THE Millennium RIGID WING HANG GLIDER

by Deane Williams

Chris Filer waits in the tow line at Wallaby. Note extra large front wheel no longer used.

Although the Millennium has been in production for a few years now, there has been much misunderstanding about it and no one has reviewed it for the general pilot population. This Pilot Report will attempt to fill that gap.

The glider represents a radical departure from today's hang glider designs, and so should be considered for its positive contributions to the advancement of hang glider technology.

BACKGROUND

The Millennium is a first-generation, foldable rigid wing produced by Bright Star Gliders of Santa Rosa, California. It evolved from the world's best-performing foot-launched tailless glider, the Swift, also designed by Bright Star and currently built by Aeriene of Belgium. The Swift was designed around 1990 by a team of aerodynamics students and professor Ilian Kroo of Stanford University. The Swift performs well but is heavy (about 130 lbs. or 59 kg) and requires a large, car-topped or trailered box for transportation. Its skin is composed of hard, composite panels, so its finish is similar to a sailplane. The design of the Millennium was an attempt to make a lighter, more easily transportable glider with a sailcloth wing that would retain most of the performance of the Swift. It has achieved this goal.

The design team consisted primarily of Dr. Steve Morris, Brian Robins and Brian Porter. Steve is one of the most knowledgeable people on control and stability of flying wings, having earned his Doctorate in this field. Brian Robins is the composites and mechanical wizard behind Bright Star, and Brian Porter, the test pilot, is a world-class hang glider pilot who has held the title of national and world champion in Class 2. The Millennium went into production in the spring of 1999. To date, 52 production models have been built.

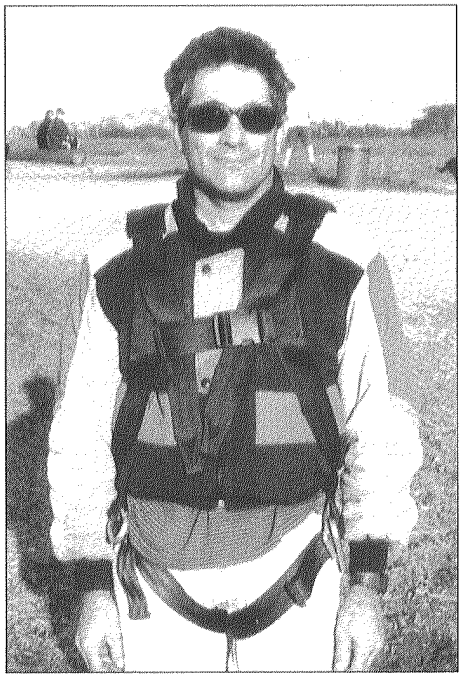
CONSTRUCTION

The wing is composed of two carbon/Kevlar composite D-tube leading edges pivoting in the center on a steel carry-back spar ("keel"). Seven aluminum ribs per side are pivoted at the spar on the rear of the D-tube. Each rib has a central hinge and folds inward during packing. Unfolding during setup is accomplished automatically by a thin steel cable attached to each central hinge ending at the steel washout strut which is hinged to the D-tube spar at the wingtip. A 3/8-inch (9-mm) diameter aluminum tube runs across the trailing edge inside the wing and pivots at each rib. This adds rigidity to the wing and allows the sail to be more evenly tensioned. The forward portion of the D-tube is exposed to the air stream and therefore is finished very smoothly and covered with a tough, white, epoxy paint. The sail attaches at the rear of the D-tube with marine-grade sail tape on both the top and bottom surfaces. Although this seems as if it might be a structural concern, the tape has held up well over several years of exposure to varying temperatures, occasional rain and typical hang glider operating environments. Some have noted that grass, dirt, etc., tend to work in under the tape near the tips, but the tape remains firmly attached. The sails are well made (by Wills Wing) and available in many custom color schemes. Zippers are located on each wing with a central zipper and two inspection zippers on the undersurface. The leading edges weigh about 20 lbs. (9 kg) each and are made in a three-day process by hand. A camera mount insert with a standard thread is located about halfway out each

