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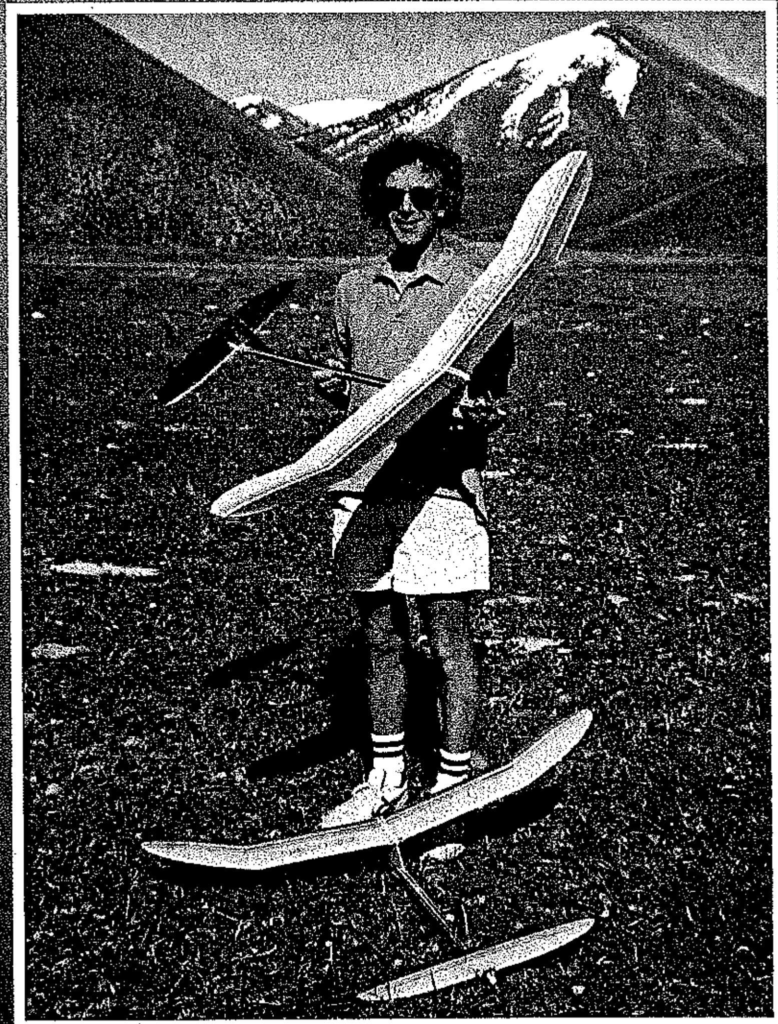


In the dark about F1J? This high-performance model can help you see the "Light"

Northern LIGHT

■ Bruce Augustus

About F1J

The rules for F1J are very simple, allowing a maximum engine displacement of 1cc (.061 cu. in.), an engine run of 7 seconds, and maximum flight time of two minutes. If more than one flier is maxed out after the basic five rounds, flyoff times increase by one minute per round. *Editor's note: there is also a 160g minimum weight for F1J models.*

Unlike F1C there are no limitations on airplane size or weight, and no fuel restrictions. The result of these simple rules has been the evolution of a high-performance free flight event using inexpensive airplanes that are great fun to fly. Without weight and size rules, airplanes can be built very strong and light using balsa and tissue.

