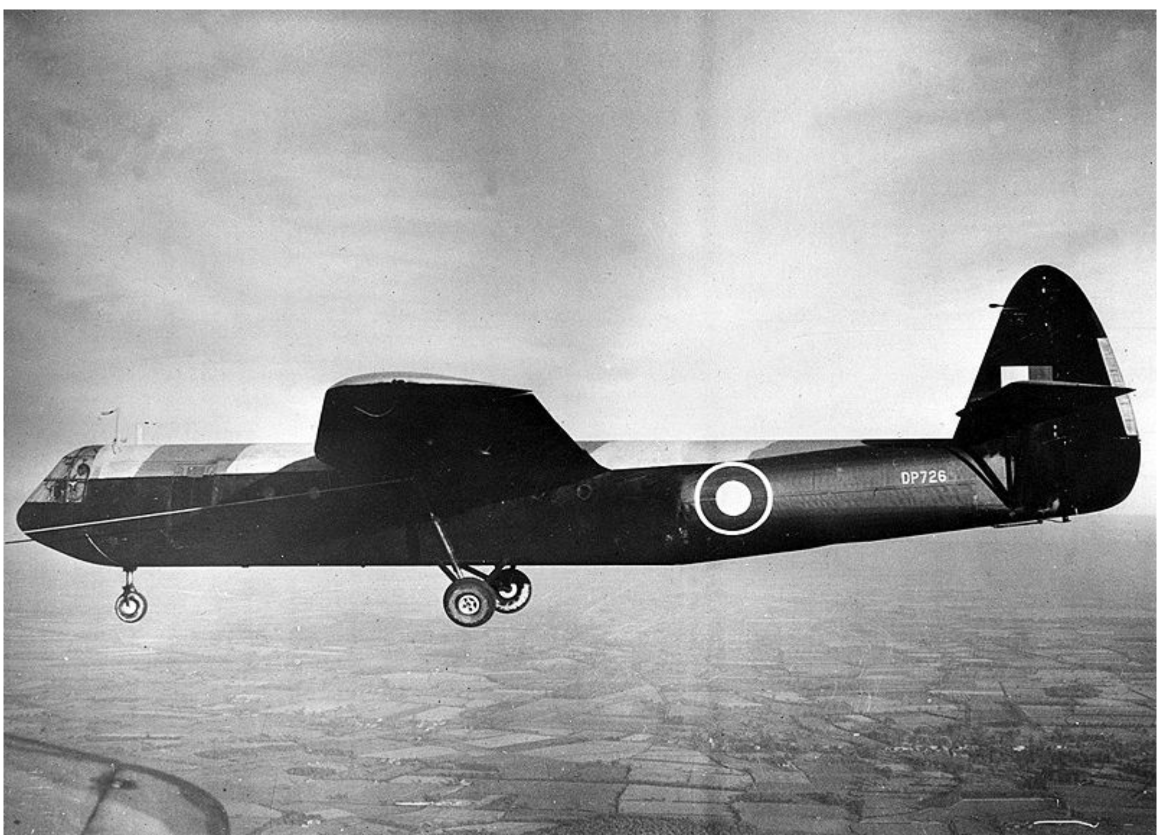
With up to 30 troop seats, the Horsa was much bigger than the 13-troop American Waco CG-4A (known as the *Hadrian* by the British), and the 8-troop General Aircraft Hotspur glider which was intended for training duties only. Instead of troops, the AS 51 could carry a jeep or a 6 pounder anti tank gun.

The Horsa was first used operationally on the night of 19/20 November 1942 in the unsuccessful attack on the German Heavy Water Plant at Rjukan in Norway (Operation Freshman). The two Horsa gliders, each carrying 15 sappers, and one of the Halifax tug aircraft, crashed in Norway due to bad weather. All 23 survivors from the glider crashes were executed on the orders of Hitler, in direct breach of the Geneva Convention which protects POWs from summary execution.

In preparation for further operational deployment, 30 Horsa gliders were air-towed by Halifax bombers from Great Britain to North Africa but three aircraft were lost in transit. On 10 July 1943, 27 surviving Horsas were used in Operation Husky, the invasion of Sicily. Large numbers (estimated at over 250) were subsequently used in Battle of Normandy; in the British Operation Tonga and American operations. The first units to land in France, during the Battle of Normandy, was a coup de main force carried by 6 Horsas that captured Pegasus Bridge, over the Caen canal, and a further bridge over the River Orne. 320 Horsas were used in the first lift and a further 296 Horsas were used in the second lift. Large numbers were also used for Operation Dragoon and Operation Market Garden, both in 1944, and Operation Varsity in March 1945; the final operation for the Horsa when 440 gliders carried soldiers of the 6th Airborne Division across the Rhine.



Horsas on the ground at Arnhem



Horsa I under tow

On operations, the Horsa was towed by various aircraft: four engined heavy bombers displaced from operational service such as the Short Stirling and Handley Page Halifax, the Armstrong Whitworth Albemarle and Armstrong Whitworth Whitley twin engined bombers, as well as the US Douglas C-47 Skytrain/Dakota (not as often due to the weight of the glider, however in Operation Market Garden, a total of 1,336 C-47s along with 340 Stirlings were employed to tow 1,205 gliders,) and Curtiss C-46 Commando. They were towed with a harness that attached to points on both wings, and also carried an intercom between tug and glider. The glider pilots were usually from the Glider Pilot Regiment, part of the Army Air Corps, although Royal Air Force pilots were used on occasion.

The United States Army Air Forces (USAAF) acquired approximately 400 Horsas in a form of "reverse" Lend-Lease. A small number of Horsa Mk IIs were obtained by the Royal Canadian Air Force for post-Second World War evaluation at CFB Gimli, Manitoba. Three of these survivors were purchased as surplus in the early 1950s and ended up in Matlock, Manitoba where they were eventually scrapped. A small number of Horsas were also evaluated postwar in India.

On 5 June 2004, as part of the 60th anniversary commemoration of D-Day, Prince Charles unveiled a replica Horsa on the site of the first landing at Pegasus Bridge, and talked with Jim Wallwork, the first pilot to land the aircraft on French soil during D-Day.

Ten replicas were built for use in the 1962 film *The Longest Day*, mainly for static display and set-dressing, although one Horsa was modified to make a brief "hop" towed behind a Dakota at Deelen, the Netherlands. During the production, seven of the replicas were damaged in a wind storm; the contingent were repaired in time for use in the film. Five of the Horsa "film models" were destroyed during filming with the survivors sold as a lot to John Hawke, aircraft collector in the UK. Another mock-up for close-up work came into the possession of the Ridgeway Military & Aviation Research Group and is stored at Welford, Berkshire.

Variants

AS.51 Horsa I
: Production glider with cable attachment points at upper attachment points of main landing gear.

AS.52 Horsa
: Bomb-carrying Horsa; project cancelled prior to design/production

AS.58 Horsa II
: Development of the Horsa I with hinged nose, to allow direct loading and unloading of equipment, twin nose wheel and cable attachment on nose wheel strut.

Operators

Horsa replica at Pegasus Bridge Museum

Canada

- Royal Canadian Air Force

India

- Indian Air Force

Portugal

- Portuguese Air Force

Turkey

- Turkish Air Force

United Kingdom

- Army Air Corps

- Glider Pilot Regiment
- Royal Air Force
    - No. 670 Squadron RAF

United States

- United States Army Air Forces

Survivors

An Airspeed Horsa Mark II (KJ351) is preserved at the Museum of Army Flying in Hampshire, England. The Assault Glider Trust is building a replica at RAF Shawbury using templates made from original components found scattered over various European battlefields and using plans supplied by BAE Systems (on the condition that the glider is not flown). Although there is some difference of opinion (now being researched), the replica at Pegasus bridge is believed to incorporate a forward fuselage section retrieved from Cholsey, Oxfordshire, England, which had served as a dwelling for over 50 years. This relic was recovered from Cholsey around 2001 by the Mosquito Aircraft Museum, of London Colney, where it was stored until being transferred to Pegasus Bridge. The airframe is not believed to have seen active service.

Specifications (AS 51)

General characteristics

- **Crew:** 2
- **Capacity:** 25 troops (20-25 troops were the "standard" load)
- **Length:** 67 ft 0 in (20.43 m)
- **Wingspan:** 88 ft 0 in (26.83 m)
- **Height:** 19 ft 6 in (5.95 m)
- **Wing area:** 1,104 ft^2 (102.6 m^2)
- **Empty weight:** 8,370 lb (3,804 kg)
- **Loaded weight:** 15,500 lb (7,045 kg)

Performance

- **Maximum speed:** 150 mph on tow; 100 mph gliding (242 km/h / 160 km/h)
- **Wing loading:** 14.0 lb/ft^2 (68.7 kg/m^2)

Chapter- 5

Aeronca L-3 and Military Glider

Aeronca L-3

L-3 Grasshopper

Aeronca L-3B belonging to the National Museum of the United States Air Force.

Role	Observation and liaison aircraft
Manufacturer	Aeronca Aircraft
First flight	1941
Primary user	United States Army Air Forces

The **Aeronca L-3** group of observation and liaison aircraft were used by the United States Army Air Corps in World War II. The L-3 series were adapted from Aeronca's pre-war Tandem Trainer and Chief models.

Design and development

The L-3 was initially designated the O-58 at the time it was first ordered by the Air Corps. The airplane was given its service tests in the summer of 1941 during maneuvers in Louisiana and Texas where it was used for various support purposes such as a light transport and courier.

At the time American ground forces went into combat around the world during World War II, the Army Air Force began using the L-3 in much the same manner as the observation balloon was used in France during World War I — spotting enemy troop and supply concentrations and directing artillery fire on them. It was also used for other types of liaison and transport duties and short-range reconnaissance which required airplanes that could land and take off in short distances from unprepared landing strips. Unfortunately, by the time that the United States entered the war, the Aeronca L-3 (and sister ship Taylorcraft L-2) were declared Operationally Obsolete, and never formally left for a foreign front; this was partially due to a nasty tendency for it to stall and spin in a left-hand turn, partially because newer and more capable aircraft were already being pressed into service. Instead they were relegated to training fields to serve as trainers and hacks. Liaison pilots would train in an L-3 and then be moved on to the standard front-line aircraft like the Piper L-4 or, in the case of the Army Air Corps, the Stinson L-5.

Research and photos indicated that some L-3s were (accidentally?) shipped to the African front, and subsequently given to the Free French Forces operating within the area at the time. It is not known how many were received by the French, nor how many survived the war. At least one of the aircraft served with US forces in Italy.

The **TG-5** was a three-seat training glider of 1942 based upon the O-58 design. This aircraft retained the O-58's rear fuselage, wings, and tail while adding a front fuselage in place of the engine. In all, Aeronca built 250 TG-5 gliders for the Army. The Navy received a small number as the **LNR-1**.

Variants

- **YO-58** — Four aircraft with a 65 hp (48 kW) YO-170-3 engine
- **O-58** / **L-3** — A civilian Aeronca Defender in USAAC markings. Identifiable by "D"-windows in rear, and side-by-side seating.
- **O-58A** / **L-3B** — Now sported greenhouse canopy (like the above photo), and tandem (one behind the other) seating. Small radio mast on vertical stabilizer(identifiable by a tiny windsock). Some were fitted with wind-driven generators.
- **O-58B** / **L-3B** — An L-3C before USAAC switched classification systems from "Observer" to "Liaison."
- **L-3C** — In response to "field" reports, body is widened by two inches to accommodate pilots flying with parachutes and other army gear. Radio mast is now a small tab over the vertical stabilizer and is little more than a grounding point.
- **L-3D** — D-J model L-3s are not actual contract aircraft, but aircraft straight from the civilian factory impressed into military service. An L-3D is merely an Aeronca 65TF Defender with a Franklin engine
- **L-3E** — An Aeronca 65TC Defender with a Continental engine.

