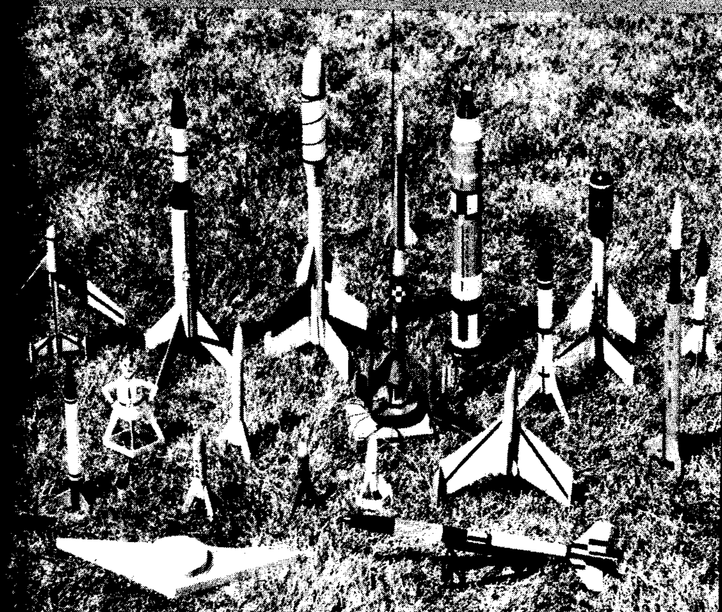
MODEL ROCKET MANUAL

Welcome to the exciting world of model rocketry! This brief technical manual for model rocketeers was written to provide both an easy to-follow guide for the beginner and a handy reference volume for the experienced rocketeer. In the next few pages you'll find the answers to the questions most commonly asked by model rocketeers. More complete technical information on all the subjects covered can be found in the many publications listed in the current Estes catalog.

We hope this manual will help make model rocketry as exciting and enjoyable for you as it is for us.



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YOUR FIRST ROCKET

BUILDING THE ASTRON ALPHA

A TYPICAL MODEL ROCKET

The construction of the Astron Alpha is shown here both to give the beginning rocketeer plans for a good first model and to illustrate the way a typical model rocket is built. The assembly techniques used in this and other model rockets are explained in greater detail on the following pages.

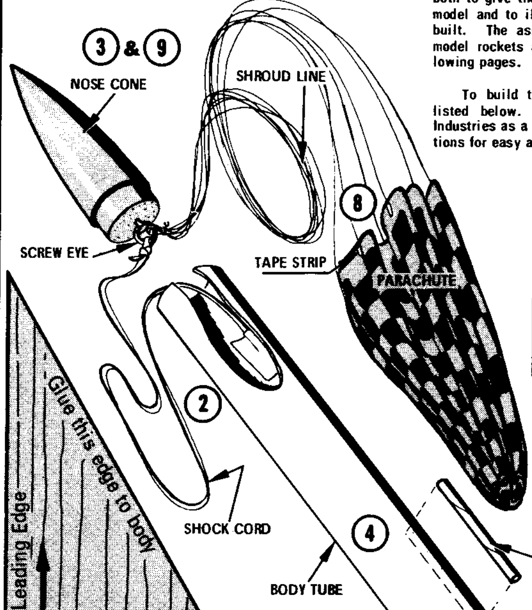
To build the Astron Alpha you will need the parts listed below. The Alpha is also available from Estes Industries as a complete kit (Kit #K-25) with detailed instructions for easy assembly.

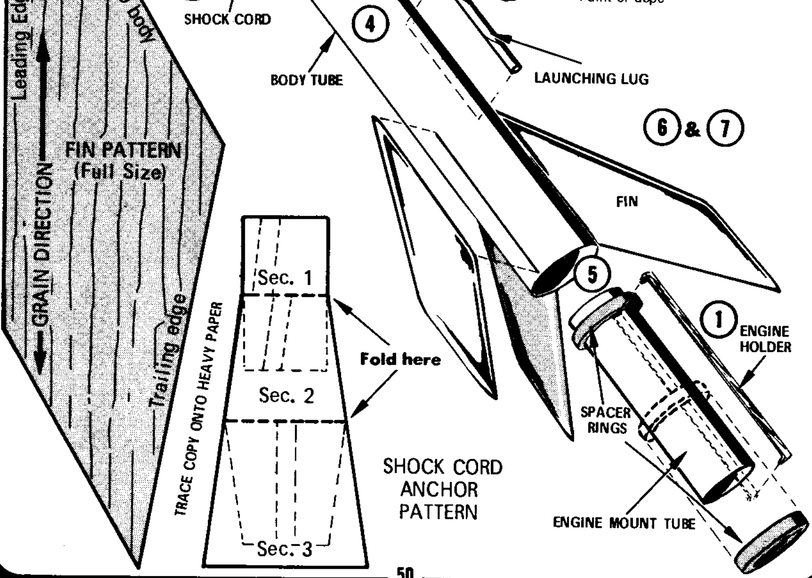
PARTS LIST

1 BODY TUBE - - Part #BT-50H
1 ENGINE MOUNT TUBE - - Part #BT-20J
1 NOSE CONE - - Part #BNC-50K
1 SHEET BALSA FIN STOCK - Part #BFS-30
1 ENGINE HOLDER - Part #EH-2
1 SHOCK CORD - - Part #SC-1
1 SCREW EYE - - Part #SE-1
1 LAUNCHING LUG - - Part #LL-2A
1 PARACHUTE - - Part #PK-12
2 SPACER RINGS - - Part #AR-2050