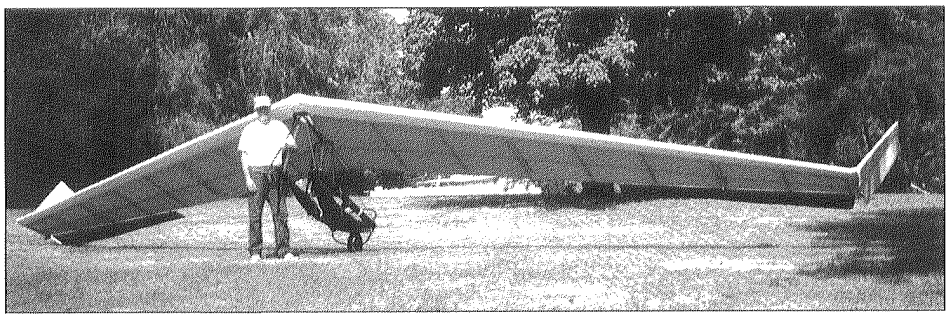
edge on the undersurface. At the tips, large winglets, with rudders attached, are plugged into the steel tip strut.

The pilot sits below the wing in a reclining position between two three-inch (76-mm) diameter aluminum tubes. The tubes are hung rigidly from the wing's carry-back spar by four 22-inch, 7/8-inch diameter chrome-moly steel tubes. This entire arrangement is commonly called a "cage." A cleverly constructed split seat allows the pilot to stand for foot launching and landing but closes beneath the pilot after launch as he lifts his body briefly above the seat. This arrangement is a compromise but results in a surprisingly comfortable and snug flying position. The pilot's feet rest on a horizontal bar. The (optional) rudder pedals are fitted on this bar, but unfortunately this restricts the pilot's foot position somewhat and can be a little uncomfortable on long flights. A headrest rail at the rear of the cage is commonly used as the mounting location for a rocket-deployed parachute system. This system is sold by BRS and is quite expensive compared to the cost of their old harness-mounted rocket systems.

A 12-inch pneumatic wheel is affixed to the rear of the cage and a small, four-inch scooter wheel and a strong skid-tube arrangement are hinged to the front. The wheels are not a necessary part of the Millennium but they add greatly to the ease and safety of the wing.



Steve Morris models the simple harness after flying his Millennium.



The author shows the planform of the Mill.

SPECS

The Millennium is a rugged and heavy-duty wing. It was designed to JAR glider specifications and has a plus/minus 10-G ultimate load. It has been truck tested to this level and it did not break! Its ruggedness (and hence, its weight) is, in part, a result of constructing it so that it can withstand the transport handling, drops and whacks that hang glider pilots subject their wings to. It handles these stresses well.

The speeds of interest are:

Stall speed
20 mph (32 kph)
Min sink speed
25 mph (40 kph)
Best sink rate
~140 fpm (.71 meters/sec.)
Best glide speed
34 mph (55 kph)
Best glide in stock configuration
17 to 1
Maneuvering speed
53 mph (85 kph)
Max speed or Vne
65 mph (105 kph)

Maneuvering speed is the highest speed at which full control deflections are allowed by design. The wing is slippery compared to the average hang glider. With its powerful pitch control this speed is attained rapidly and easily.

Dimensionally, the wing is the smallest folding rigid wing. The basic span is 37 feet (11.3 meters), and with the tip rudders installed it is 38 feet (11.6 meters) as they are canted out slightly for a better sink rate. The weight is between 105 and 115 lbs. (about 50 kg) ready to fly, depending on parachute used, instruments, etc.

