Ultralight Airplanes

The conjunction of the hang glider and the small engine has brought into being the "air recreational vehicle." A typical craft carries 200 pounds and cruises at 50 miles per hour

by Michael A. Markowski

Since the earliest days of aviation a widely sought objective has been an inexpensive airplane that is not unduly difficult to fly. From the time of the Wright brothers, however, the trend has been almost entirely toward bigger and more sophisticated airplanes. Only within the past few years has the conjunction of the hang glider and the small engine (Go-Kart or snowmobile) brought the long-sought objective into being as the ultralight airplane. The numerous models available today range in price from $2,800 to $7,000. For a pilot who has received the proper instruction and is acutely sensitive to the vagaries of the wind the craft are not hard to fly.

Until the ultralight aircraft came on the market most airplanes were designed and built principally to serve a commercial or military purpose. Even light aircraft cost so much to buy and maintain that few people could afford to have one solely for recreation. The ultralight airplane is the first to have been successfully developed and marketed as an "air recreational vehicle" (often abbreviated ARV). Last year more than 10,000 such aircraft were sold, surpassing the sales of general-aviation craft (airplanes employed for commercial purposes other than scheduled passenger service). The ultralights are now even finding commercial application in agricultural surveying, crop dusting and aerial photography. A few have been adapted for military observation service because they have the advantage of presenting virtually no radar image.

Several things besides affordability account for the popularity of the ultralights. One is the sheer pleasure of flying in this way. The pilot of an ultralight is not encapsulated in a cockpit but instead is able to be part of the wind. With the engine off the craft can be soared like a hang glider. At the end of the day the airplane can be folded up and stored at home.

In addition most ultralight airplanes do not have to be registered with the Federal Aviation Administration, nor is the operator required to have a pilot's license. Until recently these exemptions were granted only for craft that could be launched by a person on foot, as a hang glider is. As ultralights evolved, however, their larger engines and higher unloaded weight called for wheeled landing gear. Last fall the FAA set in motion a proceeding intended to establish clearer rules on what type of plane will be exempt. If the recommendations of manufacturers and other leaders in the industry are accepted, the primary criteria will be a maximum empty weight of 220 pounds and a maximum wing loading of three pounds per square foot. With these constraints the exempt craft would have sufficient structural strength and would land at a speed of less than 30 miles per hour, a necessary condition for easy handling.

Most of the models now available have an empty weight of about 200 pounds. The wingspan is 30 feet or more, the cruising speed about 50 m.p.h. and the stalling speed about 25. The glide ratio (the amount of forward movement for each foot of descent) averages 9:1 and the rate of climb is 500 feet per minute or more. Most of the craft can lift more than their empty weight, meaning that the pilot and the fuel can have a combined weight of more than 200 pounds.

In retrospect it can be seen that the ultralight airplane has its origins in the first attempts of people to fly. Otto Lilienthal of Germany made more than 2,000 flights during the 1890's in what were essentially hang gliders. Lawrence Hargrave of Australia designed and flew model airplanes powered variously by rubber bands and compressed-air and steam engines. He also invented the box kite, which served as the basis for all the externally braced biplanes made later.

In the U.S., Octave Chanute, who in 1894 had written the aeronautical classic *Progress in Flying Machines,* designed a hang glider based on the box kite and incorporating a Pratt truss, which had been patented in 1844 as a method of bracing railroad bridges. The two wings of Chanute's glider were connected by vertical posts braced by crisscrossing wires in both longitudinal and lateral planes, forming a rigid but lightweight structure that became the choice of the Wrights and all future designers of biplanes. The glider also included an aft tail assembly for stability and a curved-section airfoil for improved lift.

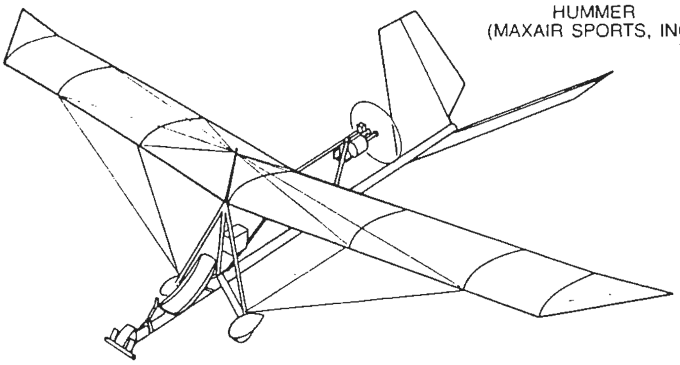
Augustus M. Herring, who had been an assistant to Chanute, was probably the first to fly a powered ultralight aircraft. He built a heavier version of the Chanute biplane hang glider (a glider he had helped Chanute with and had flown for him), mounting a two-cylinder, compressed-air motor ahead of the lower wing to drive two five-foot propellers mounted in tandem, one ahead of the wings and one behind them. On October 11, 1898, Herring made his first powered flight at St. Joseph, Mich., traveling about 267 feet in the air against a head wind approximating 25 m.p.h. He could control the glider only by shifting his weight. A few days later he made another flight. Satisfied that he had proved the feasibility of powered flight, he went on to design a steam engine and a larger aircraft, all of which were destroyed by fire in 1899. Later he organized the Herring-Curtiss Company, the first firm to manufacture airplanes in the U.S.

When the Wright brothers succeeded in piloting their "Flyer" on December 17, 1903, they achieved the first powered flight in which the pilot could control the craft by moving aerodynamic surfaces rather than by shifting his weight. The Flyer was a direct ancestor of today's ultralight airplanes. In succeeding years several other forerunners appeared: the Demoiselle of Alberto Santos-Dumont in 1909, the first truly professional ultralight of D. W. Huntington after World War I, the White Monoplane in 1920, the English Electric Wren in 1923 and the French Pou-du-Ciel in 1935. None of them achieved wide commercial success.

LARGE VARIETY of ultralight airplanes now available is suggested by the 10 versions on the opposite page. Each weighs about 200 pounds and has a wingspan of about 32 feet.