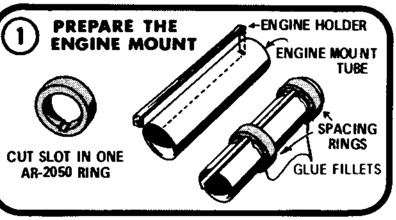
In addition you will need the following tools and supplies:

1 Modeling knife or razor blade
1 Tube extra strong white glue
1 Ball point pen or pencil
1 Sheet of extra fine sandpaper
Paint or dope

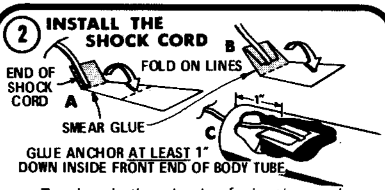




1 PREPARE THE ENGINE MOUNT



2 INSTALL THE SHOCK CORD

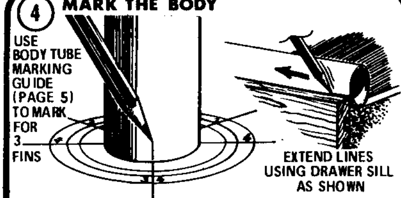


To absorb the shock of ejection and parachute opening a rubber cord connects the parachute and nose cone to the main rocket body. This shock cord must be securely attached to the body with an anchor as shown.

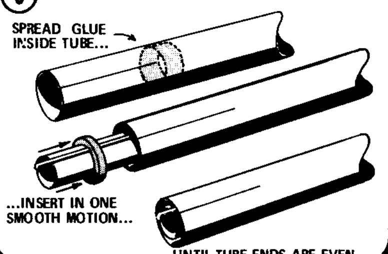
3 INSTALL THE SCREW EYE

Attach the screw eye to the nose cone as directed in section 3, page 53.

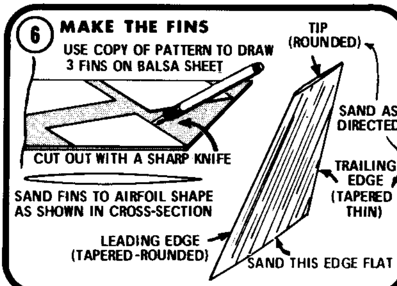
4 MARK THE BODY



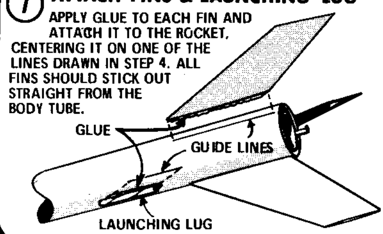
5 INSTALL THE ENGINE MOUNT



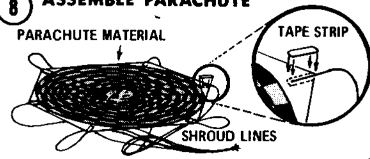
6 MAKE THE FINS



7 ATTACH FINS & LAUNCHING LUG

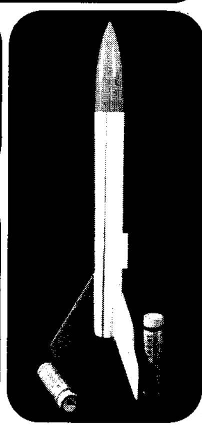


8 ASSEMBLE PARACHUTE



9 CONNECT IT ALL TOGETHER

Connect the nose cone, parachute and shock cord together as shown in the overall view on page 50.



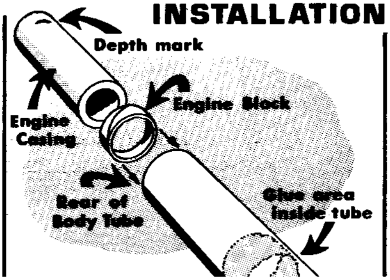
10 PAINT THE MODEL

Finish your model by sanding and painting it. See section 10, page 55 and the chapter on finishing (page 68) for detailed information.

CONSTRUCTION TECHNIQUES

① ENGINE MOUNTING METHODS

ENGINE BLOCK INSTALLATION



Some models use an engine block to keep the engine from traveling too far forward in the rocket body both when it is installed and when the rocket is launched.

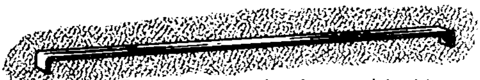
When building a model, use an engine casing to press the engine block into position. After applying glue to the inside of the tube, place the engine block just inside the rear of the body. Push the block forward into position with the engine casing in one smooth motion so the glue will not freeze the block in the wrong place.