CONTROL

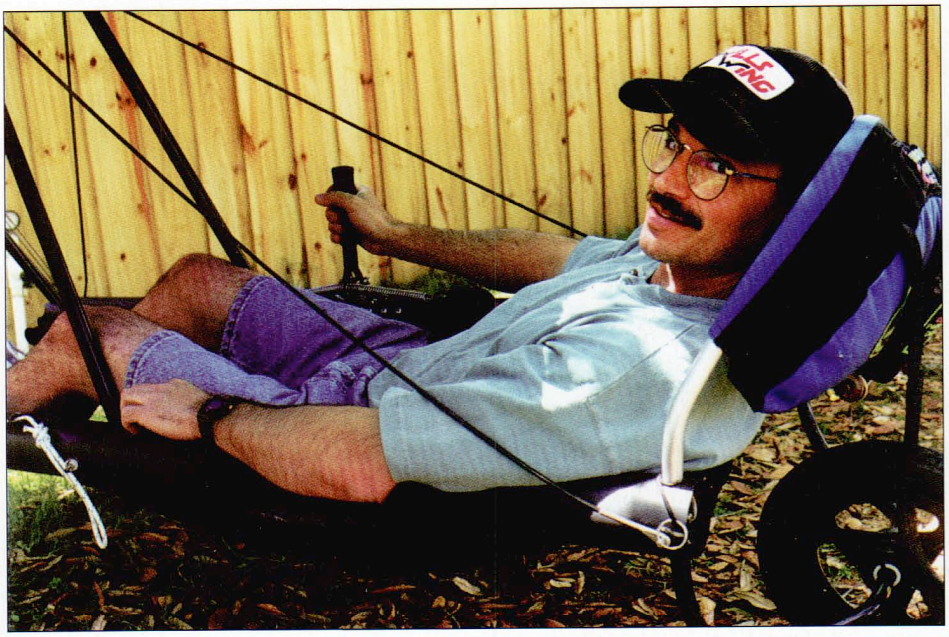
The Millennium uses a combination of elevons and tip rudders for control. Both are linked to a smooth-action control stick built into the right-hand cage tube. The stick contains an ingenious mixing mechanism to allow the elevons to serve for both pitch and roll control. Four cables run up into the wing to translate the stick motions to the control surfaces. There is no dihedral in the wing which allows for greater span efficiency. To counteract adverse yaw the tip rudder moves outward slightly whenever the stick is moved to that side. This method works well to eliminate adverse yaw. With the optional rudder pedals the pilot can augment this automatic motion if desired, but this is not normally needed. The rudder pedals are most useful for helping bank into a strong thermal that lifts one wing.

Even without the rudder pedals, 45° to 45° roll reversals have been documented at under four seconds. The roll control is good and the pitch control is outstanding, although some might say it is too sensitive. This sensitivity sometimes leads to a few minor pitch bobbles by new pilots right after launch. If the stick is moved forward rapidly while cruising, the craft will react so quickly that the pilot will momentarily become weightless. That is powerful pitch control!

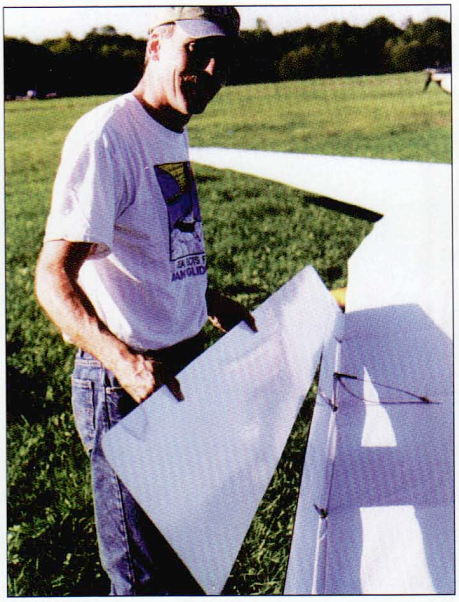
SETUP

The glider is slightly heavier than its first-generation competitor, the Exxtacy, so it's nice to have someone help you carry it to the setup spot. Many pilots have built a simple two-wheeled cart for those times when there is no one to help. The good news is that one end is much lighter than the other, so almost anyone can help. The wing likes to be set up with the nose facing a very slight downhill so that the wings tend to stay spread until fastened.

Unzip the bag and pick up the nose to allow the cage to swing down away from the wing. Pin the cage cables in place with



Mark Herman checks out the ultra-comfortable flying position.