Scientific American July 1982

HUMMER
(MAXAIR SPORTS, INC.)



CLOUDBUSTER
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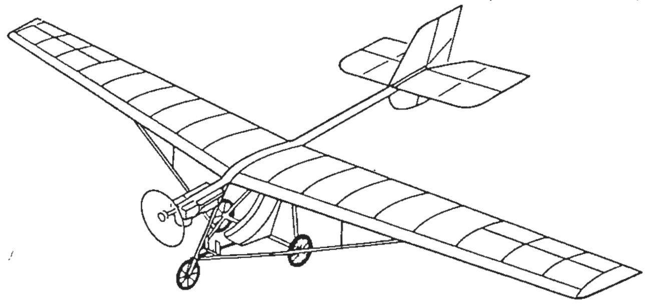

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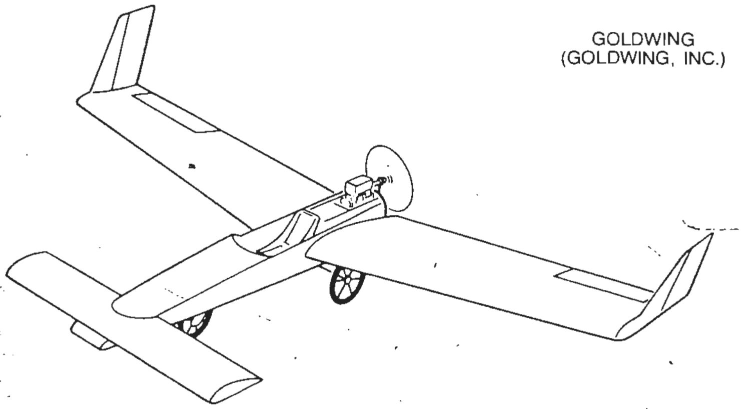
(GOLDWING, INC.)



MITCHELL U-2
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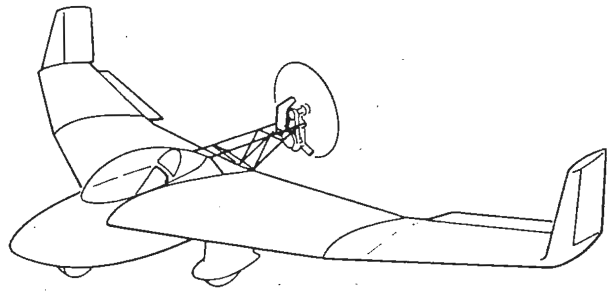

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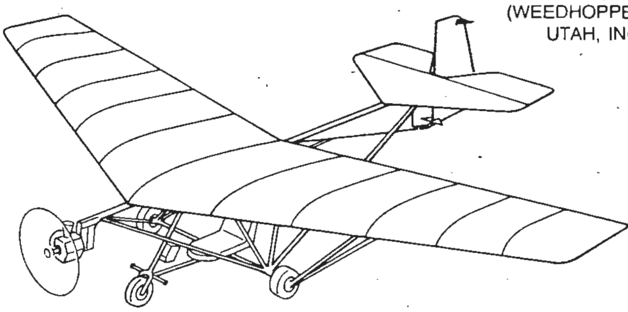
(WEEDHOPPER OF UTAH, INC.)



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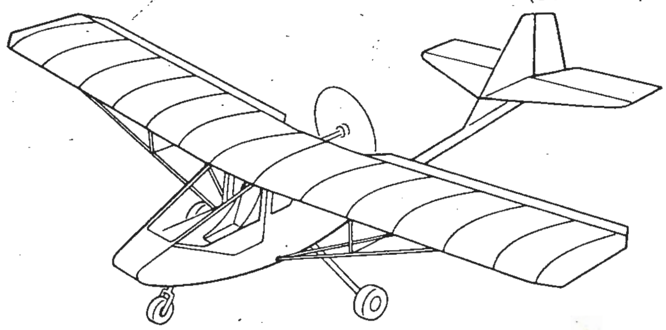

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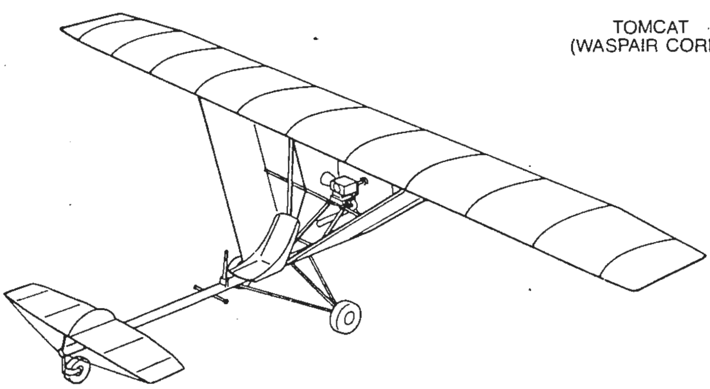
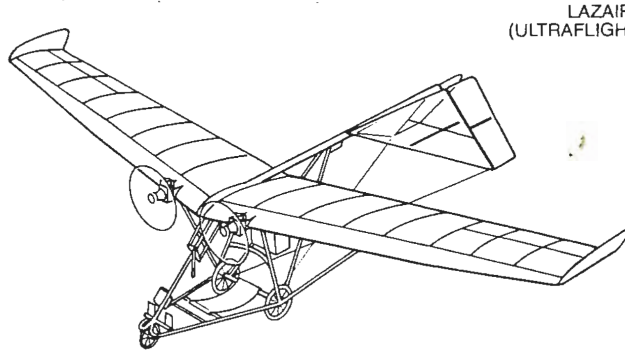


LAZAIR
(ULTRAFLIGHT, INC.)



