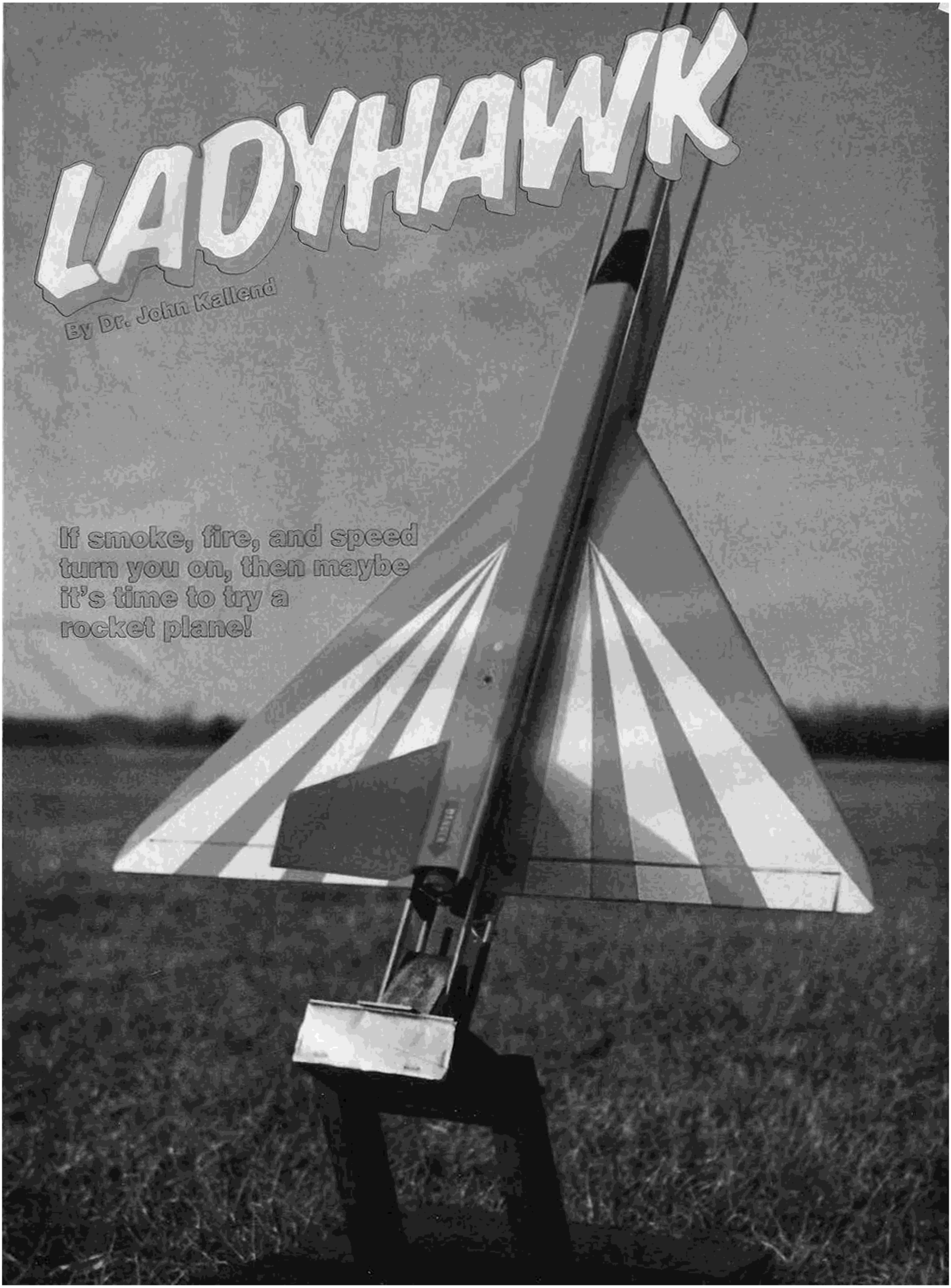
LADYHAWK

By Dr. John Kallend

If smoke, fire, and speed turn you on, then maybe it's time to try a rocket plane!



Model rocketry has been around for years. Many of you will have built rockets, or helped your children with them. Indeed, many airplane modelers have built rocket powered gliders. There are even international duration contests for such craft. However, rocketry has enjoyed a tremendous surge in interest and technology just recently. The advent of reliable, high energy density rocket motors from several manufacturers has led to the growth of the high power rocketry movement. Coupled with the availability of reliable micro radios, this has also opened up new horizons in the realm of R/C. I often assist my sons with their model rocketry activities, and I finally decided that I would like a rocket-plane of my own. I had seen two other rocket powered R/C models, but neither took advantage of the latest motors. I therefore decided to design my own plane. The model, originally unnamed, became "Ladyhawk" one summer day when a red-tailed hawk took a fancy to the model and chased it all over the sky.

The design goal was to create an R/C model that would go very, very fast, accompanied by flame, smoke, and a distinctive sound. I also wanted it to look like a high performance airplane, not like a pod and boom glider. This meant that the motor or motors would be in the tail, so the C.G. would shift as the propellant burnt off. My target airspeed of 200+ mph clearly called for a strong wing. These considerations led to the choice of a delta planform. A delta wing has a wide C.G. tolerance, good stability, and can be built stiff, strong and light while still having a small thickness and chord ratio for low drag. Early on I decided on a twin motor configuration for a more interesting flight envelope. The twin fins avoid some structural problems in the crowded rear fuselage. They look neat, too. With a micro radio the model has an all-up weight of only 13 ozs., so it can be launched on a single D11P black powder motor, all the way up to an F39 composite motor.

Rocket Motors:

Model rocket motors are described by two parameters: a letter designates the total impulse of the motor in Newton.seconds (N.sec), and a number gives the average thrust in Newtons. Each letter in the impulse designation doubles the impulse of the previous letter. Thus an "A" motor has (up to) 2.5 N.sec of impulse, a "B" motor, 5 N.sec, a "C" has 10 N.sec, a "D" has 20 N.sec, an "E" has up to 40 N.sec, etc. The burn time of the motor is the impulse divided by the average thrust. For example, an E20 motor would have an impulse of 40 N.sec, and an average thrust of 20 Newtons, meaning that it would burn for 40/20 = 2 seconds. There are 4.5 Newtons in a pound of thrust, so, for example, an F39 motor produces an **average** of 8.6 lbs. of thrust. The peak thrust is over 12 lbs. just after ignition. This is pretty spectacular in a 13 oz. plane!