Removing the carbon-fiber elevons during breakdown.

the two pip pins. Now simply swing the wings open and connect the two tip struts to the trailing edge with a spring-loaded, tube-into-tube arrangement. The action of swinging the tip struts outward unfolds and locks all the ribs and tensions the wing. Pull rearward on the carry-back spar extension and it snaps into place to tension the trailing edge tubes. Now go to the nose and install the nose catch with wing nut and pin (very important). This procedure has taken as little as four minutes and the wing is essentially rigged at this point. Now install the rear wheel and its two struts into the rear of the cage tubes. Install the front skid strut into its socket on the wing and pin it. Now we're up to about seven minutes. Remove the pins from the right elevon slot and gently rock the right wingtip to the ground. Starting from the inboard side, slide the elevon into its track, line up the two holes, install the pins with safety rings and connect the actuator cable. Repeat this procedure with the left elevon. Now remove the rudder pin and ring from its track, pick up the left tip rudder and snap it down over its mounting post. Line the rudder up with its control track and pull down on the tip to lock it in place. Install the rudder pin and safety ring. Repeat with the right rudder. Installation of elevons and rudders takes between five and eight minutes. In about 15 minutes the glider is flyable.

At this point it is a good time to do an initial preflight of the controls. Rock the glider up so both wingtips are off the ground and move the stick fore and aft. Check for smooth, identical motions of the elevons. Also make sure there is no motion of the tip rudders. Now move the stick side to side. Check for smooth, opposite motion of the elevons and insure that the tip rudder moves outward on the side the stick is moved to. Look inside the wing to inspect the condition of the cables, zip the undersurface closed and install the tip fairings (Velcro). Move to the nose, double check the important nose catch and then cover it with the nose fairing. Install the parachute, radio and instruments and you are ready to fly. As with most gliders, installing these items can take a lot of extra time. Controls should be checked again just before takeoff.

The setup is quite different from most hang gliders and a checklist should be used to be sure nothing is missed. As with any task, you get better with experience. The many features of the wing make it user-friendly. The early models did not have removable elevons which saved about five minutes during setup, but the glider was a bit more difficult to transport because of the large foam blocks in the bag used to protect them.

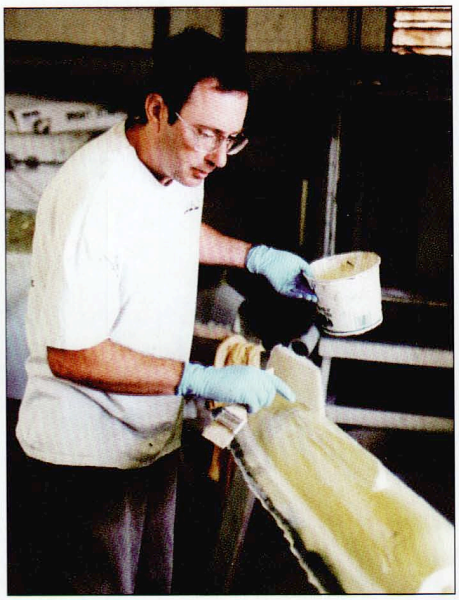
All models have four foam blocks that protect the wing from the cage when folded. These may be easily stored in the wing during flight. The cover bag is a bit more of a problem. It weighs six lbs. (2.7 kg) and cannot be easily stored in the wing. It may be folded tightly and strapped to the headrest.

LAUNCHING

The pilot wears a lightweight "harness" (included with the glider), climbs into the cage and clips in to the wing at his hips (left and right) with the usual carabiners. Be sure to double check that you are hooked in! Because of the seat and the way your forearms can support your weight during liftoff, it is possible to launch without being hooked in (especially easy to do when towing!) and fly for hours. Shoulder straps allow the wing to balance easily on the shoulders for running and help keep the pilot anchored in place in case of severe turbulence in flight. The carabiners won't let you go far even if you remove the shoulder straps in flight. Learning how to launch the glider is a bit of a challenge. The glider can be picked up by the pilot with some effort, but it is much easier if someone helps by picking up the front strut. Once up on the shoulders the stick allows the pilot the ability to keep the wing level in the wind as he walks to the launch unassisted. Like all gliders, once you get a few steps into the breeze the glider is fully supported and you can accelerate your run.

With most hang gliders the launch is the most technically difficult part of flight, and this glider no exception. Bright Star's Brian Robbins observes that pilots with marginal launch technique will do worse on the Mill, but pilots with good tech-

Flying off the ramp at Lookout Mountain in Georgia.



Brian Robins building compostie shapes at the Bright Star shop.

