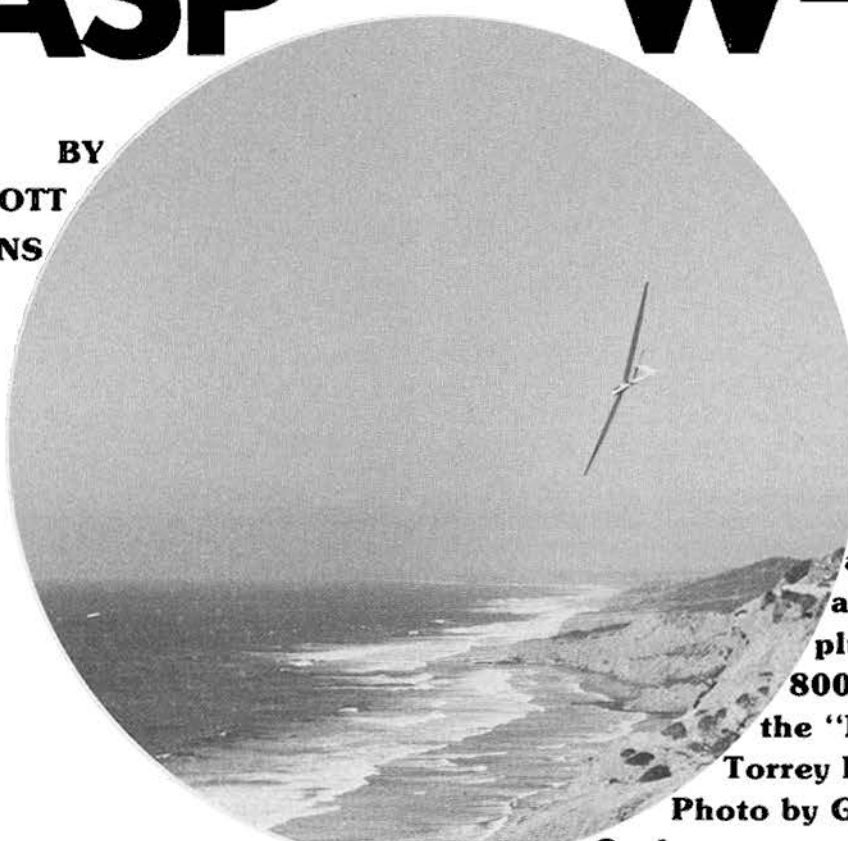
WASP W—21

BY
SCOTT
JENKINS



Banked up and cutting away after a plunge from 800 feet over the "North Face", Torrey Pines, Calif. Photo by Greg Geehan

Performance Objectives

The Wasp W-21 design was optimized for high cruise speed with good L/D in strong slope lift conditions. The higher sink rates intrinsic to high speed soaring are not a handicap in the abundant lift arising from storm winds. High cruise speed is needed to penetrate in these winds. When combined with good high speed L/D, it is possible to trade the altitude obtained so cheaply in the strong lift for speed, and then, maintain high speed for enormous distances; to really cover the countryside, carving out huge chunks of sky with minimal energy loss. These are the capabilities most needed when casting your work into a winter gale.

Design

Flying at high speed inevitably results in pulling many g's. Furthermore, strong wings inflict punishing gust loads as a result of encounter with shear lines in the wind field, or with rotors and other large scale turbulence over irregular ridge faces. To meet these demands, high strength fiber/foam construction techniques have been employed which can be mastered with a little patience and time by anyone.

Construction

Begin your efforts with the wing and the horizontal stab as thse assemblies will be needed later in shaping and aligning the intersections on the fuselage. The wing is a foam core with 0.5mm three ply stressed skins on the upper and lower surfaces which are surfaced with light fiberglass cloth. The leading and trailing edges are spruce with a full depth full span 1/8" thick spruce main spar. The horizontal tail uses balsa skins and leading and trailing edges with only one layer for light glass cloth to reduce weight.

Carefully cut and sand the airfoil templates drawn on the plans from 1/16" plywood. There are two templates for each airfoil section, one to cut the upper surface and the other for the lower surface. The two combine to give the correct airfoil when aligned at the bottom edge on a flat board and with the leading edge key flush with the leading edge of the foam blank. The extra length of template contour extending beyond the leading and trailing edges of the foam blank gives the cutting wire a guide to smoothly enter and exit the foam. The correct amount of wash out has been accounted for in the tip section templates.

A 100" high speed slope soarer that can penetrate the heaviest of winds, maintaining high speed for enormous distances - - - really covering the countryside, carving out huge chunks of sky with minimal energy loss.