- **L-3G** — 65L Super Chief with a Lycoming engine (4 planes)
- **L-3H** — 65T Defender with a Lycoming engine (1 plane)
- **L-3J** — 65TC Defender with a Continental engine (1 plane)
- **TG-5** : 250 were built as training gliders for the USAAC.
- **TG-33** : TG-5 converted for prone pilot.
- **LNR** : Three TG-5s were supplied to the US Navy.

Operators

United States

- United States Army Air Force
- United States Navy

Museum displays

- National Museum of the United States Air Force at Wright-Patterson AFB near Dayton, Ohio
- United States Army Aviation Museum at Fort Rucker near Ozark, Alabama
- Kalamazoo Aviation History Museum in Kalamazoo, Michigan
- Cavanaugh Flight Museum in Addison, Texas
- Port Townsend Aero Museum at Jefferson County International Airport near Port Townsend, Washington (flown regularly)
- Museo Nacional Aeronáutico y del Espacio de Chile, Santiago, Chile
- American Airpower Heritage Museum in Midland, Texas
- Wings of Eagles Discovery Center in Elmira, New York
- Museum of Flight in Seattle, Washington
- National D-Day Memorial in Bedford, Virginia
- Alamo Liaison Squadron in San Antonio, Texas
- Vintage Flying Museum at Meacham International Airport in Fort Worth, Texas

Specifications (L-3C)

General characteristics

- **Crew:** 2: pilot, observer
- **Length:** 21 ft 10 in (6.67 m)
- **Wingspan:** 35 ft 0 in (10.67 m)
- **Height:** 9 ft 1 in (2.74 m)
- **Wing area:** 169 ft² (15.6 m²)
- **Empty weight:** 835 lb (379 kg)
- **Loaded weight:** 1,260 lb (572 kg)
- **Powerplant:** 1× Continental O-170-3 OR a Continental O-65-8 flat-4 engine, 65 hp (48 kW)

Performance

- **Maximum speed:** 87 mph (76 kn, 139 km/h)
- **Cruise speed:** 79 mph (69 kn, 126 km/h)
- **Stall speed:** 46 mph (40 kn, 73 km/h)
- **Range:** 218 mi (189 nmi, 350 km)
- **Service ceiling:** 10,000 ft (3,050 m)
- **Wing loading:** 7.45 lb/ft² (36.1 kg/m²)
- **Power/mass:** .051 hp/lb (85 W/kg)

Military glider

Waco CG-4A of the USAF

Military gliders (an offshoot of common gliders) have been used by the military of various countries for carrying troops and heavy equipment to a combat zone, mainly during the Second World War. These engineless aircraft were towed into the air and most of the way to their target by military transport planes, e.g. C-47 Skytrain or Dakota, or bombers relegated to secondary activities, e.g. Short Stirling. Once released from the tow craft near the front, they were to land on any convenient open terrain close to target hopefully with as little damage to this cargo and crew as possible as most landing zones (LZ) were far from ideal. The one-way nature of the missions meant that they were treated as disposable leading to construction from common and inexpensive materials such as wood, though a few were retrieved and re-used.

Troops landing by glider were referred to as *air-landing* as opposed to paratroops. Landing by parachute caused the troops to be spread over a large drop-zone, whereas gliders could land troops in greater concentrations precisely at the target landing area. Furthermore, the glider, once released at some distance from the actual target, was effectively silent and difficult for the enemy to identify. Larger gliders were developed to land heavy equipment like anti-tank guns, anti-aircraft guns, small vehicles, such as jeeps, and also light tanks (e.g. the Tetrarch tank). This heavier equipment made otherwise lightly-armed paratroop forces a much more capable force. The Soviets also experimented with ways to deliver light tanks by air, including the Antonov A-40, a gliding tank with detachable wings.

By the time of the Korean War, helicopters had replaced gliders. Helicopters have the advantage of being able to extract soldiers, in addition to delivering them to the battlefield. Also, advances in powered transport aircraft were being made, to the extent that even light tanks could be dropped by parachute

Development

The early sporting objectives of gliders were quickly overtaken in the Soviet Union and in Germany by miltary applications, mainly the training of pilots. By 1934 the Soviet Union had ten gliding schools and 57,000 glider pilots had gained licences.

In 1932 the Soviet Union demonstrated the TsK Komsula, a four-place glider, designed by GF Groschev that could also be used for cargo. Larger gliders were then developed culminating in an 18-seater at the military institute in Leningrad in 1935. Luftwaffe Colonel Kurt Student visited Moscow as part of the military colloboration programme with the Sovet Union. He reported back to his superiors in Berlin details of a 1,500 man parachute drop and the large transport gliders that he had seen. The Luftwaffe opened a parachute school as a result in 1937. Further field testing convinced Student that a vehicle was needed to deliver the heavy weapons for the lightly armed parachute troops. This idea was dismissed until October 1938 by which time Student had risen to major-general and was appointed Inspector of Airborne Forces. Development of a troop-carrying glider was assigned to Hans Jacobs of the Deutsche Forschungsanstalt für Segelflug to develop the DFS 230 which could carry 9-10 fully equipped troops or 1,200kg (2,800) pounds of cargo.

German military gliders

The Germans were the first to use gliders in warfare, most famously during the assault of the Eben Emael fortress on May 10, 1940 in which 41 DFS 230 gliders carrying 10 soldiers were launched behind Junkers Ju 52s. Ten gliders landed on the grassed roof of the fortress. Only twenty minutes after landing the force had neutralized the fortress at a cost of six dead and twenty wounded. Hitler was anxious to gain maximum publicity and so several foreign attachés were given guided tours of the fortress. Consequently the British, American and Japanese became quickly aware of the methods that had been used. By mid-1940 both Japan and Britain had active glider programs.

Development then began of even larger gliders such as the Gotha Go 242 (23 trooper) and Messerschmitt Me 321 (130 trooper) to transport heavy armaments in anticipation of Operation Sealion and Operation Barbarossa.

Gliders were also used by Germany in Greece in 1941. On April 26, 1941 the troops from six DFS 230 gliders captured the bridge over the Corinth Canal accompanied by 40 plane-loads of German paratroopers. (Fortuitously the British were able to demolish the bridge a few hours later.) Next General Student then convinced Hitler that Crete could be captured using only airborne troops.Consequently on May 20, 1941 500 German transport aircraft carrying paratroopers and 74 DFS 230 gliders took off from the Greek mainland. During the capture of the island 5,140 German airborne troops were either killed or wounded out of the 13,000 sent. Among the 350 German planes destroyed in the operation, half had been Ju52s which seriously depleted the force needed for the invasion of the Soviet Union shortly after. As a result Hitler vowed never to use his airborne force in such large numbers again.

Some German glider operations continued later in the war, some examples being the rescue operation of Benito Mussolini at Gran Sasso and the emergency re-supply operations in Russia, North Africa and Eastern Europe towards the end of the war. The Junkers Ju 322 *Mammut* ("Mammoth") was the largest such glider ever built, but it was never used operationally. Not all military gliders were planned for transport. The Blohm & Voss BV 40 was a German glider fighter designed to attack Allied bomber formations but was not used.

British military gliders

The British glider development started in mid-1940, prompted by the assault on Eben Emael. Among the types developed were the 28 trooper Airspeed Horsa and the 7 ton capacity General Aircraft Hamilcar cargo glider. The General Aircraft Hotspur was used for training the pilots who formed the Glider Pilot Regiment. The most famous actions were the taking of the Pegasus Bridge during the invasion of Normandy, Operation Dragoon (the invasion of southern France), Operation Market-Garden (Arnhem Bridge over the lower Rhine) and Operation Varsity (Crossing of the Rhine). Out of the 2,596 gliders dispatched for Operation Market-Garden, 2,239 gliders were effective in delivering men and equipment to their designated landing zones.

Although gliders are still used in the Royal Air Force for cadet training by the Air Training Corps, they are not used in combat operations. No troop-carrying gliders have been in British service since 1957.

American military gliders

General "Hap" Arnold in United States War Department created the American Glider Program on 25 February 1941. Eleven compaies were asked to build prototypes but only four showed any interest and only one the Waco Aircraft Company was able to submit prototypes, the eight-seat Waco CG-3 and the fifteen-seat Waco CG-4 being the first. In 15 October 1941 Lewin B. Barringer was placed in charge of the programme. The shock of the attack on Pearl Harbor prompted the USA to set the number of glider pilots needed at 1,000 to fly 500 eight-seat gliders and 500 fifteen-seat gliders. The number of pilots required was increased to 6,000 by June 1942. After Barringer was killed in January 1943, the program was moved to Army Air Force Headquarters and directed by Richard C. du Pont. Bigger gliders were later designed such as Waco CG-13A (30 trooper) and the Waco CG-10 (40 trooper)

The most widely used type was the Waco CG-4A which was first used in the invasion of Sicily and participated in the D-Day assault on France on June 6, 1944, and in other important airborne operations in Europe, e.g. Battle of the Bulge, Operation Market Garden and crossing the Rhine. and in the China-Burma-India Theater. The CG-4A was constructed of a metal and wood frame covered with fabric, manned by a crew of two and with an allowable normal cargo load of 3,710 lb, allowing it to carry 13 combat-equipped troops or a jeep or small artillery piece. The CG-10 could hold 10,850 lb of cargo, such as two howitzers at a time. The final glider mission of the was was at Luzon on 23 Jun 1945. By the end of the war the USA had built 14,612 gliders and had trained over 6,000 pilots. The designs of the Waco Aircraft Company were also produced by a wide variety of manufacturers including Ford Motor Company and Cessna Aircraft Company as well as furniture, piano and coffin manufacturers.

Following World War II, the United States maintained only one regiment of gliders. Gliders were used in military exercises in 1949 but glider operations were deleted from the US Armiy's capabilities on 1 January 1953. However, the United States Air Force continues to this day to use gliders at the Air Force Academy to train cadets in the fundamentals of flight.

A list of American military gliders is in the List of U.S. military aircraft

Soviet military gliders

The Soviet Union built the world's first military gliders starting in 1932, including the 16-seat Grokhovski G63, though no glider was built in quantity until World War II. During the war there were only two light gliders built in series: Antonov A-7 and Gribovski G-11 - about 1,000 altogether. Also, a medium glider KC-20 was built in a small series. They were used mostly for providing partisans in Belarus with supplies and armament in 1942-1943. On 21 September 1943 35 gliders were used in the Dnepr crossing. Later types gliders were built: the Cybin C-25 (25 trooper) in 1944, Yakovlev Yak-14 (35 trooper) in 1948 and Ilyushin Il-32 (60 trooper) in also in 1948. In 1950 a Yak-14 made worldwide headlines when it became the first glider to fly over the North Pole.

The Soviet Union maintained three glider infantry regiments until 1965. However Soviet Air Force transport gliders were gradually withdrawn from service with the arrival of turbo-prop transports like the Antonov An-24 and Antonov An-12, which entered service in the late 1950s.

