Flapper Facts

Newsletter of the Ornithopter Modelers' Society

Spring 1997

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Arkville, NY 12406 USA

Membership dues, payable to the editor:
New members: $14 for one year ($21 outside USA)
Renewal: $9 per year ($14 outside USA)

Human-Powered Flapping Success!

Despite the extreme difficulty of human-powered flapping flight, a few clever inventors have managed to build machines which support the weight of a person by flapping in an aqueous medium. The earliest of these machines was Parker MacCready's Pogo Foil. The son of Paul MacCready used a pogo stick mechanism driving a submerged oscillating foil to provide propulsion and lift. As can be seen in the photo, Pogo Foil rides on floats at low speed and then rises out of the water as the flapping foil produces more lift. Top speed is reported as 11 MPH.

A similar, but apparently more advanced, human-powered hydrofoil has been offered for sale by a Swedish company under the name Trampofoil. This machine is not buoyant, nor does it contain a pogo mechanism; the pilot uses his own inertia,

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Directional Control

People who build ornithopters are without exception a bit more clever and innovative than other aeromodelers, so it is no surprise that ornithopterists have developed a number of unusual control techniques that are not used in other model aircraft. Even though a rudder and elevator work fine in an ornithopter, there is some reluctance to use these traditional surfaces because they do not resemble the implements used by birds. The vertical fin and rudder are particularly anathematic to most of us, but there are several alternatives for ornithopter directional control.

Birds, everyone knows, use their tail for steering even though they (duh) lack a vertical rudder. The way they do this is by tilting their tails: that is, by partially rotating the tail around its longitudinal axis. The tail is a lifting surface, and by tilting it in this way, the lift is partially directed to one side or the other. Since the tail is located behind the bird's center of gravity, tilting the tail lift vector to the right causes a left turn, and vice versa. Some ornithopters, unlike birds, have a tail that produces a downforce rather than lift. In this case, tilting the tail has the opposite effect. Between these extremes, if your ornithopter has a very lightly loaded stabilizer, tilting the tail will be an unreliable method of control.

To complicate the situation slightly, I would like to mention that birds do not really use their tails in the manner described above, even though it would work. I have observed that birds while turning often rotate their tails in the oppo-

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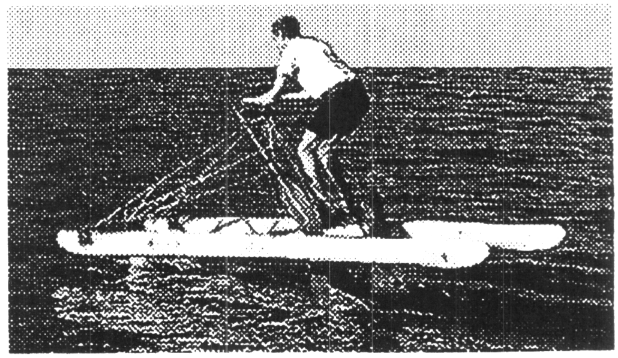
without the aid of moving parts, to move the foil up and down. These two differences from MacCready's machine reduce the weight and complexity, but the Trampofoil must remain in constant motion to avoid sinking.

The Trampofoil pilot pushes off from a jetty to get up to speed. The Trampofoil is unstable in roll, but the large wingspan allows the pilot to keep the craft in an upright position. Slightly faster than Pogo Foil, Trampofoil is reported to reach speeds of 5.5 m/s (11 kn) over a 50 meter course. It has a stall speed of 2.5 m/s (5 kn).