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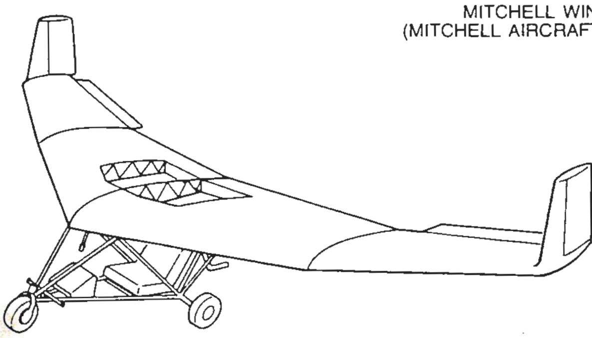
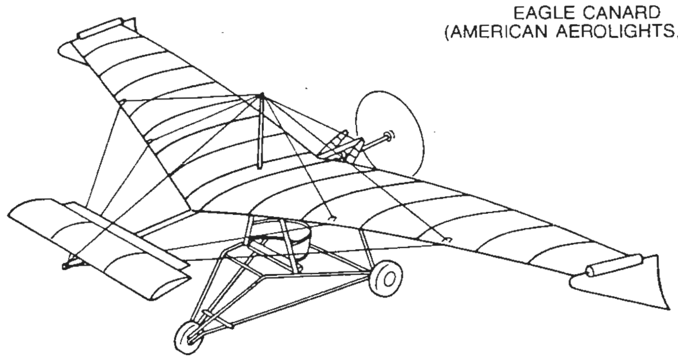


EAGLE CANARD
(AMERICAN AEROLIGHTS, INC.)



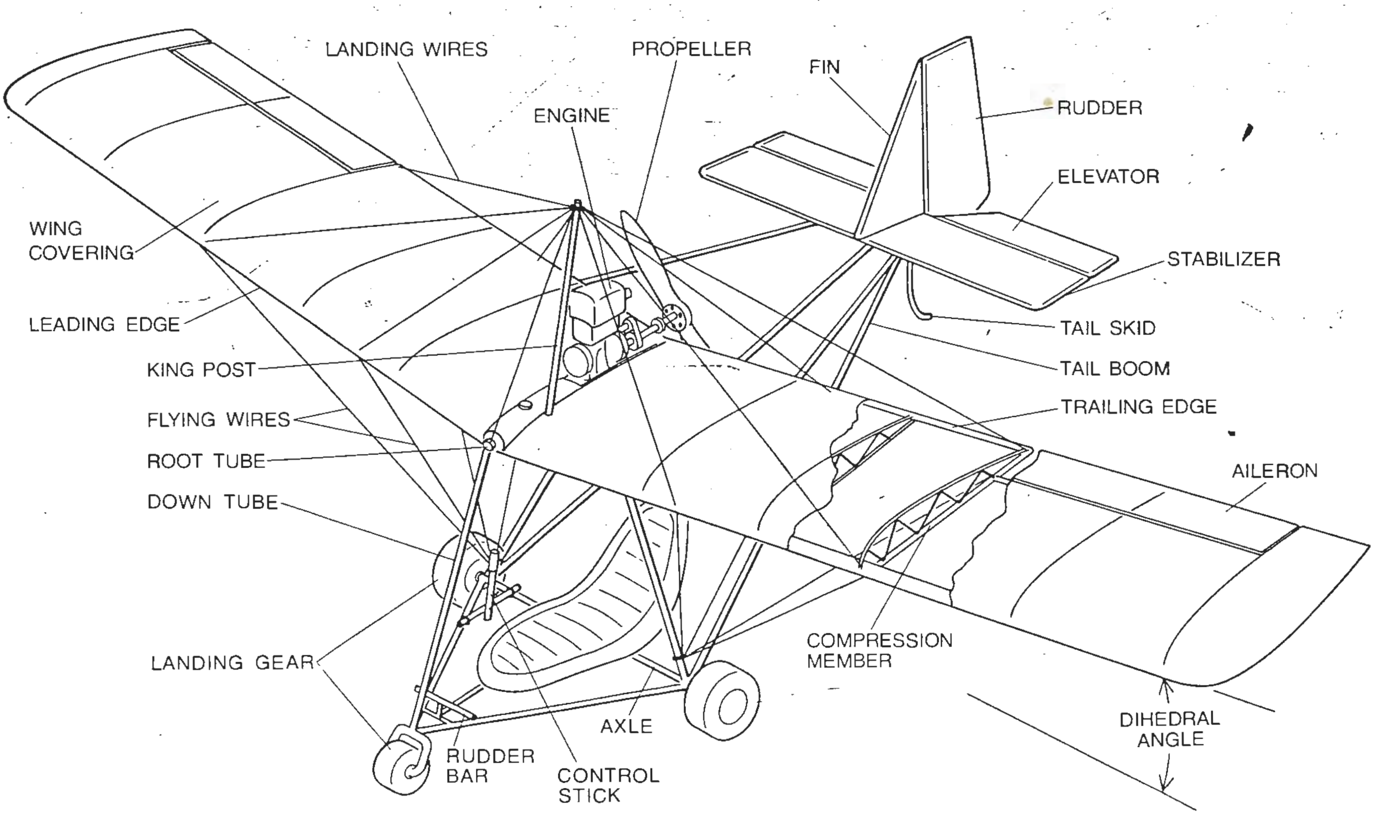
The first modern ultralight airplane was made in Wisconsin in the winter of 1974–75 by John Moody, an electrical engineer and a hang-glider pilot. He mounted a 12-horsepower Go-Kart engine on his Icarus II biplane hang glider. His aim was only to be able to climb to altitudes where he could fly the craft as a hang glider, soaring and gliding with the engine turned off until he needed to climb again. It was not long, however, before a good many of those who followed his lead began to realize that the addition of an engine to a hang glider created a new kind of craft: a small airplane that could be flown independently of the natural lift required for a hang glider alone.

Other hang-glider designs were soon adapted to power. One adventure of this type demonstrated that there is more to making a successful ultralight airplane than just bolting a small engine to a hang glider. It involved the Rogallo wing, a hang glider adapted from a triangular kite patented by Francis M. Rogallo and his wife in 1951. At first the engine was bolted to the king post on Rogallo wings being adapted for power. The high thrust line (the direction of propulsion) of that location proved to be disastrous at times when the force of gravity was not acting on the pilot. In this zero-*g* situation the high thrust line created a nose-down pitching moment the pilot could not counteract. (In normal flight, when the wing is under a positive *g* loading, a shift of the pilot's weight is effective as a control, but in zero *g* the pilot in effect has no weight.) With the nose down the sail began to luff, or flutter, and the glider was forced into either a dive that could not be stopped or an inverted loop that was likely to cause structural failure. Fortunately this dangerous flaw in design was corrected by a lower thrust line before the powered Rogallo wing was put on the market.

