BOOMERANG

A "Boomerang" is supposed to go out, do its job and return—so should sailplanes. This 2-meter effort by *M.A.N.*'s "Mr. Soaring" matches its namesake in all three areas.

by Jim Gray

BOOMERANG
TYPE: 2-Meter RC Sailplane
WINGSPAN: 78 inches
WING AREA: 600 square inches
AIRFOIL: Eppler 205
LENGTH: 40 inches
WEIGHT: 34 ounces
RADIO: 3-channel

Mr. "Soaring News," Jim Gray, poses with his latest achievement, Boomerang. A two-meter sailplane for all types of contests, the ship features an Eppler airfoil. Clean design permits speed and excellent penetration.

• For about two years I'd been seriously considering the advantages and disadvantages of two-meter sailplanes, with the idea in mind of settling on a particular size and class of sailplane for fun flying, contesting, and—yes—building, too. The Dassel proved that a shorter-span sailplane need not give up points to long-winged birds when flown in world-class competition, and the Dassel has a span of only 84 inches! That's only 5¼ inches longer than 2 meters.

Although balsa comes in 3- and 4-foot lengths in this country, which is an annoyance when you need a piece that is typically 38 or 39 inches long, the 2-meter span has much to recommend it. Consider the ease of carrying this size sailplane in your car—as opposed to carrying an Unlimited Class or even a Standard Class bird. Although two meters is not recognized as a Class by the FAI, the increasing number of contests around the country have shown that it is popular.

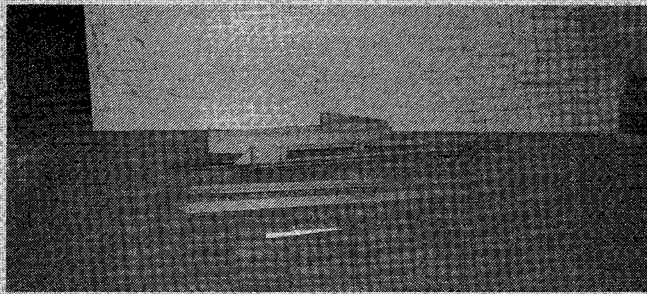
As a cost-effective means of dealing with inflation, a two-meter sailplane has a lot going for it. Consider that the cost of materials goes up as the *square* of the increase in linear dimensions, not as a direct proportion. Therefore, a Standard Class ship could cost you 60% more instead of only 26% more than a 2-meter design. Some materials increase as the *cube* of the dimensional increase, and could cost twice as much as those for a two-meter size! This might mean that you could build two of the smaller ones for the price of a single larger one. Economy!

For me, the real clincher came when I attended the Two-Meter World Cup RC Sailplane Championships in California last January. There I saw thin wings, thick wings, pod-and-boom construction, Tee tails, Vee tails, light wing loadings, and heavy wing loadings. In short, a complete spectrum of ideas about how a two-meter sailplane should look and perform—embodied in some of the most beautiful creations one can imagine. The really spectacular thing about many of these ships was the performance they were capable of producing in flying multiple tasks: duration, distance, *and* speed. The designs I liked were clean, strong, and fast, yet they looked deceptively simple and straightforward. Frankly, I faced the sure knowledge that the two-meter sailplane class was literally exploding with development—this was where the action was, and it was where I wanted to be.

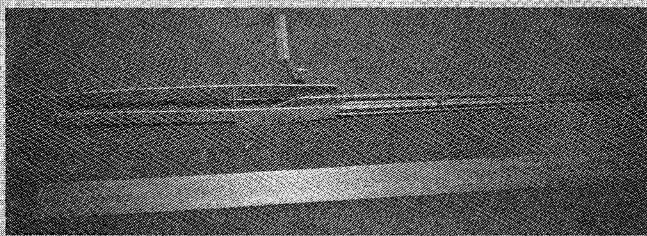
In contrast, I could find no really good reasons why I should not design and build a two-meter glider as the answer to what I personally was looking for in RC soaring; so I began the design. I chose a pod-and-boom to decrease "wetted" area and drag. I chose a slim fuselage for the same reason—lower drag. I decided that the ship had to be easy to build, so the boom was designed to be built up from a single T-shaped crutch for strength, and skinned with balsa to form a triangular cross-section. The pod would be a simple rectangular cross-sectioned box, quickly cut out and assembled; just large enough to contain the radio. The stabilizer would mount nicely on the flat top of the boom, and the fin/rudder would sit on that.

I figured that if you're going to limit the wingspan, you'd better get some area, even if the aspect ratio has to suffer, so I designed essentially a "plank" with only the outer panels swept back. The advantages of area are reduced wing loading and a good launch profile—steep and high. By choosing one of the new Eppler airfoils of semisymmetrical profile, I could offer speed without excessive weight penalty, while keeping a wing that is thick enough to provide great strength and capable of being loaded with internal ballast in the roots. Thus, the choice came down to the Eppler 193, 205 and 387 profiles—all very good, and well proven in RC sailplanes. I originally chose the Eppler 387, modified by Eric Lister to a 10% thickness and 4% camber for speed, low drag, and small pitching moment. The fact that the prototype used the 205 section only means that I had the ribs all drawn and ready to cut out, whereas I would have to draw the profiles for the 387, mod. 4-10. Lazy, some peo-