When the mark on the engine casing is even with the rear of the body tube the block will then be in the correct position. Remove the engine casing immediately.

FRICTION FIT

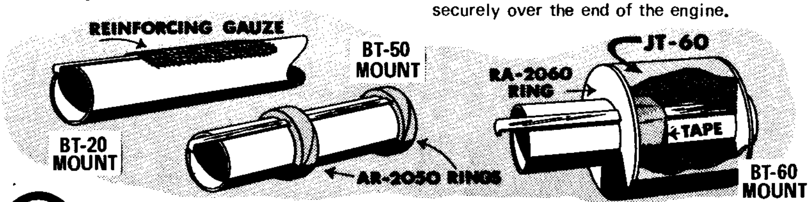
When mounting the engine in a model with an engine block, wrap the engine with masking tape until it will make a tight friction fit in the tube. Then slide the engine into place.

ENGINE HOLDERS

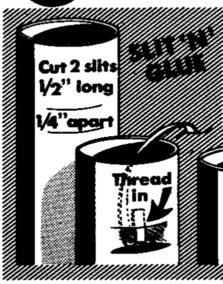


In many models an engine holder is the best device to use for mounting an engine. The drawings show how engine holders are mounted for different sizes of rockets.

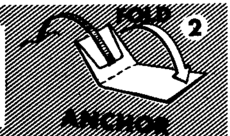
To mount an engine in a model with an engine holder, spring the end of the holder up and slide the engine into place. Check to make sure the end of the holder latches securely over the end of the engine.

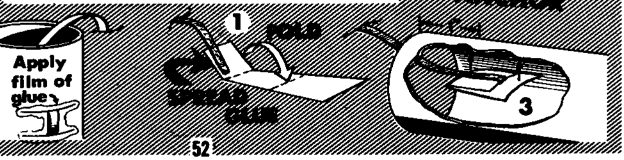


② SHOCK CORD MOUNTS

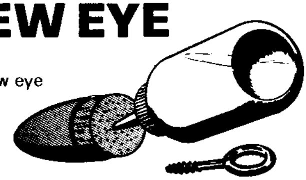


It's especially important to attach the shock cord securely. Both methods shown give good results. The "Slit-n-Glue" method is quicker; the "anchor" is neater, but can't be used on tubes smaller than BT-50.



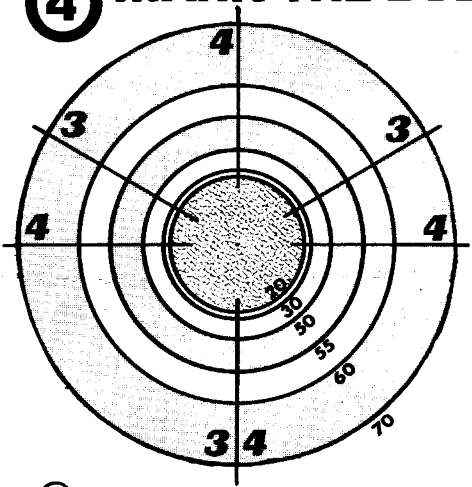


③ SECURING A SCREW EYE



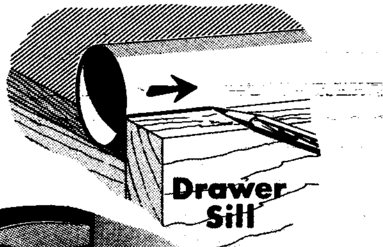
To avoid losing your nose cone, make sure the screw eye is securely attached. Make a hole by inserting and removing the eye. Squirt glue into the hole and replace the eye.

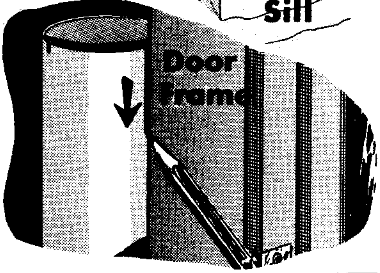
④ MARK THE BODY



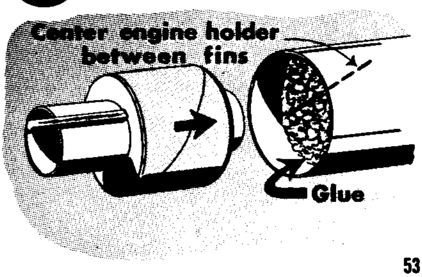
Ⓐ This Fin Spacing Guide will space equally three or four fins on all popular body tubes sold by Estes Industries. To space the fins, center the end of the tube in the circles, then mark at the (4) lines for four fins or on the (3) lines for three fins. Draw lines from these marks as shown in the drawings at right.

Ⓑ When marking the body tube for fin alignment, use the "V" notch of a drawer sill or door frame as shown. Match the edge of the notch with a spacing mark; run a pencil along the edge to draw your guide line. When all three or four lines are drawn, glue the fins to the body on the lines and they will be straight.