The most popular bolt-on engine installation for the Rogallo wing positioned a pusher propeller at the aft end of the keel, which is the center tube of the wing. The rig consisted of a Go-Kart engine mounted above the pilot's head and a long shaft running parallel to the keel. The same unit could be bolted to almost any flexible-wing hang glider. A glider thus fitted out was launched from level ground on foot, that is, by a pilot who held the rig over his head and ran into the wind. Since the thrust line was still higher than the center of gravity, flight in turbulent conditions was not recommended because the craft tended to become longitudinally unstable with the engine running. In calm conditions, however, the arrangement was workable. The rig was employed primarily to gain altitude for soaring rather than to cruise under power.

Until 1977 most ultralight airplanes received their thrust from a Go-Kart engine turning a propeller bolted directly to the engine shaft. The arrangement was simple and mechanically trouble-free, but the engine ran at such a high number of revolutions per minute that the propeller had to be quite small (about 28 inches in diameter) in order to keep the propeller tips from exceeding the speed of sound. As it was, the propeller turned at more than 9,000 r.p.m., quite close to sonic speed, with the result that the propeller noise was extremely loud and the propulsive efficiency was only about 50 percent. The performance of the early powered hang glider was therefore quite marginal. The cruising speed was only slightly higher than the stalling speed, and the rate of climb was a dangerously low 100 feet per minute. Furthermore, the engines themselves were short-lived because they had to run at such high speeds in order to deliver enough power. It seemed clear that the ultralight aircraft would not gain wide acceptance until the level of performance was improved.

An enterprising experimenter, Charles Slusarczyk, approached the thrust problem in a scientific way. Aware that a propeller is most efficient when its tips are moving at a rate well below sonic speed, he devised a reduction-drive system for powered hang gliders; it was patented last year. His idea was to move a large volume of air as slowly as possible through the disk formed by



COMPONENT PARTS of a generalized ultralight airplane are identified. The craft represents the most recent stage of design in that it incorporates an independent three-axis control system: pitch (the up and down movement of the nose) is regulated by moving the control stick back and forth, roll by moving the stick from side to side (making one aileron go up and the other down) and yaw by operating the rudder bar with the feet. An ultralight airplane with this control system is flown in much the same way as a heavier airplane.

the turning propeller while minimizing the drag from compressibility that absorbs a great deal of power near sonic velocity. The result is a vast improvement in thrust and efficiency and a substantial reduction in propeller noise. Nearly all contemporary ultralight aircraft incorporate a reduction-drive propulsion system that gets superior performance out of a small engine. A typical figure for today's reduction-drive transmission is 10 pounds of thrust per horsepower.

Before long the Go-Kart engine was largely replaced by the snowmobile engine, which has a larger displacement and runs at a lower r.p.m. The tuning of the engine is modified from its snowmobile specifications, thereby enhancing its thrust, improving its reliability and increasing its expected service lifetime. Typically the carburetion is reduced or the compression is lowered; sometimes both are done.

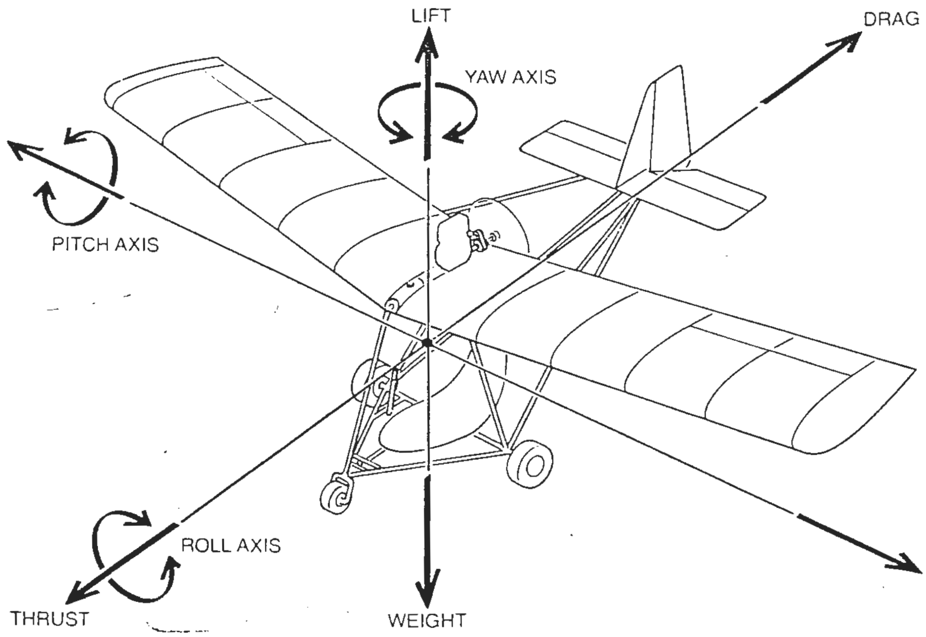
A change resulting from the switch to snowmobile engines was the wheeled landing gear. A hang glider with a direct-drive Go-Kart engine had an empty weight of about 100 pounds and could be launched on foot. The snowmobile engine, the associated reduction-drive components and a strengthening of the frame brought the empty weight to something over 160 pounds and made launching on foot dangerous.

The incorporation of landing gear made for a complete ultralight airplane. Once landing gear was accepted it was possible for engineers to design an ultralight craft around the propulsion system instead of simply bolting an engine to a hang glider. The result was a new generation of designs, most of which moved the new aviation away from its origins in the powered hang glider and toward the "little airplane."