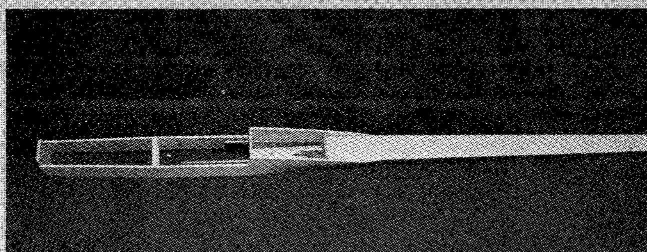
FUSELAGE CONSTRUCTION



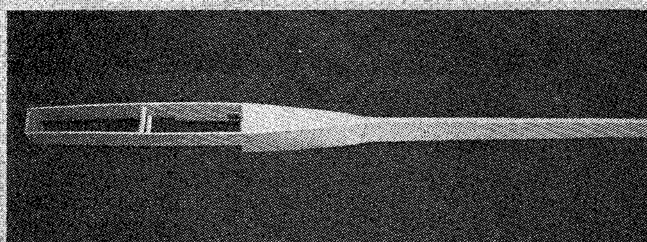
Fuselage components laid out before assembly. Note pod sides, boom crutch assembly, formers, Nyrod tubes ready to be glued together.



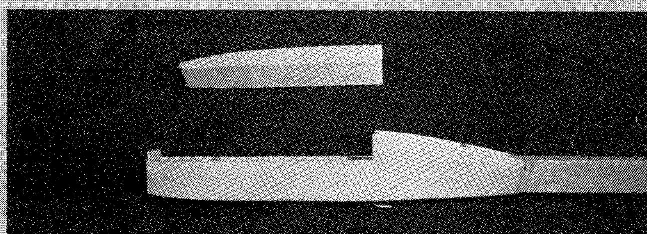
Fuselage primary structure shown with pod sides joined to the boom in inverted position. Note T-shaped boom structure with lightening slots cut in the keel; Nyrod antenna lead in place.



Fuselage primary structure shown with pod joined to the hoom and in the upright position. Portion of boom keel in front of rear former is tapered but could be flush at rear former.

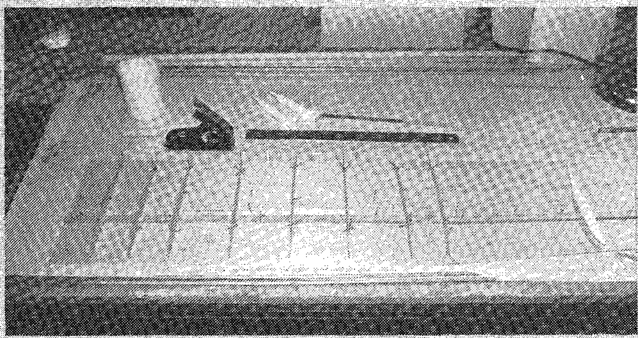


Fuselage bottom view showing sides pinched in to match the vee-shaped boom that is now skinned. Part of pod bottom is covered up to wing carry-through former; simple and light.

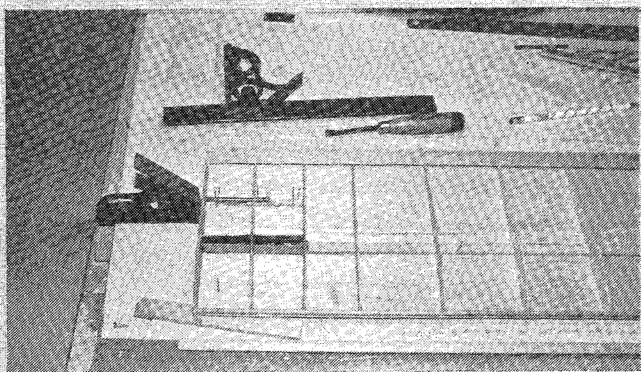


Completed fuselage with tow-hook mounted to carry-through former. Note the built-up canopy made of 1/16" balsa sheet. Canopy base can be cut out to allow greater receiver space.

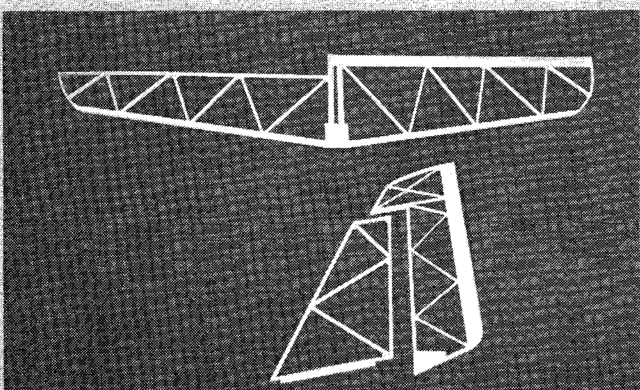
WING AND TAIL CONSTRUCTION



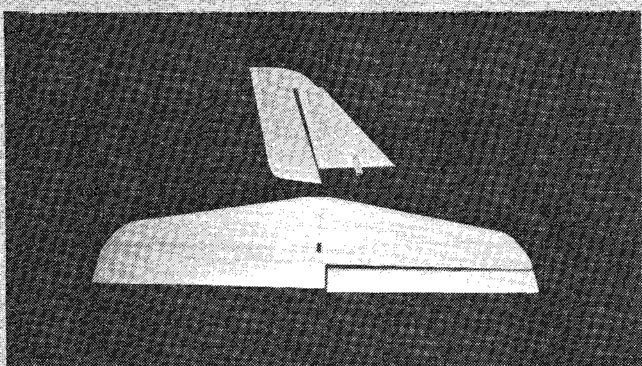
Wing bottom skin of 1/16" sheet balsa has been cut to shape and pinned to plan. Bottom spar and some ribs have already been glued in place. Flat building surface mandatory.