Most model rocket motors have an ejection charge in the front that is used to deploy the recovery system after a suitable time delay. The delay time is often given as part of the motor designation. This feature is **not** wanted for an R/C rocket plane. Estes, the biggest manufacturer of model rockets, makes a plugged motor, the D11P, for its AstroBlaster rocket glider. The D11P does not have an ejection charge.

Two types of propellants are used. Black powder is the traditional fuel, often packaged in cardboard motor casings. It is easy to ignite, and reliable. More recently, manufacturers such as Aerotech have been producing composite propellant motors. These use ammonium perchlorate based fuels, similar to the fuel in the Space Shuttle solid boosters. Composite fuels have nearly three times the specific impulse of black powder. Further, different mixes are available giving various flame/smoke characteristics. Aerotech makes three mixes, designated J, W, and T in their catalog. Blackjack™ (J), gives dense black smoke but no flame. White Lightning™ (W) has a long white flame, grey/white smoke, and a splendid sound; the third mix is Blue Thunder™ (T), a high thrust, fast burn propellant that gives a small blue flame and not much smoke. The disadvantage of composite propellants is that they are more difficult to ignite, especially in larger size motors.

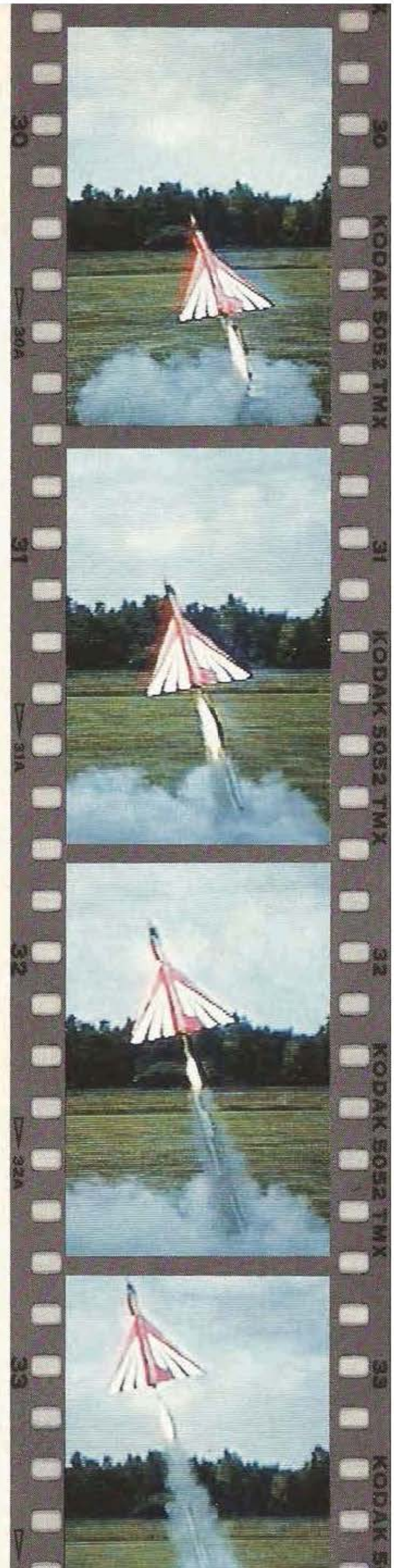
Electrical ignition is used for all these motors. Each manufacturer makes igniters and launch controllers for their own motors. The detailed procedure for setting off the motors varies between brands, so you will have to follow the manufacturer's instructions for the motors that you use.

Motor manufacturers have settled on several standard external dimensions for their motors. Ladyhawk takes 24mm

diameter motors, such as Estes D11P or Aerotech E15W.

Safety:

The hazards of model airplane engines and their propellers and fuels are well known. With reasonable care, certified model rocket motors are probably less hazardous than that spinning propeller, but the hazards are different. The NAR model rocketry safety code is included with all commercial rocket motor packs. The NAR safety code is mostly good common sense and will not prevent you from enjoying the hobby. Compliance with this code is almost certainly a requirement of your liability insurance, whether from AMA or another source. Ladyhawk complies with the weight and power restrictions of the AMA safety code for rocket powered airplanes.

