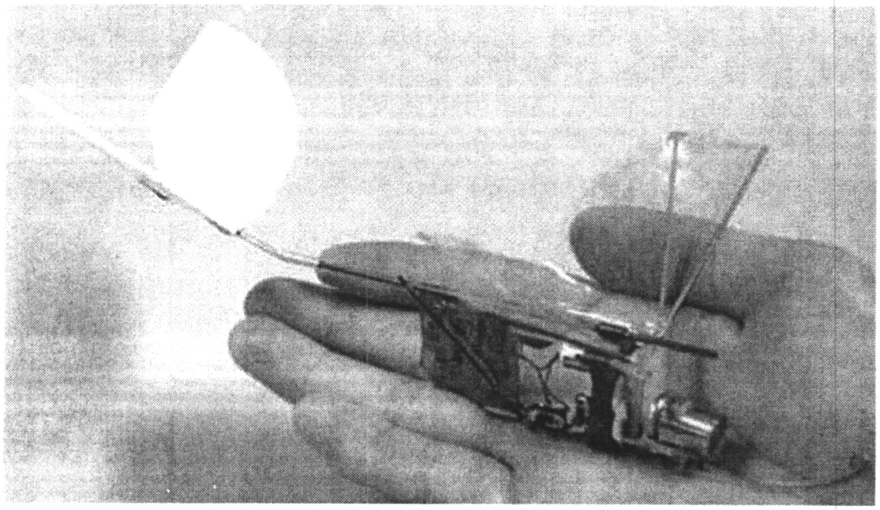
Summer 2000

Flapping Wings

THE ORNITHOPTER SOCIETY NEWSLETTER



Caltech's MicroBat ornithopter.

New Online Newsletter

Flapping Wings is catching up to the digital age with the announcement of a new online newsletter. Flapping Wings Update will contain current news items (press releases are welcome), while the print edition will contain a wider selection of material, much of it not found in the online version. This new service is part of a major restructuring of the OS web sites. We are introducing a new site called The O-Zone, which offers a collection of resources for serious ornithopterists separate from the general audience Flapping Flight Web Site. The O-Zone can be accessed at http://indev.hypermart.net. You can sign up for the online newsletter by visiting this site today! Back issues won't be available.

Competition Heats Up!

We're nearing the end of the Ornithopter Society's year-long Millennium Postal Contest, and competition is intense! Akihiro Danjo of Japan still holds the best times in both categories, with flight times of 7 minutes 20 seconds in Cat A and 6:05 in Cat B. Do you have what it takes to beat these times? Cat A is open to any rubber-powered, indoor ornithopter. Cat B encourages use of the flapping surfaces to produce lift. The Millennium Postal Contest allows you to submit flight times by mail. For complete rules, visit http://indev.hypermart.net or send an SASE to the editor.

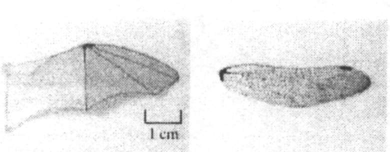
MicroBat

Researchers at California Institute of Technology have recently taken on the sizable challenge of building tiny ornithopters. The United States government Defense Advanced Research Projects Agency (DARPA) is sponsoring this work, along with various other projects, to develop micro aerial vehicles (MAVs) for indoor reconnaissance missions. The department has set a 15 cm maximum wingspan for such vehicles, so that is the span of Caltech's ornithopter. Researchers from University of California - Los Angeles, and Paul MacCready's AeroVironment also participated. Researchers include T Nick Pornsin-Sisirak, SW Lee, H Nassef, J Grasmeyer, YC Tai, CM Ho, and M Keennon.

The objective of this project is to develop the first battery-powered ornithopter MAV. Electric ornithopters made their debut around 1990, but not counting one tethered ornithopter, all have been much larger than the 15 cm span required of a MAV. In addition, the team wanted to study the unsteady-state aerodynamics of flapping-wing flight. They developed a titanium-alloy MEMS (micro electro-mechanical systems) wing technology and studied the unsteady-state aerodynamics of many MEMS wings. For the MicroBat itself, they built a lightweight power-transmission system that includes a battery, DC-to-DC converter, motor, gearbox, and crank-type flapping mechanism. The group reports successful flight durations of 5 to 18 seconds, limited mainly by the power system.