Leading edge hardwood dowel glued in place while arrowshaft for wing pins has been partly boxed in to spar structure at root. Match rib curve by shimming skin with scrap.



Empennage was built up to keep tail light. Slot in center of stabilizer matches tongue added to fin bottom; provides strength and alignment. Surface tips are bass bent to shape.



A sheet balsa empennage may also be constructed. Note center stab spar of spruce, 1/8" x 1/2", to provide bending strength. Single elevator simplifies linkage and construction.

ple would say. You can use any of the three, with nearly equal results.

The tip sweepback provides a tiny bit of *effective* dihedral (polyhedral) in the outer wing without actually building it in as polyhedral—thus saving on the drag. The roll rate is slightly improved by the sweepback, too, and responsiveness for thermal flying and pylon turning ain't all that bad! I made the wings just short enough so that I could experiment with tip shapes made from foam, capable of being plugged into two small tubes built into the wing tips, without exceeding the two-meter projected span. In fact, winglets are planned for a development project on this design.

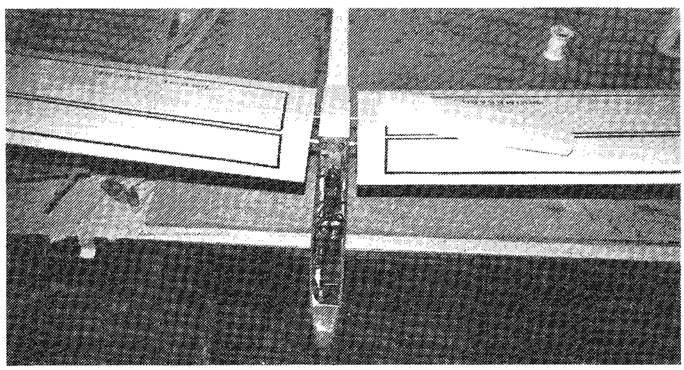
The tail arm is made slightly longer than usual for a couple of reasons. One is to reduce "twitchiness" at high speed, while permitting almost free-flight stability at lower speeds. I also wanted to make it possible to use 100" wings for comparison tests—or to fly in the "standard" class now and then, if desired. I calculated moments and areas to yield what I hoped would be optimum handling, and even borrowed an idea from the Mirage, Blaine Rawdon's beautiful creation — the elevator on one side of the stabilizer only. I didn't feel that I needed all the pitch travel available from full-span elevators, and at high speeds even less! This would simplify flying and tend to minimize overcontrol on launch, which often creates problems of its own. The vertical tail was made to provide a satisfying shape, adequate area, and a slightly slanted hinge line to help keep the nose up in turns. The aerodynamic balance in front of the hinge line helps rudder power, reduces servo load (insignificant anyway), and just *might* reduce tendency to flutter at high speeds. We shall see.

Ken Fields, my flying buddy as well as a first-class engineer and builder, designed the clever fin post arrangement whereby the stabilizer could be moved up and down during trim flying to adjust the angle to perfection before finally cementing it in place. (Note: I used a wing angle of incidence, relative to the top of the boom, of 3 degrees; but I wanted to be able to change the decalage around that figure to provide the best trimmed glide without having to use up- or down-elevator.)

I've included provision for spoilers in the wing, just behind the main spar. The servo can be placed between the wing rods, and just behind the CG, where there is extra space for just this purpose—or for ballast, if you don't need or want spoilers. My prototype built by Ken (following these instructions) didn't have spoilers installed at first, but they can be easily added later.

The wings are fully sheeted underneath for strength and smoothness. One school of thought says that the wing bottom surface is important, too, and I didn't want to take a chance by ignoring it! The top of the wing is sheeted back to the spar, forming a strong D-tube structure, and the ribs have capstrips to help the covering and create a better top surface, as well as to add strength. The trailing edge of each wing rib is enclosed between the bottom skin and a large trailing-edge top skin. This

(Continued on page 102)



A completed Boomerang displays its radio installation; battery not in position. Covering is MonoKote for all surfaces and the fuselage; Goldberg black trim tape and transfer lettering used.

BOOMERANG SAILPLANE

(Continued from page 16)

makes for a straight trailing edge, and a stronger one. Try it—you'll like it! I tried to make the wings as strong as possible, believing that a few extra ounces added to provide stiffness and strength would be security on a 12-volt winch in a 15-knot breeze. Hence, the spars are spruce all the way to the tips, and are 1/8" x 3/8". (My prototype used 1/8" x 1/2" spars!)

Just ahead of the spar, a ballast tube 3/8" in diameter can be installed; this is for carrying lead. Weight carried in the wings is better than weight in the fuselage. Don't believe it? Well, it reduces wing-root bending loads for one thing, and I believe in making the wings carry the weight everywhere possible.