Chapter- 6

Politechnika Warszawska PW-5, Slingsby T.21 and Schweizer X-26 Frigate

Politechnika Warszawska PW-5

PW-5 Smyk

Role	World-class sailplane
National origin	Poland
Manufacturer	Politechnika Warszawska
First flight	1993
Number built	ca. 200

The **Politechnika Warszawska PW-5** ***Smyk*** (Polish: "Little rascal") is a single seater sailplane designed at the Warsaw University of Technology (Polish: "Politechnika Warszawska") and manufactured in Poland. It is a monotype World Class glider.

Development

The PW-5 was designed for, and won a competition held by the International Gliding Commission for a simple, low cost sailplane that would form the basis for a new competition class, the "World Class". Unlike other soaring competition classes, the World Class designation would guarantee that all pilots participated on an equal footing, and that pilots could not gain advantage by spending large amounts of money. PW-5 was unanimously chosen from 42 design proposals in IGC international World Class design competition. In November 1989, the IGC issued a worldwide call for proposals. By February 1990, it had received 84 requests for design specifications from 25 countries. By August 1990, the IGC had received 42 design proposals from 20 countries. In September 1990, after reviewing the proposals, many of which came with models, the IGC recommended that 11 designs from 9 countries proceed to the prototype competition. In October 1992, the IGC inspected and tested 6 prototypes from 5 countries at Oerlinghausen Germany. After further review and collecting manufacturing data, in spring 1993 the IGC declared the PW-5, designed by a faculty/student team at Warsaw University of Technology, the first World Class glider.

The glider was designed at the Faculty of Power and Aeronautical Engineering of the Warsaw University of Technology under the supervision of Roman Świtkiewicz. It was originally built by PZL at its factory in Świdnik and first flew in 1993. By the end of 2000 the new private company PZL-Bielsko1 was established by the original members of the design team from Warsaw University of Technology and the DWLKK company. A new factory at Bielsko produced a modified version of PW-5 glider called B1-PW-5.

It did not sell as well as expected. In total fewer than 200 PW-5s have been built, though over 70 have been exported to the United States, where there is a keen following.

Design

- The structure is all glass-epoxy composite.
- The wings are of trapeze contour with bow-shaped ends, shoulder-set on the fuselage, having a monospar structure with sandwich shells.
- Schempp-Hirth-type air brakes extend on the upper wing surface only.
- Fuselage shell of glass-epoxy composite monocoque structure, stiffened with frames.
- Fabric covered rudder.
- Fixed undercarriage consisting of main wheel behind the pilot, with shock absorber and drum brake, a smaller front wheel and a tail skid with a diminutive wheel to prevent scraping on the ground if overrotation takes place.
- Two tow releases, for aerotowing and winch-launching respectively.

Variants

There are only two versions of the PW-5. The Bielsko version, identified as B1 PW-5, has a few safety and performance related improvements:

- Automatic hook-up of all controls upon assembly
- Tow release for winch-launching moved forward; this follows a winching accident in New Zealand
- Ballast holder in the tail to allow centre of gravity corrections
- Total energy probe on the vertical empennage

There is a project in progress for building a motoglider designated PW-5M based on the PW-5.

The PW-5 has a two-seater derivative, the PW-6.

Specifications

General characteristics

- **Crew:** One
- **Length:** 6.22 m (20 ft 5 in)
- **Wingspan:** 13.44 m (44 ft 1 in)
- **Height:** 1.86 m (6 ft 1 in)
- **Wing area:** 10.2 m² (109 ft²)
- **Aspect ratio:** 17.8
- **Empty weight:** 190 kg (419 lb)
- **Gross weight:** 300 kg (661 lb)

Performance

- **Maximum speed:** 220 km/h (140 mph)
- **Maximum glide ratio:** 32
- **Rate of sink:** 0.65 m/s (130 ft/min)

Slingsby T.21

Slingsby Type 21

Slingsby T.21B

Role	Training glider

National origin	United Kingdom
Manufacturer	Slingsby Sailplanes Ltd
Designed by	Fred Slingsby
First flight	1944
Primary user	Royal Air Force (as Sedbergh TX.1)
Number built	ca. 226

The **Slingsby T.21** is an open-cockpit, side-by-side two-seat glider, built by Slingsby Sailplanes Ltd and first flown in 1944. It was widely used by the RAF Air Cadets and by civilian gliding clubs, and is still a very popular machine.

Design and development

The Type 21 prototype, the T.21P, first flew in 1944. It was of wooden construction covered with fabric, and was in most respects a scaled-up development of the single-seat German Grunau Baby, which Slingsby had built under licence before the war. The strut-braced wings had a span of 50 ft, and the upper decking section of the nose was removable, in order to expose the crew to the airflow in the same way as a primary glider. It was designed for use by the Air Training Corps, but was rejected by them and put into storage.

After the end of the war it was bought by the London Gliding Club, who found it very useful. Improvements were suggested, and the result was the T.21A, first flown in 1947, which had its wingspan increased to 54 ft, and dispensed with the removable nose section. Only one was built, but a slightly modified version, initially known as the T.28, was ordered by the Royal Air Force for Air Cadet training. This was the T.21B, which first flew in December 1947 and went into quantity production both for the RAF (named the Sedbergh TX.1 after the public school of that name) and for civilian clubs. Large numbers were exported to India, as well as to Egypt, Jordan, Kenya, Malaya, the Netherlands, Pakistan, Portugal, South Africa and Sweden.

Up to this time most training had been solo, on single-seat primary gliders, but the introduction of the T.21, together with its cousin, the tandem two-seat T.31, meant that virtually all initial training was being carried out in two-seaters by the early 1950s. The T.21 was popularly named "The Barge", after its boat-like hull and sedate flying qualities, while the T.31 was often referred to as "The Brick", again after its flying qualities.

Another one-off version was the **T.21C**, also known as the **T.46**, which flew in October 1957. The wings were lowered so they were placed either side of the upper fuselage, rather than on a pylon above the fuselage. This had the effect of increasing the span to 56 ft 6 in. It also had an enclosed cockpit and redesigned tail surfaces.

Approximately 226 T.21Bs were built, with production ending in 1966. This total included 19 built for the RAF by Martin Hearn Ltd. at Hooton Park in 1950, and about five built by clubs and individuals from kits or spares.

Operational history

The RAF received 95 Sedberghs, and the type remained in service until the mid-1980s, when all their wooden gliders were replaced by Grob Vikings. By this time most of the civilian clubs no longer flew T.21s, but the RAF fleet was auctioned off, and the type gained a new popularity with groups seeking recreational flying, in Germany and the Netherlands as well as the UK.

Specifications

Slingsby T.21 at Windrushers Gliding Club

General characteristics

- **Crew:** Two
- **Length:** 8.16 m (26 ft 8 in)
- **Wingspan:** 16.46 m (54 ft in)
- **Wing area:** 24.15 m² (260.5 ft²)

- **Aspect ratio:** 11.3
- **Wing profile:** Göttingen 535
- **Empty weight:** 268 kg (599 lb)
- **Gross weight:** 478 kg (1,050 lb)

Performance

- **Maximum speed:** 168 km/h (105 mph)
- **Maximum glide ratio:** 21
- **Rate of sink:** 0.89 m/s (167 ft/min)

Schweizer X-26 Frigate

X-26 Frigate

An X-26A sailplane on display at an air show

Role	Research and training aircraft
National origin	United States
Manufacturer	Schweizer
Designed by	Ernie and William Schweizer
Primary user	U.S. Navy Test Pilot School
Number built	7?
Developed from	GS 2-32
Variants	QT-2, QT-2PC and X-26B

The **X-26 Frigate** is the longest-lived of the X-plane programs. The program included the X-26A Frigate sailplane and the motorized X-26B Quiet Thruster versions: QT-2, QT-2PC, and QT-2PCII. All were based on the Schweizer 2-32 sailplane.

Development

The **X-26A** was used by the U.S. Navy (USN) to train test pilots in the condition of yaw/roll coupling. Since jet trainers were known to be dangerous in this condition, the X-26 was based on the Schweizer SGS 2-32 sailplane. Sailplanes react much slower and are easier to control than jet aircraft, making the X-26 a much safer training platform. Four aircraft were originally ordered. Three of the original planes crashed. The USN purchased a replacement for each of the crashed units.

Operational history

Two Schweizer 2-32s [(67-15345 and 67-15346) from the U.S. Naval Test Pilot School X-26 Program (USNTPS)] were modified to QT-2 configuration (QT for Quiet Thruster) by the Lockheed Missiles & Space Co. (LMSC) and civil registered as N2471W and N2472W. In 1967 the aircraft were modified by adding a Continental O-200 engine, V-Belt RPM reduction system, four-bladed fixed pitch wood (Fahlin) propeller, and airframe upgrades.

After demonstrating quiet flight, the aircraft were again modified to military QT-2PC configuration (known only as Tail Numbers "1" and "2"): with GFE avionics and camouflaged for night operation. They were successfully evaluated in Southeast Asia (Prize Crew OpEval) for covert (A.K.A. Stealth) tactical airborne observation in the spring of 1968 (during Têt). The two QT-2PCs were returned to USNTPS in 1969 and re-designated X-26Bs.

The #1 QT-2PC was re-designated "67-5345" and the #2 aircraft was used for spare parts. The original X-26 glider version was then designated X-26A.

LMSC continued the covert airborne surveillance program with one Q-Star (House Test Aircraft) and eleven pre-preproduction YO-3As.

QT-2PC, QT-2PCII, and X-26B

QT-2PC #1 in the Soc Trang, RVN Army Airfield Hangar in 1968

Role	Experimental Covert Reconnaissance Aircraft
National origin	United States
Manufacturer	SACUSA and LMSC
Designed by	2-32: Bill and Ernie Schweizer, QT-2 and its variants: Stanley Hall
First flight	QT-2: July, 1967, QT-2PC: Dec, 1967
Introduced	1967
Retired	1969 as X-26Bs
Status	#1: Unknown. #2 Operational as a glider at Mile High Glider
Primary user	Tri-Service (USA, USAF, USN, and USMC)
Developed from	SGS 2-32
Variants	QT-2, QT-2PC, X-26B

The remaining X-26B aircraft, known to most of the original development team (us) as QT-2 N2471W and QT-2PC #1, remains of the aircraft are unknown

The other X-26B aircraft (known to most of us as QT-2 N2472W and QT-2PC #2) has been retro-verted to SGS 2-32 Configuration and is being operated (and known as "72 Whiskey") at Mile High Glider in Boulder, Colorado.

The Q-Star was the first aircraft to use a rotary combustion chamber (Wankel) engine. It is currently being returned to flight status.

The YO-3As were tactically evaluated in Southeast Asia from mid 1969 to late 1971. They were later used by the Louisiana Dept of Wildlife & Fisheries (LDWF) and the Federal Bureau of Investigation (FBI) in law enforcement, and by NASA for scientific applications.

YO-3A 69-18007 is currently being returned to flight status. YO-3A 69-18010 (NASA 818) is down for an engine upgrade.

Accidents

- US Navy 157932 crashed March 1971, pilot killed.
- US Navy 157933 crashed May 18, 1972, pilot killed.