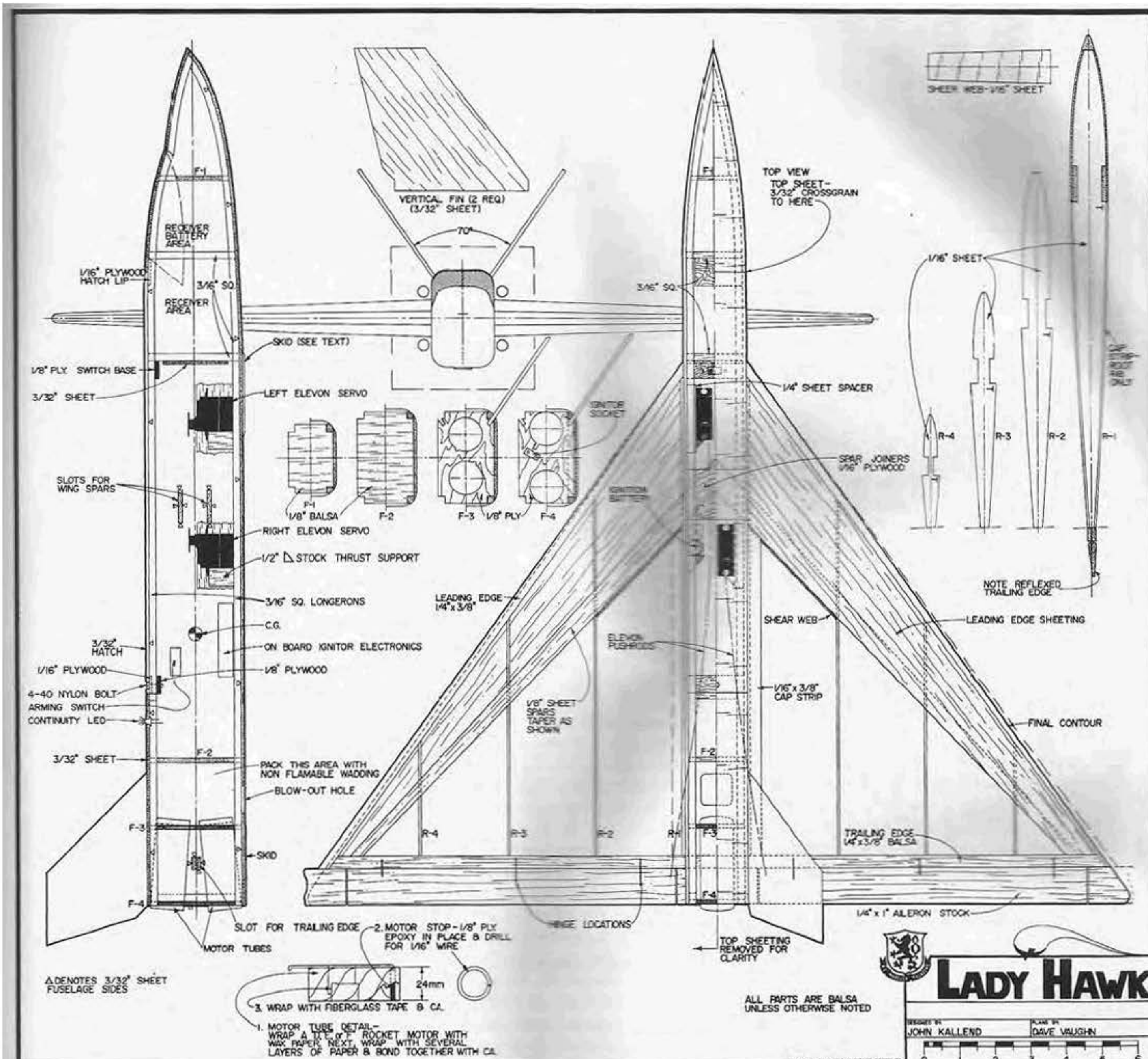


RIGHT: Four shots taken from video. These are 1/30 second apart, illustrating the acceleration of the model off the ramp (E18W motor used). There is 0.1 second between the first and the last picture.

CONSTRUCTION

General:

Light weight is imperative for good performance. You will lose about 10% in performance for every ounce overweight. Choose medium to light grade for all balsa parts unless stated otherwise on the plans. Use cyanoacrylate glue for all construction except where stated. If you normally build .40 size models and upward, the structure will seem flimsy by comparison, especially in the fuselage. It is quite strong enough for a 15G launch, and there is no vibration to



FULL SIZE PLANS AVAILABLE SEE PAGE 223

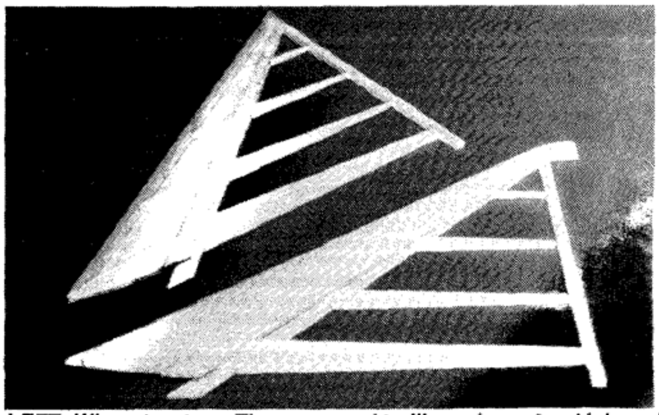
PLAN NO. 1153

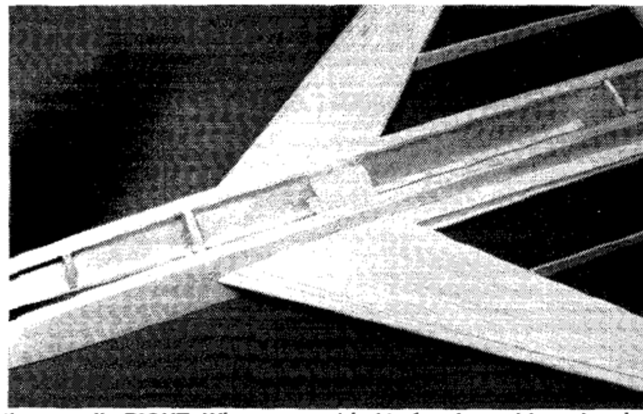
worry about. There is no point in trying to crashproof the model — nothing will survive a 200 mph crash anyway!

Wings:

Build the wings first. The spars are cut from 1/8'' balsa sheet, and are tapered in width. They extend inboard of the root rib so they can be joined inside the fuselage. The T.E. also extends into the fuselage. The ribs are **not** symmetrical — the trailing edge is reflexed upward. That means that the underside of the rib is parallel to the underside of the T.E. Make sure to mark the top of the ribs so you can keep them right side up. Also note that the leading edge sheeting overlaps the spars, and the notches in the ribs are cut to accommodate this.

The following sequence is recommended: (a) Cut out the ribs and spars. spars. Use a sanding block to taper the spars slightly where they touch each other between R4 and the tip — this will make it easier to apply the leading edge sheeting later on. Cut out the capstrips for the root ribs. The capstrips are to stiffen the root rib and to provide secure attachment for the wing covering material. (b) Pin the root rib bottom capstrip and the 1/4'' x 3/8'' T.E. to the plans. Put 1/16'' scrap spacers along the line of the lower spar (it needs to be raised 1/16'' above the building board), then pin the lower spar in place. Do not glue the spar to the T.E. yet. (c) Glue the root rib to the spar, T.E., and its capstrip. Tilt the root rib to the correct angle (it is 1.5° off the vertical to compensate for the taper in thickness from root to tip). (d) Glue the other ribs to the spar and T.E. When the glue has set, carefully raise the T.E. and insert 1/16'' spacers underneath. (e) Glue the top spar in place, and glue both spars to the T.E. at the tip. (f) Glue the L.E. in place. It joins the T.E. at the tip. (g) Using 1'' x 1/4'' T.E. stock, glue the T.E. tips in





LEFT: Wing structure. The spars and trailing edge extend inboard of the root rib. RIGHT: Wings assembled to fuselage sides, showing the top spar joiner.

place. (h) Sheet the L.E. with 1/16" medium balsa, and fix the top capstrip to the root rib. (i) Remove the wing panel from plan and turn it over. Affix the underside L.E. sheeting. (j) Sand to airfoil section. Make sure that the root rib is flat for later attachment to the fuselage. (k) Put a 1/16" balsa shear web (with grain vertical) in the first rib bay, behind the spars. This is to stiffen the wing root where the bending loads are greatest. Cut the elevons to fit, and locate the hinges. Do not attach the elevons until after covering.