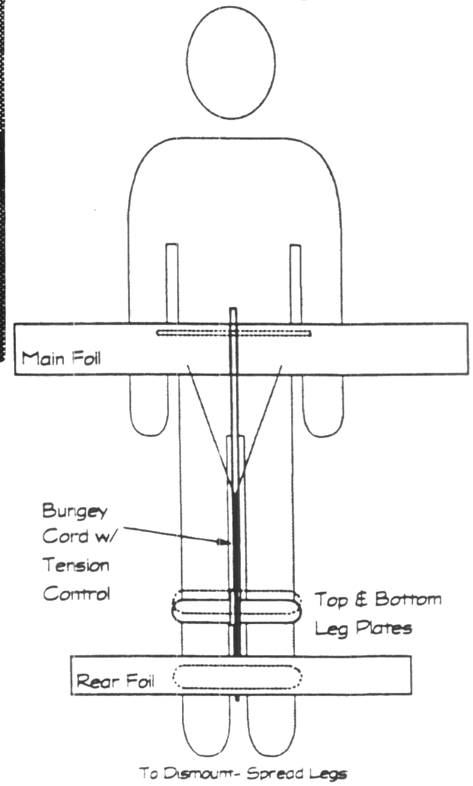


Parker MacCready's Pogo Foil

Trampofoil launch technique

Trampofoil in flight

John Flaherty's Super Fin



A third aquatic flapping device is being promoted by John Flaherty as an improvement over traditional swim fins. As in the other machines described here, an oscillating foil provides propulsion. In this case, however, the oscillation is provided directly by the legs. A bungee cord regulates the incidence of the foil and can be adjusted for different swimming speeds. Two versions of the Super Fin use a vertical foil motion; the foil may be located either behind the user or below his body. Flaherty has also worked on a device in which the foil moves from side to side behind the swimmer.

Flaherty says US Navy SEALs found his Super Fin almost twice as fast as traditional fins over a 1500 meter course. He reports speeds of 5.5 kn (6.375 MPH) in underwater sprint.

These watercraft have more in common with ornithopters than one might initially think. Apart from the obvious use of flapping foils for propulsion, the first two devices use the foil to support much of the weight of the craft and pilot, just as aircraft wings must do. Also, both derive their inspiration from biological examples. Not only do fish use flapping foils, but birds use a sort of flapping foil to assist their takeoffs from water. Building a motorized, flapping hydrofoil would be a fascinating project that might pave the way for an ornithopter that could take off from the surface of a pond.

More information on Pogo Foil and Trampofoil is available on the Internet at popularmechanics.com/popmech/sci/tech/U015Q.html and www.trampofoil.se, respectively.

Carl Czerny

THE RUBE GOLDBERG
OF SELF-DESTRUCTION

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A frustrated Austrian inventor, Czerny ended his frustration with an invention that ended his life. Sixty years before Jack Kevorkian, he perfected a suicide machine and successfully tested it on himself.

Prior to effecting his own demise, Czerny had spent two harebrained decades developing a "Flying Flapper" - a motorized scooter rigged to birdlike wings which would place the miracle of flight within the average nudnik's hands. Czerny envisioned a New Age of human pterodactyls fluttering across the sky. He published Der Schwingenflieger, a monthly newsletter which served as the house organ of his "flap-flying club." Despite his enterprise's seeming improbability, he was said to have fashioned a prototype which actually worked. Several Austrian journals commended his efforts, but he failed to scrape together enough schillings to mass-market the device. "The fate of Austrian inventors," wrote the embittered father of flap-flying in July 1929, "is the fate of typical Austrian stupidity - imposing monuments after neglect has brought them to the grave."

Five months after penning those words, Czerny burned the blueprints to his Flying Flapper and then finished work on his final invention. He fastened a string to a cork in his bedroom's gas piping. The string led to an alarm clock in which he had silenced the bell device. He tied the string to the revolving alarm mechanism, set the timer, and bade himself good night. At the appointed time, the clock quietly wound up the string, which pulled off the cork and filled the room with lethal fumes. Czerny died painlessly while he slept, flapping his way to the great aviary in the stars.

Suicide Note:

Do not look for plans. The secret of bird flight shall go with me to meet death. Amen.

site direction from what one would expect! In these situations, the tail is strongly depressed so there can be no doubt that it is producing lift, yet it acts against the direction of the turn. The obvious inference is that the bird is using its wings to turn and using the tail only to prevent excessive yaw.

If birds use their wings for directional control, one might try to do the same with ornithopters, and there are several ways of doing this. Bees are said to increase the flapping angle (amplitude) of one wing. This increases the thrust on that side and causes a turn. This method was very effective in Nathan Chronister's Electric Dawn 54 free flight ornithopter, but its implementation in RC models is difficult. Another method is to increase the area of one wing; this increases the lift and thrust on that side and causes a turn to the opposite side. Although most ornithopters do not have wings of variable area, the technique is used by birds and butterflies. In most ornithopters, it might be more practical to use membrane tension instead.