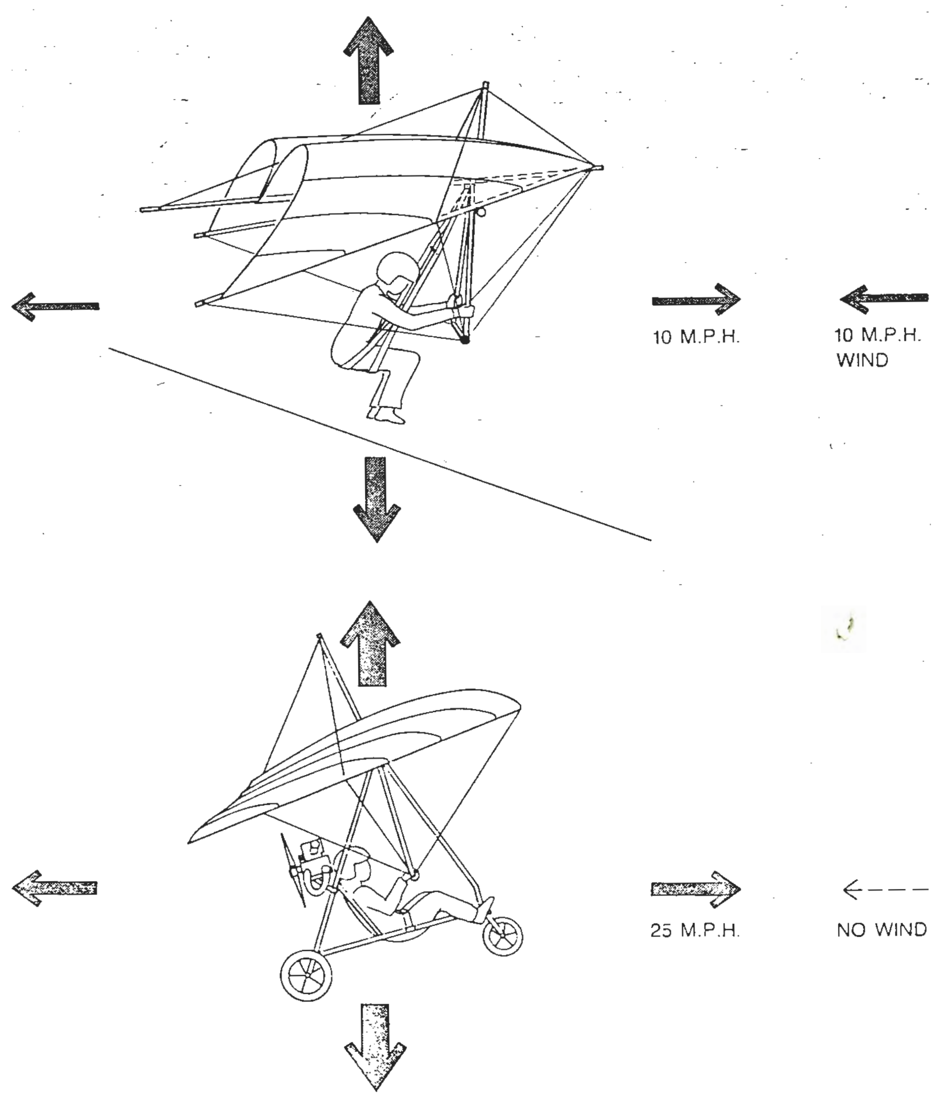
The ultralight aircraft of today can be grouped in four categories, which reflect the basic construction embodied in each design: Rogallo, cable-braced, strut-braced and cantilevered. The order of the grouping also approximates the relative level of performance of each type, particularly with respect to the top speed.

The Rogallo types include not only the foot-launched versions with a bolted-on engine but also the craft known as a trike. A trike (from tricycle) is a pyramidal tubular frame that holds the engine, the pilot's seat and the landing gear. The entire unit is bolted onto a Rogallo-wing hang glider. As a result of this arrangement the owner has in effect two aircraft: a hang glider and an ultralight airplane. In either form the method of flying is the same: the pilot pushes and pulls on a control bar for pitch and shifts his weight to one side or the other to make the craft bank.

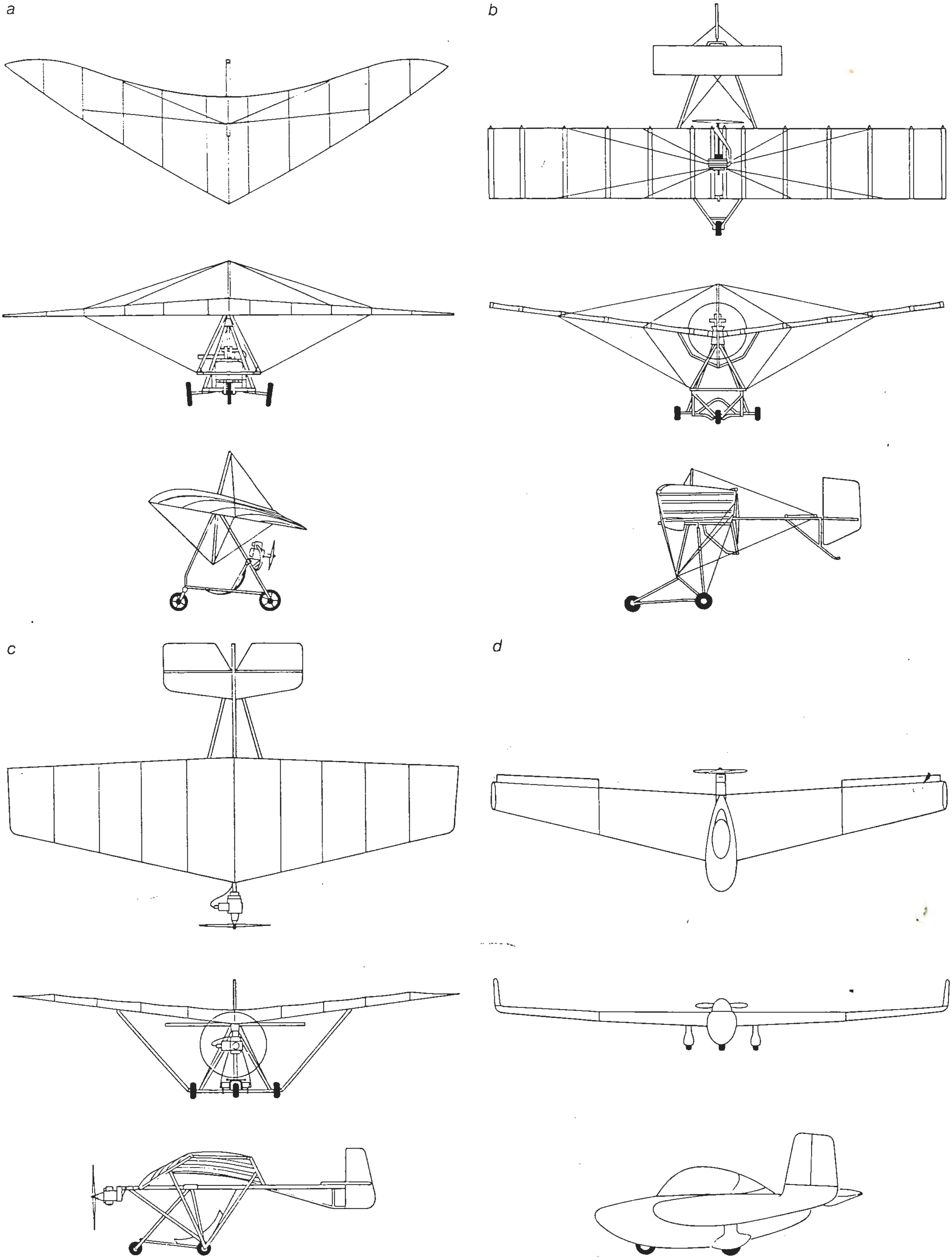
One current ultralight airplane, the Eagle, incorporates a hybrid Rogallo wing plus a canard. The main wing is a



