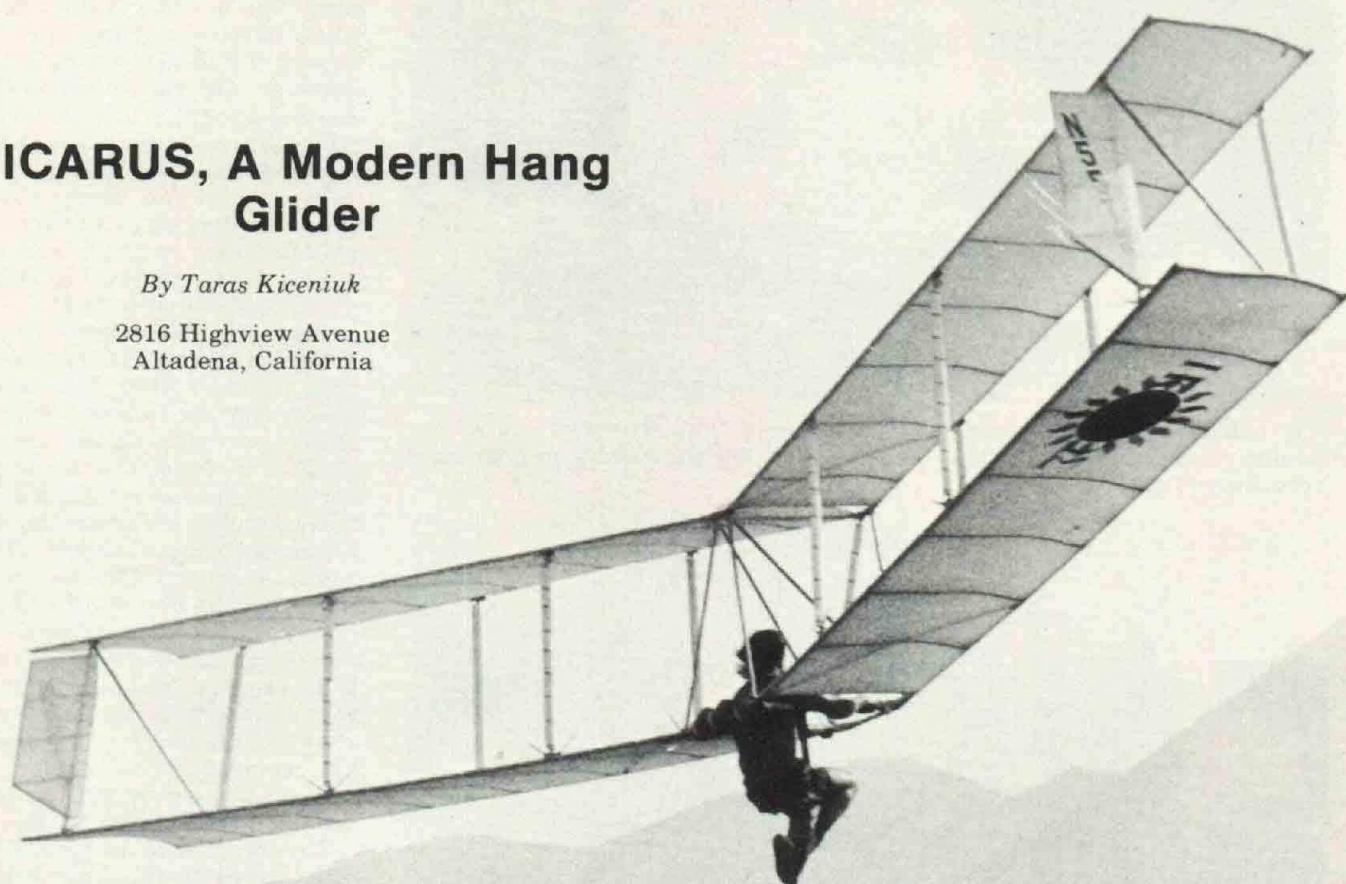


# ICARUS, A Modern Hang Glider

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*Editor's Note: Since the submission of this article, the author has provided the following update information: "On June 17, my son, Taras, racked up a few "firsts" at Torrey Pines - two successive foot-launched flights, one of 20 minutes and another of 48 minutes duration! The ridge soaring flights were made in on-shore winds of only 10 to 11 miles per hour.)*

Taras climbs and turns parallel to the ridge to utilize upslope wind currents practically within sight of Riverside's Flabob Airport.