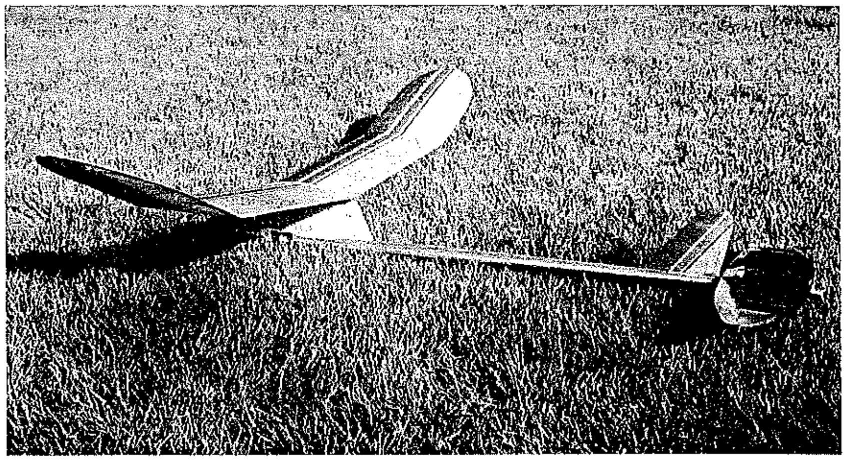
We began flying F1J in the western US in 1988, and for the first year everyone flew his best Cat. II 1/2A. It rapidly became apparent that such airplanes could easily make the two-minute rounds if well flown, but something better was needed for the longer-duration flyoffs.

About that time the Chinese CS ball-bearing 1cc engine became available for slightly more cost than a tuned Cox TD .049. A new breed of specially designed F1J models immediately followed including the Northern Light.

In 1990 the BV Shuriken 1cc engine was introduced by Baldwin and Van Arsdall in Indianapolis, and the appeal of 20 grams less weight and American factory support enticed me to switch to the Shuriken.

I flew the airplane with the Shuriken for a year and then acquired an AD .06, built by Alberto Dall'Oglio in Italy. The AD weighed the same as a Shuriken and outperformed the other 1cc engines, so it was installed in the airplane in 1991 and has been there since. CS and Shuriken engines are still being flown in F1J as well as the Russian Stels and VA, and the venerable Cox TD.

Bruce Augustus



Design reflects author's preference for a relatively simple AMA Gas-type model for F1J competition. Weight is 7.75 ounces with AD .06 power. Fuse DT is used.

F1J is perhaps the fastest-growing free flight event. Originally comprised mainly of 1/2A fliers, it has now attracted participants from most of the power classes, including F1C (the large FAI power class). The event is flown at most major AMA and FAI contests, and beginning in 1995 it has been included in the prestigious America's Cup competition. And it has been suggested that F1C should be replaced by F1J for the Junior World Champs.

Two schools of thought have evolved concerning the best way to design an F1J model. One group believes that since F1C airplanes are the epitome of power models, it stands to reason that a good F1J should emulate F1C. So a group of mini-F1C designs has come about, best represented by Bill Lynch's Pegasus and Dave Parsons' Cathexis Redux. These airplanes are high-aspect-ratio, full-bunting, synthetic material, technological wonders, and they fly very well indeed.

The other school of thought, represented by Northern Light, is that the rules of F1J are much different from those of F1C and so the designs should take advantage of the rules. The F1J rules are more like AMA Gas than FAI, so I began the design process with an AMA-type airplane. Exotic materials are not needed for strength nor to meet a minimum weight. In spite of the availability of space-age materials, models built from balsa are still the lightest 1/2A airplanes.

Northern Light has been under development since October 1989. The design objective was to build a simple fixed-tail F1J that would fly as well as an auto surface airplane.

One goal was to avoid dependence on complex mechanical devices such as heavy multifunction timers, and therefore have an airplane that was reliable and easy to fly. The requirements demanded inherent stability, low drag, and light weight.

Maybe it's old-fashioned, but I still believe you can achieve ultra-high-performance with careful design and fixed geometry. I will concede that perhaps *ultimate* performance can be achieved only with ultimate-technology equipment, but one of the chief attractions of F1J over F1C is that ultimate performance is not yet necessary. With only five rounds to fly, the contests always finish in one day and we fly the long flyoff rounds in the afternoon instead of a 10-minute dawn flyoff as in F1C. So the event still frequently boils down to thermal picking.

The current (third) version of this design differs from the prototype on only minor ways. Covering material and stab size were changed, the pylon has been lowered and narrowed, and a timer-start button has been added.