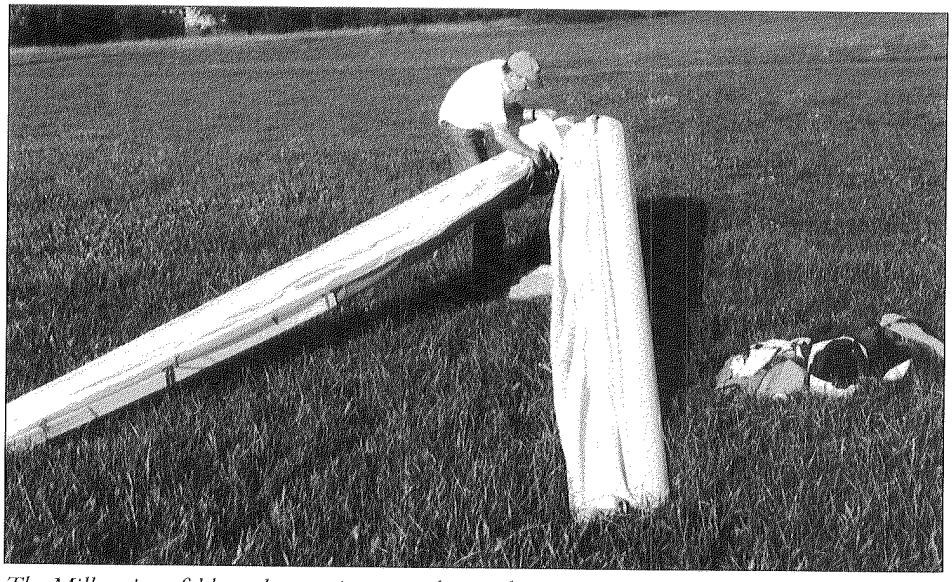
nique will find launches to be at least as easy as with a flex wing. The wing is surprisingly easy to launch in most conditions. As you might expect, light winds and shallow slopes of limited length present the greatest challenge. It's always best to wait for the most wind in a cycle. Using a good run with a moderate breeze, the glider lifts off with neutral stick and the excellent glide ratio keeps you off the ground. It shows no tendency to mush or stall on launch. Higher winds are easy if they are smooth. Because of the very short chord (four feet or 1.2 meters) the wing can pivot on the shoulder straps in rapidly changing (gusty) winds. In these conditions the use of the stick becomes more important. Starting the run with a walk and accelerating to a run is helpful as the pilot "feels out" the wing, correcting for any inadvertent roll motions with the stick. It's best not to use any pitch input unless needed, and then only to pull back for liftoff if required.

Beginners may tend to put weight on their forearms without knowing it, thus causing the wing to be loaded before sufficient speed is attained. This is commonly known in the sport as "jumping into it (early)" and must be avoided on any hang glider.

Once off the ground the pilot should fly supported entirely by the harness until stable and away from the hill. Once away from the hill a quick but careful push on the forearms is all that is needed to lift the pilot's body and swing the legs up onto the footrest. This motion will result in a small but meaningless pitch bobble. The glider is quite sensitive to pilot position, more so than most hang gliders because the pilot is so close to the wing and the chord is so short. After a few flights you will find that this motion is eased by pushing gently forward on the stick to lower the nose. You will find that your feet float effortlessly up onto the footrest and the seat closes up beneath you as you lift your body. You usually need to reach under you and give a few tugs to fully close the gap in the seat for maximum comfort. Now you are on your way, supine and comfy.

FLYING THE MILLENNIUM

This is what it's all about. The extra effort required in owning this craft pays off when you're in the air. The first thing you notice is that you are part of the wing, not just dangling below it. Every little motion of the wing is transmitted through the seat of



The Millennium folds at the nose into a pack size about twice as wide as a flex wing

your pants and your forearms. Thermals seem to cause a wonderful upward acceleration. The next thing you become aware of is that your legs are just 22 inches (55 cm) below the wing and your head is just behind it. You can reach up and touch the trailing edge! Clouds are visible by just looking straight up. It's easy to head for the best part of a cloud with visibility like this. The wing sticks out 19 feet on either side of you with no wires or struts supporting it, and you get to see it all. It is as rigid as an I-beam.