FOUR FORCES that act on an aircraft in flight are lift, weight, thrust and drag. Lift is provided by the pressure difference of the air around the wings developed by the flow of air over them. Weight is a reflection of gravity. Thrust is provided by the propeller. Drag results from a variety of forces that tend to hold the airplane back. Pitch, roll and yaw axes are also shown.



FORCES ON TAKEOFF are indicated for a hang glider (*top*) of the Rogallo-wing type and an ultralight airplane (*bottom*) also incorporating a Rogallo wing. The hang-glider pilot takes off by lifting the glider over his head and running downhill into a fairly brisk head wind. The lift and thrust are much weaker on the hang glider than they are on the ultralight airplane.



FOUR BASIC TYPES of ultralight airplane are the Rogallo (*a*), represented by the Jet Wing; the cable-braced (*b*), represented by the Quicksilver, which is also the airplane shown on the cover of this issue; the strut-braced (*c*), here the Weedhopper, and the cantilevered (*d*), which has a wing on each side of the fuselage supported only by its attachment to the fuselage. The cantilevered craft shown here is a Mitchell U-2. The level of performance of the planes, particularly their top speed, is approximately reflected by the grouping.

Rogallo wing that has been modified by the insertion of ribs into the sail and the addition of drooped "tip draggers," or rudders, at the wing tips. The canard is an inflexible wing with an elevator (a movable flap) that serves to control pitch. Pitch control is augmented by the ability of the pilot to shift his body fore and aft.

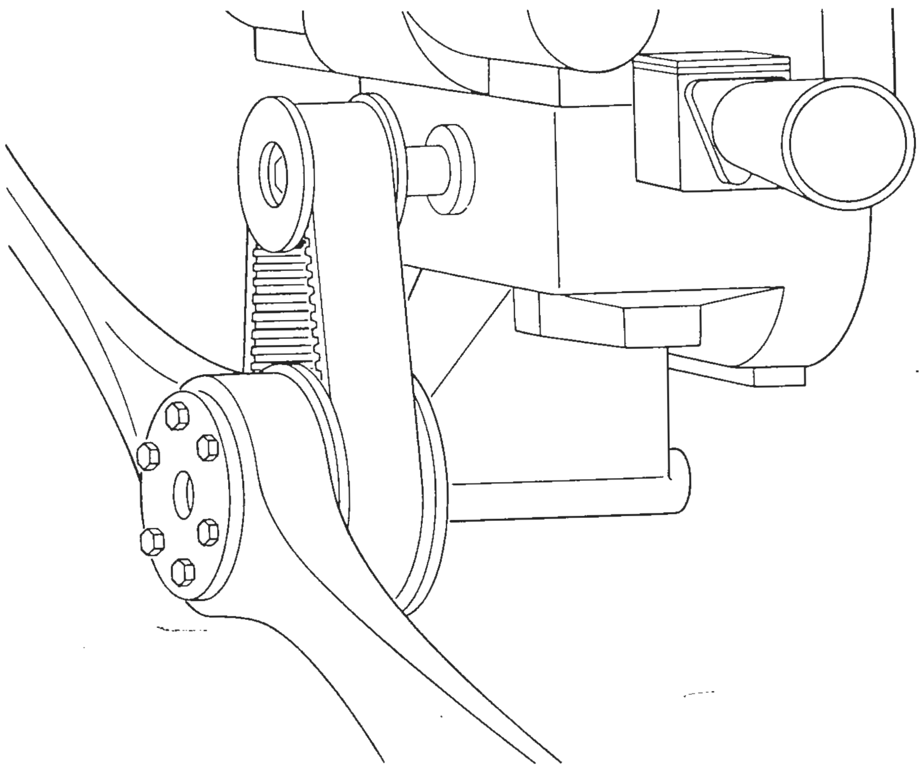
Most contemporary ultralight airplanes are in the cable-braced category. A typical arrangement consists of a pyramidal tubular frame surrounding the pilot and a tricycle landing gear attached to the frame. A ladder-frame wing is connected by a pin to the top of the pyramid and braced by cable to the bottom of the pyramid and to a king post above it. Another tube arrangement runs aft of the wing and holds the tail, which is also braced by cable to the pyramid, the king post and the wing.