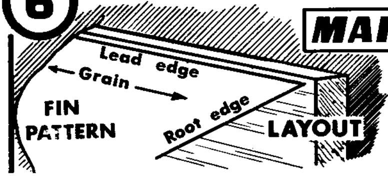
⑤ INSTALL THE ENGINE MOUNT

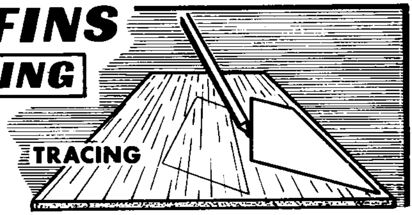


It's best to draw the fin alignment lines on the body *before* installing the engine mount. Position the mount so the engine holder is midway between two fin lines for easier operation. First make sure the mount slides easily in the body tube. If it's tight, sand it until it does slide easily. Smear a liberal amount of glue around the inside of the body over the area where the mount's rings or coupler will fit. Insert the mount into position in one smooth motion. DON'T pause, or the glue will "grab" with it in the wrong place. Support the tube "nose-up" while the glue dries.

6 MAKE THE FINS

MARKING

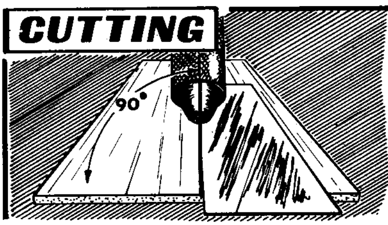


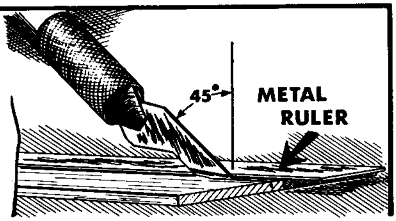


Model rocket fins are almost always made from thin sheets of balsa wood. When making fins, *always* be sure the grain of the wood is *parallel* to the leading edge of the fin.

Draw a full-size fin pattern on stiff paper or cardboard. Cut out the pattern, position it on the fin stock, and trace around it with a pencil or ball point pen to mark the balsa for each fin.

CUTTING





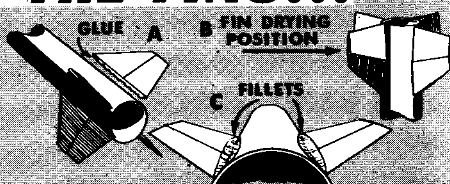
Use a metal straightedge whenever possible. Hold knife or saw blade at 90° angle to surface being cut, & handle at about 45° for clean cut. If blade is dull or held too high balsa tends to tear.

SHAPING

For general purposes, sand all edges round except the root edge (the edge that glues to the body). Make the root edge straight and square. The sides of the fins should be sanded smooth.

On high performance models try to sand the fins to the shape shown. The front (leading) edge of the fin should be slightly rounded; the back (trailing) edge should come to a knife edge.

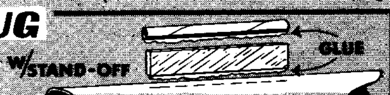
7 ATTACHING THE FINS...



Always use a high-strength adhesive such as white glue for attaching fins. After marking the tube and sanding the fins, apply a line of glue to the root edge of a fin. Let it set a minute or two, then press it into place on the body tube. Attach the other fins in the same way. Support the rocket body in a vertical position while the glue dries.

Sometime after the first glue on the fins has dried completely, the joints should be reinforced. Do this by applying a "fillet" of glue as shown. Always support the body in a *horizontal* position while fillets are drying.

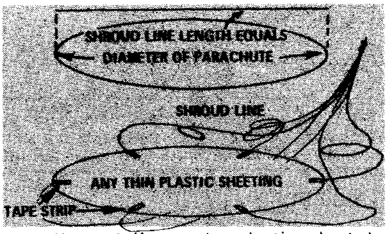
...and LAUNCHING LUG



Launch lugs are attached in much the same way as fins. If a stand-off is used to keep the rod from hitting a large diameter payload section, attach the lug to the stand-off piece first, then attach the unit to the body.

(8) ASSEMBLE PARACHUTE

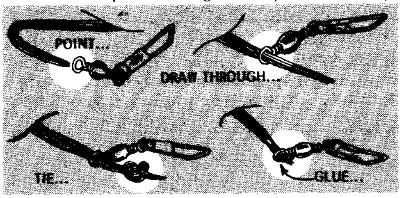
In addition to regular, pre-printed model rocket parachutes, a rocketeer can use a wide variety of thin plastic sheeting to slow his model's descent. When making a chute



from "scratch," cut the plastic sheet to shape, then attach 6 or 8 shroud lines, each as long as the diameter of the parachute, as shown. Gather all the loose ends of the shroud lines and tie a knot at the extreme end of the group.

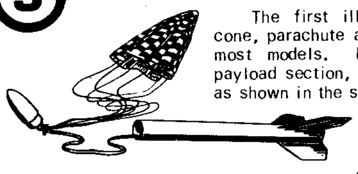
It's often worthwhile to be able to quickly switch a parachute from one model to another or to replace a 'chute with a new one.