The speed is a comfortable 24 to 27 mph (40 kph) with the stick in the neutral position. Centering springs keep it in this position with no pilot input. The trim speed can be increased by sliding forward in the seat. Heavier pilots will notice a greater change than lighter pilots. Moving the stick left or right results in a gentle rolling motion. Follow that motion with a small pullback and the glider fairly leaps into a turn. As the turn reaches the desired bank angle move the stick to the opposite side, as needed, to keep a constant bank. This is just like "high siding" a glider but it's so much easier to do with your wrist. Watch the airspeed and keep it around 25 mph (40 kph) for thermaling. Turns are that easy.

Anyone with any kind of stick experience, even radio-controlled sailplane time, will quickly adapt to the controls. It is very predictable and intuitive. Speeds of 45 to 55 mph (88 kph) are easy to obtain and hold without feeling like you are diving out of the sky. These are the useful speeds that rigid wings need to hold for long glides to maximize cross-country performance.

ABOUT SPINS

All rigid wing gliders will spin. The modern view by most authorities is that spin awareness and spin avoidance are preferable to "practicing spins." In fact, spinning a glider is no longer part of FAA sailplane pilot licensing requirements. The Millennium recovers quickly and easily from spins. The procedure is to return the stick to center and push it forward a bit. As soon as the rotation stops (very quickly) ease back on the stick to return to normal flying speed. If turning very slowly in a turbulent thermal you should always expect that *any* glider may begin to spin. For this reason the pilot must be diligent to carry extra airspeed when thermaling low to the ground. The amount of turbulence will make a large difference in the tendency of a wing to spin.

It's easy to recognize the beginnings of a spin. While turning, the rate of rotation will suddenly start to increase and the nose will drop. Immediately pushing the stick will halt the incipient spin. The novice pilot may think that rolling the opposite way will get him out of this predicament, but that has no effect.

If the spin is allowed to develop into a full spin the recovery method is the same. A full spin in a Millennium is an effective escape method for strong cloud suck. Richard Parzoch has measured the descent rate as 4,200 feet per minute (21.3 meters per second) and the exit speed as 54 mph (87 kph). (Never exceed Vne when exiting a spin.)

PERFORMANCE

Glide ratio performance is a rather subjective and difficult parameter to measure accurately, but in comparison tests with other gliders the Millennium shines. The factory lists the L/D as 17 to 1. If you like to tinker with your flying machines, the Mill is a diamond in the rough. It's easy to see that the cage structure is the easiest thing to clean up. There are five vertical members totaling about 11 feet (3.3 meters) of tubing (about the same as a control bar) that can be easily faired. Calculations predict this will add about 0.9 points to the best glide. Other areas for improvement by fairing are behind the pilot by use of a tail cone and fairing the pilot's feet by means of a streamline shape. Bright Star has tested a full fairing adapted from a Swift, although there is not much interest in it. This has a large positive effect on the overall performance. There is a partial pilot faring constructed of stiff fabric that is available, and this has been shown to increase performance as well.

At higher speeds the Mill excels in part because the downward deflection of the elevons effectively removes some of the washout. Also, it's easier to hold the wing at high speeds for long periods of time because of the control stick.

Best sink rate is quoted at 150 fpm (.76 meters/sec.) but it may be better. Comparisons show the Mill to sink as well as the second-generation rigids in coastal air. Rigids in general show an advantage in climb compared to flex wings, especially in very light thermals. In broad thermals any rigid will often outclimb a flex wing within a few minutes from hundreds of feet below. If you are a longtime flex wing pilot, as I am, you'll find that the Mill is a joy to fly because of the range the pilot can cover and the ability to stay up while others sink out. This will continue to amaze you.

LANDING

As a result of the glide performance it is often necessary to degrade it when it's time to bring it in. The tip rudders can be deflected simultaneously using the rope and jam cleat to provide variable glide angle control on approach. (Be aware that in this configuration the rudders cannot do their normal job of compensating for adverse yaw, so this is more noticeable. Plan your approach to mini-

mize turns close to the ground.) Glide can be reduced to about 10 to 1, making the glide similar to the range we are used to. Use of an after-market drag parachute can reduce the glide even further. I highly recommend a drag chute for any rigid wing or kingpostless design if you intend to fly X-C. With both devices fully deployed you can really feel the drag pulling you down, and the approach angle steepens deeply to about 5 to 1 as you increase speed.