ON MAY 23, 1971 at Corona Del Mar, California, a score of flying enthusiasts mysteriously appeared on a grassy hillside to commemorate the birthday of early flight pioneer Otto Lilienthal. Instead of speeches and eulogies, the celebrants brought an assortment of sticks, wires, and gayly colored plastic. These bits and pieces were assembled into odd looking flying machines in which brave men and boys launched themselves helter skelter down the grass covered hillside. The event seemed more like a reincarnation than a birthday party. The modern hang glider movement had begun in earnest.

One of the crude machines participating on that day belonged to my 17-year-old son, Taras (EAA 47482), and several of his friends. Making up in courage and skill what their bamboo and polyethylene Rogallo wing lacked in performance, the boys were able to delight the hundreds of onlookers with smoothly executed flights and easy landings. It was obvious that many of the other planes possessed the promise of better performance, only to leave it unrealized on account of poor stability and lack of control.

Some of the would be flyers had built replicas of ancient flying machines and provided them with equally ancient and ineffective controls, while others blindly copied more modern configurations and devices without first looking into the real requirements for this kind of

craft. The long succession of crack-ups that resulted were due either to a stall immediately after take-off (pilot error), or to a spiral dive into the hillside on account of insufficient lateral stability in the presence of excessive directional stability. This maneuver usually produced the instant tailless airplane, since the tail booms almost always snapped during the ground loops that resulted when the wing tips of these Chanute-type gliders contacted the ground.

Before the meet was over, the specifications for the "ideal" hang glider began to take shape in the mind of young Taras. The next day found him building a one-sixth scale flying model of the swept flying wing that was to be ICARUS. The design philosophy went something like this:

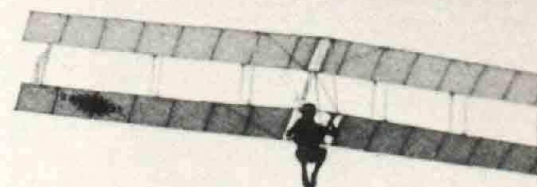
1. The craft must be very stable about the pitch and roll axes, so that it will fly itself without requiring corrective action by the pilot, a practical necessity if a novice is to learn to fly without prior dual instruction.

2. The directional, or weathercock, stability should not be so great as to cause it to spiral if a wing dips because of a gust or a shift in the pilot's position. Instead, the glider should continue pointing in the original direction until the resulting slip causes the wing to rise.

3. While pitch control may be very effectively provided by shifting the pilot's weight, lateral control must be achieved through the use of aerodynamic surfaces.



A few energetic steps from the crown of the hill starts a ridge soaring flight.



Not so low and not so slow. ICARUS II flies at 20- mph air speed, and has completed 360 degree turns 500 feet above the ground.



Twist controls on hand grips connect to tip-mounted drag rudders. Sling seat and foam-covered rear spar are visible as ICARUS makes an overhead pass.



The "newest" aviation sport is one of the oldest. It's easy to understand the exhilaration felt in participating in this sport.



Absence of fuselage and tail, plus empty weight of only 54 lbs., means one man can load and unload the ICARUS aboard the family car. Single-handed assembly takes 45 minutes.



The model which Taras built incorporated all the features he felt would insure the kind of stability and rigidity a pilot hanging from his armpits would expect from his sole means of support. Performance was deemed desirable, but at this stage it was not to be sought at the expense of safety! Hence the resulting configuration — a swept-wing tailless biplane with pronounced sweep, washout, stagger, and dihedral. Also, for good measure, a reflex (upturned trailing edge) airfoil was used, as was a positive decalage of  $2\frac{1}{4}$  degrees.

This might be the time to point out a few differences between conventional aircraft and hang gliders insofar as handling requirements are concerned. Because the hang glider flies so slowly and because it weighs much less than the pilot, it will respond very quickly if sufficiently stable; indeed, it can be made like a giant model airplane. At the same time, forward and aft movement of the pilot's weight has a powerful influence on the speed and attitude of the craft. Also, like a model, adequate lateral control can be achieved with rudder along, if the wings have enough dihedral.

This means that the craft will have to be held in turns with continuous control pressure, since it will quickly resume straight and level flight if flown hands off. On conventional airplanes such extreme stability would produce a relatively rough ride in turbulent air.

On ICARUS, two wing-tip rudders were employed, individually controlled by twist grips on the hang bars. The rudders can be deflected outward only so that the drag of the rudder is as important as side force in producing a yawing moment. As soon as the craft is yawed, the aforementioned dihedral and sweep produce a brisk roll in the intended direction of bank.