Specifications (X-26A Frigate)

General characteristics

- **Crew:** two
- **Length:** 26 ft 9 in (7.92 m)
- **Wingspan:** 57 ft 1.5 in (17.37 m)
- **Height:** 9 ft 3 in (2.74 m)
- **Wing area:** 180 ft² (16.7 m²)
- **Empty weight:** 857 lb (389 kg)
- **Loaded weight:** 1,430 lb (650 kg)
- **Max takeoff weight:** lb (kg)
- **Powerplant:** × , () each
- **Wing aspect ratio:** 18

Performance

- **Maximum speed:** 158 mph (254 km/h)
- **Range:** miles (km)
- **Service ceiling:** ft (m)
- **Rate of climb:** ft/min (m/s)
- **Wing loading:** 39 kg/m² (7.9 lb/ft²)
- **Power/mass:** 0.07 hp/lb (0.12 kW/kg)
- **Rate of sink:** 0.6 m/s (120 ft/min)

Specifications (X-26B and QT-2PC)

General characteristics

- **Crew:** two
- **Length:** 30 ft 9 in (9.33 m)
- **Wingspan:** 57 ft 1.5 in (17.37 m)
- **Height:** 9 ft 3 in (2.74 m)

- **Wing area:** 185 ft² (16.7 m²)
- **Empty weight:** lb (kg)
- **Loaded weight:** 2,500 lb (kg)
- **Max takeoff weight:** lb (kg)
- **Powerplant:** 1× Continental O-200 horizontally opposed 4-cylinder air-cooled engine, 100 hp (75 kW)
- **Propeller:** Ole Fahlin four-blade, 8 inch chord, fixed-pitch 100 inch diameter
- **Wing aspect ratio:** 18
- **Fuel Capacity:** 20 gallons (nominal)

Performance

- **Service ceiling:** 13,000 ft (m)
- **Rate of climb:** 200 ft/min (m/s)
- **Wing loading:** kg/m² (lb/ft²)
- **Power/mass:** hp/lb (kW/kg)
- **Flight endurance:** Planned = 4+ hours; demonstrated = 6.7+ hours
- **Quiet cruise speed:** 70 - 80 mph

Chapter- 7

Powered Hang Glider

Powered hang glider

Foot-Launched Powered Hang Glider.

Part of a series on **Categories of aircraft**	
Supported by lighter-than-air gases (aerostats)	
Unpowered	Powered
• Balloon	• Airship
Supported by LTA gases + aerodynamic lift	
Unpowered	Powered
• Hybrid moored balloon	• Hybrid airship

Supported by aerodynamic lift **(aerodynes)**	
Unpowered	Powered
Unpowered fixed-wing	Powered fixed-wing
• Glider • hang gliders • Paraglider • Kite	• Powered airplane (aeroplane) • **powered hang gliders** • Powered paraglider • Flettner airplane • Ground-effect vehicle
	Powered hybrid fixed/rotary wing
	• Tiltwing • Tiltrotor • Coleopter
Unpowered rotary-wing	Powered rotary-wing
• Rotor kite	• Autogyro • Gyrodyne ("Heliplane") • Helicopter
	Powered aircraft driven by flapping
	• Ornithopter
Other means of lift	
Unpowered	Powered
	• Hovercraft • Flying Bedstead • Avrocar

A **foot-launched powered hang glider** (**FLPHG**), also called powered harness, nanolight, or hangmotor, is a powered hang glider harness with a motor and propeller in pusher configuration. An ordinary hang glider is used for its wing and control frame, and the pilot can foot-launch from a hill or from flat ground, needing a length of about a football field to get airborne, or much less if there is an oncoming breeze and no obstacles. Although the main appeal of FLPHGs is to the already experienced hang glider pilot, interest in these machines is growing rapidly, particularly in areas where there are no hills for foot-launching.

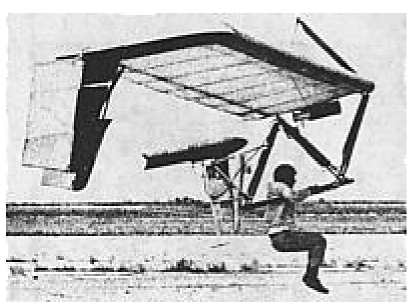
The pilot can cruise in good weather at speeds of 40 to 72 km/h (25 to 45 mph), but powered harnesses have limited power, range, and thrust, so are best used as self-launch devices to achieve enough altitude to find a warm-rising air thermal for soaring.

History

Glider flights have been recorded since as early as 875 AD. However, most early glider designs did not fulfill safe flight, largely because early flight pioneers did not understand the underlying principles that made a bird's wing work. Starting in the 1880s technical and scientific advancements were made that led to the first truly practical gliders. Otto Lilienthal, a German engineer, duplicated some of his contemporaries' work and greatly expanded on it from 1874. He rigorously documented his work, strongly influencing later designers including the Wright Brothers. For this reason, Lilienthal is one of most well-known and most influential aviation pioneers. His type of aircraft is now known as a hang glider.

In 1951 Francis Rogallo and Gertrude Rogallo together applied for a patent for a fully flexible wing, the *flexible wing* or *Rogallo wing*. In 1957 NASA began testing in various flexible and semi-rigid configurations in order to use it as a recovery system for the Gemini space capsules. The various stiffening formats and the wing's simplicity of design and ease of construction, capability of slow flight and gentle landing characteristics, did not go unnoticed by hang glider enthusiasts. Some designers soon adapted Rogallo's flexible wing airfoil onto elementary hang gliders, producing the most successful hang glider configuration in history.

Adding propulsion



Icarus V hang glider powered with a G8-2 rocket engine, 1979.

John Moody's powered *Icarus II*. Southeastern Wisconsin Aviation Museum.

The reaction of most pilots would be to say that powered microlights (ultralights) developed from hang gliding in the late 1970s, but it was not that simple. In fact, microlights are a rebirth, a return to the love of low-speed flight which the earliest aviators felt so keenly, but which was subsequently lost in the quest for military superiority. For a second time in aviation history, during the 1970s, motorization of simple gliders, especially those portable and foot-launched, became the goal of many inventors and gradually, small wing-mounted power packs were adapted. These early experiments went largely unrecorded, even in log books, let alone the press, because the pioneers were uncomfortably aware that the addition of an engine made the craft liable to registration, airworthiness legislation, and the pilot liable to expensive licensing and probably, insurance. Inventors from Australia, France and England produced several successful microlight motor gliders in the early 1970s and very few were portable wings.

Don Mitchell

Surprisingly, what really launched the powered ultralight aviation movement in the USA was not the Rogallo flexible wing but a whole series of rigid-wing motorized hang gliders. The *Icarus V* flying wing appeared with its tip rudders and swept-back style wing was used as a base for some powered experiments. Differently, a rigid biplane designed also by teenager Taras Kiceniuk, Jr--the Icarus II-- was a foundation for a modification in Larry Mauro's UFM Easy Riser which biplane started to sell in large numbers; Larry Mauro would power his tail-less biplane; one version was solar powered called the Solar Riser. Hang gliding record holder Don Mitchell fitted his BF-10 with a motor, though he still used the pilot's legs as undercarriage, an arrangement which persisted until his *B-10 Mitchell Wing* appeared. Then there was the *Manta Fledge IIB*, the *Pterodactyl* series, and the Quicksilver created in 1972 by Bob Lovejoy. However, foot-launched powered hang gliding as we know it today had been unsuccessful prior to 1976 because three basic elements were unrefined:

- Most hang gliders had poor performance.

- Small engine technology was underpowered and unreliable.
- Piloting skills and experience were limited.

Barry Palmer

In 1963 and during his free time, aeronautical engineer Barry Palmer built and experimented with a foot-launched powered hang glider at Bloomfield, Connecticut. It was powered by a 7 hp (5 kW) West Bend engine and mounted on top of a Rogallo-type flexible wing hang glider; the propeller was 3 feet (1 m) in diameter and was made of balsa wood, covered with fiberglass and mounted in pusher configuration. But the engine was quite underpowered and the craft could not achieve flight. It is now estimated that a modern flexible Rogallo wing hang glider requires at least 6 hp (4 kW) at the prop shaft and about 45 lbf (200 N) of thrust just to maintain level flight. Barry Palmer build during 1967 what is likely the first weight-shift powered trike aircraft.

Bill Bennett

In 1973, Australian Bill Bennett, who was one of the most skilled pilots of the time and the largest U.S. hang glider manufacturer, was following in Barry Palmer's footsteps and attempting to motorize a flexible hang glider. Bennett built a McCulloch engine backpack that drove a small caged propeller. It did not, however, work particularly well, as the prop was almost completely masked by his back, and what little efficiency remained was further reduced by the thick wire guard with which Bennett was prudent enough to surround the propeller. In practice, when used with the best hang glider of the day, it was nothing more than a glide extender.

In the late 1970s, light two-stroke engines started to become more powerful and reliable and hang glider pilots were developing their skills to such an extent that they no longer considered it normal to crash each time they flew. The only unanswered questions were where to fit the engine, the size and pitch of the propeller and how it was driven.

John Moody

On March 15, 1975 John Moody successfully added a 12.5 hp (9 kW) West Bend engine with a 71 cm (28 in) propeller to an UFM Easy Riser biplane hang glider designed by Larry Mauro. Moody opened the throttle and ran until he lifted from the frozen surface of a lake west of Racine, Wisconsin, and he flew for 30 minutes. Then on July 27, 1976 John Moody demonstrated ultralight aviation at the annual EAA fly-in convention in Oshkosh, Wisconsin, with a foot launched McCulloch 101 powered *Icarus II* in front of thousands of aviation-loving spectators, starting the modern ultralight aviation revolution in the USA. Later he added wheels to the aircraft and by the end of 1979, there were almost 100 competing companies selling powered ultralights (microlights) but very few were foot-launchable.

Steve Hunt

During the mid-1970s in England, Steve Hunt experimented by fitting a Scorpion glider with a McCulloch chainsaw engine driving a keel-mounted ducted fan via a reduction gear unit, but he stopped development "because it was too heavy". However, he visualized the need for a clutch unit to facilitate starting and to reduce shock loading on the drive system.

Soarmaster

Meanwhile, powered hang glider flight was progressing in the United States and in 1977 the Soarmaster company located in Scottsdale, Arizona, produced the first commercial foot-launched powered hang glider, the *Soarmaster*. The unit was recommended for fitting on an *Electra Flyer Cirrus* or *Olympus* hang glider, as the mounting brackets and thrust line calculations had been done for these two gliders only. The Soarmaster company had developed a two-stroke engine unit with splash box-lubricated chain reduction system, clutch and long drive-shaft that bolted just below the hang glider keel. It produced about 10 hp (7 kW) for about of 80 lbf (360 N) of static thrust and sustained climb rate as high as 150 ft/min (0.762 m/s). The keel-mounted transmission rendered the aircraft pitch unstable under power so a fine balance existed between applying too much power, causing the aircraft to overtake the pilot or not enough power for flight. Though marginal and difficult to fly, the Soarmaster was an encouraging development, until strange accidents began to happen; when the pilot pushed out or stalled the wing, propeller-related injuries to their feet ensued, earning it nicknames such as *ToeMaster* and *SawMaster*. It turned out that when the pilot went weightless or stalled under power, the glider would tuck forward violently because the line of thrust was well above the centre of gravity.

Jerzy Kolecki

In 1979, a powered backpack called the Motolotnia - White Eagle, designed by Jerzy Kolecki, became available for sale. It consisted of a 90 cc McCulloch chainsaw engine with a direct drive 61 cm (24") wooden prop, producing a quoted 77 lbf (340 N) of thrust; the rate of climb was about 150 ft/min (0.76 m/s) and flight duration was limited by the small fuel tank and engine overheating after several minutes. Other powered harnesses to reach the market in the 1980s were The Ranger and the Relax 220.

Johan Åhling

Mosquito powered harness.