Some pilots will land on their feet but most prefer a wheeled landing. The wheels provide an extra margin of safety and take the pressure off the pilot to select the perfect moment to flare. Dropping any 100+ pound glider is not a pretty sight even though the Mill is rugged enough to take it. Landing on wheels is just too easy: Approach the ground with moderate speed and attempt to keep the wing flying with the wheels just six inches off the ground by trading off airspeed for altitude in tiny increments. When stall speed (in ground effect) is reached at about 19 mph (30 kph) the glider settles onto the wheels. The rollout can be shortened by removing the front wheel and just using the skid.

TOWING

The Millennium is one of the easiest hang gliders to tow. Its inherent stability and tip fins cause it to track straight behind the tow vehicle no matter what type it is. The wheels make cart launch dangers and hassles a thing of the past. One possible glitch is that most new pilots will over-control in pitch for a few cycles as soon as they are off the ground. This is due to the strong pitch control the craft possesses, however, the pilot quickly learns how to smooth this out. Platform tows are best conducted by reeling out a hundred feet or more of rope and launching from the ground surface. The Millennium uses an ingenious and dirt-simple tow release designed by John Borton ("JB"). A bushing is installed in each side cage tube just ahead of the center of gravity. A weak link is tied to each end of a 10-foot rope bridle and the weak link loops are fed through the bushing on each side and secured inside the cage by a hitch pin attached to a hand loop. Either side may be used for release, giving the security of a built-in secondary release. The bridle is pulling from very near the CG, so this arrangement can be used for platform, static or aerotowing.

Foot-launching at Ellenville, New York.

X-C CONSIDERATIONS

If you like to fly X-C then a rigid wing is the best machine to fly these days. You will find that you get to altitude faster, get more X-C flights, sink out less often and enjoy longer flights, guaranteed. My first X-C attempt in the Mill yielded a 102-mile flight from Lookout Mountain Flight Park. This is a rare treat on the east coast. The long-flight comfort, high-speed performance and low sink rate of the Mill make it a good choice. The drag rudders and a reliable drag chute are the hot setup for short-field X-C landings. I have not found an LZ yet where the wheels didn't work just fine. Plowed fields, low brush and tall hay all have been landed in without problems. The glider's weight presents a challenge once on the ground, but the glider can be walked or wheeled around depending on the surface you landed on.

SUMMARY

As you might have guessed by now the biggest objection that a pilot might have to owning the Millennium (other than cost which at $9,400 is comparable to other rigids) is its weight. Most pilots own gliders that weigh about 30 lbs. (14 kg) less. I dislike heavy gliders, but back when I purchased the Mill it looked as if rigid wing gliders would never be much lighter. I had to come up with some new tricks to deal with the machine on the ground. Sometimes new challenges can be fun. Now that I'm used to it, living with the weight is not the daunting problem I imagined it would be. Brawny pilots will have less concern than lighter ones.

Prospective Millennium pilots should have stick-type flying experience to be sure their reactions are instinctively correct before flying the Mill. Pushing the stick the wrong way in a panic situation could be disastrous if near the ground. It's always best to seek training when transitioning to a radically different glider.

Currently Bright Star is not producing the Millennium, but the talented Bright Star team continues to evaluate new concepts in flying wings and may produce a glider in the future. Parts and service continue to be provided by the shop. For new developments check their Web site: http://www.sirius.com/~mlbco/.

The Swift Web site is http://www.ping.be/~ping4026/aeriane.htm. Aeriane is reportedly working on a light version of the Swift that will weigh something similar to the Millennium at a slightly higher cost.

IN CLOSING

There has been some discussion about the Millennium. Is it a hang glider or an ultralight sailplane? The answer is, it's both!

Because the Mill doesn't have a conventional control bar it hasn't been as popular as the control-bar rigids. After all, it is human nature to resist change. Most of the pilots who are able to purchase a rigid wing have been flying with a control bar for many years. Yet, from my experience, I am sure that if more pilots were able to experience the performance and comfort of "cage" flying they would thoroughly enjoy it. ■