WASP W-21
Designed By: Scott A. Jenkins

TYPE AIRCRAFT
High Speed Slope Soarer
WINGSPAN
100 Inches
WING CHORD
5½" Root — 2¾" Tip
TOTAL WING AREA
483 Square Inches
WING LOCATION
Shoulder Wing
AIRFOIL
Mod. Eppler 374
WING PLANFORM
Double Taper
DIHEDRAL, EACH TIP
Inboard Panel (2.5°)
Outboard Panel (0.5°)
O.A. FUSELAGE LENGTH
42½ Inches
RADIO COMPARTMENT AREA
(L) 10" X (W) 2" X (H) 2¼"
STABILIZER SPAN
17 Inches
STABILIZER CHORD
3" (Avg.)
STABILIZER AREA
48 Sq. In.
STAB AIRFOIL SECTION
Symmetrical
STABILIZER LOCATION
T-Tail
VERTICAL FIN HEIGHT
7½ Inches
VERTICAL FIN WIDTH (incl. rudder)
6" (Avg.)
REC. ENGINE SIZE
NA
FUEL TANK SIZE
NA
LANDING GEAR
NA
REC. NO. OF CHANNELS
2
CONTROL FUNCTIONS
Rudder & Flying Stab
BASIC MATERIALS USED IN CONSTRUCTION

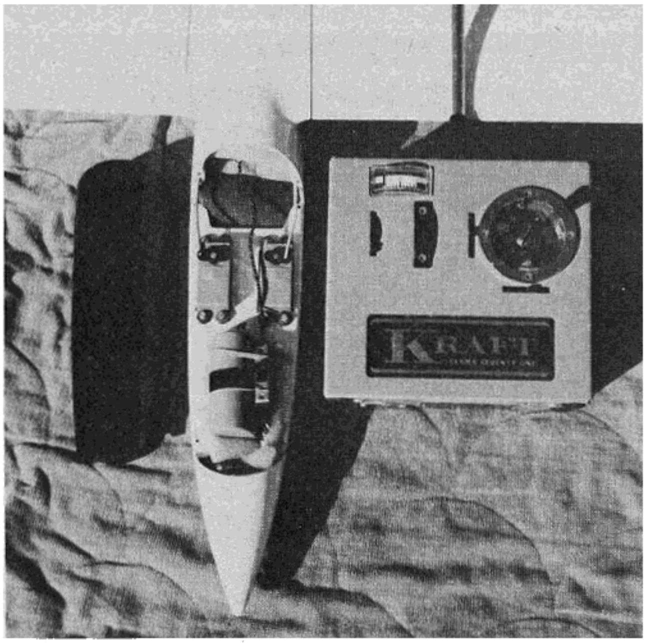
Fuselage	Foam & Ply
Wing	Foam, Ply, Spruce & Balsa
Empennage	Foam, Balsa & Ply
Wt. Ready-To-Fly	67 Oz.
Wing Loading	20 Oz/Sq. Ft.

Cut the foam blanks to the correct planform for the inboard and outboard wing tapers and for the horizontal stabs, noting the correct leading and trailing edge cuts for the core from that given on the templates. Use 1.0" thick 2 lb/ft³ density blue styrofoam of either aircraft grade or the cheaper fire retardant insulating foam made by Dow Chemical Co. Do not use white "popcorn" type expanded polystyrene as this variety has insufficient compression and shear strength for thin high aspect ratio wings. Use a cutting bow just slightly longer than the taper to be cut with a 30 gauge, 0.011" diameter, nichrome cutting wire. Use just enough heat to cut a groove the width of the wire. Weigh down the foam blanks on a straight board to remove any warps in the foam and pin the templates to the ends of the foam using small diameter nails. Cut the bottom surface contour first so that the diameter of the cutting wire is not subtracted from the airfoil thickness. If you are unable to maintain continuous even pressure on the cutting wire, and the core develops burn lines as a result, then try again on another blank using a slightly hotter wire. If the core has waves or the wire rides up off the template, then you are either tugging too hard on the wire or your wire is too hot. With the highly tapered outboard taper, or with the horizontal stab, use greater pressure on the end with the larger chord in an effort to come out of the trailing edge at the same time at both ends of the blank. Otherwise, the trailing edge of the core will be irregular in thickness.