The first truly successful foot-launched powered harness was the Mosquito, designed and produced by Swedish inventor Johan Åhling, of Swedish AeroSport. It did not have a keel-mounted motor, but the complete power unit was incorporated in the harness' frame. The harness was hooked on to the glider by a regular hang strap, placing the center of mass well below the keel, the ideal position for effective weight-shift control and thrust transmission. Åhling's Mosquito flew first in 1987, but it could only muster 10 hp and a few problems had to be worked out. When the Mosquito was released again in 1990 with a reliable 15 hp (10.2 kg, 118 cc) go-kart engine its appeal grew first amongst European and Australian hang glider pilots, and it was not until the late 1990s that the Mosquito started to become somewhat popular in North America, that by then, was obsessed with larger and heavier ultralights and undergoing a decreasing hang glider pilot population. Åhling's Mosquito was later redesigned and released in 2000 as the NRG.

Others

As of 2008, there are a few harness designs similar to the Mosquito/NRG, each sporting unique strengths, and produced by other FLPHG manufacturers. The latest generation of powered harnesses bear names such as Wasp, DoodleBug, Raven, X1, Zenon, Explorer LD, Fillo, and Flyped.

On April 30, 2003 a modified DoodleBug named "JetBug" took to the skies over England while powered by a 95 pounds force (420 N) thrust gasoline turbine engine. The JetBug was produced in collaboration between Flylight Airsports Ltd. and MicroJet Engineering; it was piloted first by Ben Ashman and then by Stewart Bond. Its flight autonomy was only of ten minutes at 1 Liter/min. The JetBug is an occasional guest at air shows across England.

World records

La Fédération Aéronautique Internationale (FAI) is the international standard-setting and record-keeping body for aeronautics and astronautics, so it also oversees the official records by foot-launched powered hang gliders, currently under the **RWF1** category. The Medium Ropuleim microlight piloted by Yves Rousseau holds the official foot-launched altitude and climb records. Rousseau made use of a 42 hp (31 kW) Rotax 447 motor and performed a foot-launch:

Place	Date	Aircraft	Pilot	Class	Record
France	July 18, 1992	Medium Ropuleim	Yves Rousseau	RWF1	Altitude above sea level: 5230 m (17,159 ft)
France	July 18, 1992	Medium Ropuleim	Yves Rousseau	RWF1	Climb time to 3000 m: 24 min (410 ft/min = 2.08 m/s)

Unofficial Records

Unofficial FLPHG World Records - Confirmed but not validated by the FAI.

- In October 1977, Trip Mellinger successfully flew his *Easy Riser* from mainland California to Catalina Island some 42 kilometres (26 mi) offshore.
- On 5 August 1978 French pioneer Bernard Danis mated a Soarmaster unit to this 168 square feet (15.6 m^2) *SK 2SS* wing and climbed to 1,825 metres (5,988 ft) above sea level at the Southern Alps.
- May 9. 1978, David Cook becomes the first pilot to cross the English Channel while flying on a foot-launched powered hang glider; he used a *VJ 23F* glider.
- In 1979, American pilot Larry Mauro flew 162 kilometres (101 mi) on a foot-launched *Easy Riser* powered hang glider.

Gerry Breen - London to Paris in FLPHG. August 25, 1979.

- On 7 May 1979 British pilot Gerry Breen set a new distance record for FLPHG of 325 kilometres (202 mi) from Wales to Norwich, a non-stop world distance record that still stands today; using a Soarmaster, the flight took about 4 hours with a tailwind of about 25 knots (29 mph) and reportedly consumed 25 litres (5.5 imp gal) of fuel. Three months later, on August 25 through 28, inspired by the film "Those Magnificent Men in their Flying Machines" and sponsored by British Airways, Breen flew his powered hang glider from London to Paris: Wishing to use a British made aircraft, Gerry Breen and Steve Hunt set about building with their version of the powered Soarmaster, but had no clutch. The unit, including glider, was considerably heavier than the Soarmaster and *Olympus* glider combination but the wing was much more robust. The hang glider was a *Hiway Super Scorpion* with a 10 hp (7 kW) McCulloch 125 cc engine mounted on the keel just forward of the hang strap. The journey was plagued with mechanical failures but Breen overcame them and completed the trip.

- In July 2002, Italian hang gliding champion and conservationist, Angelo d'Arrigo, guided a flock of 10 endangered Western Siberian Cranes, bred in captivity, with an Icaro hang glider equipped with an NRG powered harness 5,300 kilometres (3,300 mi) from the Arctic circle in Siberia, across Kazakhstan to the shores of the Caspian Sea in Iran, avoiding Afghanistan and Pakistan where they fall victim to the abundant guns. For the most part, he relied on the sun and wind for propulsion in order to teach the young cranes to soar long distances. This exhausting $250,000 USD experiment lasted for six months and finished in winter 2002. If repeated a few times, scientists hope the new migratory route will be passed on from parent to fledgling for generations of cranes to come.

- In 2005, Chris Streat soared his Explorer harness and *Litesport* hang glider over Mt. Cook, in the Southern Alps, New Zealand, at an altitude of 4,114 metres (13,497 ft) above sea level (ASL) while aided by mountain wave lift.

- On April 24, 2005, English pilot Stewart Bond flew his DoodleBug and *Aeros Discus-14* glider in still air at an altitude of 3,706 metres (12,159 ft) ASL.

- On July 16, 2005, American pilot Bruce Decker performed a 3,048 metres (10,000 ft) high density altitude takeoff in Colorado, USA using an X1 harness on an *ATOS 146* rigid wing hang glider; the wind was only 4.8 kilometres per hour (3.0 mph).

Patrick Laverty - altitude world record: 5,348 metres (17,546 ft). U.K., May 24, 2009

- On May 24, 2009, Irish pilot Patrick Laverty broke the foot-launched powered hang glider altitude world record. He used an *Aeros Discus 15* hang glider coupled to a supine custom-made harness equipped with a 29 hp ROS 125 engine with the *Tuna* carburation system on a WB32 carburettor. Takeoff was at sea level and he flew to an altitude of 5,348 metres (17,546 ft) ASL over Talybont, Ceredigion, Wales, UK. He carried oxygen and 10 litres of fuel, per U.K. regulations; his variometer indicated 30 to 50fpm climb rate at the time fuel ran out.

Systems

Currently, there are two harness configurations: prone (face down) and supine (sitting). Both configurations allow the pilot to takeoff and land on his/her feet. Foot-launched powered hang glider (FLPHG) harnesses are built around a light metal frame with the engine and propeller mounted on the rear in a pusher configuration. Current powered harnesses weigh 22–32 kg (50-70 lb) not including the safety parachute and fuel, and fold neatly into a 1.5 metres (4.9 ft) long harness bag with a handle. Most powered harnesses in production are equipped with the 'Radne Raket 120' two stroke engine which is based on Husqvarna XP3120 chainsaw parts. It has a displacement of 118 cubic centimetres (7.2 cu in) and produces about 15 hp (11 kW) at 8900 RPM if equipped with a tuned exhaust; when coupled to a 1:3.5 belt-driven reduction drive and a 52" x 22" propeller, it produces about 100 lbf (440 N) of static thrust. For heavy pilots or pilots operating from higher than 1,500 metres (4,900 ft) MSL fields, a powered harness equipped with an 18 hp (13 kW) engine is recommended. It is now estimated that a modern flex wing hang glider requires at least 6 hp (4 kW) at the propeller and about 30 or 40 lb of thrust to maintain level flight at 'best glide' speed.

The motor is supported on the ground by two retractable skids, holding the propeller just off the ground. The 4 Liter aerodynamic fuel tank is attached to the top of the control frame or is enclosed in the harness. Getting into the harness requires passing both legs through padded straps and wearing the harness like a vest, with a zipper and/or buckles at the front. The powered harness is hooked to the glider via a regular hang strap. The whole aircraft is easily maneuvered on the ground into takeoff position with the pilot buckled into the harness and ready to start the unit by themselves either with a manual or with an electric starter. The throttle is activated during takeoff by means of a mouth-throttle in order to have both hands free for proper weight-shift control. Once airborne, a foot throttle, thumb throttle or cruise control can be used. Zipping up the harness also retracts the rear skids, which are then clipped into clamps on the side of the harness. The propeller is locked in place while soaring power-off, as a windmilling propeller has more drag than a stationary one: Expect a 10 to 20% decrease in glide performance with a windmilling propeller (clutched units) and 2 to 4% decrease with a locked propeller. A folding propeller is often preferred by pilots who want optimum soaring and cross country performance with the engine turned off.

Engine controls

Hang gliders are controlled by simply shifting the pilot's weight, but a powered harness must have engine controls and the pilot must know exactly where they are, without having to look and find them. Engine controls are ergonomically positioned at the sides of the harness, chest or shoulder straps and generally consist of throttle, choke, propeller lock, recoil starter handle or electric starter button and decompression valve. During training, it is very important to hang the harness from a solid location, climb in and practice often so that the pilot can automatically reach and activate any engine control without first looking to find it.

Training & safety

Good gliding weather: Light wind and cumulus clouds with dark flat base.

Hang gliding is an extreme sport but perhaps often viewed as a higher-risk sport than it actually is. Nonetheless, there is great potential for injury for the reckless or ill-prepared. Unlike powered paragliding, it is absolutely essential that the aspiring pilot first take lessons in an unpowered hang glider at a certified school and achieve some solo experience in order to develop all needed skills to perform automatic control inputs and consistently safe landings. Tow is the best launch method for progression to FLPHG. Basic aerodynamics, flight concepts, some meteorology, local regulations, field choice, safety and emergency procedures must also be learned during training.

Soaring

Although it started out as simply gliding down small hills on low performance wings, hang gliding over the last 120 years has evolved to the ability to soar for hours with hawks and eagles, gain thousands of feet of altitude in thermal updrafts, and fly cross country over distances of hundreds of miles. If the pilot finds lift, he/she may wish to shut off the engine and soar. While soaring, the propeller is locked or folded to reduce drag. In-flight engine restarts can be a powerful didactic tool for learning or improving thermalling skills, as the pilot does not have to land every time he does an incorrect decision and loses the lift. This brings about significant increase in soaring airtime and opportunities needed to better understand lift, usable cloud life, sink, drift, ridge lift, timing transition glides, etc.

While soaring a prone unit power off, the biggest difference will be the extra mass at one's feet when roll for a turn, which requires additional effort at stabilizing the wing during mild or moderate turbulence. Unpowered glider pilots can stay airborne for hours. This is possible because they seek out rising air masses or lift from the following sources:

Thermals
The most commonly used source of lift is created by the sun's energy heating the ground which in turn heats the air above it. This warm air rises in columns known as thermals. Soaring pilots quickly become aware of visual indications of thermals such as: cumulus clouds, cloud streets, dust devils, soaring birds and haze domes. Having located a thermal, a glider pilot will circle within the area of rising air to gain height. In the case of a cloud street, thermals can line up with the wind creating rows of thermals and sinking air. A pilot can use a cloud street to fly long straightline distances by remaining in the row of rising air.

Ridge lift
Another form of lift occurs when the wind meets a mountain, cliff or hill. The air is deflected up the windward face of the mountain forming lift. Gliders can "surf" and climb in this rising air by flying along the feature. Another name for flying with ridge lift is slope soaring.

Mountain wave
The third main type of lift used by glider pilots are the lee waves that occur near mountains. The obstruction to the airflow can generate standing waves with alternating areas of lift and sink. The top of each wave peak is often marked by lenticular cloud formations.

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

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

Instruments

In order to maximize a pilot's understanding of how the hang glider is flying, most pilots carry a series of small instruments, often interconnected. The most basic being an airspeed indicator, a variometer and altimeter. Many pilots also use two-way communication radios and some also carry a map and/or GPS unit. Some pilots also make use of a small tachometer to ensure the engine is developing full power prior to takeoff. Hang gliders do not have instrument panels as such, so all the instruments are mounted on the control frame of the glider, except for the radio and tachometer which are mounted on the harness.