Fuselage and Fins:

Cut out the fuselage sides. Cut holes in the fuselage sides for the spars and T.E. to pass through. Mark the former and stiffener locations on the sides, and the line for the fin/stabilizer slot. Glue the 3/16" square longerons in place along the entire length of the fuselage side, top, and bottom. Also glue in place the vertical 3/16" square stiffeners as shown.

Cut out the formers. Note that F2 and F3 are the same shape, but F3 has holes cut in it for the motor tubes. You can purchase 24mm motor tubes from some hobby stores. Alternatively, you can make your motor tubes by winding 1" wide strips of very thin card (0.010") in a spiral around a used 24mm rocket motor (use Saran Wrap on the motor to prevent permanent attachment). Use two layers of card with the seams staggered, bonded together with CA. **Caution!** Estes D motors are slightly undersize. If you use these to make a mandrel for the motor tube, wrap masking tape around the motor first to increase the diameter to 24mm.

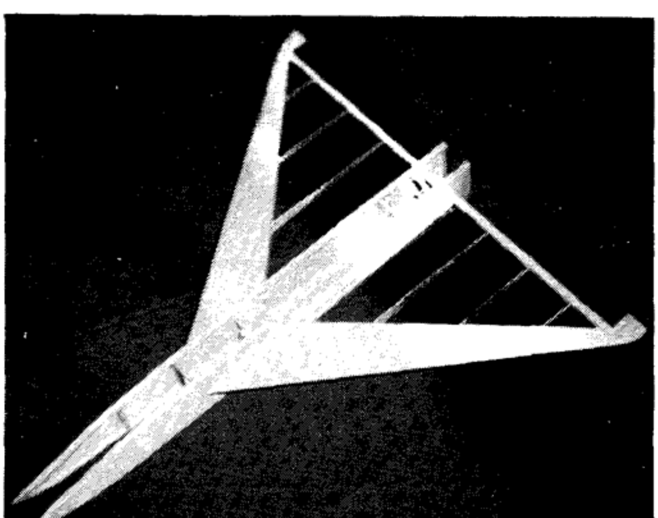
The motors are located above and below the centerline of the rocket, so their thrust lines are angled to minimize trim changes under power. The formers F3 and F4 incorporate the required thrust lines, which are also shown on the side view of the fuselage.

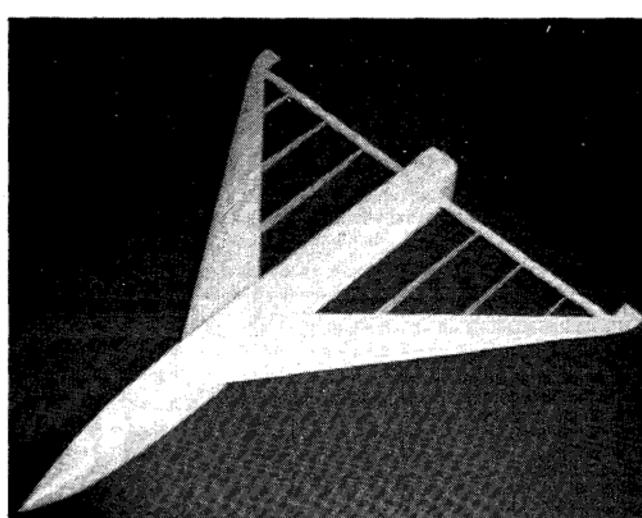
The motor clip can be commercial, or you can bend one from 18 gauge wire. There is a hook on each end of the motor clip — at the front it sticks through the motor tube wall to help retain the clip. Make a fillet of CA to reinforce this point. At the rear, the clip prevents a motor from falling out at an inopportune moment. The clip is fastened to the motor tube with filament tape or a wrap of fiberglass tape. Put slow CA, or epoxy, on the motor tube thrust inserts, and use an old motor to push these (from the front) into position in the motor tubes. These stop the motors from moving forward under power. Try to avoid glue runs inside the motor tube. If you plan to use an Aerotech RMS reusable composite motor, make sure that the delay charge housing fits through the motor tube thrust insert! Make sure that motors can be inserted and removed from both tubes without undue force. Check the fit of the motor tubes to F3 and F4, but do not glue yet.

Make a trial fit of the wings and motor assembly to the fuselage sides. The formers F2, F3, F4, the trailing edges, and the spars should all fit snugly. Each wing should be exactly perpendicular to the fuselage side. Trim as necessary, then remove the wings. Glue F2 and F3 to one side, using a square to ensure correct alignment. Then fix the other fuselage side, making sure that the two sides are parallel. Locate two 3/16" square horizontal spacers between the longerons, by the location of the L.E. of the root ribs.

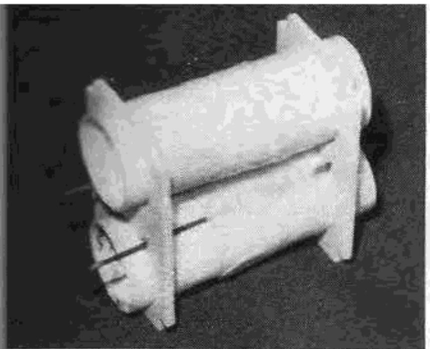
Put slow CA on the wing roots, and fix the wings in place on the fuselage sides. Make sure that the spars and T.E.s are aligned on the centerline, and CA at these points, too. Make a 1/16" ply joiner for each spar, and for the T.E. The joiners extend the entire width of the fuselage, and are glued to the fuselage sides, too.

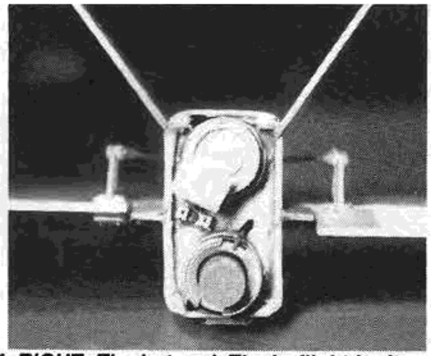
You can now insert the motor tubes in F3, and then thread F4 over the rear of the tubes. Locate F4 in the rear of the fuselage. When everything is in the correct place, use CA to attach F4, and run fillets of CA around the motor tubes where they pass through F3 and F4. Pull the sides together at the nose, to