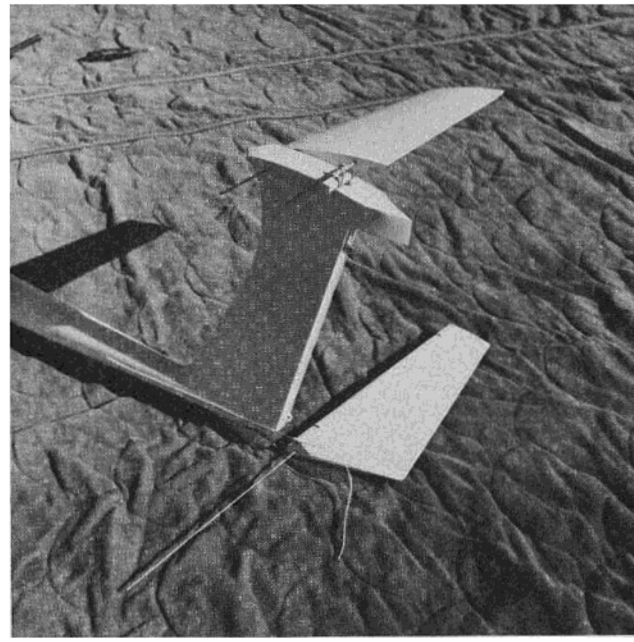
RIGHT: The W-21 perched as a lone sea bird in the late winter light above the sandy beaches at "Secret Spot", California. Photo by Scott Jenkins.

Locate and cut the boxes for the wing tubes in the root section of the cores of the inboard wing taper. Line the forward and aft faces of the boxes with 1/16" plywood with the grain running vertically. Place and align the cores in the lower halves of the blanks and epoxy a slightly undersized 3/32" balsa rib to the root section of each core. This rib maintains the airfoil shape of the root section until the wing tubes are installed and the boxes are filled with epoxy and microballoons.

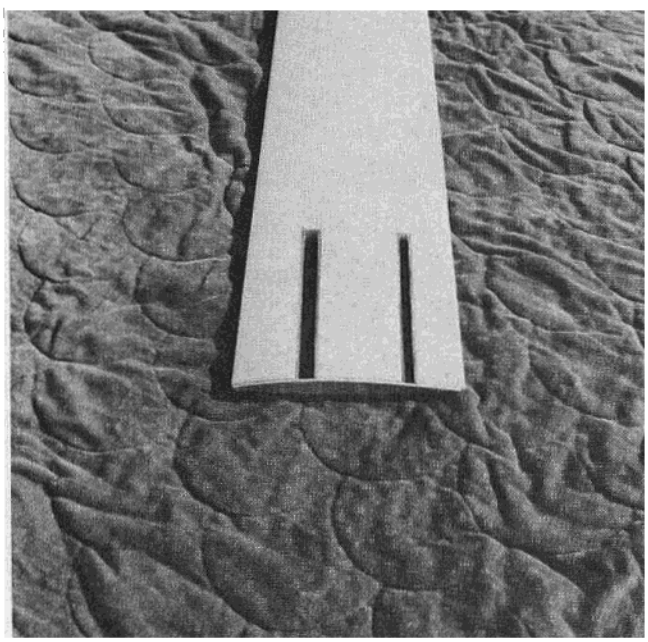
Lightly sand the fuzz off the cores for good adhesion to the contact cement used to bond the skins. Sig Core Bond or Southern Sorgum are preferred by the author. Brush the contact cement on the core and skin sparringly and evenly to keep down weight build-up and allow to dry until the cement will not break away from the surface upon touching and withdrawing of your finger. Skin the lower surfaces first after placing the core



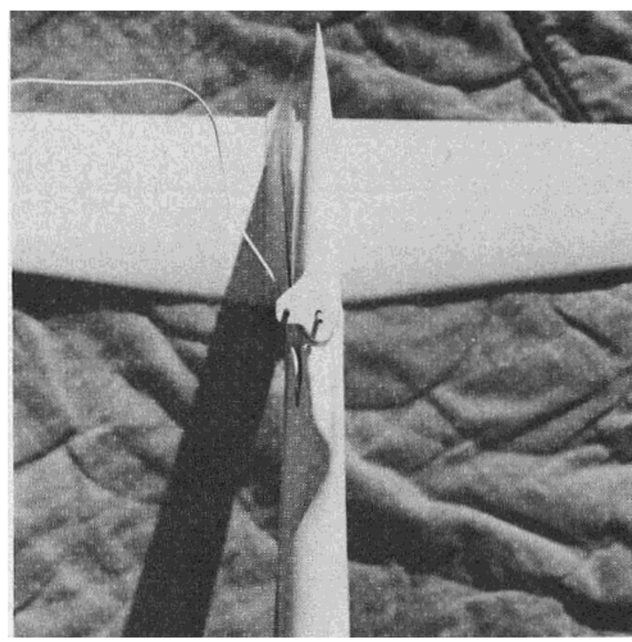
Through wind and rain, a trusted old friend! A factory re-built Series 71 Kraft 3 ch. has been the long time favorite of the author.