The tow hook is epoxied to the main carry-through bulkhead, as are the main wing rods. This plywood bulkhead transfers all flight and launching loads from wings to fuselage, and from fuselage to wings. Just behind it, there is another, similar bulkhead that carries the rear wing rods. You'll see that the rods are 1/4" and 1/16". respectively, again a concession to strength.

I didn't round the corners of the fuselage very much. You can, if you want to. Notice how the top of the wing root rib and the top of the fuselage are the same shape; this is to keep a continuous smooth surface and smooth airflow going in an area that is often the cause of early separation of flow. and inefficient drag. In my next version, to be built as Ken's airplane, he will taper the sides of the fuselage above and below the centerline, slanting them inwards, and making a still thinner cross-section of elongated hexagon or lozenge shape, instead of a rectangle. The boom will remain triangular in cross-section, however.

The prototype was everything I had hoped for—and even more. On the first flight, I couldn't wait for the wind to decrease from its 18-25 mph range, because the day was sunny and bright, and the first really flyable day since the project began. Besides, a sailplane is going to have to be flown in wind someday anyway, and less-than-ideal conditions on the test day would quickly show up any faults. The field was wet from several days of rain and about two inches of remaining snow that was rapidly melting. Large puddles were everywhere, and the northwest wind came in gusts, blowing little ripples on the puddles. Even our coffee cups had whitecaps!

I waited for a lull, checked the balance for the umpteenth time (using the forward wing rods as the CG point), tried the controls, and javel-launched the bird as straight as possible. It flew straight, without any control inputs needed until upset by an off-direction gust. A dab of rudder straightened it out, and slight up-elevator brought it in for a nice landing. The high-start was on the ground, but the chute was filled from the wind, and was bouncing up and down from ground level to about ten feet in the gusts. Should I fly? Heck, yes! It would be less gusty at altitude.

I hooked it to the high-start, pulled back for about eight pounds worth of stretch, and let it go (with trembling knees). Like a rocket, it went straight up—then out, catching a thermal. A nudge of down and it was off the line, searching for lift. A quick turn and into the thermal, up we went. In spite of the wind, which I guessed was 30 mph at altitude, we circled up and away. I let it drift back until it was necessary to penetrate for all it was worth to get back. Straight now, slight down-elevator, and Boomerang shot forward, slicing the wind as nicely as can be, all the way upwind to the edge of the field, and then a zoom and climb for the final circle to landing approach. It came in, cautiously, very little correction needed; not being badly bounced, but gaining altitude in each gust! Finally, I stretched the glide to try for a flat spot, and it landed—right in the largest puddle of water on the field! DRAT!! Ken ran to it, fetched it out, dripping water from the radio compartment, and brought it back. My Boomerang had returned, appropriately launched with melted snow instead of champagne!

To sum up this flight, I'd have to say that *there is nothing I would change!* I plan to increase rudder throw by one hole toward the center, and may add some ballast later. Frankly, it doesn't need it until you go for the speed runs. The flying weight was 34 ounces, for a wing loading of just a tad over 8 ounces per square foot. You can build yours lighter, easily, and come out at 7 1/2 ounces per square foot. I needed exactly 4 ounces of lead in the nose to bring it to balance. If you build your tail boom lighter, and use built-up elevator, stabilizer, rudder and fin instead of the sheet I used, you may not need any balance weight at all!

The prototype Boomerang flew without the tips I plan to add for drag reduction. It also can be cleaned up still more here and there, as minor refinement dictates. The subsequent half-dozen proving flights were every bit as successful as the first flight promised. This bird is silk-smooth to fly, strong, very stable and docile, and a thoroughbred in every way. It has a fine turn of speed, but does drop its nose a bit in turns—just letting me know that it needs a little more speed to continue flying properly. I have been amazed at the extraordinary slow-speed qualities, and this is without the planned tip shapes or detail clean-up at the wing-root/fuselage intersection. I'm planning fillets to insure the least amount of drag and smoothest flow possible.

Right now, I'd have to say that it flies better than anything I've tried in the two-meter category, and as well as most Standards, too. Perhaps the most amazing feature is how it performs in wind, with just the tiniest bit of center-section ballast. Put in a half-pound, and I think you'd find it phenomenal! I haven't had the chance to try that much yet, but 6 ounces allows me to fly in gusts to 25 with no problem.

In short, this Boomerang will be fun to fly—and will bring back the trophies in every contest, providing its pilot is willing to put in the time needed to learn to fly competitively. Boomerang is a winner!

FUSELAGE CONSTRUCTION. Begin by cutting the top surface of the boom from 1/16" sheet balsa, and pinning it to the building surface on the fuselage/boom top view. Next cut out the side view of the "keel," also from 1/16" sheet balsa, and cut the lightening holes in it, as shown in the side view. Now set the keel piece on the centerline of the top piece you pinned down, and glue it in place, making sure that the two pieces form a right-angled T shape to each other. Pin, and let dry. After the "backbone" is dry, or while it is drying, add the triangular formers that you have cut out from sheet stock, gluing them in place where shown to form the bulkheads in the boom. You may wish to cut the holes to pass the control rods and antenna tube before gluing them in place, just to make an easier job for yourself. The boom can now be set aside until you've made the pod.