Variometer

Vario-altimeter

People can sense the acceleration when they first enter a rising thermal, but they cannot detect the difference between constant rising air and constant sinking air, so they turn to technology for help. A variometer is a very sensitive vertical speed indicator; in other words, indicates climb or sink rate with audio signals (beeps) and/or a visual display. These units are generally electronic, vary in sophistication and often include, an altimeter and airspeed indicator. More advanced units often incorporate a barograph for recording flight data and/or a built in GPS. The main purpose of a variometer is in helping a pilot find and stay in the ‘core’ of a thermal to maximise height gain, and conversely indicating when he or she is in sinking air, and needs to find rising air. Variometers are sometimes capable of electronic calculations based on the 'MacCready Ring' to indicate the optimal speed to fly for given conditions. The 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. Some electronic variometers make the calculations automatically, after allowing for factors such as the glider's theoretical performance (glide ratio), altitude, hook in weight and wind direction.

2 meter band radio

Radio

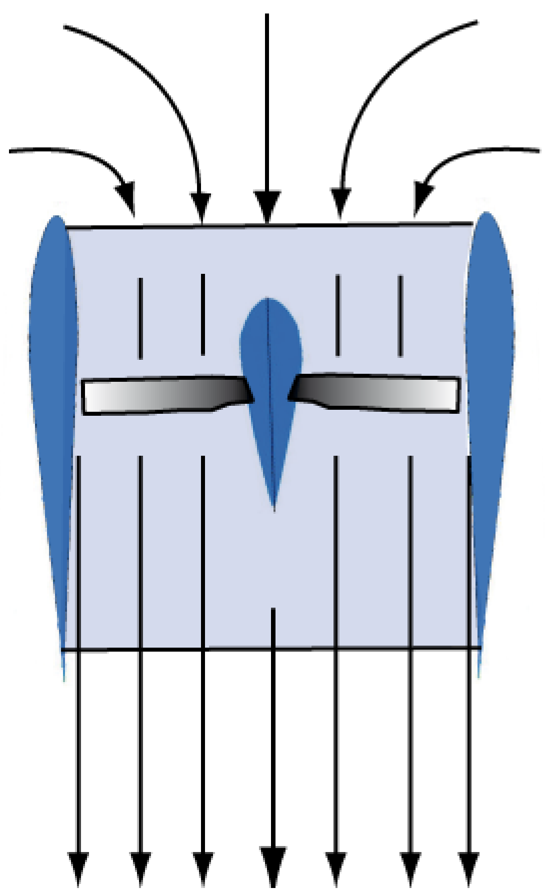
Pilots use radio for training purposes and when traveling on cross-country flights. Radios used are PTT (push-to-talk) transceivers. Best range is achieved with FM VHF 2-meter band (144–148 MHz) radios. Usually a microphone and earphones are incorporated in the helmet and the PTT switch is strapped to a finger.

GPS
GPS (global positioning system) is a necessary navigation accessory when flying competitions, where it has to be demonstrated that way-points have been correctly passed. More common uses include being able to determine drift due to the prevailing wind, providing position information to allow restricted airspace to be avoided, and identifying one’s location for retrieval teams after landing-out in unfamiliar territory. It can also be interesting to view a GPS track of a flight when back on the ground, to analyze flying technique. Computer software is available which allows various different analyses of GPS tracks. More recently, the use of GPS data, linked to a computer, has enabled pilots to share 3D tracks of their flights on Google Earth. This fascinating insight allows comparisons between competing pilots to be made in a detailed 'post-flight' analysis.

In development

Powered hang gliders' technology is quite young and continuously evolving and improving.

Ducted fan



Sechematic of flow through a ducted fan

Advantages:

- A ducted fan offers greater propulsive efficiency and a smaller frontal area.
- By reducing propeller blade tip losses and directing its thrust towards the back only, the ducted fan is more efficient in producing thrust than a conventional propeller advancing at low speed (80 knots).
- Ducted fans are quieter than propellers: they shield the blade noise, and reduce the tip speed and intensity of the tip vortices both of which contribute to noise production.

Challenges:

- Complex duct design.
- Requires of high RPM and minimal vibration - Electric or Wankel engine needed.
- A significant weight increase even if constructed from advanced composites.
- Tradeoff between additional power and drag increase during glide (power off) and also, at an angle of incidence of 32^{o}, parts of the duct would be stalled and producing drag.

Electric motors

On 1979, Larry Mauro added a landing gear to an electric *Solar Riser* hang glider; although it was the first solar airplane, it may not be universally held as the first *foot-launched* electric powered hang glider. Advances in batteries, solar cells, and ultracapacitors are being considered for bringing electric powered paragliders and hang gliders to practical and affordable use.

- Designers Csaba Lemak and Patrick MacKenzie constructed a powered paraglider powered by 112 Lithium Polymer (Li-Po) batteries and a 17 hp (13 kW) custom wound three phase motor weighing 1.5 kg coupled to a 3.6 to 1 reduction drive. Their electric powered paraglider flew for the first time on June 6, 2006 in Ontario, Canada. With flight autonomy of only 35 minutes, it has many advantages, such as ease of operation, minimum maintenance and power output is not altitude dependent.

- Richard Kruger-Sprengel (Helix Propeller) and German designer Werner Eck, have produced at least two electric powered paraglider (EPPG) prototypes, their first machine flew in 2001 for 3.5 minutes and was the first EPPG; their latest prototype was tested again on March 2008 and it uses a motor described as: LEM 200 / Fa. Lemco, brushes – disc / 5.5 kg, direct current, 10 kW at 2.200 rpm, 50 Volt at 200 Ampere. Controller: Fa. Brusa, 48 V / 500 A / 1,7 kg. Battery: 14 accumulator Saft 35 Ah connected in series 14 x 3,6 V = 50,4 V. Lithium-Ion-Technology. Weight: 15 kg. Time to charge: 20 min to 2 hours. The latest efforts are described on Werner Eck. Since 2007 Werner Eck is using a personal brushless direct drive outrunner; it is visible on website SLS

- ElectroPropulsion Ltd. and Electric Flight Systems Ltd. have teamed up with the Defence Academy of the United Kingdom scientists to assist in research and development of electric powered flight optimised for the leisure aviation market.

Advantages:

- Superb reliability.
- Extremely easy re-start.
- Simple operation and maintenance.
- Small size components.
- No flammable fuel or oil required.
- No exhaust gases.
- Minimal cooling required, allowing for better aerodynamic profile.
- Noise produced only by the propeller.

Challenges:

- Battery weight, cost, and recharge method.
- Flight autonomy time.

Chapter- 8

Motor Glider

DG-808B 18m self-launching

A **motor glider** is a fixed-wing aircraft that can be flown with or without engine power. The FAI Gliding Commission Sporting Code definition is: A fixed wing aerodyne equipped with a means of propulsion (MoP), capable of sustained soaring flight without thrust from the means of propulsion.

History

An occasional or auxiliary motor that could be retracted was suggested by John Carden in 1935

Types

Most motor gliders are equipped with a propeller, which may be fixed, feathering, or retractable.

Fixed or feathering propeller

Touring motor gliders

Motor with fixed or full feathering propellers are generally classified as Touring Motor Gliders (TMGs). TMGs can take off and cruise like an airplane or soar with power off like a glider.

Scheibe SF25C - an older touring motorglider with tube and fabric fuselage construction.

They are fitted with front mounted engines, similar to a small airplane. The large wingspans of TMGs provide a moderate gliding performance, though worse than that of unpowered gliders. However TMGs are more efficient than conventional light aircraft.

Most TMGs are designed with engines of 80 to 100 hp (75 kW) and typically cruise (under power) at 85 - 100 knots (190 km/h). Most have fuel tanks capable of holding 50 and up to 100 liters (13 to 26 US gallons) of fuel, giving a range under power of up to 450 US nautical miles (approximately 830 kilometers).

Some TMGs are equipped with folding wings to allow them to fit in standard small airplane T-hangars. Touring motor gliders must self-launch, because they are not equipped with tow hooks for launching like a conventional glider. The self-launch requirement however, is most desirable to those pilots who wish to fly a glider, but have no access to tow planes or ground launching equipment.

Some TMGs, like the Europa, can also be supplied with interchangeable wings so that they can be flown as a standard touring aircraft as well as a TMG.

Grob G109B touring motor glider, with fibre-reinforced plastic construction.

The landing gear configuration on TMGs usually incorporates two fixed main wheels, allowing it to be taxied on the ground without a wing walker. While some TMGs have only one main wheel, with auxiliary trolley wheels on the wings for taxiing, it is becoming more common to find them being manufactured with tricycle and conventional (two fixed main wheels - i.e. a "tail-dragger") landing gear configurations.

Since the additional drag of the stopped propeller and landing gear reduces their gliding performance, TMGs are seldom used in competition.

Retractable propeller

Schleicher ASH 26e self-launching motor glider, with the engine mast extended. A Stemme S10 is in the background with the nose cone extended.

The retractable propeller is usually mounted on a mast that rotates up and forward out of the fuselage, aft of the cockpit and wing carry-through structure. The fuselage has engine bay doors that open and close automatically, similar to landing gear doors. The engine may be near the top or bottom of the mast, and newer designs have the engine fixed in the fuselage to reduce noise and drag.

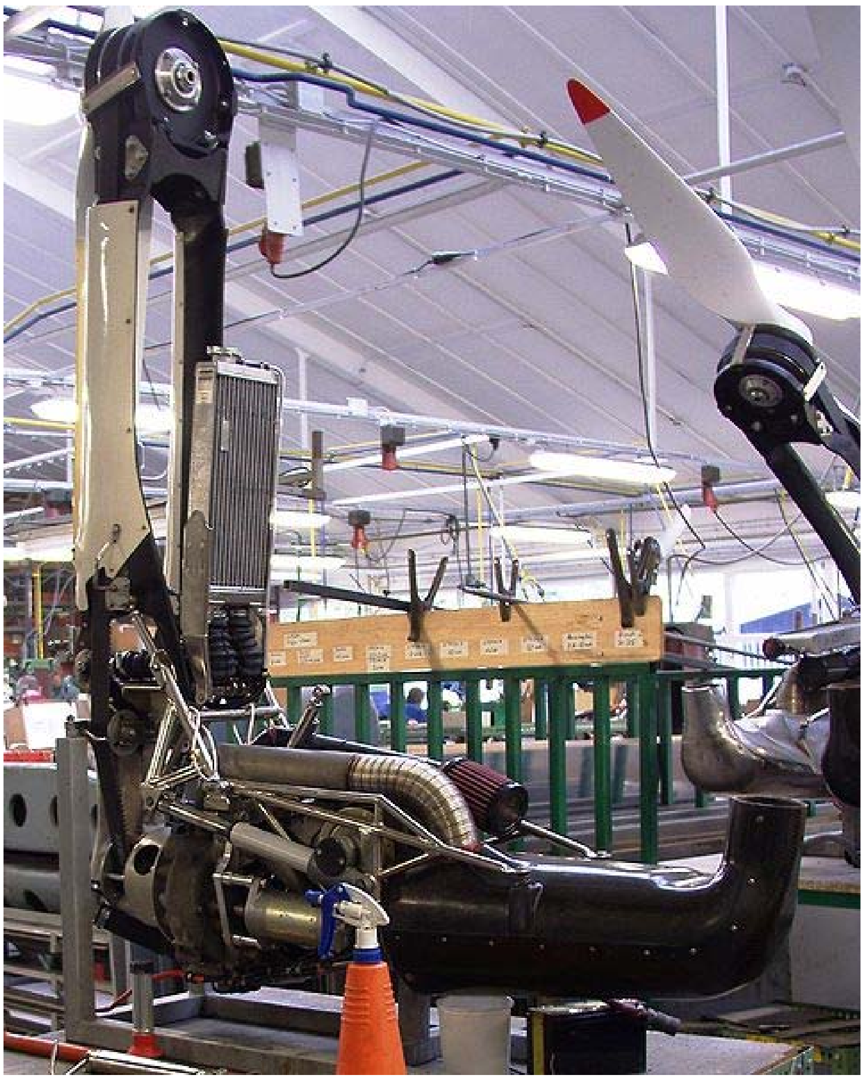
Unlike TMGs, most gliders with retractable propellers are also fitted with a tow-hooks for aero-towing or ground launch. They have a single axle retractable main wheel on the fuselage like most unpowered gliders, so they do require assistance during ground operations. The two-stroke engines commonly used are not efficient at reduced power for level cruising flight, and instead must use a "saw-tooth" flight profile where the glider climbs at full power, then glides with the propeller retracted.