Tail Assembly. Rudder is removed by withdrawing 1/16" O.D. aluminum hinge pin from the base. "Missing Link" couples drag pin on the flying stab to the elevator pushrod.



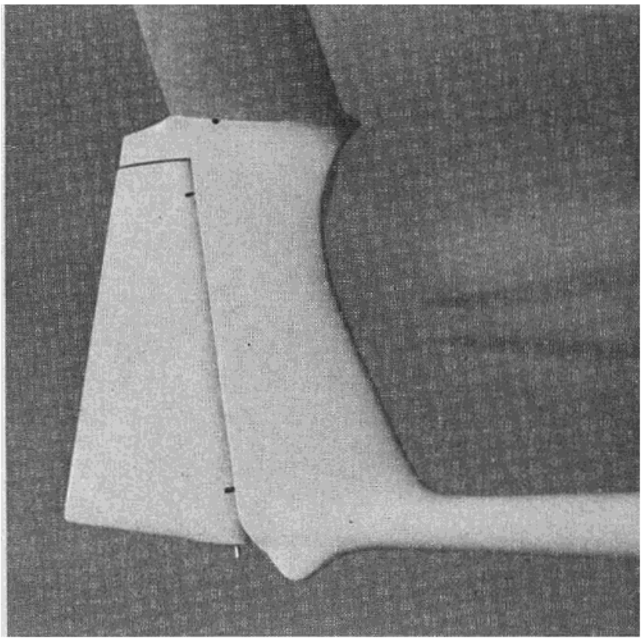
Root section of the foam wing core prior to sheeting. Balsa crutch rib holds the airfoil shape after wing rod boxes have been cut and lined with 1/16" plywood.



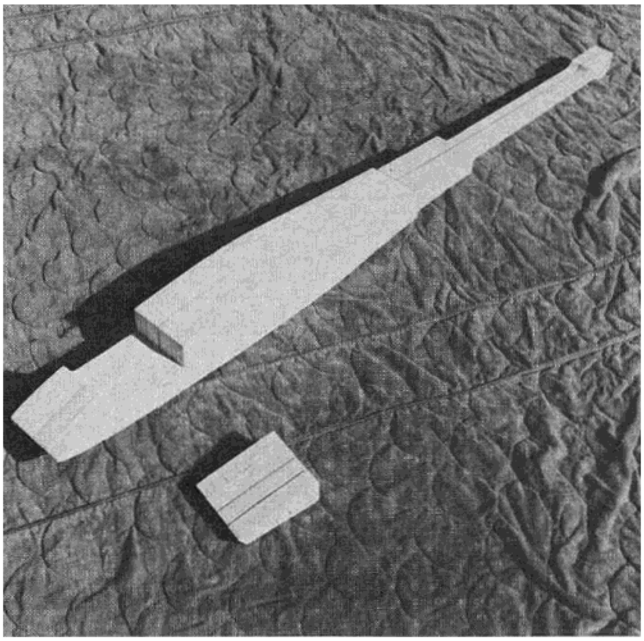
Access to the hinge pin is from the base of the rudder. Keep the gaps here as tight as possible.

in the remaining upper half of the foam blank, holding both flat to the cutting board with weighted shims around the edges of the core. Make the first contact between the skin and the core in the center of the taper by bending the skin downward in the middle, while holding each end above the core preventing premature contact. Then pressing down on the skin where initial contact is made, slide your thumb along the skin towards one end, allowing contact as you proceed. Repeat towards the remaining end and then stroke your fingers back and forth advancing from the thickest point of the airfoil towards the leading and trailing edges. This procedure assures even bonding without waves and wrinkles in the skins that result in a crooked wing. Flip the cores over and place in the lower half of the blank and repeat. Skin the inboard and outboard wing tapers independently.