Airframe drag is minimized by the use of tapered-tube fuselage, built-up pylon and fin, recessed timer, internal fuel bladder, and internal DT and rudder lines. The built-up pylon and fin have lower drag than flat structures and are less critical to construction misalignment.

Northern Light

Type: FF F1J

Wingspan: $53^1/_2$ inches

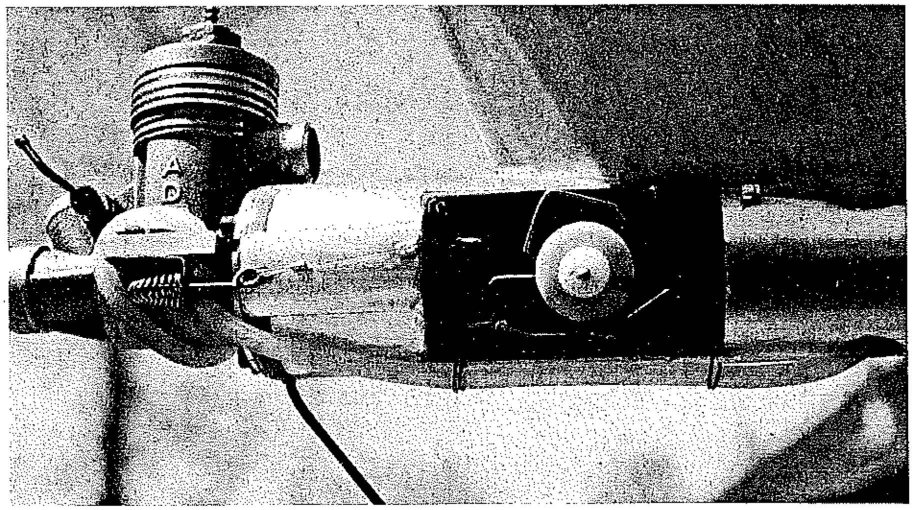
Wing area: 330 square inches

Engine: AD .06/strong $^1/_2$A engine

Flying weight: 7.75 ounces

Construction: Built-up

Covering/finish: Japanese tissue and dope/epoxy on wing & fuselage; $^1/_2$-mil mylar on stab



Three-function timer made from windup toy controls auto rudder, quick-DT for test flying, and remote fuel line pinchoff for engine shutdown.

The author launches NL 330 at the 1994 US Free Flight Championships, Lost Hills, California. Fred Terzian photo.

Covering the wing with tissue allows a lighter structure than would be required if synthetic covering was used. If an all-weather airplane is desired, I recommend a heavier wing structure and Mylar covering for water resistance. A few additional ribs and slightly larger wood sizes should suffice.

The airfoils were derived from Tom Hutchinson's excellent Maverick, which in turn used Ron St. Jean's Ramrod sections thinned by one percent. An elliptical planform is used for lower induced drag and to please the eye.

A three-function windup toy timer weighing five grams is used for weight reduction and simplicity.

An APC 5.7 x 3 propeller is used, and with high-nitro fuel, the AD .06 can be expected to turn in the range of 26,000- 27,000 rpm. With a flying weight of 220 grams (7.75 oz.) the wing loading is 3.4 ounces per square foot. The aspect ratio is 8.8 and the wing section is 8.5% thick. Stab area is 26% of the wing with an 8.4% section. Center of gravity (CG) is at 78%.

The airplane has had a gratifying contest record and was selected by the National Free Flight Society as the 1993 Small Power Model of the Year. A 280-square-inch Stels .049-powered $^1/_2$A version has slightly different proportions, weighs $1^1/_2$ ounces less, and flies about the same.

CONSTRUCTION

There are no exotic materials or special tools or techniques required for construction, but this is not a beginner's project, so at least average building skills are needed and careful planning is a must.

