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oms flapper facts

Newsletter of the Ornithopter Modelers' Society

Free Bird Plans

I have finally completed a plan sheet for a good beginner's ornithopter. It is intended to be easy to build and not too delicate, in order to maximize the chances of success. Performance is several times better than that of Tim Bird, yet construction is simpler than any other ornithopter. For those of you who have been wanting to give ornithopters a try, now is the time.

Indoor Flying

I just returned from the Rockwood School District Science Expo at Laffayette High School near St. Louis. Roy White and friends gave indoor FF demonstrations and unlimited advice and encouragement to all attendees. The ceiling in the gym was about 27 or so feet. Roy flew a J3 Cub (peanut I think) profile model, which flew for about three minutes. He also flew his record holding (see current Model Aviation: Category I and Category III indoor national records) ornithopter many times. I timed only one flight; it was an incredible 5:34.02 seconds. Roy designed and built the model himself. The model weighs under a gram, uses mylar film covering, a rolled balsa, boron-reinforced fuselage, and a kevlar and balsa suspension structure opposite the Pirelli rubber. (I asked Roy if he inherited the Pirelli from his grandfather; he said "You bet. They haven't made any in years, but I still have a little bit of it.") The model's mechanical assembly was made of boron-reinforced balsa, teflon (I think), I.V. tubing, ss wire, hard work, and genius. Roy told me it was adapted from an Australian design and had been refined with computer help by an American. Roy makes the film himself by pouring a concoction on still water. He uses Ambroid as his only adhesive. The model was extremely delicate. When carrying it, Roy walked SLOW. The sight of the ornithopter flying really excited the kids, and most adults stared in gape-jawed wonder at what their eyes were seeing.

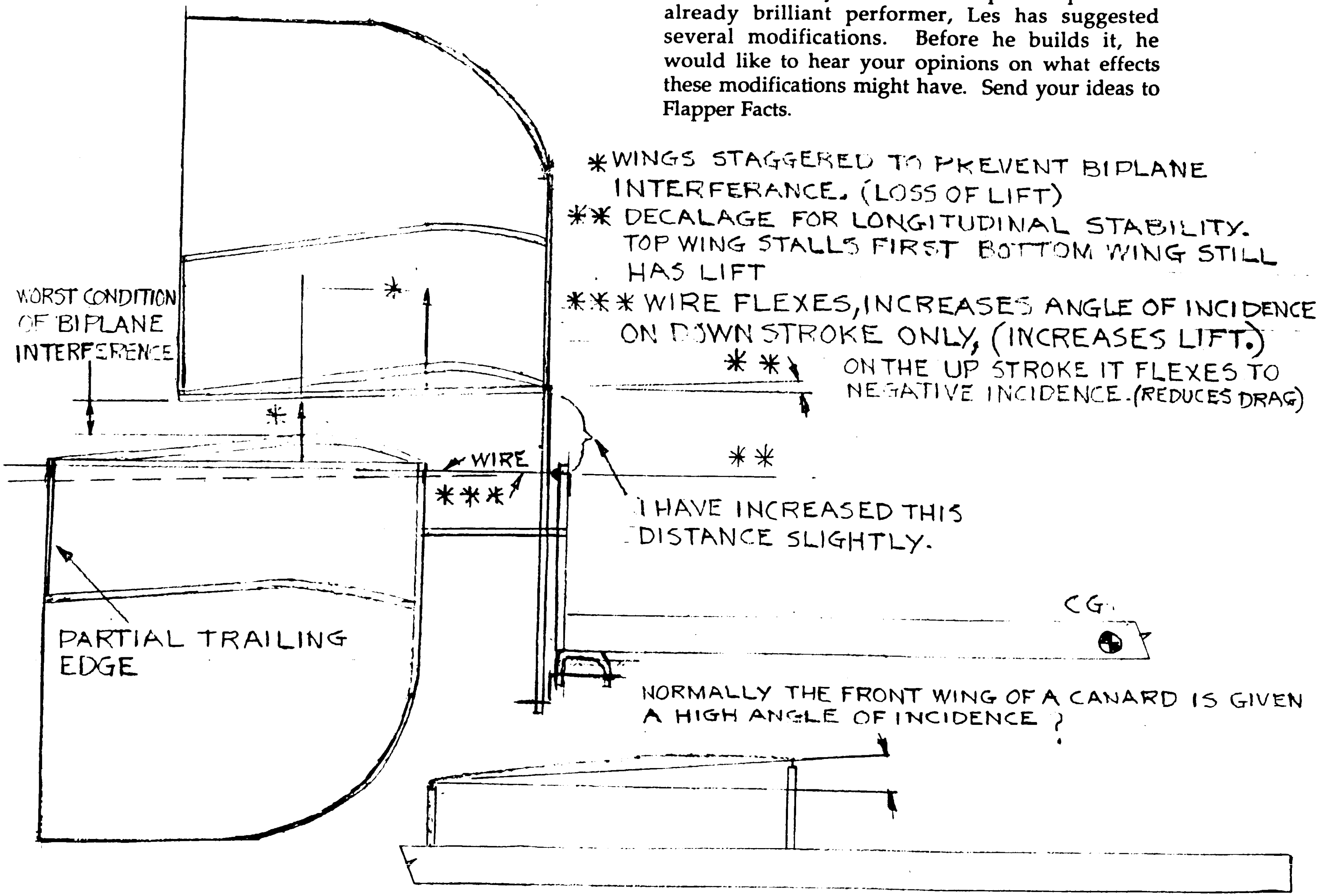
One of Roy's cohorts was flying an Easy B (I think) that stayed aloft for many 10 minute or so flights. The Easy B would climb as it flew over the crowd due to the thermal generated by the heat of their bodies, not something you can entirely believe without seeing it a few times. The Easy B had film covering that was not smooth; the builder said he thought it gave the plane better aerodynamics. He didn't mention Reynolds numbers or boundary layer effects. He attached the covering with 3M 77. The "B" was built of sub 3.5 lb balsa obtained from a source in Oregon. He used FAI tan rubber and raved about it. The last three or so batches could be used right out of the box without "conditioning" and could be reflown immediately and repeatedly without resting. He and Roy had winders that counted the turns and used a torque gauge to show when to stop winding. He said the current indoor records would fall because of the superior quality of the new FAI tan rubber. They both preferred "Son of a Gun" as a rubber lube.