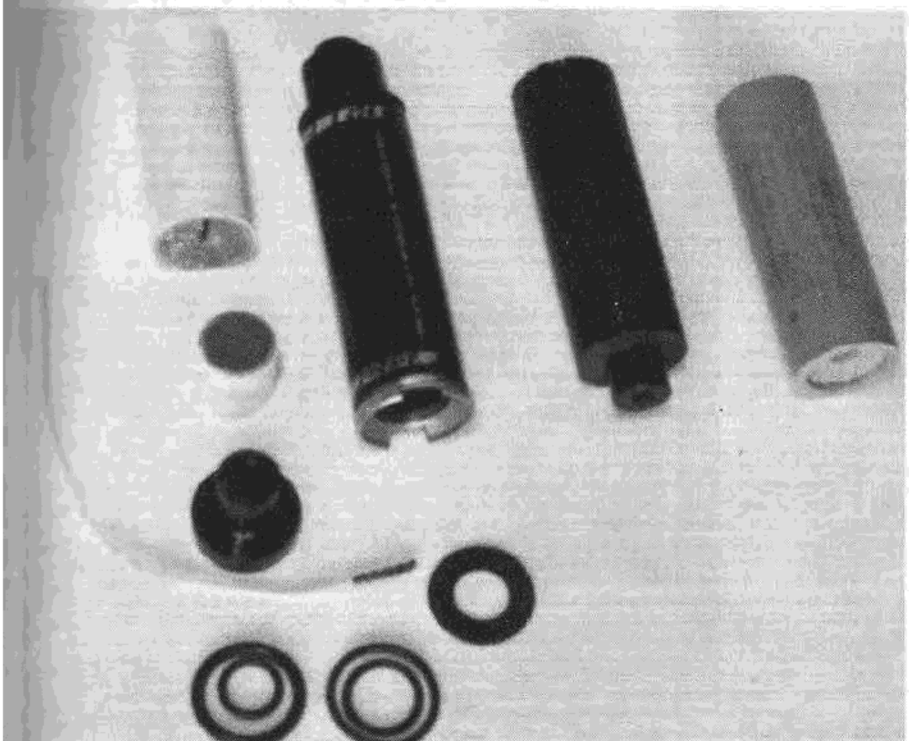


LEFT: Wing/fuselage structure. RIGHT: Top and bottom sheeting completed. The airframe weighs less than 5 ounces!





LEFT: Trial fitting of motor tubes to F3 and F4. RIGHT: The hot end. The in-flight igniter socket is at the left, between the motors.



Black powder motor, single use composite motor, and reloadable composite motor (showing its components). These are all 24mm motors.

hold F1 in its place, and glue when correctly aligned. Fit all remaining 3/16'' spacers between the sides. (Cut the spacers to accommodate the natural curve of the sides.)

If you intend to use in-flight motor ignition, install the wires now. Also, if you want to use an internal antenna, put it in the wing before covering. You can run it through a drinking straw to make it easier to remove and replace.

Sheet the fuselage bottom with 3/32'' balsa, cross grain. Make a 7/8'' square cut-out in the bottom between F2 and F3. This for fire protection; the hole is for pressure relief in case a motor blows out forward. The compartment is also stuffed with noninflammable wadding to act as a flame trap. I have had two motors that burned out the front, but in both cases this precaution prevented any damage to the model.

Sheet the front top fuselage with 3/32'' balsa, cross grain. Cut a hatch cover from 3/32'' sheet (grain lengthwise) to fit the hatch opening. The hatch is attached at the front with a 1/16'' ply tongue, and at the rear with a 4/40 nylon screw going into a 1/8'' ply plate glued to the underside of the longerons. The screw is recessed into the hatch cover. Reinforce the underside of the cover with a small piece of 1/16'' ply at the screw hole location. Then sheet from the rear of the hatch to the rear of the model with 3/32'' balsa, cross grain.

Next, cut out slots for the fins, and trial fit them. The V-tail angle between the fins is 70°. Remove the fins, and sand the entire fuselage to final shape. Glue the fins in place, carefully checking them for symmetrical alignment. To reduce interference drag you can make a fillet around the fin roots with your favorite lightweight filler.

Temporarily attach the elevons, and glue short pieces of T.E. stock in place as filler between the elevons and the fuselage. The completed airframe should weigh 5-6 ozs.

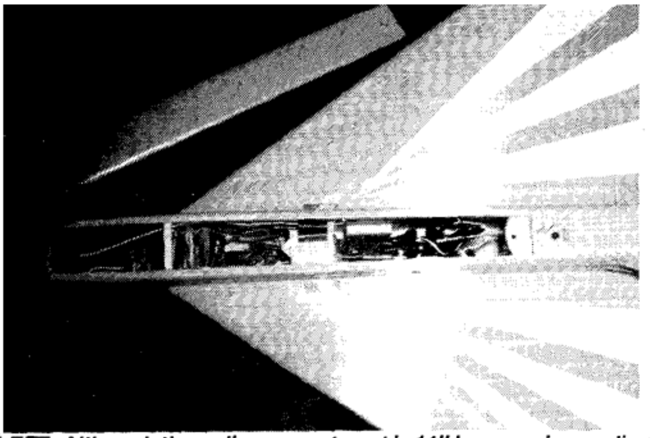
You do not want to have to add ballast to the model, so put two loaded motors in the tail, and provisionally locate your radio components to achieve the correct C.G. The C.G. position shown is the maximum rearward position. Delta wings have a wide C.G. range, but come as close as possible to the position shown. The radio compartment is 16'' long, so you can shift things around quite a lot to get the C.G. right. I use 100 mAh batteries for the radio. 50 mAh batteries will be okay if your radio works well with them and you have a means of checking them at the flying field.

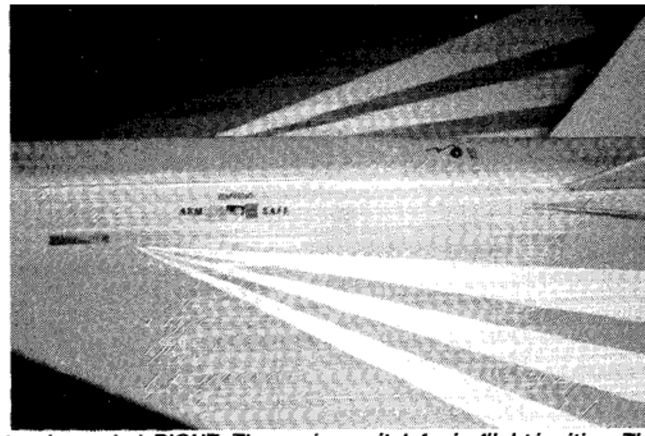
Cover the model with a high strength plastic film covering (e.g., MonoKote or UltraCote). A high visibility color scheme is advised, as this is a small, fast model. Put a strip of plastic adhesive tape over the blow-out hole on the underside. Make skids for the bottom from foam servo-tape (double-sided, sticky stuff) 1/2'' wide, with a 1'' wide strip of plastic adhesive tape stuck on top. These skids will be low drag, lightweight, durable, and easily replaced if