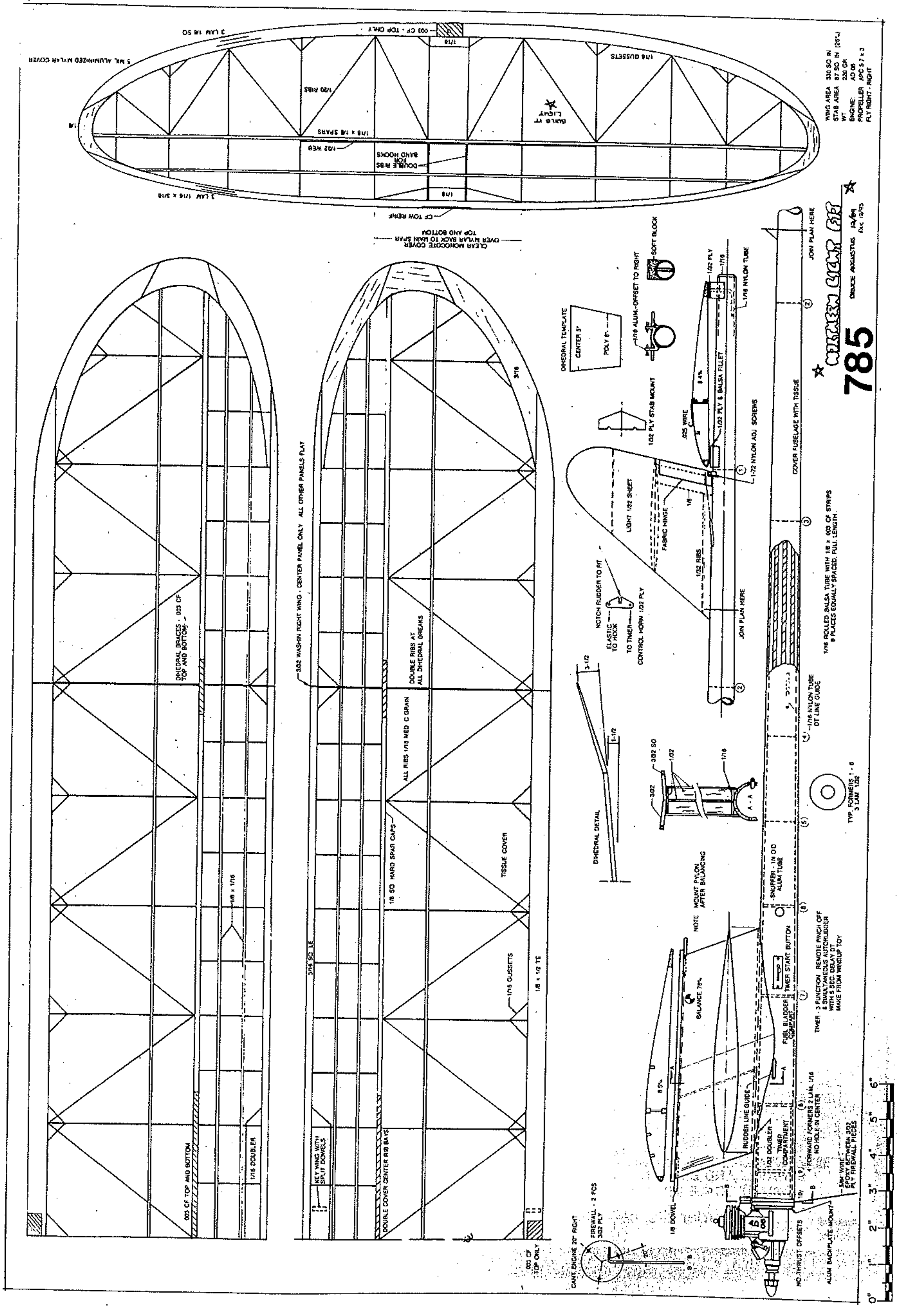
The design is based on light weight and low drag, so it should weigh no more than 7.75 ounces complete with propeller. To accomplish this goal it is necessary to weigh all materials; do not substitute any heavier structure.