> Not all birds have flat tails. Male grackles (genus *Quiscalus*) fly with a pronounced V-tail, and although its main function is sexual advertisement, the unusual tail might also provide directional control. Sometimes gull tails adopt a V shape as well, though it is rather shallow.

The tension of a membrane wing, like the area and flapping amplitude, affects the lift and thrust of the wing. This is so because a slack membrane, compared to a tighter one, has a higher incidence angle in the upstroke and more negative incidence in the downstroke. P. H. Spencer was the first to use differential wing tension for directional control. In his Orniplane, a cord connecting the root ribs of the two outer flapping thrusters increased the tension of one membrane while decreasing the tension of the other.

Despite their potential utility, wing tension differences have long been regarded as a problem in ornithopter modeling. If the builder inadvertently constructs two wings that differ in tension, the ornithopter is likely to turn one way or the other or even go into a spin. Last November, Sean Kinkade wrote to me about his experiences in this area, saying that his engine-powered models tend to turn toward the more slack wing. At about the same time, I was experimenting with various sorts of membrane wings on an electric ornithopter. I too found that the model was sensitive to tension differences, but it turned in the opposite direction! Why should two models be oppositely affected by differences in wing tension?

Joss Levy offered an analogy to explain the disparity between my results and Kinkade's. Imagine a twin-engine airplane with variable-pitch propellers. For any given flight speed, there is a particular propeller pitch that is optimal. If the pitch is too low, the propellers will have an insufficient angle of attack to produce much thrust, whereas if the pitch is too high, the angle of attack will be too high also. If both propellers have too little pitch, increasing the pitch of one propeller will increase the thrust on that side and cause a turn to the other side. If both propellers have too much pitch, however, increasing the pitch of one of them will decrease the thrust on that side and cause a turn to the same side. Levy suggested that for ornithopters, there is an optimum wing tension just as propellers have an optimum pitch. If both wings have too little tension, then increasing the tension on the left wing will increase its thrust and cause a turn to the right. If, however, both wings are excessively tight, increasing the tension of the left wing will cause a turn to the left!

My electric model had a bad tendency to turn to the right because of the slightly asymmetric action of the flapping mechanism. I tried putting control surfaces on the V-tail, but these did little to correct the turn. I tried adjusting the wing tension, and once I figured out which way to adjust it, that turned out to be a very effective means of control. A tension cord connected the two unbraced root ribs, and moving this cord to the left or right by as little as an eighth of an inch dramatically altered the flight path.

When I later converted the model for radio control, I decided to use this wing tension system as the sole method of directional control. It can just barely compensate for the right turn tendency, which increases with power level, but I suspect I'd have the same problem with a rudder. Although the differential tension system might work poorly if the membranes were near their optimum tension, the method is elegant for its lack of visible control surfaces and it is easy to implement in RC models.

Letters

I have been building a steam-powered ornithopter for several years now. It has recently been fired and driven. It has a 17 foot wingspan. It is not intended to fly, but to be used in parades and flight breakfasts at airports, etc. The steam powers a three cylinder homebuilt radial engine. It is connected to an automobile transmission and rear end.

— Bob McKenna

The craft I am building will be based off of a Gentle Lady two meter class sailplane. The wings have hinges on them that allow the wing to partially fold up during the upstroke and extend on the downstroke. I've figured out a way to point the front edge of the wings up during the upstroke and face slightly down during the downstroke. A problem I have encountered is that the kit I'm using does not use supports and struts for the body. I will pretty much have to scratch build a new body. The way it is designed, I will be able to use two high torque motors that have a speed of 115 RPM unloaded. I'm not sure if these engines will work so I'm looking at some of the more powerful RC car engines and glider electric engines.

I belong to an Explorer Scout group led by scientists that meets at Nasa Lewis Research Center in Cleveland, Ohio. Occasionally a group leader will ask me exactly WHY I am trying to build an ornithopter. I give them the simple answer "Why not?"