To install a snap swivel, simply gather the ends of the shroud lines and dampen them so as to form a fairly stiff "point," then thread this point through the eye of the snap

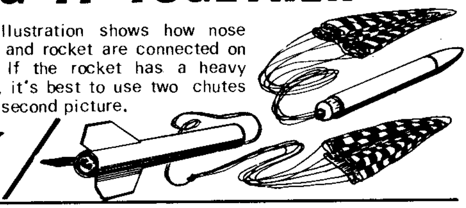


swivel as shown. Once through the eye the lines are tied together in a tight knot and pulled back against the eye. Apply a drop of glue to the knot.

(9) CONNECTING IT TOGETHER



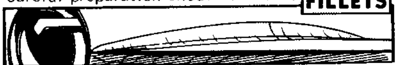
The first illustration shows how nose cone, parachute and rocket are connected on most models. If the rocket has a heavy payload section, it's best to use two chutes as shown in the second picture.



(10) PAINT THE MODEL

Nothing does quite as much for the appearance of a model as a good paint job. Before the paint can go on, though, a lot of careful preparation should be done.

FILLETS



Make sure all glue fillets are smooth and have no air holes. If a fillet isn't right, apply another layer of glue and smooth it out with your finger tip.

WOOD SEALING

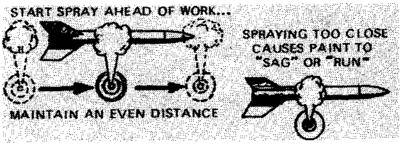
All balsa surfaces should be "filled." To do this, apply a coat of sanding sealer, let dry completely, and sand with extra-fine (or finer) sandpaper. Apply another coat, let dry, and sand again. Continue this procedure until all the tiny holes (pores) in the wood are filled and the surface is perfectly smooth.

. . BRUSH - ON PAINTS

If you use a brush, make sure the brush is clean. Old dope will mix with and discolor fresh dope. Dope can be thinned 50% for a smoother finish. Avoid "brushing over" as the surface sets rapidly. Unnecessary brushing can produce an uneven finish. Always let the paint dry completely between coats.

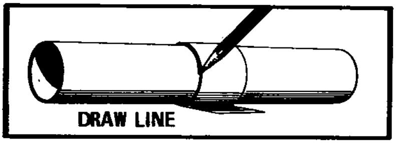
SPRAYING . . .

Spray paints will give the beginner a better than average finish. Apply spray paint in light, even coats. Let each coat dry completely before applying the next coat.

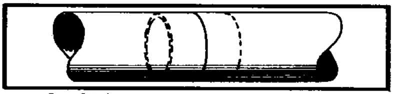


CUTTING TUBES

Many models call for special lengths of body tubes; the rocketeer has to cut the tube himself to build the rocket. Here's how to get a neat cut every time.

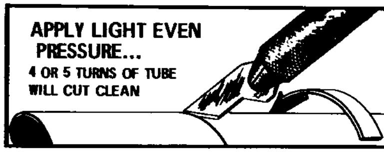


(1) Mark the tube at the point where the cut is to be made. Wrap a straight strip of paper around the tube and align the edge with the mark. Draw a line completely around the tube.

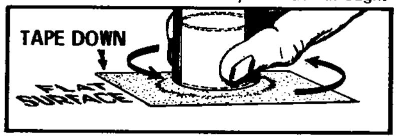


(2) Slide a stage coupler into the tube--center it under the cut position to support the tube.

(3) Cut lightly along the line, rotating the tube as you cut. Use a sharp blade but



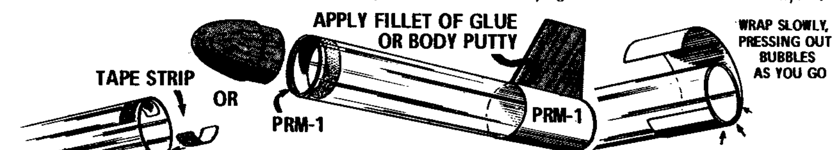
don't try to cut all the way through on the first turn. Use a light pressure on the knife for several turns until you cut through.



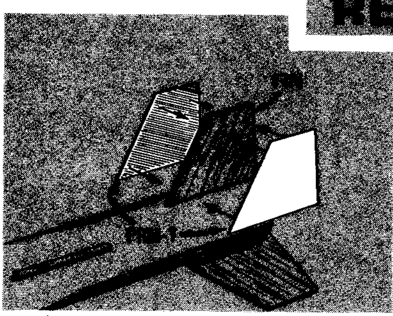
(4) Slide the stage coupler into the cut end of the tube. Hold the tube near the cut end and work it over a flat sheet of *very* fine sandpaper with a circular motion as shown to remove burrs and rough edges.

MYLAR BODIES

BT-10 is an ultra-light mylar plastic tube which is recommended for use with the featherweight recovery system. It will withstand the heat of an ejection charge only when the engine is ejected from the rocket body by the charge. Paper reinforcing material must be used to glue parts to the tube, as ordinary glues will not stick to mylar.