LADYHAWK
Designed By:
[illegible]
TYPE AIRCRAFT
[illegible]
WINGSPAN
[illegible]
WING CHORD
7½ Inches [illegible]
TOTAL WING AREA
175 Sq. [illegible]
WING LOCATION
Middle of Fuselage
AIRFOIL
Symmetrical
WING PLANFORM
Delta
DIHEDRAL, EACH TIP
None
OVERALL FUSELAGE LENGTH
24 Inches
RADIO COMPARTMENT SIZE
(L) 11'' x (W) 1½'' x (H) 2½''
STABILIZER SPAN
NA
STABILIZER CHORD (incl. elev.)
NA
STABILIZER AREA
NA
STAB AIRFOIL SECTION
NA
STABILIZER LOCATION
NA
VERTICAL FIN HEIGHT
3¾ Inches (Vee Tail)
VERTICAL FIN WIDTH (incl. rud.)
3 Inches (Avg.)
REC. LAUNCH MOTOR
D11P, 2 x D11P, E15W, E18W, F12J, F24W, F39T
FUEL TANK SIZE
NA
LANDING GEAR
NA
REC. NO. OF CHANNELS
3
CONTROL FUNCTIONS
Elevon & [illegible]
(micro system [illegible])

BASIC MATERIALS USED IN CONSTRUCTION

Fuselage	[illegible]
Wing	Balsa
Empennage	Balsa
Wt. Ready To Fly	13 Ozs.
Wing Loading	10.7 Oz./Sq. Ft.





LEFT: Although the radio compartment is 11" long, a micro radio system is needed. RIGHT: The arming switch for in-flight ignition. The warning LED is on the fuselage top.

necessary. Attach the elevons, keeping the gap to a minimum. The micro servos are attached with servo tape to 1/4" balsa spacers glued to the fuselage sides. No provision is made for a mechanical elevon mixer — it would be too bulky and heavy for this model, and reliability would be a problem in high G launches. The elevon mixing should be performed in the transmitter. Try to avoid slop in the controls — I haven't had any problems with flutter, but there's no point in tempting fate. The reflex built into the wing should be just right for the elevator trim. The aileron movement should be ± 1/8" maximum for first flights, and the elevator movement ± 3/16". Make another C.G. check to determine the final position of the receiver and batteries.

The peak acceleration on an F39 motor is over 15G, so make sure that your radio gear will not shift under these conditions. I put triangular braces behind each servo and behind the igniter battery (to be described later), and a cross brace behind the receiver/battery compartment. The receiver on/off switch is mounted to this cross brace.

In-Flight Ignition System:

Although Estes calls for **six** volts to fire one of their Solar Igniters,™ this relates to the use of alkaline batteries. NiCd cells have much lower internal resistance than alkaline cells, and I have found that a Solar Igniter can reliably ignite a black powder D11P motor using just two 50 mAh NiCd cells for power. For a weight penalty of about one ounce, you can carry an on-board system for in-flight motor ignition. Make sure that all soldered joints are insulated with heat shrink tubing, so that accidental shorts cannot occur.

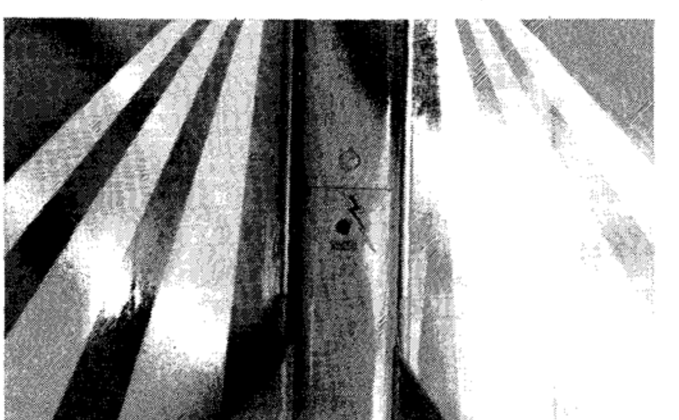
My in-flight ignition system consists of the following parts: **Battery**: two 50 mAh cells, held in place in the rear fuselage by a Velcro patch. **Battery plug**: a polarized Dean's plug is used. For safety, the igniter battery is **always** kept unplugged until just before launch. **Arming switch**: this is a mini SPDT switch from Radio Shack, mounted on the fuselage side. A prominent ARM/SAFE label is put by the switch. Arming the ignition system with this switch is the last task before launch. **Electronic switch**: I use a Jomar electronic switch on the throttle channel. It weighs 1/2 oz., and is electrically isolated from the receiver battery. It is arranged to turn on only at full throttle with full trim. The Jomar switch also has a warning LED that glows when the switch is ON, so you can check for a safe condition before arming the system. Make sure to connect up the electronic switch according to the instructions. **Continuity LED**: Connect a Radio Shack Blinking LED (Cat. No. 276-036c), across the arming switch as a continuity indicator. Make sure that you observe the proper polarity in connecting the LED. The LED is mounted to look like a flashing beacon on the top of the fuselage. When the switch is in the SAFE position, moving the throttle stick to the fire position causes the LED to flash if there is continuity through the igniter. If this LED is flashing, **do not arm the system or the motor will fire immediately.** You can use an ordinary (not flashing) LED, but you **must** put a 50-100 ohm resistor in series with the LED. **Igniter socket**: This is 2 elements cut from a 14 pin DIP IC socket from Radio Shack (Cat. No. 276-1993), screwed to the rear of F4. **Igniter**: Use Estes Solar Igniter,™ but trim the ends of the wires first to remove burrs. These igniters plug into the socket quite easily once the burrs are removed. I loaded the holes in the socket with contact lubricant to provide some protection against the corrosive exhaust gases. See attached schematic for circuit details.