Sustainer

Sustainer motor gliders must be launched like an unpowered glider, but can climb slowly to extend a flight once the engine is deployed and started. They generally do not have an alternator or starter motor, so the engine is started by "wind-milling" the propeller in flight. The propeller may be a rigid 2-blade design, or may have more than two blades that fold at the hub when the engine is retracted. The propeller hub is usually attached directly to the crankshaft, but there is at least one example of a sustainer with a belt reduction drive, the DG-1000T.

The smaller sustainer engines are usually not equipped with a throttle, but instead have a cable to open decompression valves in each cylinder to allow the engine to turn freely for starting. Sustainer engines are typically two-stroke two-cylinder air-cooled engines in the range of 18-30 hp (14-22 kW). They are lighter in weight, and simpler to operate than self-launching powerplants.

Self-launching



Powerplant from a Schleicher ASH 26e self-launching motor glider, mounted on a test stand for maintenance at the Alexander Schleicher GmbH & Co in Poppenhausen, Germany. Counter-clockwise from top left: propeller hub, mast with belt guide, radiator, Wankel engine, muffler shroud.

Self-launching retractable propeller motor gliders have sufficient thrust and initial climb rate to take off without assistance, or they may be launched as with a conventional glider. The engines also have a starter motor and a large battery to allow the engine to be started on the ground, and an alternator to recharge the battery. A two blade propeller is typically coupled to the engine via a belt reduction drive. In older designs, the propeller alignment must be checked by the pilot using a mirror, before it is retracted into the fuselage however in current production gliders, propeller alignment is fully automatic.

Another solution is the single-blade propeller that offer the advantage of a smaller opening in the fuselage to retract the engine.

Internal combustion engines can benefit from mounting in the fuselage, rather than on the propeller mast. This allows them to be connected to a larger muffler for reduced noise when operating, something which is mostly relevant to European operation. It also allows the belt tension to be relieved when the engine is retracted to extend the life of the belt and bearings. The drawback of this arrangement is that engines fixed low in fuselages are more difficult to pre-flight and service and highly stressed power transmission belts should not be bent or twisted.

Self launching engines are equipped with a throttle that allows the engine power to be adjusted for ground operations. Self launching engines are typically in the range of 50-60 hp (38-45 kW). The higher engine output power requires liquid cooling with a separate radiator mounted on the propeller mast. Engines commonly used are two-stroke piston engines, or Wankel rotary engines.

Other types

Cross-over

On the Stemme S10, the propeller folds into the nose cone, and is connected to the rear mounted engine with a drive shaft. It also has two retractable main wheels, allowing it to be taxiied without assistance, and to soar with low drag. These features make it a cross-over between the touring and retractable propeller motor gliders. It does not have a tow-hook, so it must self launch. The S10-VT variant has a two-position variable pitch propeller and a turbocharger on the engine, which allows the aircraft to cruise at altitudes up to 30,000 feet (9,000 m).

On the AMS Carat, the propeller folds forward, pointing straight ahead like a spear.

Electric

Although most motor gliders have gasoline fueled internal combustion engines, recently electric powered self-launchers such as the Antares 20E and the Silent 2 Targa LE (Lithium Electric), as well as the Air Energy AE-1 have been developed.

Other examples include the Apis2 and the Pipistrel Taurus.

Jet

Bob Carlton's jet powered glider.

There was one example of a factory produced self-launching motor glider fitted with a jet engine, the Caproni Vizzola A21J Calif. The jet engine was mounted inside the fuselage behind the wing, with fixed intake and exhaust ducts coupled to the outside air stream for engine operation. A variant of this aircraft, the Caproni Avi-America featured a copy of the British Nene jet engine, with a pressurized cabin. It was reportedly able to reach 70,000 feet (21,000 m) altitude and, with a glide ratio of 1:100 (with the engine turned off), a range of several thousand miles. Elements of the U-2' spy plane aircraft's design were incorporated into the A21J.

Security considerations prevented this aircraft from being marketed and awareness of what was probably the most high-performance civilian glider of all time apparently has been suppressed. An ASW20CL-J has been built by Klaus Meitzner in Hoya, Germany (Segelflugverein Hoya). The Jonker JS-1 Revelation is a design available with a sustainer jet engine. The highly modified Alisport Silent Club-J is a self-launching aerobatic jet motor glider shown on the U.S. airshow circuit and all over the world by Bob Carlton, powered by twin AMT-USA AT-450 jet engines (200 N (45 Lbf) of thrust each) originally developed for radio-controlled aircraft. An experimental self-launching motor glider LET L-13TJ Blaník was fitted with a jet engine TJ100C (take-off thrust 1,0 kN) from První brněnské strojírna Velká Bíteš

Use of engines - in Self-Launch Sailplanes (Gliders)

The engine cannot always be relied upon to start in flight, so the pilot must allow for this possibility. The generally accepted practice is to get in position for landing at a suitable airport, or off-airport out-landing field, before extending the propeller and attempting an engine start. This allows for a safe landing in the event that the engine cannot be started in time.

In soaring competitions, starting the engine is usually scored the same as an out-landing in an unpowered glider. To detect the use of the engine, GNSS Flight Recorders used in motor gliders must have a noise sensor that allows recording the sound level along with position and altitude. In many competitions, the rules require that the pilot start the engine at the beginning of the flight, before starting the task, to ensure an engine start later in the flight will be detected.

Schempp-Hirth Nimbus 4M with engine running.

Gliders without an engine are lighter and, as they do not need a safety margin for an engine-start, they can safely thermal at lower altitudes in weaker conditions. So, pilots in unpowered gliders may complete competition flights when some powered competitors cannot. Conversely, motor glider pilots can start the engine if conditions will no longer support soaring flight, while unpowered gliders will have to land out, away from the home airfield, requiring retrieval by road using the glider's trailer.

The presence of an engine can increase the safety of gliding, as a powerplant increases the ability of the pilot to avoid storms and off-airport landings. An opposing view is that motor gliders are against the spirit of the sport, and, more importantly, that they sometimes give pilots a false sense of security.

Touring motor gliders are seldom used in competition, but they can be useful in training for cross-country flights. After take-off, the engine is switched off, and the trainee flies the aircraft as a glider. Landings in unfamiliar fields can be practiced while the motor idles. If the trainee chooses an inappropriate field, or misjudges the approach, the instructor can apply power and climb away safely.

Fournier RF-4D in England (2009).

Power Assisted Soaring (PAS) - in Touring Motor Gliders (TMG)

Power assisted soaring.

The History of PAS:

Traditionally the philosophy and practice of gliding (soaring) was confined within the limited sphere of what is commonly referred to as “gliding”, though the technically correct term is “soaring” - and the aircraft commonly used, though incorrectly referred to as: pure “Gliders” (the technically correct term is: Sailplanes, which obviously included – self launch sailplanes). Inadvertently “all forms of soaring” resorted under “Soaring Societies” - with customary limited mandate, failing to recognise the inimitability of PAS.

Power Assisted Soaring (PAS) as a unique mode (form, method and approach) of flying was neglected as a defined and recognized unique flying discipline – due to conventional aviation heritage, rather than “wisdom”. Primarily because of the misguided recognition (of the use / application) and subsequent definition and classification of the particular type of aircraft used – namely Touring Motor Gliders (TMG) or rather the technically correct term: Touring Sailplane (TS), these are perceived - either as Powered Aircraft – or as Sailplanes (or self-launch gliders), for various reasons of convenience / ignorance. Aviation authorities (legislators, regulators, associations) the world over traditionally failed to recognize TMG as a distinctively separate type of aircraft – with unique features, capabilities and operational requirements - both in terms of pilots (human elements) and the environment / conditions. Though, on face value the doctrine of PAS suggests a hybrid of soaring and power flying elements / activities, the traditional view (depending on the school of reference / pilot licence orientation) is that a TMG is primarily either operated as a Sailplane (self launcher / engine off), or as a power aircraft (engine operable, providing thrust to maintain straight and level flight).

The reality of PAS however is much different. Pilots with a proper understanding of the total operational envelope (flight limitations / advantages / applications) of the TMG type have always inadvertently practiced PAS to various degrees, combining simultaneously - elements of soaring and power flying. Of cause - Touring Motor Glider (TMG) pilots regularly fly their craft as powered aircraft and as pure gliders. Further, soaring per se, makes for exceptional good practice for all spheres of flying. There are however - very rarely general conditions (thus only with exceptional conditions) – will actually flying with the engine off in the average TMG will provide a true advantage over competent PAS practice. (PAS is flying a TMG to the full envelope of design – whilst engine off soaring is only one facet, - as is “power flying” the other extreme of the craft).

Touring Motor Glider (TMG) is indeed an independent National Pilots License (NPL) category – under Recreation Aviation - Part 62, in South Africa contained in subpart 17 – for obvious reasons to the educated and informed.

(Note: PAS is NOT relevant to - Self-Launch / sustainer gliders!)

The phrase - PAS:

The phrase: "Power Assisted Soaring" – was coined by a South African Christophe Jonathan Roelofse, - as late as 2003 in the history of aviation, for what seemed a logical conclusion to this – “ideal mode of flight”. Though he entertained the expression “Power Assisted Gliding” (PAG) for a while. Finally in essence he based the compilation (expression of “PAS” – as an activity) on the actual technical correct verb – for gliding, ie “soaring” and subsequent argumentative technically correct revised definitions for a Touring Motor Glider (ie “Touring Sailplane” (TS)). The universal definition offers an – substantiated apparent inclusiveness, that a TMG / TS - as a requirement to type: The enige must contribute (assist) to a better “gliding / soaring performance”. (Unlike the case with an obvious pure glider (sail plain) and particularly - the “self launcher sailplane” – in which case the soaring ability increased with the engine stowed away). Hence the actual primary activity: “Power Assisted Soaring”. Though the “act of flying” a TMG is sometimes referred to as “Touring Motorgliding” (with no explicit definitive content to the actions employed) – the technically correct terms / act is "Power Assisted Soaring" – as a technical term (verb / noun) with a definitive "unique explicit technical content".