To some extent, this project was informed by a study of natural flyers in the MAV size range. The theoretical understanding of flapping flight is especially limited in this size range. The weight of the MAV ornithopter therefore fell approximately within the range of birds, bats, and insects of MAV size, about 7 to 10 grams. MAV wings were tested against real insect wings in a wind tunnel, giving valuable insights into design requirements. A low-speed wind tunnel at UCLA allowed testing the unsteady-state lift production at various advance ratios. The advance ratio is the ratio of flight speed to wing tip speed, and tends to be higher for large flying animals than for small ones.

The MEMS wing technology offers higher precision and repeatability than handmade, carbon-fiber wing structures, which were also studied. The wings were constructed using a photolithography process. Some OS members have been using this method to make small parts such as wing hinges, but not entire wings. Here's how it works: First, the titanium alloy sheet from which the wings are made is coated on both sides with a resist material. The resist is removed in selected areas, determining the final structure of the wing frame. A chemical etching solution (dillute HF and HNO_3 solution) removes the titanium alloy where it is not protected by the resist. The resist material, reapplied to the back of the frame, acts as a substrate for parylene C membrane deposition. The resist can be removed, allowing a second coating of parylene C to be applied from the back of the frame onto the existing layer of parylene C. The process is remarkable for its ability to replicate complicated wing structures



Silicon wings with parylene C membranes, produced through photolithography.

Weight each, mg	220	220	170	170
Frame material	C	C	Ti	Ti
Membrane material	mylar	paper	parylene	parylene
Angle of batten	45	none	10	10
Length x width, cm	7x5	7x3	7x3	7x3

Component	Weight, g
Wings	0.4
Motor, gearbox, mechanism	3.1
Ni-Cd cell	3.0
DC-to-DC converter	1.9
Fuselage, tail, switch, wires, etc.	2.2
Total	**10.6**

of bats and insects. Those shown here used silicon in place of titanium for the wing frame. OS member Robert Michelson of Georgia Tech Research Institute has used stereolithography to produce similarly complicated insect wings from plastic.

By making the whole wing this way, it is possible to build complex structures that closely resemble the wings of natural flyers, in appearance if not function. Using a low-speed wind tunnel at UCLA, the team tested wings made to resemble those of bats and insects, and found that, because the artificial wings lacked the spanwise rigidity and correct torsional flexing of their natural counterparts, they were useless for flapping flight. These wings showed a decreasing lift coefficient at the low advance ratios typical of MAV-sized birds and insects. Real cicada wings were also tested, and revealed the opposite: increasing lift coefficient at low advance ratios, and much more lift overall.

This problem was solved by using a simpler ornithopter wing design, similar to that used by Frank Kieser in some of his indoor ornithopters circa 1985. These designs consist of a simple sail with a diagonal batten as shown on page 1. No reason is given for this support, nor is it apparent that the team tried to eliminate it. Perhaps the bracing permits a larger wing area without having to increase the wing span above the allowed 15 cm. The current MAV ornithopter wing design requires 1 watt to flap at 30 Hz, about the rate required for flight.

In actual flight tests, at two different ornithopters were built. One used a pair of 1-farad capacitors for power. The total weight of this ornithopter was 6.5 grams. This ornithopter had a bench flapping duration of under one minute and flight times up to 9 seconds.

For longer flights, a Ni-Cd cell was used for power. The motor required 4 to 6 volts for adequate power, but the smallest available Ni-Cd cells are too heavy to allow use of a 4 cell battery pack. Therefore, a DC-to-DC converter was used to increase the voltage from a single 1-volt cell. The output voltage could be adjusted from 4 to 6 volts. This cell is a Sanyo N-50. By trimming its casing, the team was able to reduce the weight from 3.5 grams to 3.0 grams.

The motor is of the type used in vibrating pagers, which have also been used for indoor model airplanes in recent years. The motor, gearbox, and flapping mechanism together weigh 3.1 grams. The gear ratio is 22 to 1. The total weight of the Ni-Cd powered ornithopter is 10.6 grams, giving the ornithopter the high wing loading that one would expect from an aircraft designed within a wingspan constraint.