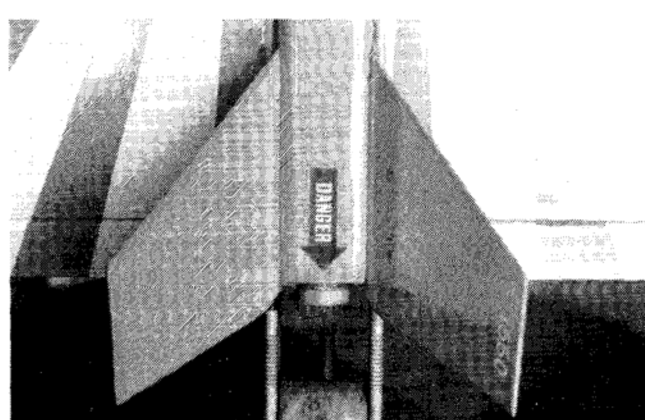
Test your in-flight ignition system thoroughly using a 3 volt flashlight bulb **before** trying it with a live igniter!

If you want to ignite anything other than an Estes D11P motor in flight, you will have to devise your own scheme. If you know anyone in the Tripoli High Power Rocket Association, they may be able to help you with such methods as flash bulb ignition and Thermalite fuse.

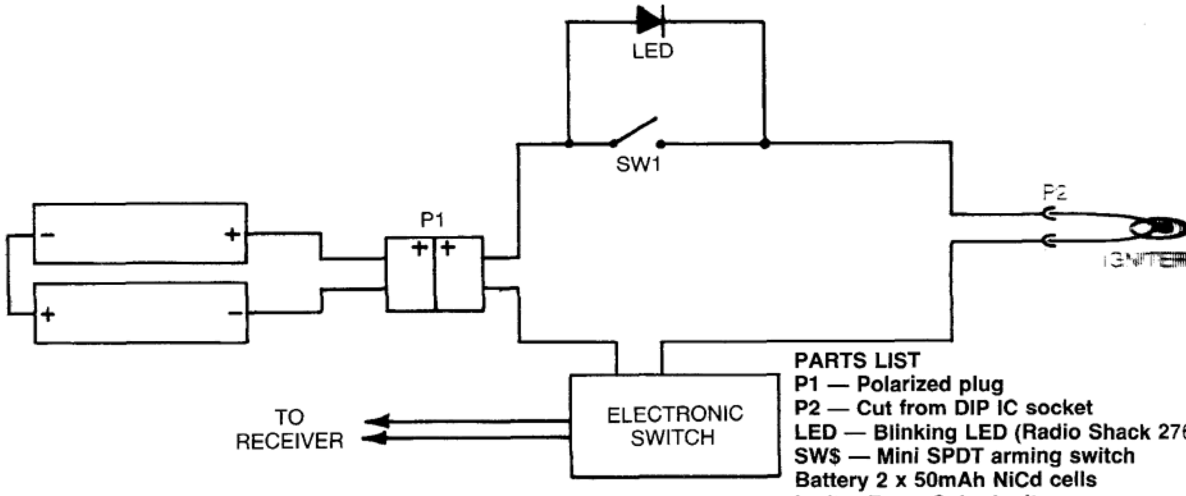
Launch ramp:

Mine has four parallel 36" x 5/16" aluminum rods stuck into a 4" x 4" x 1.5" wooden block in a rectangular pattern. These rods pass one above and one below the wing on each side of the fuselage. The wood block is covered with thin aluminum





LEFT: The ignition continuity/warning LED. RIGHT: Tail end, on the launching ramp.



PARTS LIST
P1 — Polarized plug
P2 — Cut from DIP IC socket
LED — Blinking LED (Radio Shack 276036c)
SW$ — Mini SPDT arming switch
Battery 2 x 50mAh NiCd cells
Igniter Estes Solar Igniter

sheet for protection from the hot blast, and a 1/16" aluminum sheet blast deflector is screwed in line with each motor. A 1/4" threaded rod passes through the block as a pivot to enable the elevation to be adjusted. The block is held between two uprights by the threaded rod, tightened with wing-nuts. The uprights are screwed to a 12" x 15" baseboard. A standoff is needed to hold the rear of the model about 3" above the block — I simply wrapped plastic tape between the aluminum rods to do this. This launcher sounds elaborate, but it takes about 30 minutes to make. It gets covered with soot, so budget your decorating time accordingly. Wipe down the aluminum rods after launches to prevent corrosion.

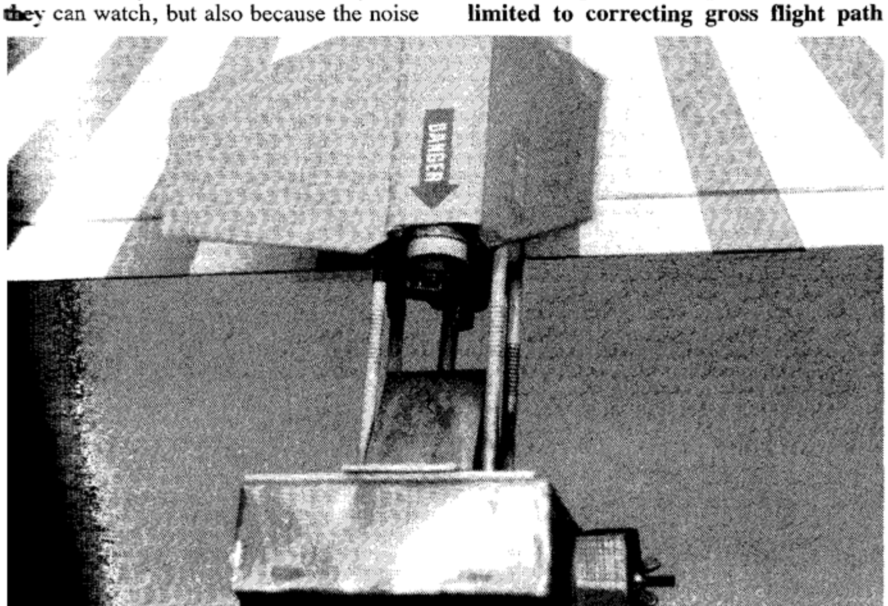
Flying:

You can test glide the model over tall grass to get an approximate glide trim established. It is best to have a helper hand launch the model while you operate the transmitter. The launch should be fast and parallel to the ground.