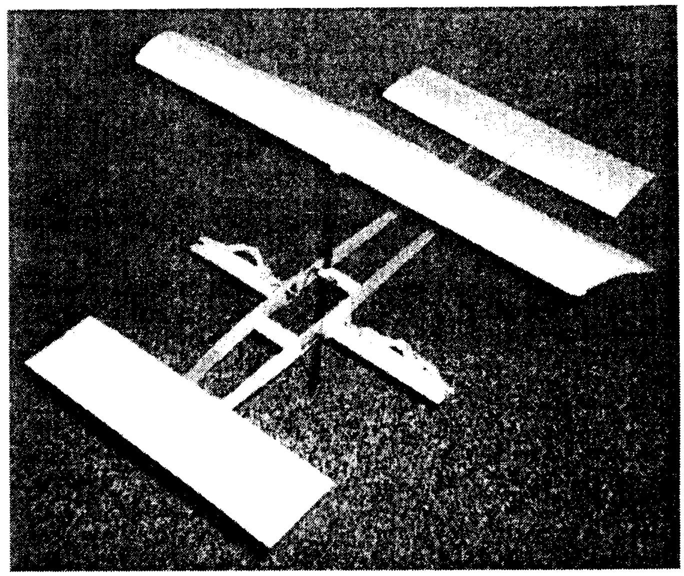
— Phil Jones

What is *THAT*?!

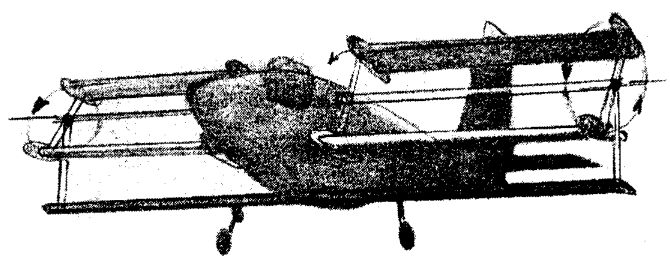
Georges Chaulet was kind enough to send a photo and schematic of one of his recent models. Instead of having wings hinged near the model centerline like most ornithopters, this one has a rigid wing that moves in an elliptical path. Here's how it works: A pair of transverse rubber motors drives a crank. A brass tube on the crank arm is rigidly attached to a stick which drives the wing. The other end of the stick slides up and down in a slot. As the crank rotates, the angle of the stick and thus the wing incidence angle change. As a result, wing incidence is negative during the downstroke and positive during the upstroke. Chaulet points out that the incidence changes more quickly at the end of the downstroke than at the end of the upstroke, and he says this is also true of birds.

Chaulet says the 50 gram model does not fly horizontally but rather descends at about the same rate as an unpowered glide. I don't know whether this poor performance indicates inefficiently or merely excessive weight. Either way, the unusual mechanism is interesting.

A similar concept was used by Marcel Chabonat in a 1975 engine-powered ornithopter. The wings were in balanced pairs and they revolved about each other on a circular path. Chaulet says the model flew successfully but had some difficulty because the ascending wing had to pass through the wake of the descending wing.



Above and facing page: George Chaulet's recent rubber-powered ornithopter with elliptical flapping.