REINFORCING FINS

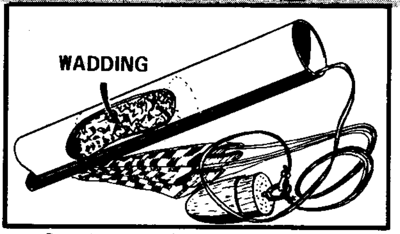


When a model is built to be flown many times, it's often wise to strengthen the fins. The easiest way of doing this is to use self-adhesive paper reinforcing material (PRM-1).

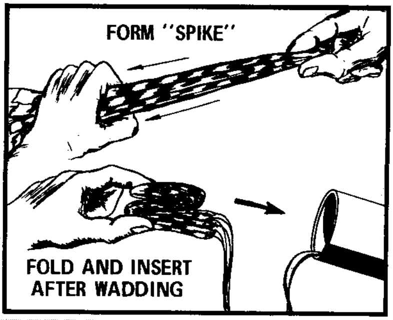
Cut out two "mirror-image" pieces of reinforcing material for each fin. Peel off the backing and apply one piece to each side of the fin. Rub the reinforcing down on both sides so it is securely attached, then seal around the edges with white glue.

Fins reinforced in this manner give up to four times the strength of plain balsa wood with only a little more weight.

Preparing for Flight

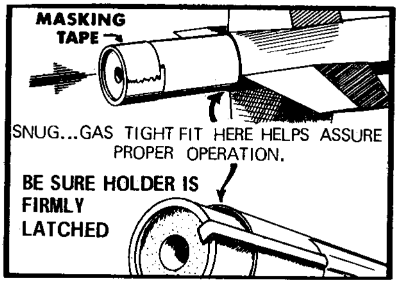


Parachutes and streamers must be protected from the heat of the ejection charge. This protection is supplied by first loosely packing enough flameproof recovery wadding into the tube to fill it for a depth of at least twice the body diameter. The wadding should fit against the side of the tube all the way around to give a good seal.



To fold the parachute, hold it between two fingers at its center and pass the other hand down it to form a "spike" shape. Fold this spike tightly into several sections as shown. Push the folded 'chute down into the tube on top of the wadding. Pack shroud lines and shock cord in on top of the 'chute, then slide the nose cone into place.

To activate streamer or parachute recovery gear correctly, the engine MUST be held in place SECURELY. This may be done by wrapping the nozzle end of the engine with tape until it makes a snug fit in the body tube or engine mount.



On models using engine holders, make sure the end of the holder latches securely over the end of the engine.

Countdown Checklist

Use a countdown check list when you launch your models. You'll find it makes your rocket flights more successful and enjoyable. The following procedure is recommended for most 'chute or streamer models. For other types of rockets, try to develop your own complete check list.

12) Pack flameproof recovery wadding into the body tube. Insert the parachute or streamer.

11) Install the nose cone or payload section. Check condition of the payload (if any).

10) Apply enough masking tape to the engine(s) for a tight friction fit in the body tube(s). When launching a multi-stage rocket be sure that the engines are in their proper relative positions and that a layer of cellophane tape is wrapped tightly around each engine joint. Mount the engine in the rocket.

9) Install a nichrome igniter in the engine.

8) Place the rocket on the launcher. Clean and attach the micro-clips.

7) Clear the area, check for low flying aircraft, alert recovery crew and trackers.

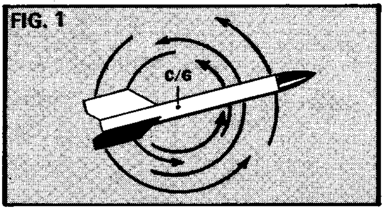
6) Arm the launch panel.

5) 4) 3) 2) 1) LAUNCH!

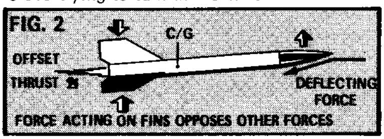
STABILITY

One of the first things a model rocket designer learns is that a vehicle will not fly unless it is *aerodynamically stable.* By stable we mean that it will tend to keep its nose pointed in the same direction throughout its upward flight. Good aerodynamic stability will keep the rocket on a true flight path even though some force (such as an off-center engine) tries to turn the model off course.

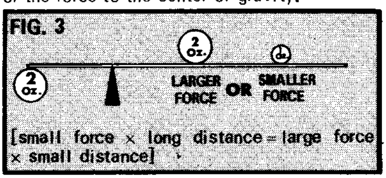
If a model is not stable, it will constantly turn its nose *away* from the intended flight path. As a result, it will try to go all over the sky, but end up going 'nowhere.' An unstable rocket will usually tumble to earth after the engine burns out, damaging the model.



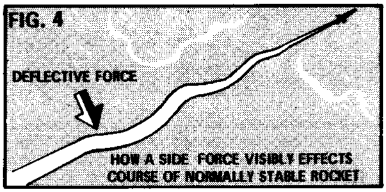
When a free-flying object rotates, it always rotates around its balance point. (The proper term for the balance point is the *center of gravity,* abbreviated as C.G.) Thus the balance point (C.G.) is the pivot for all forces trying to turn the rocket.