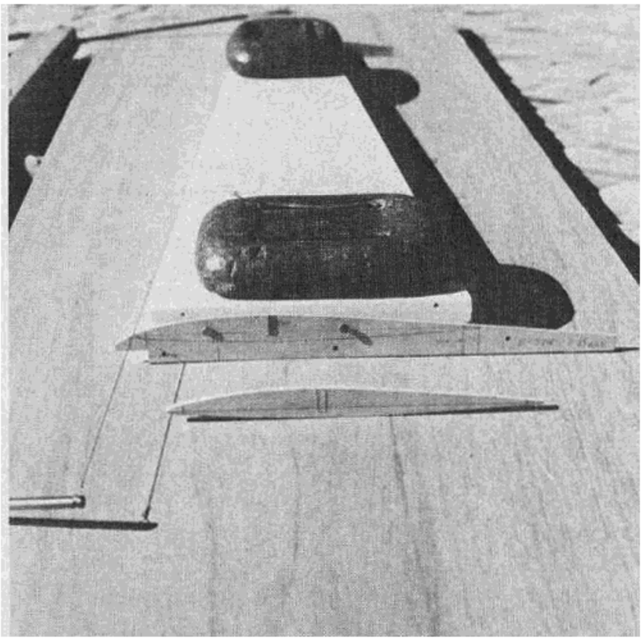
Trim and sand the excess skins flush to the foam cores and place the tapers back in the lower halves of the foam blanks. Press flat to the building board with weights and butt joint the 3/16" x 1/4" spruce leading edges and 3/8" x 3/16" spruce trailing edges in place using Titebond and securing position with Scotch tape. When dry, locate and draw the centerline of the leading and trailing edges with a fine line ball point pen. Plane down the excess L.E. and T.E. stock with a razor plane, protecting the skins from knicking with several lines of masking tape. Do the final shaping and blending of the leading and trailing edges by block sanding with 180 and 220 grit on a 3"-4" block. Titebond the wing tips cut from 3/8" balsa stock



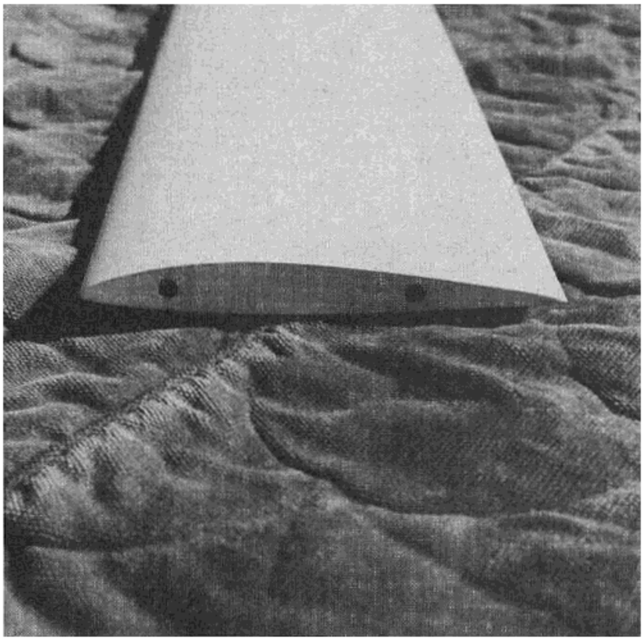
Fillet detail around the tail group. After blocking and roughing to shape, remaining corners are filled with micro-balloons.



Foam fuselage plug with canopy cut out. After shaping, coat with Devcon 5-minute epoxy before glassing with successive layers of 2 oz. glass.



Cut the foam cores from 2 lb. density blue sytrofoam. Weight the blanks flat to the cutting board to insure against a twisted core.



Wing root section plugs onto two 3/16" tempered steel wing rods which flex and sometimes bend to soak up most flight abuses.

using leading and trailing edge lines drawn to the correct contours to guide your eye while shaping. Do not sand or knick the plywood wing skins as they are very thin and such blemishes serve as stress concentrators.

Place the two wing tapers upside down over the plans and shim up the junction of the two tapers with 1/8" scrap balsa. Note any gaps in the joint between the two tapers and block sand lightly until a clean knife edge junction is achieved. Butt joint the two tapers together with Devcon 5-Minute Epoxy, working quickly and checking to see that the correct planform is maintained and that the two airfoil sections are properly aligned before the epoxy sets. The 0.5° junction angle has now been set.

Locate the position of the main spar and draw two parrallel lines on the upper wing surface at that location with slightly more than 1/8" spacing between the lines. With a routing bit in a Moto-Tool, cut the spar groove through the upper wing skin down through the core, stopping when the lower wing skin is reached. A short length of scrap aluminum is helpful in guiding the router along the locating lines. It is not difficult avoiding penetration of the lower wing skin because the foam is so very much softer and the routing bit does not cut readily going straight down. Be sure to cut the groove slightly wider than the spar to avoid distorting the airfoil when the spar is inserted. Weight down the wing in the lower foam blanks and lay two lines of masking tape on either side of the spar groove to avoid contaminating the upper wing skin with epoxy. Fill the groove with epoxy and insert the 1/8" spruce main spar cut slightly wider than the spar depth. Remove excess epoxy and, when cured, file the spar flush to the upper wing skin using the masking tape strips to protect the skins from knicks.