The prototype pod was made from 1/16" sheet balsa, laminated to 1/32" plywood (inner face) for strength. The side-view outlines are traced on the wood and cut out with X-acto knife and/or Dremel Moto Saw. The formers are cut from 1/8" ply (wing root locations) and 1/16" balsa (elsewhere). The nose former should also be made from 1/8" plywood. Be sure to cut a T-shaped slot in the rear former to take the T-shaped boom crutch, or keel assembly. The prototype used plywood for this former, too, to get the desired strength at the joint between boom and pod. The pod bottom was made from a piece of 1/8" basswood, but plywood would do as well. The pod top can be 1/16" sheet balsa.

Assemble the pod so that both sides are straight and parallel, held apart by the main wing-root area formers. Use aliphatic resin glue (such as Titebond) or epoxy for gluing the pod. After gluing, let them dry in a simple jig to keep them straight and in alignment. Next glue in the nose former, holding it in place with a clamp or rubber band against the springiness of the pod sides. Notice that the bottom rear of the pod is "pinched in" to match the shape of the boom cross-section, but the top rear is straight.

After all is dry and solidly attached, you can slip the boom crutch or keel into the slot in the pod former, gluing it in place with epoxy or Titebond. I'd suggest that you glue it in and support the assembly on a flat surface, making sure that the alignment of pod and boom is as good as you can get it. We don't want any twists, warps, or out-of-line here. A simple jig can help you with horizontal and vertical alignment, while the glue sets up. The bottom of the boom and the bottom of the pod—up to the tow-hook position—form a straight line.

Run the control tubes (the prototype used Nyrods) through the holes in the formers and alongside the keel, gluing them in place with instant adhesive, such as Super Jet. You can put in the antenna tube, too. Ken used a "Golden Arches" soda straw! (Guess he was having a Big Mac attack at the time.)

Add the pod top, remembering that part of it will be cut out later for hatches and access to radio and ballast compartments. Install the tow hook, made from a piece of bent piano wire, into the main former. Cover the sides of the boom with 1/32" sheet balsa to form the completed triangle, gluing the balsa in place with Titebond, or using Super Jet. Blend the pod and boom sides together at the rear, using bits of scrap balsa if needed to get a smooth transition and joint, filling up any gaps, and increasing strength. Add the remaining fuselage formers. I can't tell you where they will go, since each radio will be different. You can add them where best suited to your equipment, but the prototype didn't use any between the nose former and the main wing-rod bulkhead. Install the servo-mounting crossmembers, or rails, as required.

Finally, add the 1/16" plywood bottom to the fuselage, leaving a slot to pass the bent tow hook. You may wish to leave the servo-mounting wood pieces until after the bottom is on—your choice—whichever is easier.

Glue a hardwood nose block (pine, or very hard balsa) onto the front end of the pod. Shape it when you sand the pod and boom.

WING CONSTRUCTION. Extend the rib and spar location lines on the plan with light pencil lines so they project beyond the wing outline. This will enable you to place the ribs and spars accurately, after you have covered the plan with the bottom wing skins. Edge-join a couple of 1/16" balsa sheets, and cut them to the wing outline, leaving an extra 1/8" at the leading edge to compensate for the slight Phillips entry. Ambroid cement, Super Jet, or whatever adhesive you choose can be used to join the sheets. Pin the shaped balsa sheet to the plan, making sure that the plan is covered with waxed paper or equivalent transparent, protective material. The leading edge should be blocked up with some strips of material, to give the semisymmetrical shape required at the nose and to match the rib curvature there. Also, plan to block up the trailing edge at the tips, starting at the sweepback point on the span and increasing to about 3/16" at the tip rib. This will serve as built-in wash-out.

The ribs are made by the stack method, using plywood end ribs as the patterns or templates. Rectangles of 1/16" balsa, as many as there are ribs in the straight portion of both wings, are sandwiched between the 1/8" plywood root-rib templates, jigsawed and sanded to shape. The tapered outer wing will require that you make two ribs, one for each wing tip, at every rib location. These are cut out two at a time to insure identity. If you are a lightness "nut," the outer ribs can be made from 1/32" sheet to save a few grams of weight. The rib patterns can be traced onto the balsa by your favorite method.

Begin assembly by gluing the 1/8" x 3/8" spruce spar to the bottom skin that you've pinned and blocked to the plan, using the extended pencil lines as a guide. You can use your favorite glue, but the prototype used a glue that is similar to Titebond but dries to a handling stage just a bit more quickly. You might want to "paint" the seam, after initial gluing, with a thinned mixture of water and glue, using a small watercolor brush. The ribs should all be vertical except for the root rib, which will be angled to match the dihedral. I didn't do this on the prototype, so a fillet was required to blend the root rib and the fuselage. A template can help you get the angle right.

After you have added the ribs and they are firmly adhered, add the shear webs of 1/16" balsa between each rib, at the center of the lower spar, and make sure that the height of each web does not protrude above the base of the top spar notch. At the inboard rib bays, you will notice that the shear webs are made from 1/16" plywood for extra strength. (Do not glue these in yet.) In the case of the balsa webs, make sure the *grain* runs vertically, perpendicular to the plan, and not parallel to it. After the webs are in, add the top spruce spar cap. Use enough glue to cover all mating surfaces. Your glue gun or syringe will help here. The webs between the root ribs and the first several ribs outboard from the root are not added at this time because you will need to insert the wing-rod tubing between the spars at this location. Be patient, we'll get there!