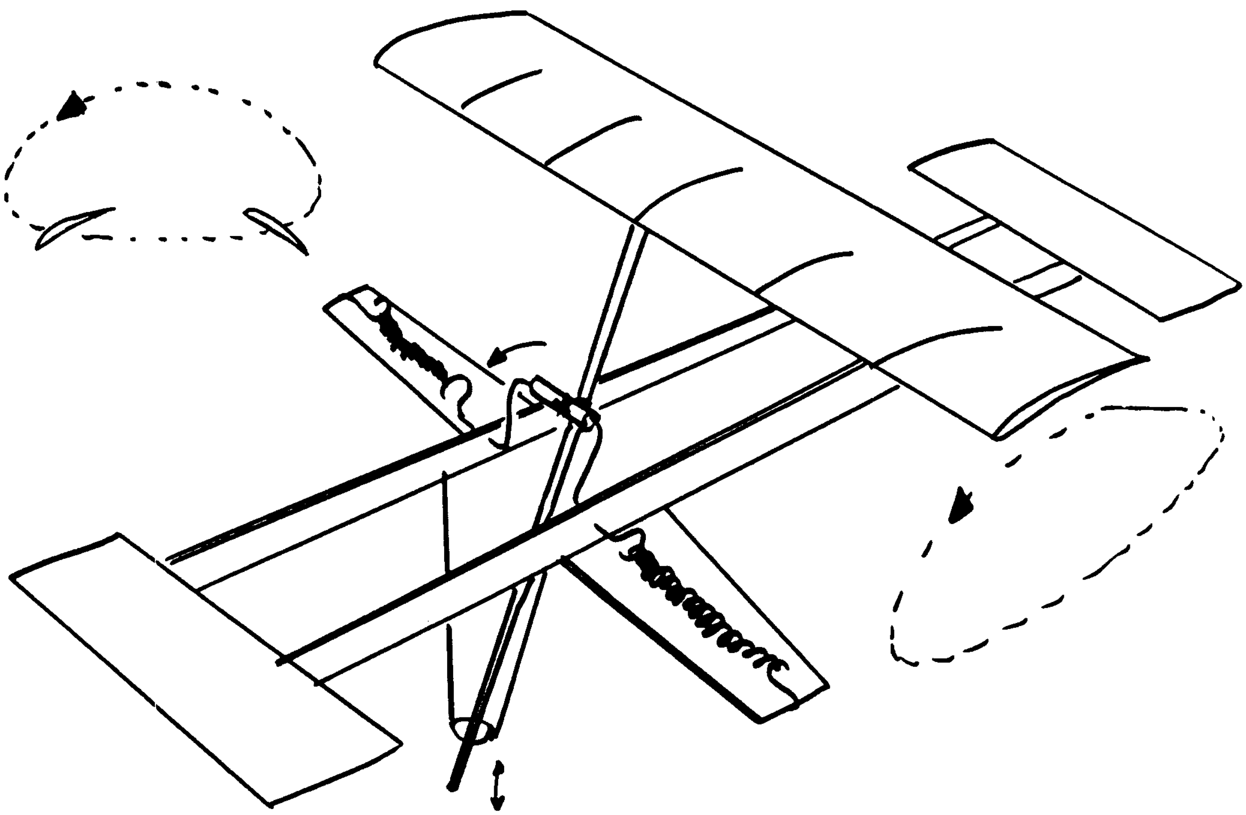


Marcel Chabonat's 1975 engine-powered ornithopter with revolving wings.

NEXT ISSUE:

Sean Kinkade's new RC ornithopter success!

See it *now* on the Ornithopter Home Page.
www.earthlink.net/~pazuzu/orn.html

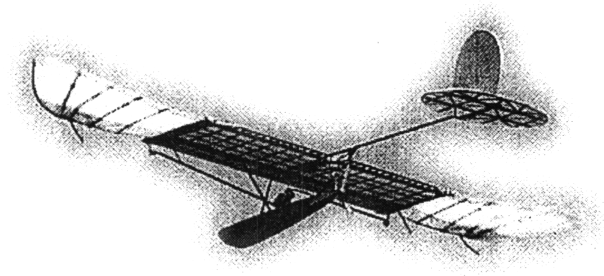


Twist and Shout!

Although most ornithopters have membrane wings, greater efficiency can be achieved with aeroelastic, ribbed wings. Such wings respond to aerodynamic (and inertial) forces by twisting to the appropriate shape for each moment in the flapping cycle. The spar twists, hopefully without excessive bending, and the amount of twist determines the pitch angle of each rib. Good performance requires just the right amount of torsional flexibility. Charles Pell describes a wing spar structure he has used for controlling wing spar torsion in both the upstroke and the downstroke independently:

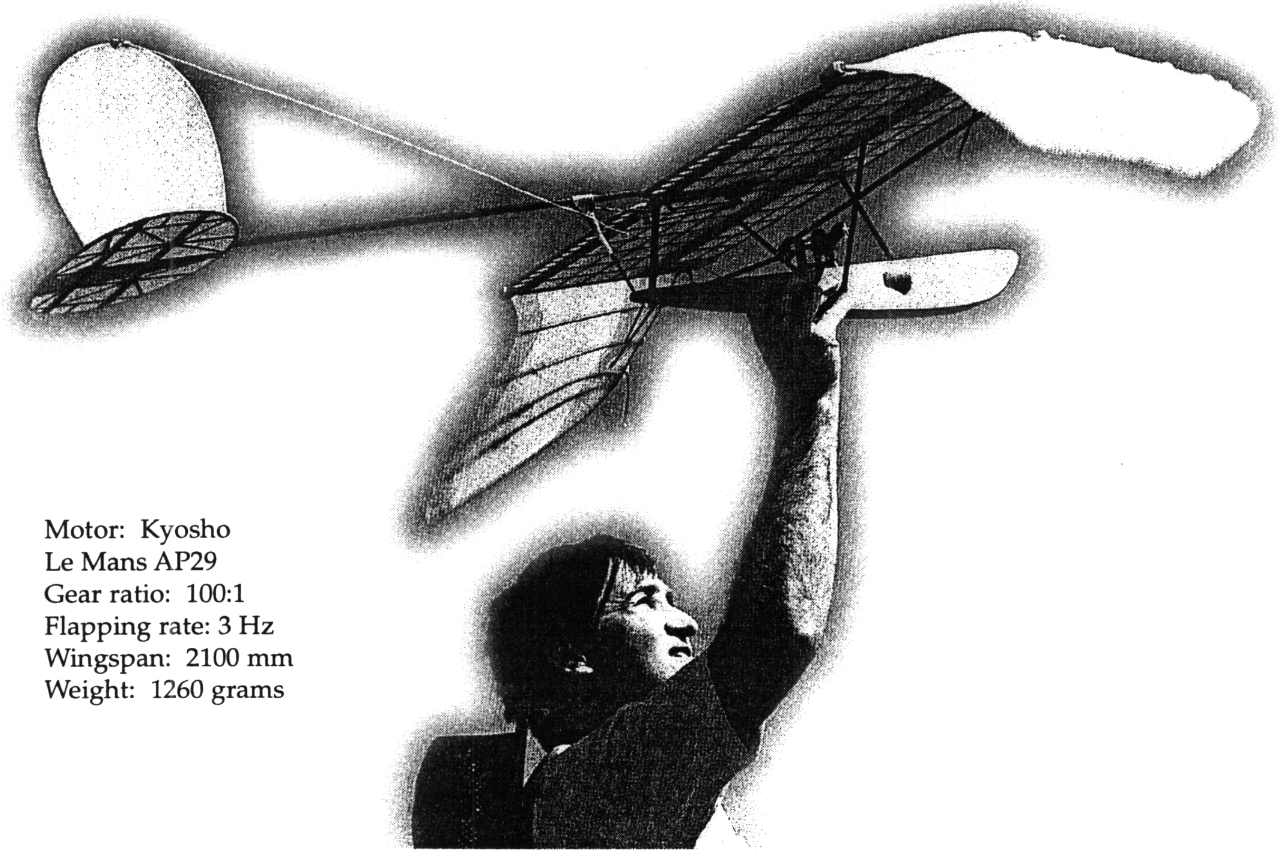
Try a high-modulus fiber wrapped helically around the spar (looking at wing root the trajectory is CCW) such that DS loading puts the fiber in tension while US loading releases it. The fiber angle can be varied along the spar to control washout on DS for all positions along the spar; varying the modulus along the length of the fiber can control washout and local pitching velocity; multiple fibers can control individual ribs to make washout wave to or away from the wing root. A US fiber (CW) can be of a different modulus or can be strain-limited to allow low US loading levels to deform the wing until the desired US pitch angle (where the thrust:downforce ratio is maximized) is reached.

Preliminary dissections of some flying vertebrates have uncovered functionally analogous passive elastic structures as well as muscularly-modulated ones (see for example recent work by Dial and check his biblios). Similar functionally analogous passive and active mechanisms are known for wing pitch control in large insects (see Enos, Ellington, Dickinson, 1970s and 1996). None of these depend on single fibers (usually there are networks) but it has been shown that higher pitch velocity at the end of the downstroke is crucial to flappers in air (see refs).



RC Electric in Europe

Photos from September 1996 Flug-Und Modelltechnik show Fred Ludwig's RC electric ornithopter. Studying the pictures reveals that the model has ailerons on its central, non-flapping wing panel. The structure of the flapping panels is similar to that used in Joss Levy's CO_2 model. If you know Fred Ludwig, please send me his address so I can ask him for more details.



Motor: Kyosho
Le Mans AP29
Gear ratio: 100:1
Flapping rate: 3 Hz
Wingspan: 2100 mm
Weight: 1260 grams