Wrap the taper junction of each wing panel with 2 or 4 ounce glass cloth with polyester laminating resin. Then glass both upper and lower surfaces of each panel with two layers of 3/4 ounce glass cloth on the inboard taper and one layer on the outboard taper using K & B surfacing resin. The glassing procedure is the same throughout. Cut an oversized piece of cloth and place it dry on the panel. Mix several ounces of resin catalyzing with 5 or 6 drops per ounce. Do not over-catalyze or else insufficient working time will remain before the resin solidifies. Brush generous amounts of resin over the cloth, beginning in the middle of the panel and working towards the edges. The resin flows by capillary action into the weave and between the cloth and the surface. To soak up the excess resin and press the cloth flat against the surface, use a roll of toilet paper just as if it were a rolling pin. Press the paper roll against the wet glass surface in the center of the panel and roll it towards the ends, stopping with each revolution to unwind the wet tissue. Be sure and roll in a direction such that the roll does not unwind as you proceed. Once a line has been rolled full span, proceed to roll in a cord-wise direction from this line towards the leading and trailing edges. As soon as the resin has gone off, trim the excess cloth and repeat the procedure on the opposite side. Though shrinking is very minimal with light cloth and a thin resin coat, prompt glassing of the opposite face will insure no warping or curling of the thin trailing edge. Once both surfaces are glassed and trimmed, the weave can be filled with a second coat of K & B polyester resin, applied to both surfaces at the same time, to avoid trailing edge warpage. The runs are removed and the panel surfaces made wave-free by careful block sanding. If you penetrate to the weave at any point, circle that area in heavy black pencil, and avoid hitting it again. The glass is enormously important to the total wing strength, so do not eliminate it from construction.

The fin and rudder are of classical 1/16" balsa D-tube construction, except the main spar and shear web is replaced by a solid 3/16" plywood sandwich from three 1/16" ply webs. Cut the 3/16" diameter holes in the ribs of the fin for the elevator pushrod guide tube and epoxy it in place just before completing the sheeting of the fin. Cut the two rudder hinges from a length of 1/16" aluminum angle stock. Roughen one surface of each hinge and drill the other surface for a 1/16" aluminum hinge pin. Locate the 3/32" diameter aluminum hinge pin guide tubes on the base of the rudder so that they mate with minimal slop to the hinge spacing. Cut the rudder control horn from a scrap piece of 1/16" epoxy glass printed circuit board material and epoxy it to the underside of the rudder. Install the horizontal stab platform and fillet after the fin has been mounted to the fuselage and the angle of incidence of the wing has been set. At this time, the incidence of the horizontal stab is set at −2° with respect to the fuselage center line. The fillet is then built up from micro-balloons and K & B resin filler to blend smoothly to the horizontal stab.

The fuselage is a seamless glass shell laid up over a foam plug. Cut a side profile of the fuselage, less fin, from a length of 1/64" plywood. With this plywood profile, trace the outline onto two sheets of 1½" thick blue styrofoam. Cut out the canopy where marked on the plans. Once the foam profiles have been cut out, epoxy them together on a flat surface with plywood profile sandwiched in-between.

Trace the horizontal profile onto the underside of the composite foam profile. Block sand the sides with the canopy spot-glued in place until they meet with horizontal profile lines. You now have a foam box fuselage with the correct contours when viewed from the sides or from above. Next, round off the corners with a coarse sanding block until a graceful pod and boom of ovular cross section has been achieved, eyeballing your work frequently to ensure the same contours on either side of the plywood stringer. Break the foam canopy loose and set aside. Cut two grooves down the left and the right sides of the foam fuselage plug for the rudder and elevator pushrod guide tubes. Epoxy the vertical stab in place on the foam plug, checking alignment carfully with a 90° triangle. Then, epoxy the pushrod guide tubes into their respective grooves, scraping the excess epoxy flush to the fuselage contours. A third guide tube is embedded in the underside of the foam plug to house the receiver antenna.

The surfaces of the foam fuselage and canopy plugs are prepared for glassing by coating with Devcon 5-Minute Epoxy. This is necessary to prevent the polyester resin from dissolving the plug during glassing. Do not use any of the Hobbypoxy glues for this purpose since these poison the polyester catalyst, preventing the resin from curing. Sand the plug lightly to remove any burrs and then apply a couple of layers of 2 ounce glass cloth with laminating resin, pressing the weave flat and soaking up excess resin by blotting with wads of toilet paper. Heavier glass or too many layers at one time will not conform readily to the small radius compound curves. Glass as much in one application of the total surface as possible. After curing, flip the fuselage over and glass the remaining surface area, overlapping the glass along the sides. Repeat the procedure after curing until 6 layers have been built up over the pod and nose, 4 layers on the tail boom and canopy, and 1 or 2 layers over the vertical stab. When fully cured, dissolve the foam plug out of the canopy with acetone. Chisle enough foam from the cockpit area to accommodate the radio. Cut the servo tray from 1/8" plywood and glass it to the interior of the fuselage using laminating resin.