It is also vital to keep the tail end light. Part of the model's stability and "forgiveness" can be attributed to the short nose moment, which can be attained only with a light aft end.

An accurate gram scale is required, as well as a circle template with holes in the range from $^1/_2$ to $1^1/_8$ inches. A 12-inch T-bar sander is an indispensable tool, and I use a mini block plane to shape leading and trailing edges. Notch sticks are very useful, and may be made up from spruce sticks with strips of sandpaper glued on. Finally, a mandrel is required to roll the fuselage tube, and a standard five-foot one-piece pool cue works fine.

Carbon fiber (.003) is used for dihedral braces and to reinforce the rolled balsa fuselage. No machining or special hardware is required except for the radial engine mount, which is merely a new engine

Full-Size Plans Available–see page 168



backplate with enlarged flange for mounting.

Wing: I usually build the wing first, so I can dope it while building and rigging the fuselage. Wing construction provides a high stiffness-to-weight ratio when covered with tissue (again, synthetic coverings are not recommended unless the structure is beefed up).

Select all lumber for the wing before beginning. Hereafter, all balsa weights shall refer to a 3 x 36 sheet, or a 36-inch stick—not the wood density.

The 1/8 square main spar caps should weigh 2-2.5 grams. Leading and trailing edges are made from 4-5g stock and ribs from 13g stock, except for dihedral break ribs which are 18-20g. The aft spar will be stiff enough at 1.2g.

Spruce sticks for the forward spars are quite uniform in weight (about 2g). Make the 1/32 spar web from 10-11g wood.

Your lumber will not weigh out perfectly, so place the heavier wood on the right side of the wing, and if the wing still does not come out right-heavy when complete, place a small amount of ballast in the tip.

Cut the parallel ribs to shape (including the half-ribs) and notch for spars using a spruce stick with 120-grit sandpaper glued to it. Make your notches tight so you do not rely entirely on the adhesive to hold the wing together. Cut the diagonal ribs to approximate shape; make them a little long and do not notch for the aft spar. Drill a 1/16 vent hole in each rib.

Build the center panels first, and build 3/32 washin in the right main panel only. Glue all parallel ribs, half-ribs, and gussets in place. Make a balsa dihedral template and use it to set the angles on the center and polyhedral ribs. Install the top spar cap, forward spars, and 1/32 vertical-grain shear web.

The diagonal ribs are notched after installation by using a long notch stick guided by the notches previously cut in the parallel ribs. Glue the aft spar in place and then sand the tops of all the ribs roughly to shape with the T-bar.

Remove the center panels from the plan and shape the leading edge with a mini block plane. Sand the end ribs so they are flat and the spar ends are flush. Final-sand the top of the wing so all ribs are alike; they may be sanded straight between the forward spars, since the covering will be straight anyway.

Build the tip panels the same way, but cant the trailing edge of the polyhedral rib 1/8 inch outboard. This creates a slight sweepback of the tips, which has an aerodynamic effect similar to washout, so no tip washout is needed. Reduce the thickness of the two outboard ribs so the top spar bends gradually down to the tip pieces.

Block up the panels to set the dihedral and washin, and if the rib angles do not come out exactly right, sand each side slightly with a block. Glue the panels together with slow cyanoacrylate (CyA) glue, and when complete and sanded, press the carbon-fiber dihedral braces in place with waxed paper and sand off any excess glue. (Before applying any carbon fiber, sand well with fine sandpaper to prepare the surface and remove the mold-release agent.)

Stabilizer: Cut all the ribs the same size from 10-12g 1/20 or 1/16 balsa, and notch for all three spars. (The stab airfoil is 8.4% thick, which is between 13/32 and 7/16. Final-sand your stab to this thickness before covering.) Pin the tip pieces on the plan and hold the leading and trailing edge laminations in place with pins. Do not stick the pins in the wood. Glue the laminations with white or nitrocellulose glue (Ambroid) to save weight—every gram counts.