Glue in the leading-edge hardwood dowel piece at this time, using the notches you have made in each rib with a drill or rat-tail file, lining everything up with a straightedge. It's better to have to cut the rib notch a bit deeper than it is to have a wavy leading edge. Make them straight, and your wing will love you.

Finish the other wing this far, place both wings together root-to-root on a flat work surface, and you can put in the carry-through members.

CARRY-THROUGH TUBING. The wings are held to the fuselage by means of 1/4" o.d. steel rod and 1/8" o.d. music wire. The forward, larger rod is carried within the wing by a piece of 1/4" i.d. arrow-shaft tubing, or a piece of brass tubing, if you prefer; and the rear, smaller wire is carried within the wing by a brass or aluminum tube of 1/8" i.d. Select the rod and tubing beforehand for a sliding, easy fit—not a tight one! In order to have everything fit exactly right and line up perfectly, be careful with the next steps.

Place each wing on your workbench in perfect alignment and flat, with the spars and roots aligned fore-and-aft and spanwise. Cover the work surface with something to prevent possible glue damage. Pin the wings down, or weight them, or both, so they won't move, no matter what. You can use the plans for an alignment guide, if you wish, but a straightedge is just as good if not better.

Now assemble a 6" length of arrow-shaft tubing on each end of the wing rod. This tubing will be just exactly long enough to reach between the root rib and the next several outboard ribs. It will also fit between the top and bottom spar caps, where you haven't yet added the shear webs. In fact, the tubing should fit in holes you have drilled in the root ribs to receive it, and in the other ribs as well, centered exactly between the top and bottom spars and on the centerline of each spar.

Once everything is lined up, wedge and block the rod and tubing so it doesn't move.

We now have to wedge and epoxy the tubing between the spars to make a tight fit, so pack above and below the tubing with pieces of hardwood, not balsa, or plywood until all the gaps above and below the tubing are filled snugly. Epoxy these to the *tubing,* but don't get any on the wing *rod.* A drop of oil or grease on the rod will keep epoxy from adhering to it. Each tube is now securely locked into place in each wing root, so you can remove the rod, but first I'd suggest you repeat this procedure with the rear wing rod and tubing. Since you don't have spars there, you'll make a false spar out of hardwood to sandwich the tubing. Use the same technique as you did for the main (front) wing rod. *Now* you can remove the rods, since they can't help anymore right now.

If you like, you can temporarily "tack" the wood and the tubes into place between the spars, using instant glue, following up with epoxy after all is secure. Your choice. It's another acceptable method.

Cut a piece of 1/16" plywood that will fit between the root ribs all the way out to W-4 on the rear spar face, and to W-6 on the front spar face. The plywood is the full height of the spar, to the outer (top and bottom) surfaces. Actually, you will have to slice each rib to do it. Alternatively, you could have allowed for this when making the root ribs, and made them in sections, permitting you to fit the front spar face as a first step; but I prefer to assemble solid ribs instead of sections. Ken didn't say which he prefers!

The plywood faces form a box with the spar caps, completely surrounding and enclosing the carry-through tubes in the wing. Epoxy each plywood spar-face strip in place, taking care that epoxy covers the inner surface of each web completely and will touch the balsa and tubing between the spars, filling the joints.

Next tip the wing up so you can look at the rear face of the spar—the face not yet covered by the rear-face plywood web—and liberally coat the arrow-shaft tubes, the hardwood packing strips, and the spar cap edges. Set the plywood rear-face pieces in place between each rib, clamping them and completing the spar box. Here again you have the choice of making the plywood spar-box facing of one piece, cutting the ribs as needed (stronger), or making the facing in sections to go between the ribs. I'd suggest that if you do the front side one way, do the rear side the other way.

The rear tubes don't have to be quite as carefully boxed, because they don't carry the loads that the main spar does; however, make them strong and be sure to arrange the packing around them to spread the loads to the skins and the ribs. The flight loads are carried, in order, from the skins to the spars, to the tubes, to the rods, and to the fuselage where the rods will ultimately be fastened against the major carry-through bulkhead. The idea is to make the wing "look" like a one-piece structure, even though it is a two-piece structure. Repeat the operation with the other wing. When finished, you can slip the rods and wires into the tubes, and they will keep the wing straight and in line. Don't worry about dihedral now; we will add it in a later step. Wings are not complicated to build, just time-consuming. Doing a careful job here will repay you a thousand times over in the air, believe me!

This is a good time to add the ballast-carrying tubing in the root section. Drill holes of the proper size in the plywood root ribs; then, using a sharpened end of the tubing itself as a hole-cutter, make holes in the balsa ribs. Coat the 6" long tubing, the ribs, and the spar face with epoxy, and cement the tubes in place. Now you can add the top leading edge sheet. Take a sheet of 1/32" balsa, wide enough to extend from the spar to the leading edge, and attach it all along one edge (only) to either the spar, or the leading edge dowel. Clamp, tape, pin, or clothespin it in place and let it dry. Do *not* bend it to fit over the ribs yet. Just do one edge for the moment. Let everything dry thoroughly. (The prototype used 1/16" sheet.)