Drill four 3/16" diameter holes through the glass walls of the fuselage at the locations for the wing rods using a small drill point in a Moto-Tool. Insert the wing rods through these holes, eyeballing for parallel alignment. Dissolve any foam inside the fuselage in the vicinity of the wing rods with acetone on a Q-Tip so that several layers of 2 ounce glass may be laid over the rods and bonded to the ceiling with laminating resin. This prevents any rotation of the wing rods in an abrupt landing. Cut two wing root ribs from 1/8" plywood and drill two 3/16" holes in each to match the wing rod spacings. Slip these ribs over the wing rods and position at the base of the wing fillet. Check to be sure an incidence of +1° is the same on each side. Build up the wing fillet between the plywood root ribs and the glass fuselage sides with a thick mixture of micro-balloons and K & B resin. File and sand to shape and then cover with two layers of 3/4 ounce glass.

Cut two more 1/8" plywood root ribs identical to those used to construct the wing fillets. Drill these in the same positions for 7/32" diameter brass wing tubes. Insert the wing tubes into the ribs and slide the assembly onto the wing rods, checking alignment with the wing fillet. When satisfied, epoxy the tubes to the root ribs and plug up the ends to be inserted into the wing boxes with a wad of toilet paper and epoxy. Block sand the wing roots flush to the foam cores to remove the 3/32" balsa crutch ribs. Fill the wing tube boxes with a mixture of Hobbypoxy II and micro-balloons. Support the fuselage upright on a large flat surface and align the vertical stab perpendicular to that surface. Insert the root rib/wing tube assemblies into the root sections of the wings and wipe off the excess epoxy which overflows from the wing tube boxes. Plug the wings onto the wing rods, align with the wing fillet, and block up in several places to support the wing until the epoxy sets. Measure from the vertical stab to each wing tip to insure the wings are square to the fuselage. Also, check the dihedral and incidence of the wing, measuring from the table surface to the leading and trailing edges along the span to ensure that everything is the same on either side. This is your last chance to make any slight corrections in dihedral, canter, or incidence, but the long cure time of Hobbypoxy II allows you to adjust and check many times.

Fill the weave in the cloth on the exterior of the fuselage with a dilute slurry of micro-balloons and K & B resin. Block sand to a smooth surface using 220 grit wet-or-dry paper wrapped around a small wooden block. The 220 grit leaves tiny scratches in the surface which are ideal for good adhesion with the primer coat. However, sand the underbelly of the nose pod with 400 W/D to remove these scratches in order to lay up the glass skid pan. Brush a smooth coat of polyvinyl alcohol (PVA) over this area to serve as a releasing agent. Then, lay up three layers of 8 ounce glass over the PVA using laminating resin and pressing the glass tightly against the nose with the now familiar wads of toilet paper. Fill the weave with K & B coating resin. When cured, pop the skid pan off the fuselage. Sand the remaining PVA off the fuselage with 220 grit paper. Trim and sand the edges of the skid pan to the proper shape.

Finishing

Block sanding of the resin surfaces has already produced a fairly smooth and even surface. Inspect the entire structure closely under good light for any significant low spots or depressions, and level these with a local coat of micro-balloons and K & B resin. Roughen these low spots first for good adhesion. Check the leading edge radii for consistency on each side, sanding and filling where necessary.

Protect the wing rods from primer by covering with masking tape. Spray on a coat of K & B Super Poxy primer sufficient to hide all structural detail. A mixture of 1:1:1 of primer/catalyst/thinner works well with a compressor capable of at least 30 psi through an airbrush. A water trap in the air line prevents water condensation from causing pellet sized holes in the coat when priming or painting. Block sand the primer coat with 320 or 400 W/D paper, wrapped around a large rubber eraser. Use 600 grit on the leading edges and other small radius contours. The quality of the finish is given by the care taken in sanding at this point. Natural sunlight at an oblique angle is best for spotting waves and blemishes. After sanding, vacuum the structure and wipe with a tac-rag **very gently**! The best conditions for painting are outside in mid-morning sunlight on a warm day. A light dust coat with K & B Super Poxy enamel, diluted 50% in thinner, is quickly sprayed over the small radius curves of the design. This coat is followed immediately with a flow coat of the entire structure. Keep the airbrush continually moving, applying enough paint to "wet out" the orange peel effect of the individual paint droplets in the spray. Allow the paint to cure about two days, then remove any dust or orange peel by several applications of Dupont white polishing compound.