The official definition – developed by Roelofse, and supported by PASASA was presented to the South African CARCOM (Civil Aviation Regulation Committee) in and published in May 2008 in the government gazette:

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    2.0    PROPOSAL TO AMEND REGULATION 1.00.1 OF PART 1 OF THE CIVIL
AVIATION REGULATIONS (DEFINITIONS) –
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(*C) "Touring Sailplane" means a fixed wing aerodyne, with a maximum all-up mass not exceeding 850kg, with 2 or more deferent and independent control surfaces, that is mainly supported in free flight by an operative engine and the dynamic reaction of the air against its fixed lifting surfaces in soaring, with a non-retractable engine unit, and non-retractable or feather propeller, having sailplane characteristics when the engine is inoperative; [Roelofse May 2008]*

In his various writings on the subject Roelofse states that: PAS is not about minimum fuel burn for maximum flight time (fuel efficiency per hour) – as the common misbelieve, which merely renders - efficient power flying methodology. He makes the fundamental observation and paradigm shift - to "total energy management" – of both the craft and the environment.

Roelofse defines PAS as:

"The continuous in-flight practice - of the conscientious exploration of the total (potential, latent, etc) energy index of the aircraft – and the environment – in the ideal combination - to cover the greatest land distance in the shortest space of time with the least amount of "total" energy (including fuel) consumption and the highest energy yield harnessed from the environment".

Philosophy: Total energy versus speed (time) / distance. He has developed a definitive methodology for the practice of PAS, and formulation to equate an – Efficiency Index.

Chapter- 9

LET L-13 Blaník and Orlican VSO 10

LET L-13 Blaník

L-13 Blaník

Penn State Soaring Club L-13 flying over State College, Pennsylvania showing forward swept wing

Role	Two Seater class sailplane
National origin	Czechoslovakia, later Czech Republic
Manufacturer	Let Kunovice
Designed by	Karel Dlouhý
Number built	over 3,000 including variants
Variants	Blanik TG-10

The **L-13 Blaník** is a two seater trainer glider produced by Let Kunovice since 1956. It is the most numerous and widely used glider in the world. In United States Air Force Academy service, it is designated **TG-10C** and is used for basic flight training.

Development

The L-13 Blaník was designed by Karel Dlouhý of VZLÚ Letňany ca. 1956, building upon the experience gained with the Letov XLF-207 Laminar, the first Czech glider to employ laminar flow wing profiles. The L-13 was developed as a practical glider suitable for basic flight instruction, aerobatic instruction and cross-country training. This design concept was combined with true and tested technology: metal construction, NACA laminar profiles and many standard-issue components of the Soviet aerospace industry.

The Blaník entered production in 1958 and quickly gained popularity as an inexpensive, rugged and durable type, which was easy to fly and operate. It was widely adopted in the Soviet bloc and was exported in large numbers to Western Europe and North America. Total production was in excess of 2650, or more than 3000 if variants are included. More than half a century after its first flight it is still the most common glider in the World.

In the cross-country role the Blaník achieved many two-seater World distance records during the 1960s in spite of having only fair performance.

The Blaník inspired other designs, notably the Démant and L-21 Spartak single-seaters developed to equip the Czechoslovak team in the 1956 and 1958 World Championships.

Characteristics

The effectiveness of the Blaník as a primary trainer is due to a blend of characteristics that facilitate progress of *ab initio* students towards solo flight, namely: slow landing speed, ample control deflections and an effective rudder. These are in effect typical of wood-and-fabric primary trainers such as the ASK 13, which the Blaník resembles in handling, though not in materials, construction and aerodynamics.

For this reason, pilots trained in the Blaník require *differences training* in a modern two-seater before transitioning to high performance plastic single seaters.

The Blaník was originally stressed for simple aerobatics, including inverted flight where the aircraft has a single occupant. As a result of this latter requirement, intermediate level aerobatic training in the Blaník was done in solo flight with the instructor on the ground or in another aircraft. Following a manufacturer airworthiness directive in June 2010, all aerobatic manoevres were forbidden.

There are two design issues that pilots should be aware of. The wheel retracts counter-intuitively, with the gear handle moving forward for wheel up and back for down (this is reversed on the L-23). More importantly, the spoiler and flap handles have the same shape and are close to each other. This has led to a number of incidents where pilots have mistakenly operated the wrong handle, particularly in the landing pattern. Instructors recommend that a positive visual check of the spoiler operation be made during the prelanding checklist, and that the pilot's hand stay on the handle right through full stop.

The Blaník empennages are vulnerable. The horizontal stabiliser is low enough to be damaged when landing in brush, and one must not push on the vertical fin when ground handling as it is not stressed to carry loads fore-and-aft.

Construction

Flaps deployed for landing - torpedo tips clearly visible, and air brakes partially open

Motorglider LET L-13M Blanik over Vecaki, Riga - Latvia

- Fuselage of semi-monocoque construction employing longerons and bulkheads, with an ovoid cross-section. The cockpit is covered with a two-part acrylic glass canopy.

- Trapezoidal single-taper wings with forward (negative) sweep, single-spar, all-metal construction. Metal ‘torpedo’ tips. Flaps and ailerons have a metal frame and are covered in fabric. Metal DFS type spoilers on the upper and lower wing surfaces.

- The horizontal tail surfaces fold up parallel to the fin for transportation and storage.

- The elevator and rudder are metal frames covered in fabric.

- The landing gear is semi-retractable and sprung with an effective oleo-pneumatic shock absorber, excellent features which assure landings with little or no damage even if the wheel is left (forgotten) in the raised position.

Main spar fatigue

A Blaník was involved in a fatal accident in Austria on 12 June 2010 when a wing spar failed at height, leading to separation of the wing and loss of control of the aircraft. The cause of the failure was attributed to fatigue. As a result, the manufacturer issued an emergency bulletin on 18 June 2010 mandating that each aircraft was to be grounded pending a full inspection of wing spars and compilation of usage patterns from logbook records. Following inspection, the aircraft was permitted to fly on a non-aerobatic basis only. Following further discoveries from the accident investigation, this method of investigating for fatigue has not proved conclusive and so the type remains grounded by the EASA and the FAA.

Europe

Following the accident, EASA released a number of directives regarding all Blaník variants. Initially, the directives mandated the aircraft be grounded unless logbook records show that dual flying hours comprise less than 50% of the aircraft's total flying time. Further investigation into the original accident has shown that these limits and analysis of flight records (such data also not being guaranteed to exist) will not be sufficient to guarantee safe operation of the type.

United States

Emergency airworthiness directives were published by the FAA. A subsequent Airworthiness Directive disallowed use of inspection solely by 10X magnification because of the possibility of metal fatigue that might not be observed by this method. As a result, on August 30, 2010, so inspected L-13 Blaníks were again grounded pending further consideration. This AD covered all L-13s without regard to serial number or category.

Australia

During the 1970s & 1980s, the Gliding Federation of Australia recognized the potential fatigue-life limitations of the Blaník and in conjunction with the Ansett Airlines NDT laboratory and the Civil Aviation Authority of Australia developed an inspection programme culminating in the issue of GFA AD-369, designed to monitor the condition of the fatigue-critical components. Most of these fatigue-critical components are called into question by the accident on 12 June 2010. GFA AD-369 gave 3 options for continued operation beyond 5000 hours or 18,000 launches.

- Option A. total wing replacement
- Option B. major spar modification
- Option C. periodic eddy-current inspection.

In 1984 Dafydd LLewellyn and Riley Aeronautics received Department of Aviation certification for a modification of the wing to extend its fatigue life. Nine Blaníks in Australia were modified and re-certificated as L-13A1 (option B in AD-369)..

GFA AD 663 was issued on 25 June 2010 imposing the operational limitations specified by the Type Certificate holder. GFA AD 663 does not apply to Blaníks which have been modified to L-13 A1 (Llewellyn Modification).

Variants

- The **L-13 AC Blaník** is primarily intended for aerobatic training with a wider flight envelope enabling dual training up to intermediate-level. It combines the wings and cockpit of the L-23 Super Blaník with the single-piece canopy and conventional empennage of the L-13. This model is considered stronger and different enough from a conventional L-13 not to be affected by the FAA grounding.

- The **Vivat** is a touring motorglider derivative. The wings, fuselage and tail surfaces of the L-13 are mated to a cockpit featuring side-by-side seats and a conventional firewall-forward engine installation with either a Mikron M III AE four-cylinder inverted inline engine or a Limbach L 2000.

- An **auxiliary-powered** Blaník was also developed, with an external engine permanently mounted on a pylon above the rear fuselage. The **L-13 J** was Blaník with Jawa motor.

- The **SL-2P** twin fuselage Blaník was developed by Sportinë Aviacija in Lithuania as a flying laboratory for testing of laminar airfoils. The specimen profiles are fixed to a supporting frame erected between the fuselages. This variant is similar in concept to the modified Janus once operated by the DFVLR (today the **DLR**, or German Aerospace Center) for the same purpose.

- The **L-13 TJ** (OK-3801) single-seat experimental motor glider fitted with a jet engine TJ100C with take-off thrust 1,0 kN from První brněnská strojírna Velká Bíteš.

- The **L-13 B Bačostroj** (OK-8902) single-seat experimental motor glider with Walter Mikron IIIA, 48 kW

- The L-13 A1 (Llewellyn Modification) to extend the fatigue life to nominally three times the basic Blanik L-13 life.

Specifications

General characteristics

- **Crew:** Two
- **Length:** 8.40 m (27 ft 7 in)
- **Wingspan:** 16.20 m (53 ft 2 in)
- **Height:** 2.08 m (6 ft 10 in)
- **Wing area:** 19.2 m² (207 ft²)
- **Aspect ratio:** 13.7
- **Empty weight:** ca. 292 kg (645 lb)
- **Gross weight:** 500 kg (1,100 lb)

Performance

- **Maximum speed:** 253 km/h (158 mph)
- **Maximum glide ratio:** 28
- **Rate of sink:** 0.82 m/s (161 ft/min)

Orlican VSO 10

VSO 10 Gradient

VSO 10 Gradient

Role	Club-class sailplane
Manufacturer	Orličan Národní Podnik
First flight	1977
Introduced	1979
Number built	225

The **Orlican VSO 10 Gradient** is a Czechoslovakian club-class sailplane designed by Orlican Národní Podnik as a replacement for the VT-116 Orlik II.

Development

Development of the VSO 10 started in 1972 and the first prototype flew on 16 September 1977. The Type Certificate was granted on 15 May 1979, with the first production gliders entering service with Czechoslovak aeroclubs soon after. In 1990 the company ceased production when they started to build Schempp-Hirth gliders. Schempp-Hirth are the current holders of the VSO 10 Type Certificate.

Design

The VSO 10 is a single-seat cantilever shoulder-wing monoplane with an enclosed cockpit and retractable landing gear. It has a two-piece wooden wing, a T-tail empennage of aluminium alloy structure, a glass composite forward fuselage and an aluminium alloy rear fuselage. The VSO 10C has a fixed landing gear.

Variants

VSO 10B Gradient
: Retractable landing gear variant

VSO 10C Gradient Club
: Fixed landing gear variant

Specifications (VSO 10)

General characteristics

- **Crew:** 1
- **Length:** 7 m (22 ft 11½ in)
- **Wingspan:** 15 m (49 ft 2½ in)
- **Height:** 1.38 m (4 ft 6½ in)
- **Wing area:** 9.30 m² (100.104 ft²)

- **Aspect ratio:** 24.2
- **Empty weight:** 234 kg (516 lb)
- **Gross weight:** 379 kg (836 lb)

Performance

- **Maximum speed:** 250 km/h (155.3 mph)
- **Maximum glide ratio:** 36.2
- **Rate of sink:** 0.6 m/s (118 ft/min)