Fit the bottom spar cap and doublers, and shape the trailing edge with a plane or sanding block. Set the bottom notch of each rib on the bottom spar cap and cut off the ends of each rib to fit. Using a notch stick, deepen the top notches of the three outboard ribs slightly on each side to allow the top spars to gradually bend down to the tip, and shape the ribs with your T-bar. Spars should weigh 1-1.2g; leading edge laminates 1.3g; trailing edge laminates 1.5g. Avoid excess glue. As with the wing, drill a vent hole in each rib.

Fuselage: The fuselage is a rolled tube formed on a standard pool cue using A-grain balsa weighing about 12-14 grams. A 36-inch-long trapezoid, 3 1/2 inches on one end and 1 1/2 on the other, will yield the correct size fuselage. This may be obtained from a single three-inch sheet by cutting two trapezoids $1^3/_4$ at one end and $^3/_4$ at the other and gluing them together.

The wood is soaked and doped to start the curl, then wrapped around the pool cue and wound with an Ace bandage to dry overnight. The cue should be well varnished to prevent it from warping, and it should be wrapped with waxed paper.

Remove the tube from the mandrel, sand the edges, remount, and glue. The formers are pushed down the tube from the forward end using a long half-inch dowel and drip glued in place. Use a circle template to determine the former sizes, by sliding it onto the fuselage. Formers can be cut and tried, and released from the fuselage by turning them edgewise and pinching the tube.

Install $^1/_{16}$ nylon tubing guides for the DT and auto rudder lines before former seven is installed. Formers seven and eight do not have cut-out centers because the fuel bladder compartment must be sealed and epoxied.

If you intend to use a timer-start button, install a $^1/_{16}$ nylon guide tube through the bladder compartment, along the fuselage inner wall, where it will not interfere with the bladder. Keep the tube as straight as possible, using gentle bends so as not to bind the .020 trip wire.

After former eight is installed, roll a sheet of $^1/_{32}$ balsa to fit as the internal doubler and glue in place with slow CyA. Don't glue the seam until the doubler is in place. The exact location of the formers is not critical as long as there is enough room for the bladder and timer.

The landing skid can laminated between the two firewall pieces or placed behind the engine mount in a machined groove. Blind nuts for engine mounting are installed in the firewall before it is glued in place, and the engine is offset 20° to the right so the exhaust will clear the pylon on the side of the airplane opposite the timer. (A simple and light exhaust extension can be made from an aluminum cigar tube, high-temperature epoxy, and some aircraft safety wire.) Mount the firewall as square as possible, with any deviations in alignment resolved in favor of slight down and left thrust.

Cut eight strips of .003 carbon fiber $^1/_8$ wide, sand and glue to the tube using medium or slow CyA. Cut the timer hole with a fine-tooth razor saw so that the top and bottom edges of the faceplate just fit flush with the fuselage skin.

Glue blocks to the formers at the front and rear of the timer compartment to support the timer and accept the timer mounting screws. Drive very small wood screws into the wood, remove, and harden the screw holes with thin CyA. Glass from the firewall back to the edge of the timer compartment with .75-ounce cloth, using medium CyA.

The pylon is built from very light $^1/_{32}$ balsa weighing no more than 7.5 grams per sheet. Cut the center core of the pylon to exact shape and glue it perpendicular to the bottom pylon rib, which should be cut from $^1/_{16}$ stock weighing 15 grams per sheet. Add the two rectangular side formers and the top rib.

Make the side pieces slightly oversize at top and bottom to leave material for fairing into the fuselage and wing mount. Be careful gluing on the first side piece, because this is the point at which the straightness o f the pylon is determined. Trim off the excess at leading and trailing edges and glue on the other side. Use the wing to form the correct wing mount angle, and apply full-length strips of .003 carbon fiber to stiffen its edges. Sand the dihedral angle into the pylon top using a T-bar sander and attach the wing mount.