This was my first exposure to national class indoor flyers and I was extremely impressed by what they were able to do with less than a gram of mass.

-Mike McCole

Indoor Design Ideas

Sid Davidson has based this biplane design on Les Garber's Butterfly I. In an attempt to improve the already brilliant performer, Les has suggested several modifications. Before he builds it, he would like to hear your opinions on what effects these modifications might have. Send your ideas to Flapper Facts.



Harris and DeLaurier fly R/C Ornithopter

A number of ornithologists have calculated the amount of power used by birds in flight, and it turns out to be somewhat less than that used by model airplanes (see Bird Flight Performance by C. J. Pennycuick). The amazing low-power flapping flight of birds has encouraged several ornithopter theorists to claim that these machines will eventually be far more fuel-efficient than conventional aircraft. Whether this is true or not, it will be possible to reduce ornithopter power requirements substantially from their present level.

A major step in this direction has been taken by Jeremy Harris and James DeLaurier, who have built one of the few successful gas-powered ornithopters, and one which addresses the power-to-weight problem through aerodynamics rather than brute force. Their ornithopter, which is called "Mr. Bill" as a reminder of the crashes it suffered during testing, actually has a similar power-to-weight ratio to other model aircraft, while less-advanced ornithopter designs require more than twice as much power as airplanes.

Jeremy Harris is a research engineer at the Battelle Institute, Columbus, Ohio, and James DeLaurier teaches aerospace engineering at the University of Toronto. Harris has been interested in the ornithopter problem since the late 1960s, and was joined by DeLaurier in the early 70s. They decided to base their work on a strong theoretical foundation, and in doing so practically reinvented the ornithopter. This approach is likely why it took 20 years to get the ornithopter flying, but it also gave Harris and DeLaurier the ability to apply their work more easily to future ornithopters. "We can fairly accurately set the characteristics of an ornithopter at any scale," says Harris. Mr. Bill first flew in sustained flight on September 4, 1991, at Newton-Robinson, Ontario. Two flights were made that day, each about 2 minutes in duration.