Once the sheet has dried and bonded to the wing, you can now plan to bend it and glue it to each rib, and to whichever (dowel leading edge, or spar cap) you didn't glue it to at first. Take a small sponge and soak it in water (this step is needed only if you used 1/16" sheet), then wring it out until it is just moist. Wipe the outer surface (top surface only) of the sheet with the sponge, wetting it. Soon it will begin to curve naturally, as the balsa swells on that surface. *Now* you can add thin beads of glue to all ribs and to all areas that the top sheeting will touch; again, with paint brush or glue gun. Fasten the sheet in place with pins, clamps, tape, weights, and rubber bands, making sure that it is touching all points required. Let it dry thoroughly. The wing strength comes from the cooperation between the spars and skins, so do it carefully.

Add the 1" wide trailing edge top sheet of 1/32" balsa by gluing it in place to each rib. At the very tip of each rib trailing edge, the top sheet should actually touch the bottom sheet with no gaps. If you need to sand the ribs a bit to make this happen, do it! Pin and tape or weight it in place until the glue has set. Then add the rib capstrips of 1/32" x 1/4" balsa between the trailing edge and the spar. The entire top surface of the wing should be smooth and flush, except at the root where the top intermediate skins haven't been added yet. These can now be added to complete the wing. When this is finished, sand the leading edge skins to blend smoothly with the dowel. Sand the top trailing edge skin to a taper.

TAIL SURFACES. The empennage (fancy word for tail surfaces) may be built up from balsa strip stock or, alternatively, be made from sheet stock with lightening holes cut in it. Both versions are shown, so take your choice. Ken built the prototype with both types, and we tried them for stiffness, finding that *neither was adequate without some extra stiffening!* Consequently, he used 1/8" sheet balsa, with a 1/8" x 1/2" piece of spruce edge-glued to balsa on either side to form a single sheet with a central "spar" stiffener to carry the bending loads. Perhaps this isn't exactly necessary, but Ken has seen me "strain" my gliders through the wires at speed, so he wanted me to have an indestructible ship! Well, almost . . .

Hinges may be made from iron-on material, from adhesive-one-side plastic tape, or regular slot-and-insert plastic types. The prototype used iron-on covering material, and it works great. Before leaving the tail surfaces, round the leading edges and taper-sand the trailing edges to a thinned section. It saves a little weight and is a bit more streamlined. Ken made the prototype leading edges on fin and stabilizer of 1/8" x 1/8" basswood.

FUSELAGE CARRY-THROUGH. Trace the root-rib outline on the fuselage sides where the wing will be located. Note that the wing is slightly higher at the leading edge than the trailing edge, when using the top of the tail boom as reference (about 3 degrees). Carefully drill the front and rear wing-rod holes—a bit oversize is okay. Now, using a vise and soft-faced hammer, a pair of blocks, or whatever method you prefer, take the main wing rod and bend it at the center so that each side will make an angle of 6 degrees from the horizontal; or, an included angle of 168 degrees. Check your bending against the angle shown on the plans. This will give you the correct dihedral angle.

Place the fuselage on the table, blocking it up as needed to hold it in place. Block the wings up on each side of it, making sure the dihedral angle under each tip is correct by elevating that tip to the height shown on the plans. Next insert the wing rods into one wing, through the fuselage holes, and into the other wing. Realign everything. When all is secure and correctly aligned on all three axes, clamp it all in place and epoxy the main and rear wing rods to the bulkheads against which they rest. Don't move anything until the epoxy has set.

Now you can pick everything up, slide the wings off the rods, and add the J-bolts that will give added holding power to keep the main rod against the carry-through bulkhead. Add more epoxy. Be liberal and make a nice, full, solid joint. The stresses have to "think" it's one solid structure.

When all this is done, you're just about—but not quite—ready to cover (or paint). Mark the location of the stabilizer on the tail boom, and mark the location of the fin support spars on the stabilizer and fuselage. Slot the stabilizer and fuselage carefully to receive these mating portions. Then pencil-mark all pieces, so that you won't cover or paint where they must be glued together. Covering material does not make a good glue joint between pieces of wood! Pre-fit the pieces to insure a good match.

COVERING. Using your choice of covering material, cover all surfaces and paint those you'd prefer to paint. The prototype was covered with MonoKote; white on top, red on the bottom of wings and fuselage—except for the rudder-fin, which I chose to make contrasting colors. Choose your own color scheme, and stripe as desired.

Add the radio equipment, using the pushrod guides and the extra guide for the antenna. Mark the desired balance point on the fuselage, if you like. I used the forward wing pin, and a string sling, balancing in a slightly nose-down position. As you gain flight experience, you can move the CG aft, and change trim as needed. The tow hook can also be moved aft by simply adding a plywood "extender" inside the wire, epoxied in place.

Although the prototype needed 4½ ounces of nose weight ahead of the battery to balance properly, your version should not, as the plans show a lengthened nose. Your battery pack ought to just be able to balance it properly in the forward position. Also, by building the tail boom lighter than on the prototype, exact balance can be achieved merely by sliding the battery back and forth. The 3-channel Cox-Sanwa radio I used allows each servo to be placed side-by-side, the receiver on edge, and the battery *vertical*. I cut out the "canopy" floor to allow the battery and receiver to project vertically up into the "cockpit" space. Each radio will be slightly different, so you're on your own.