To fit the pylon to the fuselage, wrap 150-grit sandpaper around the fuselage 12 inches aft of the pylon location and sand the pylon bottom until the bottom rib is partially contoured ($^3/_8$ to $^1/_2$ wide). This is a slow, careful operation to ensure a straight pylon and correct incidence angle. Check incidence before gluing, and if you are not using an engine and timer with a combined weight of 70 grams, it would be best to glue the pylon on last to ensure correct balance.

The fin is fit and attached in the same manner as the pylon. Draw a line on the fuselage to help mount them both straight.

The photographs show an alternate version of the fuselage, constructed of 1 mil hard aluminum foil wrapped around the balsa tube instead of the carbon fiber. Techniques for the fabrication of this type fuselage are beyond the scope of this article; a brief description of the method is set forth by Randy Archer in the 1991 NFFS *Symposium*. The two fuselages types are equivalent in strength and weight, so the choice is left to the builder.

Mechanisms: This airplane is designed for a 1cc racing engine weighing about 64 grams. A screw-in backplate mount is used to avoid the extra weight of a beam mount.

The engine runs on a bladder made of $3/16$ surgical tubing with about $1/32$ wall thickness. It need be only about $3/4$ long with a knot tied in one end. It is located aft of the timer to minimize the CG shift when fuel is burned. An engine-mounted pinchoff device is used, with a length of monofilament line running to the timer.

Windup toy timers are used in all my small airplanes, and I have found them to be more reliable and less sensitive to vibration than commercial timers. After a short learning period, a timer can be assembled in an hour or two, and the weight saving is half an ounce or more. A detailed construction article for lightweight timers appears in the 1994 NFFS *Symposium.*

The timer provides remote fuel pinchoff, auto rudder, and five-second-delay DT for test flights (a fuse DT is used for official flights). The timer can be single-function so long as it can provide engine stop and simultaneous rudder line release.

The timer levers should be formed so that the engine and rudder lines do not come off when the levers actuate. This feature eliminates the need to hook up the lines each flight.

The timer-start button is located just behind the fuel bladder compartment, with a length of fine music wire inserted through the guide tube to the timer. The wire needs only to contact the timer pawl, so that when the button is released, the pawl becomes free to move. Locate the DT fuse far enough aft of the start button so the airplane may be launched without burning your fingers.

The auto rudder is intended to provide consistent transitions from a straight-up climb. It is a safety device and a very convenient fine adjustment for trimming.

The rudder mechanism is designed so the rudder is held during the power phase by the monofilament rudder line and then released at engine stop, to be pulled over by an orthodontic elastic band. Two timer levers are used for this purpose: one releases forward to the engine-mounted fuel pinchoff, and the other releases aft for the rudder. They are arranged to release at the same time, although the rudder lever wire can be bent to change the timing if necessary. Normal rudder limits are center to about $3/32$ right.

Covering and Finish: Cover the fuselage, pylon, and fin with tissue and finish with butyrate dope. Apply a coat of K&B Super Poxy or equivalent to the entire fuselage to prevent fuel damage. An additional coat or two should be applied from the firewall back to former four. Coat the inside of the timer compartment and slosh several coats of epoxy in the bladder compartment to protect against the inevitable bladder bursting. Allow each coat to dry overnight and don't expose to fuel for a week.

The stab is covered with $1/2$ mil aluminized mylar, with clear MonoKote wrap at the center to prevent abrasion of the delicate mylar during DT motion. You can use $1/4$ mil mylar for an even lighter tail, but it is quite fragile and must be dyed or painted for visibility.

Cover the wing center rib bays with tissue, and dope two coats. Then cover the entire wing with tissue so the center bays are double covered, being careful to preserve the washin during the process.

The center bays should receive a coat of Super Poxy (and maybe even the whole wing, depending on how much nitro you expect to use or spill). Don't overdo it; epoxy is heavy.