One of their innovations is the use of a thick airfoil rather than thin membrane for the wing. Membrane wings are fine for kites, where in most cases the lift/drag ratio is not important, but they are not suitable for efficient flapping flight. Incidentally, this does not apply to bats or birds, which can vary the span of their thin wings to prevent energy being wasted in the upstroke. Air flowing around the sharp leading edge of a thin wing forms an eddy above the wing, but around a thick airfoil the flow is smooth. Air from ahead of and below the wing flows around the leading edge and speeds up, forming an area of low pressure on the leading edge called leading-edge suction. This low pressure area contributes thrust, improving the lift/drag ratio.

Leading-edge suction also reduces the degree to which the wing must twist in order to produce thrust. However, some twist is required in all ornithopters, and this is a special problem when a membrane wing is not used. The wing structure consists of a plywood, kevlar, and carbon composite leading spar and foam ribs. This is built for just the right amount of flexibility. A more difficult problem than making a flexible frame is having the covering twist along with it without wrinkling. (Slightly twist the wing of any model airplane and see what the covering does.) Harris and DeLaurier have solved this problem with a patented system called shearflexing, which allows the top covering to slide past the bottom covering where they meet at the trailing edge of the wing. This can be modeled by bending a sheet of paper in the middle to form an airfoil shape. Note that sliding the paper across itself at the trailing edge causes this paper wing to twist.

Another clever idea embodied in Mr. Bill is the use of a three-panel wing. The outer twisting panels are hinged to an inner rigid panel. The outer panels are attached to the fuselage, via struts, in such a way that a downward motion of the center panel causes the outer panels to move upward, rotating about their point of attachment to the struts. This is how the drive train, connected to the center panel, flaps the wings. An important feature of this system is that the lift on the center panel partially balances the lift on the outer panels, reducing the load on the engine during the downstroke. This results in smoother running and reduced power requirements. Biplane ornithopters achieve a similar balance, having a rising wing linked to a falling one so that the weight of the ornithopter does not hinder the flapping. This allows the use of thinner rubber motors and is the main reason for the success of biplane ornithopters. A few other devices have been used to balance the weight of the ornithopter and reduce motor load, including springs which exert a downward force on the wings and flapping mechanisms which provide greater torque on the downstroke.

Despite aerodynamic refinements, any ornithopter must have a good powerplant with a high power-to-weight ratio. Ornithopters lose more energy to gear friction than any other type of aircraft, and are necessarily heavier than other aircraft due to the added weight of gears, flapping mechanism, and stronger structure. Harris and DeLaurier chose a .45 model helicopter engine with an output of 1 horsepower. Reduction is via toothed belt to save weight. The belts are from helicopters also, but the ornithopter requires two of them instead of one. Ornithopter geartrains must be rugged to withstand the high levels of power and torque without sacrificing reliability.

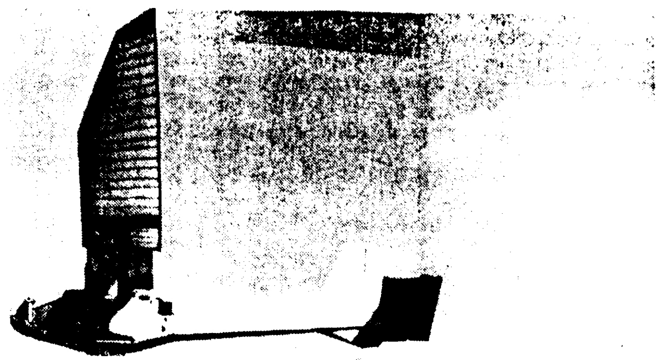
Mr. Bill does not have a clutch. A round hole on the right side of the fuselage admits an electric starter, which grabs onto a hub on the engine shaft extension. Once it is running, the model is hand launched, despite its size of 9 pounds with a 10-foot span. The lack of a clutch suggests that gas-powered, membrane-winged flappers can be simpler than was previously thought. Patrick Deshaye's awkward clutch arrangement could perhaps be eliminated from his .020 design, saving a significant amount of weight and greatly simplifying construction.