The engine is usually mounted in the center section of the wing. A reduction-drive transmission conveys the power to a pusher propeller. Envelopes of presewn Dacron slip on over the framework of the wing to create the surface that provides lift. On the upper surface of the wing preformed aluminum ribs are inserted into pockets to create an airfoil of curved shape, which enhances lift. The lower surface is flat or slightly cambered to compensate for the fact that in flight the air tends to push the surface upward. On some designs only the upper side of the wing has a Dacron "skin." Such a craft is slower than one with a double-surface wing.

The strut-braced construction is gaining in popularity as designers move to improve the aerodynamics of the ultralight airplane. The group includes a fairly wide variety of wing structures. In the simplest designs a basic ladder-frame wing is covered with a presewn Dacron envelope and ribs are slipped into the upper surface. The most advanced designs incorporate a main spar, made of aluminum tubing with a *D*-shaped cross section, that also serves as the leading edge of the wing. The ribs are made of either aluminum or a composite consisting of a foam core and a strong shell of aluminum or fiberglass. Fuselages range from simple tubular pyramids to partly enclosed structures made of foam-and-fiberglass components.

The planes of the fourth group are made in much the same way but have separately cantilevered wings, that is, a wing on each side of the fuselage supported only by its attachment to the fuselage. The cantilever design results in the most streamlined of the ultralight craft and also in the closest resemblance to a conventional light airplane. Another of the virtues of a cantilevered ultralight is that it takes the least time to assemble once it is at its takeoff site.

The controls of ultralight airplanes have also evolved significantly in recent years. When such a craft was made by simply bolting an engine onto a hang glider, control often consisted of nothing more than shifts of the pilot's weight. A few craft had in addition some rudimentary aerodynamic controls, that is, surfaces the pilot could move to affect pitch, yaw and roll. Hang-glider pilots found these familiar arrangements adequate, but to people trained to fly standard airplanes they were strange and confusing. The designers of ultralight aircraft soon recognized the problem and began developing suitable aerodynamic controls. Today it is unusual to find an ultralight airplane that depends in any way on the shifting of weight by the pilot for control.



REDUCTION DRIVE, patented last year by Charles Slusarczyk, greatly improved the thrust and efficiency of propellers on ultralight airplanes. A toothed belt transmits power from a small pulley on the drive shaft to a larger pulley on the propeller shaft. A typical reduction-drive transmission of this type provides 10 pounds of thrust per horsepower. With direct drive the propeller tips ran at almost the speed of sound, which was inefficient and extremely noisy.

The first modern ultralight airplane, the powered Icarus II hang glider, had a hybrid control system because that was how the glider was controlled before Moody thought of adding an engine. The pilot, who was suspended prone in a harness, controlled the pitch and therefore the speed by moving forward or backward. He could also move the tip draggers to make the craft yaw and thereby induce a roll. The wings on the inside of a turn lost speed and therefore lift, whereas the outer wings gained speed and lift, generating a net rolling moment and a turn. The simultaneous deflection of both tip draggers increased the aircraft's drag and so served as a means of controlling the glide path.

Another hybrid system was employed in the Quicksilver, which had appeared originally as a hang glider in the early 1970's. The pilot was suspended in a swing and could therefore shift his weight fore and aft and from side to side. To increase the turning capability of the aircraft lines were connected from the harness to the rudder, so that a sideward shift by the pilot deflected the rudder, causing a yaw and thus a roll. The system was workable, but it was still a weight-shift scheme and licensed pilots did not accept it.

The first major advance in control systems appeared in the first true ultralight aircraft (as distinguished from the powered hang gliders). The new idea was a two-axis control system. The pilot is held in place by a seat belt and cannot effectively shift his weight. Instead he grips a control stick that is connected to the rudder and its associated elevator. The wings have no movable surfaces. The control stick works partly in the conventional way: forward movement pitches the nose down, backward movement pulls it up. Sideward movement of the stick, however, moves the rudder in the same direction, generating yaw and hence roll. (In a conventional stick-controlled airplane a sideward movement of the stick actuates ailerons on the wings to achieve roll.)

In the two-axis system a deflection of the rudder causes the aircraft to yaw and skid. The velocity of the outside wing increases, generating a rolling moment and its attendant bank. The wings must therefore have sufficient dihedral (the angle at which they meet) to stop the skid as it develops. In a properly designed aircraft the resulting motion is a fairly well-coordinated turn. The major drawback of the two-axis system is that the craft becomes difficult to handle in a crosswind of more than 5 m.p.h. because the wing cannot be raised quickly enough to forestall a skid.

The most recent models incorporate the independent three-axis control system, which was the key to the success of the Wright brothers. One version of it, which is essentially the same as the conventional arrangement, encompasses control of the elevator and the ailerons with the stick and of the rudder with foot pedals. A modified version employs spoilers in place of ailerons. A spoiler is on the upper surface of each wing; deflecting one of the spoilers disrupts the airflow above the corresponding wing, reducing the lift and causing the wing to drop. The deflected spoiler also increases the drag, enhancing yaw and inducing additional lift on the outer wing because of its increased speed. By deflecting both spoilers simultaneously the pilot can control the glide path.