Preflight: When complete, check to see that Northern Light balances as shown on the plans and add ballast if necessary. For the first flights the CG can be forward as much as $1/8$ inch, but not aft. If engines with less power than the AD .06 will be used, the CG may remain $1/8$ forward.

Be sure there are no thrust offsets, and shim if required. Be sure the wing is keyed and there is an appropriate rubber band on the auto rudder.

Set the rudder straight for the power phase and about $1/16$ right for the glide. Test glided with the rudder straight and with no stab tilt, the airplane should glide in a very wide right circle due to the wing washin. Stretch a rubber band from the DT line to the quick DT lever on the timer.

Flying: Northern Light is easy to fly, requiring only the DT fuse and band to be installed between flights. The launch is not critical and the model does not need to be thrown.

Set the engine timer for a three- to four-second run (no less) and with the engine running close to full power on mild fuel, launch the airplane straight up. Do not throw the model— just release it—and do not attempt low-power test flights.

It should accelerate very fast in a nearly vertical climb or right spiral with a left roll. (Northern Light rolls to the left as it turns to the right. The washin causes the right wing to rise against the right turn, which keeps the nose up in the climb.)

If it should appear to lay over to the right just before the engine quits, that it normal. It is the effect of the auto rudder, and only appears to happen before engine cutoff because of the sound delay.

If the pattern is not as described, adjust the rudder in very small increments (not more than .010—the thickness of a business card). Keep the engine time about four seconds until the pattern is correct.

Northern Light can be safely flown either straight up with no turn, or with a very slight turn to the right. I prefer the right turn, because trimming for straight up is a little like balancing on a razor blade: it's great when it works, but so often goes awry.

It works well as long as the climb is vertical, but if you have a poor engine run, a bad launch, or the model is struck by a wind gust and the nose drops toward the horizon, it's dangerous. It also requires advancing the rudder timing so it kicks in before engine cutoff.

So the right turn is the safest, easiest to adjust for consistent flights, and provides good transitions with minimal rudder deflection. Very little turning motion is required, and little altitude is sacrificed.

Use the rudder to control the direction and amount of turn, but avoid using left rudder. If the airplane insists on turning too tightly to the right even with the rudder straight, shim in a little left thrust or take out some incidence by shimming up the leading edge of the stab .010 at a time. Some ballast may be required at the tail to compensate the glide.

It might also be necessary to warp in some additional washin if the nose does not point skyward, but $^{3}/_{32}$ really should be enough.

As soon as the four-second power pattern is correct, switch to high-nitro fuel, run the engine at maximum rpm, and repeat. Make the required adjustments following each flight, and when you are satisfied, increase the engine time in one-second increments. When the power phase is adjusted to perfection, the transition to glide may be adjusted. After engine cutoff, the airplane should coast upward for a second or two and then begin a right glide without any stalling or diving. The combination of right power turn and auto rudder will kick the airplane into a right glide circle. The less power turn is used, the more auto rudder is required, and vice versa.

The ideal situation is very little power turn, and just enough rudder deflection to cause transition into the glide circle. If the model drops into a dive after engine cutoff, it is usually an indication that the nose is too high when the speed drops off, due to insufficient auto rudder deflection. If the problem cannot be cured with rudder, decalage must be increased and the CG must be moved forward. Once the power and transition phases are trimmed, the decalage should not be changed.

Cut a DT fuse for about one minute and observe the glide. It should be a large slow circle of about 40 seconds to 1 minute. Changes in glide airspeed are made with ballast; changes in circle diameter are made with rudder. Do not reduce rudder offset below what is needed for a safe transition; if large changes in circle diameter are required, stab tilt may be used.

Keep slowing down the glide with tail weight until a slight stall is observed, then remove a small amount of weight. On windy days the glide circle may be reduced to about 35 seconds by increasing the glide rudder deflection.

I have found Northern Light to be quite versatile. It has flown in AMA $^{1}/_{2}$A