The longitudinal, or pitch, control and stability were also given careful thought. In the old days, before the concept of aerodynamic center was formulated, the airplane designer thought in terms of center-of-pressure travel and direction of lift vector — much the same as a ship designer thinks about metacentric heights. Since there is no tail and no moving horizontal surface to alter the force picture one needs only a drawing of the lift forces acting on the airfoil section as the angle of attack is changed to determine where the aircraft center of gravity must be located to insure stability. The older texts presented the information in exactly this way. With the reflex airfoil, the lift force can be considered to act about 25 percent of the way back from the leading edge. Any contributions of the sweep/twist and stagger/decalage combinations will act to improve the stability by moving the lift vector rearward with increase in angle of attack. Unlike conventional planes and gliders which are notoriously unaware of which way is down, excepting for long term effects on flying speed, ICARUS resumes straight and level flight by itself and can probably be flown under IFR conditions by a pilot with a blindfold.

The construction of ICARUS is simple and straightforward, but the geometry is something else again. With all of the complex angles of sweep, dihedral, stagger, etc., I'm amazed that Taras didn't end up with four left wings. I'm sure I would have!

The main spars are 1 in. diameter aluminum tubes, acting also as leading and trailing edges. Sheet aluminum gussets, fastened to the aluminum tubing by means of "pop" rivets, tie the primary structure together with remarkable strength and rigidity. Styrofoam sheet,  $\frac{1}{2}$  in. thick and capped with  $\frac{1}{2} \times \frac{1}{8}$  in. spruce, makes up the wing ribs. Interplane struts are also made of aluminum tubing, the wall thickness depending on the amount of loading. One-sixteenth inch aircraft cable carries the lift forces. The balsa and plywood wing-tip drag rudders are cable actuated from twist grips on the main

"hang tubes". Unique in design, the rudder post is a ball bearing supported load carrying strut.

The covering on ICARUS II is 1.8 oz. Dacron, heat shrunk and doped just enough to control porosity.

Assembly and transportation of the 55-lb. craft is easy enough — the top of a van or car will do — no trailer is required. Since the interplane wires remain attached and adjusted at disassembly, ICARUS is put together in about a half hour by two people. Because each side is structurally complete, joining the left bays to those on the right is all that's necessary to have her ready to go!

## FLYING THE ICARUS

The first pleasant surprise confronting the would be pilot and his helpers is that carrying the ICARUS to the top of a hill is not the formidable task it might seem to be. In winds of eight to ten miles per hour one actually gets a "boost" up the hill, if the craft is pointed into the wind and if the angle of attack is kept sufficiently large. Even if the path gets too narrow or winding, the absence of a tail allows the craft to be carried span-wise with ease.

For beginning flights it is best to select a slope facing **exactly** into a steady wind of between four and ten miles per hour. Although a sling seat is essential for long flights, much better ground handling is obtained just holding the tubes under the arms after lifting the craft from the ground. The center of gravity of the empty glider is nearly as far back as the trailing edge of the hang tubes, so that the machine is supported by the small of the back while the hands, on the forward part of the twist grip, serve to steady the craft and control the angle of attack. Lateral control is provided just as it will be later in flight. If a wing drops, the opposite twist grip is given a turn outward to deflect that rudder. The plane yaws and dihedral action levels the wings.

When everything seems right and steady, the pilot runs as hard as he can. This is not the time to debate whether or not to go!

The air speed increases and the nose is held level by pushing down on the twist grips. Soon the wing will support its own weight (and get off the pilot's back!) and begin lifting under his arms. Before he knows it, he's air-borne, striking out for the valley below. Hopefully, he has had the sense to pick a nice soft grassy slope of about one in four and not more than 30 ft. high. For several reasons it is a good idea to keep the air speed well above the stall. Near the ground the wind can drop 50 percent or more, leaving the pilot with an overdrawn account if he has been flying too slowly. And remember, in this game, **man** does the bouncing! As with any other aircraft the only solution to insufficient air speed is to get the nose down, a move which requires courage at these altitudes.

In the beginning it is wise not to experiment too much with fancy twist-grip play. The flyer should concentrate on maintaining sufficient air speed and on preparing for the landing.

The landing is surprisingly easy and gentle, if one levels off gradually by sliding back until a foot or so off the ground and then holding this position until the plane settles. By remembering to start the feet running, one finds that the wings still support a lot of weight and, although taking "giant steps" at speeds up to 15 to 20 mph, depending on the wind velocity, there is no special problem in bringing one's self and the machine to a safe halt. The rear center of gravity of ICARUS causes it to rear up automatically as the feet take a larger share of the body weight.

Now to attach the sling seat and get ready for a five-minute soaring flight!