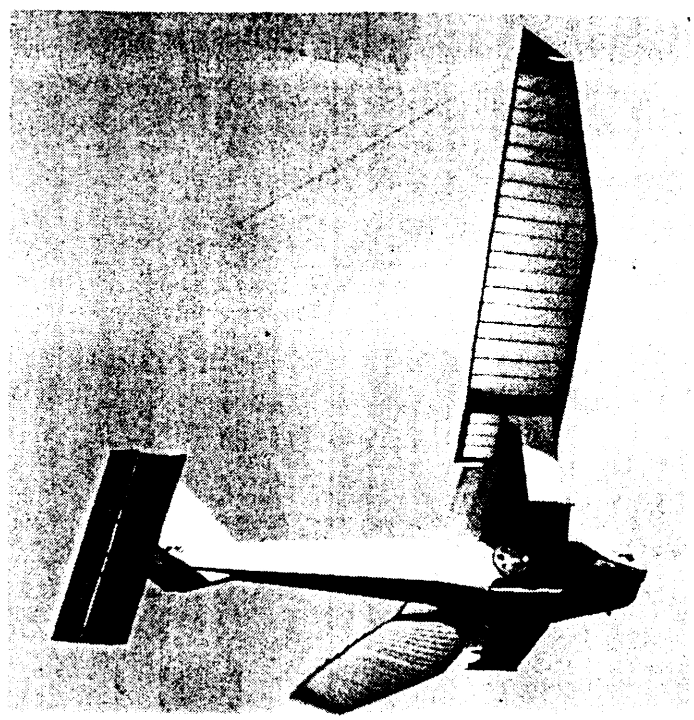
"Expothopter," the follow-up to Mr. Bill, has been touring the world as an electric-powered display model. It will be given a gas engine and 3-stage belt reduction in order to fly, and will have a centrifugal clutch allowing it to be winch-launched. It will be somewhat larger and sleeker, having a V-tail and a less-cluttered exterior.

The flapping mechanism is fairly unique, consisting of a scotch yoke. The crankshaft has a left-right orientation and is located just below the wing rather than in front. Rather than acting on a connecting rod, the crank slides back and forth in a horizontal groove in a structure attached to the center wing panel. The vertical component of the crank motion causes this structure to move up and down, flapping the wings. This arrangement allows fully symmetrical flapping. It minimizes the vertical distance between the crank and the wing and permits the use of a large-radius crank, which reduces the amount of force on the structure as amount of force on the structure as well as permitting the use of a three-panel wing.