The most significant forces acting on a model rocket in flight are caused by the thrust of the engine, the action of air on the nose and the action of air on the fins. Off-center thrust and the forces on the nose try to bring the nose of the rocket around to the rear. They are opposed by the forces acting on the fins. All these forces are amplified by the distance from the location of the force to the center of gravity.

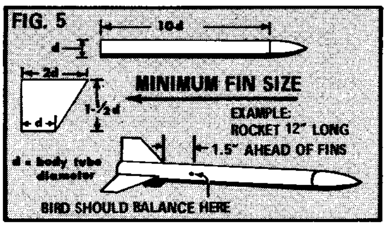


As long as the forces on the fins of the rocket are great enough to counteract the forces on the nose and any off-center thrust, the rocket will fly straight. If the fins are too small and/or too close to the center of gravity, there will not be enough force to counteract the force on the nose. As a result, the nose will swing out to the side and the model will try to chase itself around the sky.



The side forces on the nose and fins of a rocket that is flying straight are very small. When something disturbs the rocket and it starts to turn sideways, the side forces on both nose and tail increase. (There is some aerodynamic force on the body; however, it is small and can usually be ignored.) Depending on the size and shape of the nose and fins and their distances to the center of gravity, one will overpower the other and force the rocket to turn its way. If the nose overpowers the fins, it's too bad. However, if the fins overpower the nose, the rocket will swing back into line and continue on its way.

Although determining the exact relationships between various forces on a model rocket requires higher mathematics, certain practical rules can be used by even the beginning rocketeer to design stable rockets. The first rule is to use a long body. Until you have considerable experience in designing models, the length of the body tube used should be at least 10 times its diameter. This makes it easier to get enough distance between the center of gravity and the fins.



The second rule is to make the fins large. The larger the fins, the more force they will produce when the rocket starts to turn. For the first few designs, use a fin which is *at least* as large as the example in the illustration.

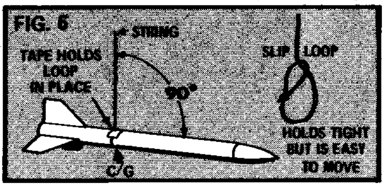
The third rule is to place the fins as far back on the rocket as possible. Generally, this means that the rear edge of the fin will meet the rear end of the body and the fin will be swept back. Do not place *any* fins ahead of the center of gravity.

Finally, the rocket should balance *at least* 1/8 its length ahead of the front of the fins. This gives the fins the leverage they will need to counteract the force on the nose.

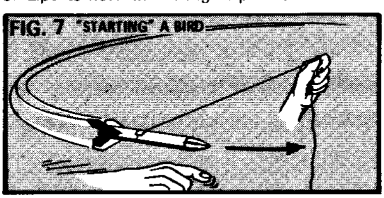
Remember that these rules are general; they are based on experience rather than precise mathematical analysis. By using more exact methods (See TR-1 and TR-9) it's possible to build rockets with less stability margin. In any event, *always* remember to test your model for stability *before* you launch it.

Testing for Stability

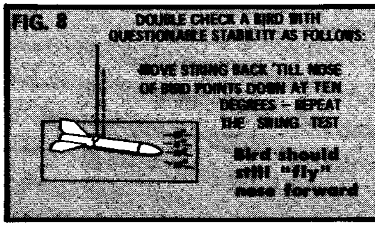
The easiest way of testing the stability of a model is to fly it--without launching it. This is done by attaching a string to the model and swinging it through the air. If the string is attached at the rocket's CG, its behavior as it is swung through the air will indicate what it will do in powered flight.



Make the test on your model by forming a loop in the end of a six to ten foot string. Install an engine in the rocket. (The center of gravity is always determined with an engine in place.) Slide the loop to the proper position around the rocket so the model balances horizontally. Apply a small piece of tape to hold the string in place.



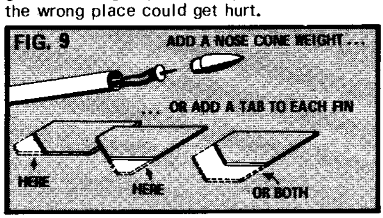
With the rocket suspended at its center of gravity, swing it overhead in a circular path. If the rocket is very stable, it will point forward into the wind created by its own motion. Some rockets which are stable will not point forward of their own accord unless they are started straight. This is done by holding the rocket in one hand with the arm extended and then pivoting the entire body as the rocket is started in the circular path. It may take several attempts before a good start is achieved.



If it is necessary to hold the rocket to start it, an additional test should be made to determine whether the model is stable enough to fly. Move the loop *back* on the body until the tube points down at a 10° angle *below* the horizontal. Repeat the swing test. If the model will keep its nose pointed ahead once started, it should be stable enough to launch.

Be careful when swinging a rocket overhead: A collision with a nearby object or person could be serious. Always do your testing in an open, uncluttered area.

Don't try to fly a rocket that has not passed the test. Most unstable rockets loop around in the air harmlessly. However, a few marginally unstable models will make a couple of loops and then become stable due to the lessening of the propellant load. When this happens, the model can crash into the ground at high speed. A person standing in the wrong place could get hurt.