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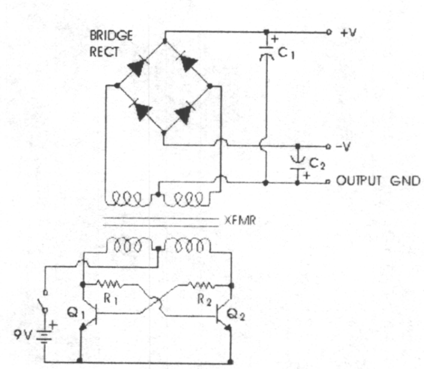
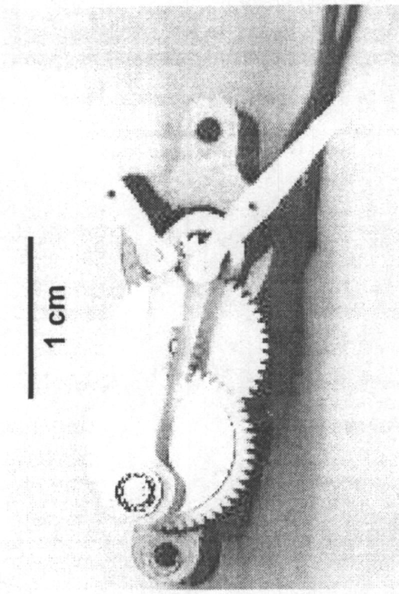


Example of a DC-to-DC converter circuit from http://elexp.com/t_dc-dc.htm.



MicroBat gearbox and flapping mechanism.

Flight duration for the battery-powered ornithopter was up to 18 seconds. The flight speed was about 4 meters per second. The tiny ornithopter was reportedly sensitive to wind conditions, stabilizer trim, and hand launching motion. The wings, however, did not break during test flights and landings.

Related publications

T Pornsin-Sisirak, SW Lee, H Nassef, J Grasmeyer, YC Tai, CM Ho, and M Keennon, "MEMS Wing Technology for a Battery-Powered Ornithopter", *Thirteenth IEEE International Conference on Micro Electro Mechanical Systems (MEMS '00),* Miyazaki, Japan, 23-27 Jan 2000.

SkyBird
Goes to France

Sean Kinkade's SkyBird ornithopter has been attracting attention as more and more people hear about the amazing RC ornithopter kit. One was sold to Dr Robert Korobelnik of Montrouge, France. He and his friend Patrick Bicheron took it to an experimental aircraft event and won the top prize, even though they didn't make the ornithopter themselves. French ornithopterist Albert Kempf was a no-show at the event.

Bicheron describes the event: "Many people were waiting until our flight. During this time, we were interviewed by many journalists: photo reporters for specialized newspapers I had worked with before, when promoting my PC interface for radio control. Finally we decided to fly when we noticed that the video cameraman and reporters were ready to take snaps and films. The engine started to run properly. So slowly that the wings did not move."

"Great moment. I held up the SkyBird and moved to the runway. A huge group of people followed us, but we were so excited that we don't see them on our back. Checking the tail, we slowly increased the power. The wings started to move and the audience stopped talking. We could hear a fly buzzing."

"The beating speed reached maximum. People could see that I couldn't hold it very long, even with my two hands. Without much of a throw, the SkyBird took off. With public applause, we flew 10 to 15 minutes. SkyBird reached the ground very softly. It was with many congratulations that we finished our unique flight. We felt that some journalists were not very optimistic about the concept, but now they are convinced. After the flight, we were interviewed by the TV channel and other reporters. Finally, at the end of the day, Robert got a trophy and he had a little speech." Korobelnik was working with an RC columnist and an article on the SkyBird is in the works.

Kinkade says Korobelnik has placed an advance order for the new EP SkyBird. This is a smaller, electric powered ornithopter Kinkade plans to make available as an ARF kit as he has done with the SkyBird.

Emery Wayman in Portland, Oregon, also bought a SkyBird. A local news channel aired a story about his

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Industrial Evolution
PO Box 376
Arkville NY 12406 USA

Ornithopter Society Membership Info

Join the Ornithopter Society or renew your membership: Dues are $12 per year in the USA. Dues outside the USA are $17 US per year. Checks are payable to *Industrial Evolution*.

Get published: Nathan Chronister, editor of *Flapping Wings*, invites you to send your articles and photos to be published in this newsletter. Send your material to the address above or E mail it to evolution@catskill.net.

http://indev.hypermart.net

SkyBird in France

Emery Wayman and SkyBird with high-start launching aid for the physically challenged.

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ornithopter. Unfortunately, Kinkade said, "the airheaded news anchors compared the SkyBird to the 'flying lawnmower' novelty, and also to a 'bad B movie monster' in their cheesy banter." As usual, the news media have a difficult time reporting about ornithopters.

Wayman has configured a launching aid for the physically challenged. He devised a plastic skid with a pin that attaches to a modified high-start. It works beautifully and doesn't require anything but throttling up and letting go of the bird. This is ideal for people who can't run or throw very easily. It's nice to see that the commercial availability of large, radio-controlled ornithopters hasn't brought an end to the innovative spirit that has characterized our endeavor from the beginning.