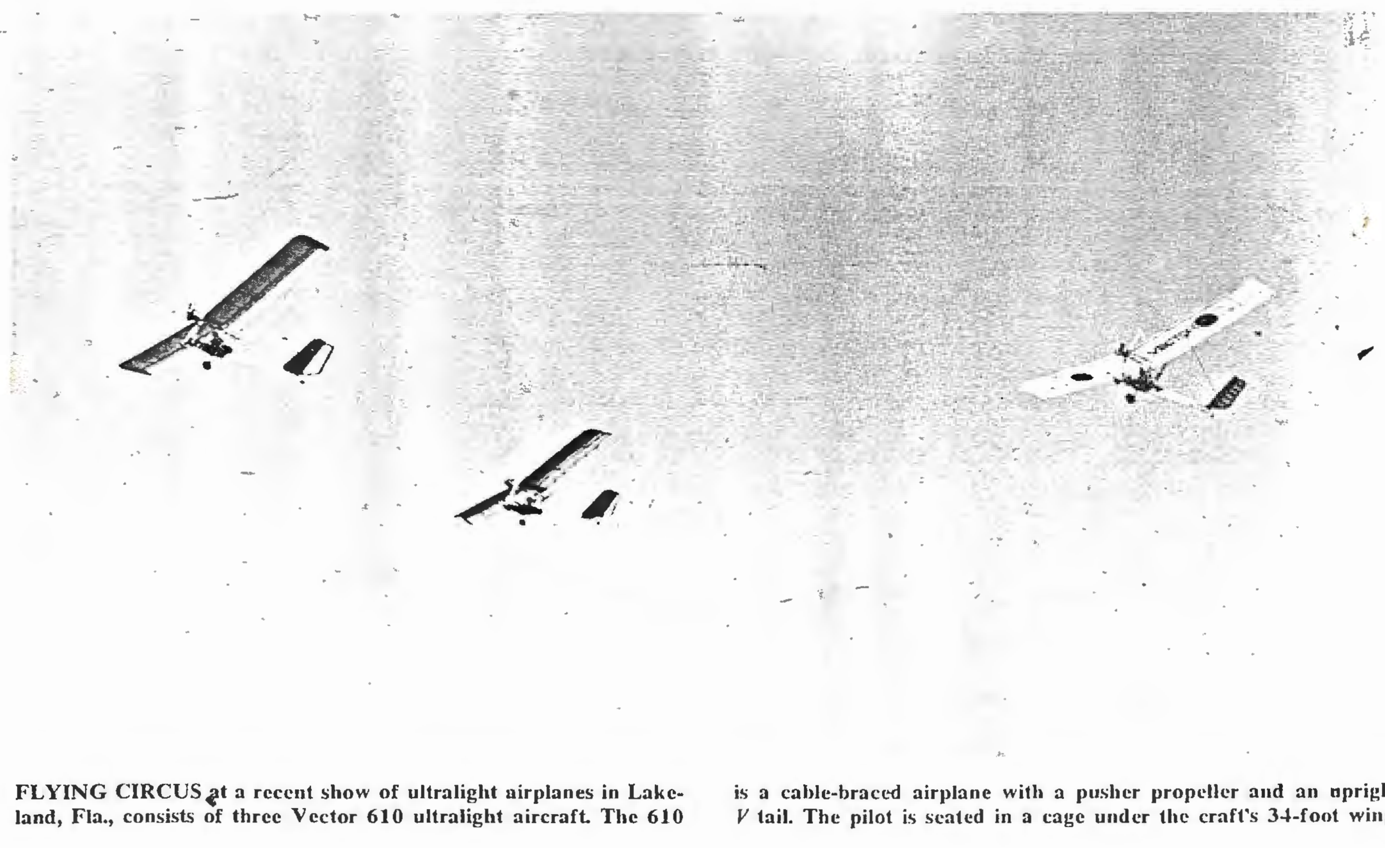
Anyone who is of a mind to try flying an ultralight airplane should have a grasp of basic aerodynamics. The four forces that act on the craft are lift, weight, thrust and drag. Lift is provided by the pressure of air under and the flow of air over the wings. Weight (of the airplane, the pilot and the fuel) is an effect of gravity. Thrust is the force supplied by the propeller. Drag is the combination of forces tending to hold the airplane back. Induced drag is a by-product of lift, and it increases with increasing angle of attack (the angle between the chord of the wing and the relative wind, or more loosely between the wing and the horizontal). Parasitic drag is generated by the parts of the aircraft that do not contribute to the lift, profile drag by the airfoil (the cross-sectional shape of the wing).

The pilot's major concern is the angle of attack. When it is high, the speed of flight is low, and when it is low, the speed of flight is high. As the angle of attack is increased, a point is reached at which the wing will stall, losing its lift and increasing its drag because the airflow becomes quite turbulent and separates from the upper surface of the wing. At a point near stall the pilot's ability to control the craft is diminished because the ailerons become virtually useless. Only a decrease in the angle of attack will enable the wing to regain lift, which is to say that the pilot must push the control stick forward so that the nose goes down and the airplane gains airspeed by losing altitude. A stall can develop into a spin, particularly during a turn. If one wing stalls first, it drops, and the airplane begins to rotate about a vertical axis as it falls. It is not always possible to recover from a spin, which is why it is important for the pilot (particularly for a novice) to know the conditions that can bring on a stall, to avoid them if possible and to apply the proper corrective steps quickly if a stall develops or seems to be imminent.

Although ultralight airplanes are basically easier to handle than heavier aircraft and no license is required to fly most of them, the FAA does require anyone who flies to be familiar with the Federal Air Regulations. All pilots of ultralight aircraft must pay particular attention to the applicable visual-flight rules. Flight near controlled airports should be avoided.

It would be foolhardy for anyone to try to fly an ultralight airplane without first acquiring a sound knowledge of aerodynamics and taking some formal flight training. An ultralight is a real airplane, not a toy, and a good deal of skill and understanding is needed to fly one safely. Many flight schools require their students to first take dual instruction in a conventional airplane and to be able to make a solo flight in such a craft. Since an ultralight is a single-person craft, the dual-instruction approach is certainly wise for anyone who is not already a pilot. You must know the basics of flight before you venture aloft alone.

I mentioned at the outset that the pilot of an ultralight airplane must be acutely sensitive to the vagaries of the wind. The necessity is reflected in the fact that licensed pilots, who make up about half of the people flying ultralight craft, often have more trouble than nonpilots in adapting to the conditions. Being accustomed to heavier aircraft, they seem not to respect the wind as much as they should and are often taken by surprise when an ultralight airplane displays its extreme sensitivity to gusts. The prudent pilot flies an ultralight airplane only when the weather is fair and the wind is gentle and steady.



FLYING CIRCUS at a recent show of ultralight airplanes in Lakeland, Fla., consists of three Vector 610 ultralight aircraft. The 610 is a cable-braced airplane with a pusher propeller and an upright *V* tail. The pilot is seated in a cage under the craft's 34-foot wing.