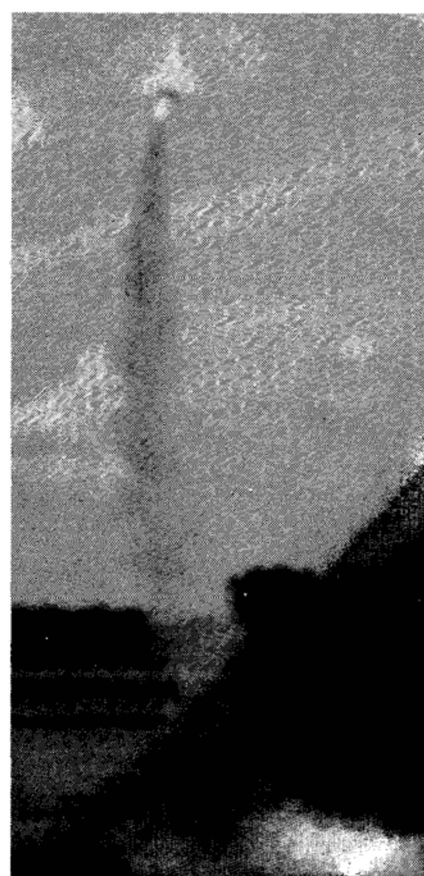
As a matter of safety, and courtesy to your fellow modelers, always announce a launch before you make it. This is not just so they can watch, but also because the noise from some of the high power composite motors is very startling.

Make your first powered test flight using one D11P motor in the bottom tube. Insert the igniter according to the manufacturer's instructions. Put a second motor in the top tube for balance, but do not wire it for ignition on this flight. Elevate the launcher to about 65-70° above the horizon. Make sure that your launch controller is not armed, and connect up the launching electrics to the igniter. Turn on the radio, pre-flight the controls, then close up the hatch. Step back to the launch control, which should be at least 25' from the model. Get your helper to arm the launch controller while you watch the model, just in case the firing button has shorted. After a countdown to warn onlookers, fire the motor. Black powder motors ignite almost immediately, and the model will accelerate to about 75 mph in just over a second. This may sound hairy, but it really is not at all hard to keep up with this level of performance. If you built it straight, it should follow a fairly straight flight path. **Control inputs under power should be limited to correcting gross flight path errors.** It will continue to coast upward after the motor burns out, but will only reach an altitude of about 200-300 ft. on this motor. Avoid stalling out at the top of the launch. Immediately think about setting up for landing, but try to get the model trimmed

Launch Motor	Speed	Altitude
D11P	80 mph	270 ft
2 x D11P	175 mph	790 ft
E15W	150 mph	770 ft
E18W	160 mph	780 ft
F12T	140 mph	810 ft
F24W	205 mph	1000 ft
F39T	240 mph	1000 ft



Ramp detail showing blast deflectors.



Launch with an F24 motor. (Dan Williamson photo.)

out for straight flight while you have the chance. The delta wing will allow you to pull a very high angle of attack on the landing flare.

Note: There is some variation in weight between motors of different brands and impulse. You should re-check the C.G. when you change motor type.

Try ''cluster ignition'' of two D11P motors as the next step. Simply wire the igniters in parallel. In this case, the model will reach about 170 mph, and an altitude of about 750 ft. if you fly a straight course. This is enough altitude to try loops and rolls on the way back (the roll rate is very fast).

Finally, try using a high power composite motor for launching. Aerotech makes both single-use and reloadable composite motors in the 24mm size. These are available up to F impulse rating, more than twice as much boost as a D motor. A good motor to start with is an E11J, E15W, E18W, or F12J.

If you use an Aerotech motor, you **must not** have an ejection charge loaded in the motor, or it will destroy your model. The single-use motor's ejection charge can easily be removed by peeling off the paper sticker from the front end of the case, and shaking out the powder. Then fill up the hole with 5-minute epoxy. For the reloadable motor, just omit the ejection charge when you load the motor. You must, however, load the delay charge, because this is needed to seal the front of the motor (besides, the delay charge leaves an attractive smoke trail).

Aerotech motors use a long igniter that must be pushed to the front of the charge. If this is improperly inserted, the motor will not develop full thrust. The igniter is held in place with a plastic cap over the exhaust nozzle. The instructions tell you to make a 1/16'' vent hole in this cap. Believe them! If you don't, the pressure build-up blows the igniter out of the engine before it starts. The composite motors take longer to fire, perhaps as long as a second after hitting the switch. Do not try cluster ignition with composite motors because of this unpredictable delay. The first time you fire a ''White Lightning'' propellant, the sound is quite startling, so be prepared. When you feel comfortable with this power level, try an F24W or an F39T for a real blast. My favorite for overall impression, with flame, sound, and smoke is the F24W.

To use in-flight ignition, prepare the model with a composite motor for launch and a black powder motor for in-flight boost. **Make sure that the in-flight igniter battery is unplugged and the arming switch is at SAFE before plugging the igniter into the socket.** Then prepare the model on the ramp and connect up the launch controller as before. When ready, turn on the radio, test the controls, and test the igniter electronic switch if it has a test LED. Then move the throttle stick to the OFF position, and plug in the igniter battery. From this time on, avoid placing any part of your body in line with the front or rear of the model. Close the hatch, and inspect the continuity LED. If it is flashing, you have a hot circuit that will fire as soon as you switch the arming switch to ARM, so don't do that. Unplug the igniter battery, remove the igniter from the motor, and find out what is wrong. Be aware that in bright sunlight the LED may be difficult to see unless you shade it.

If the continuity LED is not flashing, it is safe to arm the circuit. Once this is done, return to the launch controller, arm it, and start your countdown. You can set off the second motor during the glide by moving the throttle stick to the fire position. I recommend that you do this at a high altitude the first few times, in case there is a trim change.

In case of an aborted launch, disarm the launch controller before approaching the rocket. Approach the rocket from the side, and disarm the onboard ignition before doing anything else.

Estimated Performance:

These figures are the result of computer analysis, for a 13 oz. flying weight, considering motor type and fluid dynamic drag (adjusted for varying Reynolds Number) of the rocket going straight up. Any squirrely behavior will reduce the performance.

Manufacturers Mentioned in Article

Jomar Products, 3440 Riverhills Dr., Cincinnati, Ohio 45244, (513) 271-3903

Aerotech, Inc. 1955 S. Palm St., Suite 15, Las Vegas, Nevada 89104, (702) 641-2301.

Estes Products are available from your local hobby shop.

Radio Shack has over 7,000 retail locations, check your Yellow Pages for the one near you.

National Association of Rocketry (NAR), 2518 Ridgecrest, Garland, Texas 75041.

Academy of Model Aeronautics (AMA), 5151 E. Memorial Dr., Muncie, Indiana 47302.

Tripoli High Power Rocket Association, P.O. Box 339, Kenner, Louisiana 70063-0339. □

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