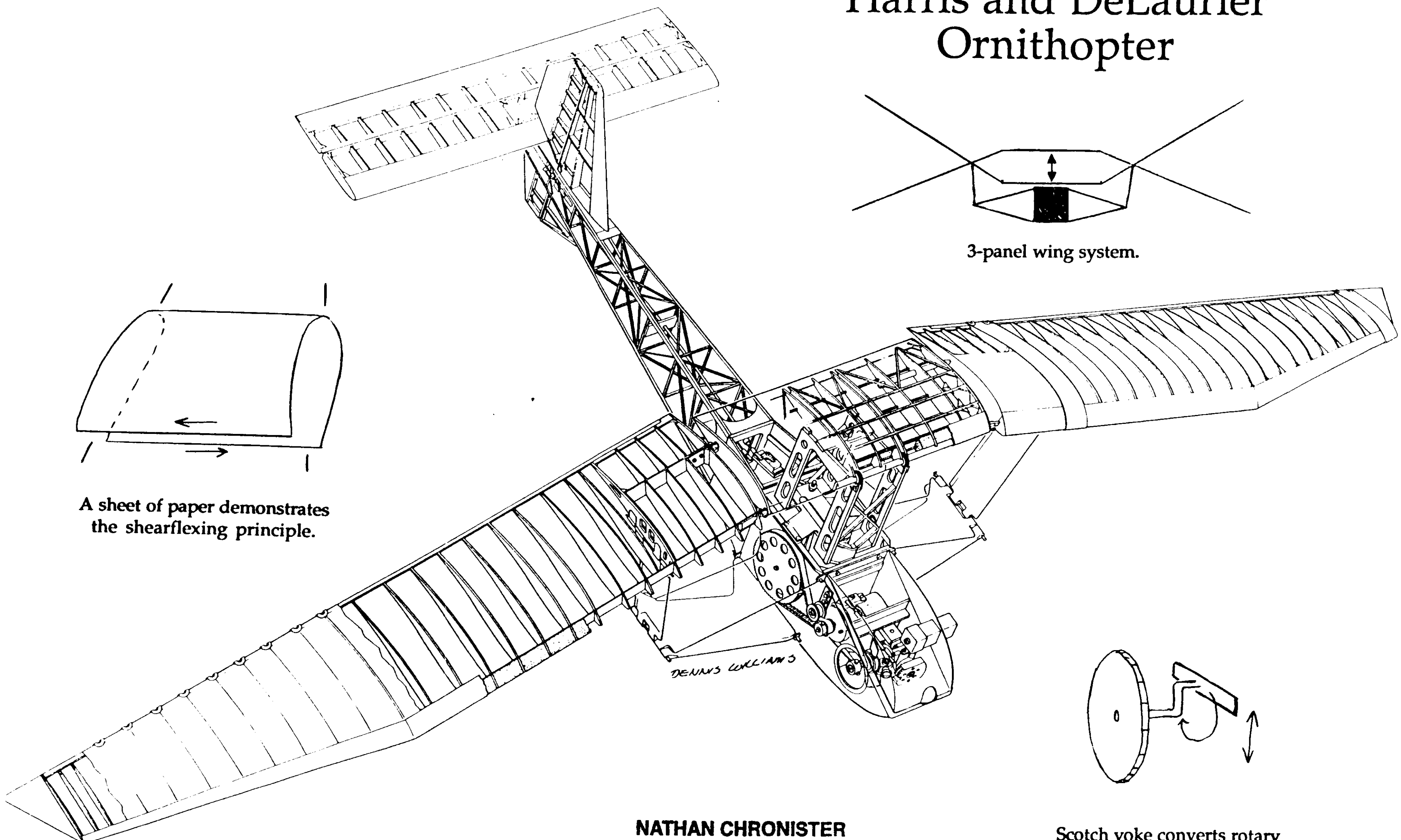
This ornithopter is a radio-controlled model, using throttle, rudder, and elevator controls. Although it is not likely to appear with plans in an upcoming issue of Model Airplane News, because of the complexity and cost, the three-panel wing might be an effective alternative to the biplane configuration for indoor competition ornithopters. The average wing position would be more horizontal, producing more lift. Also, Harris and DeLaurier's efforts at improved aerodynamics stand as a reminder that the present membrane-on-a-stick wing design needs to be improved. This will involve an increase in complexity and weight, but will pay off with lower power requirements.

The men who created this ornithopter intended it as a proof-of-concept model for subsequent, larger ornithopters and would like to build a human-carrying flying machine when they get funding for such a major project. Possible uses for such a vehicle are numerous. Not only would it have great appeal as a private, sport aircraft, but the ornithopter has potential military applications. As birds (particularly owls) demonstrate, ornithopters can be the quietest type of aircraft. They have no prop or rotor noise, and the engine and gear noise, quite loud in the case of Mr. Bill, could be suppressed. Though it is still a long way from the versatility, efficiency, and performance of bird flight, this ornithopter is a clear step in that direction. Harris suggests that ornithopters, consisting of suits that could be worn without restricting our movement on the ground as do airplanes and cars, could someday provide humans with the mobility of birds.





Harris and DeLaurier Ornithopter



3-panel wing system.

A sheet of paper demonstrates the shearflexing principle.

Scotch yoke converts rotary to linear motion.

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