Control Installation

Construct the pushrods by threading 2" and 4" lengths of threaded 2-56 rod together using 1" lengths of Gold'N-Rod as the coupling sleeves. Thread the rods into the sleeves until they are about 1/8" apart. Do not thread until the rods touch, to avoid making an antenna out of the pushrod. Do not use the Gold'N-Rod alone, as it stretches and compresses too readily under load and will surely contribute to flutter at high speeds. Use just enough Gold'N-Rod on the elevator pushrod to negotiate the 90° elbow in the vertical stab. Set up for ±40° throw on the rudder and ±7/32" travel on the trailing edge of the flying stab. If you will be flying over the ocean or in rain squawls, it is wise to insert the battery and receiver inside rubber balloons, tying off the ends with dental floss.

Set the Center of Gravity (CG) 2⅝" aft from the leading edge. This is a very aft placement, at 47% of the root chord. However, early test flights of the W-21 were made with the CG at the 33% chord line and the horizontal stab was found to require excessive negative incidence to trim for level flight. Check the lateral balance and insert nails in the wing tip of the light panel. Perfect lateral balance is essential for good roll control with high aspect ratio wings.

Flying

Do not attempt a test glide in still air. You would have to run very fast and throw W-21 very hard to achieve sufficient flying speed. Instead, wait for a booming day at the slope and just "go for it." Use a good strong heave aimed slightly down slope, exactly into the wind. The idea is to get away from the slope face and out into the lift band. Here the merciful Goddess of Lift will forgive your mis-judgements and uplift your wings while you unravel any trim problems that appear. It is possible to identify gross trim and balance problems ahead of time by holding W-21 on the CG while standing up through a sun roof of a car driving down a quiet road. About 22 mph is required for sufficient flying speed.

Continue to wait for days with solid lift conditions for the first several flights until you become familiar with the handling of the W-21. This is preferable to scratching around in light lift where there is little margin for error when carrying this much wing loading. However, the W-21 has demonstrated superior climbing ability in light wind, taking advantage of its flat glide slope to escape regions of sink and hop from one lift bubble to the next. The roll response is sluggish at slow speeds, requiring some distance to recover from high banking attitudes. With a little excess flying speed, roll response becomes quick and axial. The roll response at higher flying speeds can be enhanced or inhibited depending upon how the wing is flexed. At neutral or with back pressure on elevator, the wing is loaded positively and the wing flexes upward, increasing the effective dihedral. With more dihedral, the wing banks more rapidly when the rudder is applied. On the other hand, forward stick pressure unloads or even negatively loads the wing, flexing the wing downward and flattening the dihedral out. With diminished dihedral, only yawing is achieved with the rudder, a desirable behavior when approaching the top of a hammerhead stall. Pitch response remains quick and solid right up to stall onset, and is slightly more sensitive to down elevator than to up.

Landings are most safely executed with a little excess flying speed to maintain rapid roll response and to reduce vulnerability to turbulence while low to the ground. On the other hand, the flat glide slope will not allow you to force the W-21 out of the sky. Rather, a patient, thoughtful set-up before entry into the landing pattern is required. The easiest slopes to land on are those which roll off on the leeward side, providing a region of natural sink. Enter the downwind leg with about a 10' altitude margin over the windward face of the slope. While staying close in, execute a diving 180° turn, dropping down into the sink behind the crest of the slope. The turn is completed low, pulling back on the stick, heading back up-slope on the leeward face, trading excess speed against the sink and the up-grade, until W-21 ceases to fly. On flat top slopes with no region of usable sink, a larger, extended landing pattern is required. Enter the pattern at cruise speed and with about a 30 foot altitude margin over the crest of the slope. Fly a long descending downwind leg, using the speed you will accumulate to carve through a high banking 180° turn back up wind. The idea is to lose as much energy in this turn as possible. Upon entering final, concentrate on staying low in order to fly in under the rotors and turbulence kicked up from the lip of the slope. Fly W-21 right down onto the ground while you still have some excess flying speed. Do not let yourself get high and slow on final where the "Mean Whirlies" can grab you and slam your labor in glass on the ground. In smooth, light winds, the speed relative to ground on final will be much greater, but the W-21 can also be safely flown much slower without the danger of turbulence induced stalls. Under these conditions, final can be flown higher, using a succession of low-banked S-turns to descend to the ground. □

From RCModeler Dec. 1977