Ken built the hatch covers to permit access to the center section for adding ballast, or for connecting/disconnecting the spoiler cables from the extra servo that can be mounted there. The prototype didn't need spoilers. Notice that when you add weight to the tubes, it is slightly ahead of the CG, and weight in the ballast compartment is slightly behind the CG. This permits you extraordinary fine-tuning capability of the CG location.

An *inside* dimension of 1⅛" between the fuselage sides is *minimum*. Make it slightly larger, if needed, to fit your battery. Finally, add the on/off switch, and nose and tail skids.

Hook up the linkages to your servos and check for "left is left, and back is up"—just to be sure you will have a better-than-even chance of surviving your test flight.

TEST GLIDING AND FLYING. Bet you figured I'd never get to this point, right? Pick a nice calm morning or evening with very little, if any, breeze. Switch on, check out your controls and your trims; start with everything centered and neutral. You did charge the battery last night, didn't you? Left stick, and the rudder moves *left*, looking down from the top, with the nose pointed ahead of you, correct? Okay! Now, forward stick moves the trailing edge of the elevator *down*, correct? It better! If you added spoilers, they close completely, and open equally, don't they? Good!

With your radio on, and everything set, point the nose straight ahead, with fuselage horizontal parallel to the ground. Give it a nice, easy, smooth toss and be ready to get on the controls to correct any tendency to veer, climb, or dive.

WOW! It glides, doesn't it? Restrain yourself just a sec; did you have to add any trim to make it fly smoothly straight ahead? Think about it. If you did, and it didn't, we're going to have to check for warps and twists and balance again. Do it—now. If there aren't any warps, maybe one wing is a tad heavier than the other (mine was) and you can add a tiny weight to the tip to correct it. Tape it on for now; glue it in later. Check the angle of incidence on each wing; they should be identical. Okay.

If you didn't cement the stabilizer down, but left it pinned so that you could change the decalage by shimming either the leading edge or the spar (for delicate trim adjustments), you can try a bit of change, just to see how it affects the glide. What you are looking for is the flattest glide possible with absolutely neutral elevator trim. When you've got that, stop; glue the stabilizer permanently in that position. Bolt it on, if you prefer, so that it can be removed later—to fit into your glider carrier.

Set up your high-start or winch, hook up the tow ring on your chute, check controls and go! Hey! It goes almost straight up, right? Sure, we designed and built it that way, didn't we? Release from tow, and you're on your own. Notice how easy it is to speed up and penetrate, without much altitude loss. In a turn, she will tend to drop her nose, and here's why. This is known as spiral instability, and comes from the oversized rudder/fin. It was designed to be adequate for a 100" span, and slightly too much for the 78" span. If you plan to fly your Boomerang as a 2-meter sailplane only, reduce the stabilizer area and the rudder/fin area by 10-15%. This can best be done by making the stabilizer 4" or 5" shorter, and by reducing the fin width and height by about 1" and 2", respectively.

My flying of the Boomerang has shown that in the two-meter configuration, the excessive rudder/fin area makes it spirally unstable—that is, it does drop its nose in turns, as mentioned earlier. Making the tail areas smaller improves the flying characteristics greatly. For those who plan to use 100" wings, the rudder/fin and stabilizer are fine just as they are.

Boomerang is in her element, and if you don't mistreat her, she'll take care of you. Spend a bit of time learning how she flies, and you'll be amply rewarded with a fine two-meter sailplane that will win and win and win for you.

AFTERTHOUGHTS, ETC. What about Hoerner tips, did you ask, sir? Well, we tried 'em and found that Boomerang actually performed better with just plain squared-off tips. You can try different shapes and sizes as we did, merely by making them plug-in by tubes and wires in the outboard rib bay. Boomerang is one of the quietest gliders in flight that I've ever had "buzz" me.

Spoilers, Rollo? Naw, you he-man guys don't need 'em. If you want 'em, though, and feel better about those 100-point spots, just add 'em and hook 'em up to the servo in the center section.

Yes, the gentleman in the back . . . your question, sir. No, I didn't just fall off the turnip truck! Why do you ask? Oh . . . the leading edge dowel; it isn't tapered. Perceptive of you, sir. Reason is, I didn't want to go to the trouble of tapering the dowel. You're right, the airfoil *isn't* exact in the nose shape, and I suppose it isn't really an Eppler either. BUT, there's a good reason for keeping the leading edge a larger radius at the tips: it renders it less sensitive to stalling, and helps at low speeds.

As a matter of fact, you will be astonished at how the "Boomer" can be slowed, and slowed, and slowed . . . on landing, without any tendency to drop a tip or stall abruptly. Very nicely mannered, you'll find. Good old Ham-Handed Hans will like this feature.

Would I make any changes on the next one? Sure, anybody would; nothing's ever 100% satisfactory. I'd make an even more streamlined fuselage, maybe egg-shaped in cross-section; or even lozenge-shaped as Ken's is going to be. I'd use lighter, thinner materials. I'd cover with dope and Dacron polyester cloth. Nothing major, you understand, just refinements. I'm sure you'll think of others. If you do, and they work, let me know. Also, when you win that trophy, write and let me know; I'd be proud to hear from you. Jim Gray, P.O. Box 186, Peterborough, NH 03458. ■