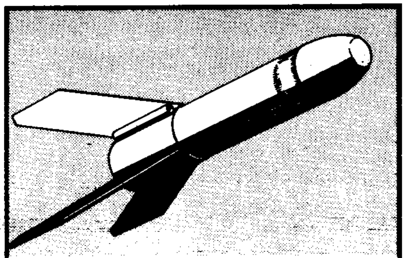


If your rocket does not pass the stability test, it can usually be made stable. Two methods can be used: The balance point can be moved forward or the fins can be enlarged. To move the balance point forward, attach nose cone weights to the base of the nose cone. Fins can either be replaced with larger ones or extra tabs can be glued to the rear or tip edges of the fins. (Some scale models use supplementary plastic fins.) After making your changes, test the model again to be sure it is now stable.

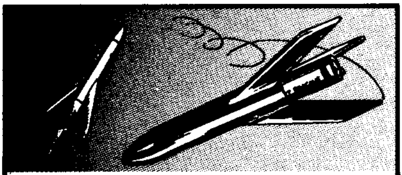
RECOVERY SYSTEMS

The recovery system is one of the most important parts of a model rocket. It is designed to provide a safe means of returning the rocket and its payload to earth without damaging the rocket or presenting a hazard to persons on the ground. Also, the recovery system provides an area for competition when rocketeers hold contests to see whose rocket can remain aloft the longest. In addition, rocket recovery is an area for valuable experimentation and research as rocketeers develop new and better methods of returning their models to earth or study air currents.

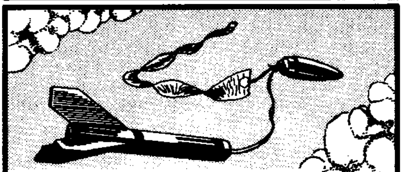
Most recovery systems in use today depend on drag (or wind resistance) to slow the rocket. Each changes the model from a streamlined object to one which the air can "catch against" and retard its descent. Six main recovery methods are used by model rocketeers today. Following is a brief description of each:



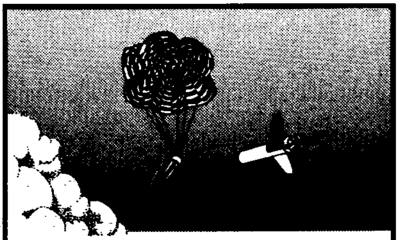
1. Featherweight Recovery (i.e. Astron Streak): The model is designed for extra light weight (under 1/4 ounce without engine) and has a blunt nose. When the engine is ejected from the rocket, the model is so light compared to its size that it lands safely. The lightweight, aerodynamically unstable, spent engine casing tumbles back separately.



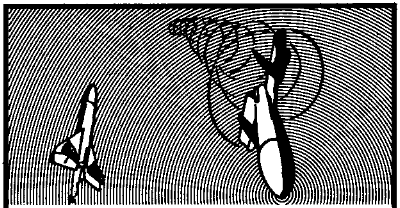
2. Tumble Recovery (i.e. Astron Scout, Sprite): The ejection charge shifts the weight of the engine in the rocket rearward. This makes the rocket unstable. With the balance point of the rocket further toward the rear, air pressures ahead of the balance point are greater than behind, forcing the rocket to start turning. When the rocket is tumbling, air drag on it is much higher and it falls slowly. Estes Pat. No. 3,114,317



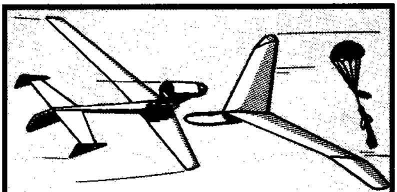
3. Streamer Recovery (i.e. Astron Mark): A model with a small streamer will act like a tumble model. If the streamer is large though, it develops enough drag by fluttering to actually hold the rocket back in its descent and it lands gently.



4. Parachute Recovery (i.e. Astron Alpha): The ejection charge forces a parachute connected to the model out of its body tube. The parachute deploys, filling with air, and supports the model on its return.



5. Helicopter Recovery (i.e. Astron Gyroc): Vanes on the model, activated by the ejection charge, catch the air in a way that makes them spin on the way down. The spinning vanes disturb the flow of air past the rocket creating a large amount of drag.

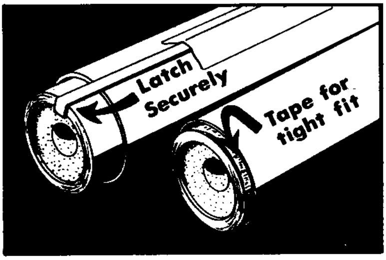


6. Glide Recovery (i.e. Astron Falcon, Nighthawk): The model ascends vertically like a conventional rocket. At ejection either the balance of the model or the position of its aerodynamic surfaces is changed. Instead of streamlining straight down, the wings generate lift, pulling the nose up, and the model goes into a glide. Models of this type are called "Boost-gliders". Estes Pat. No. 3,157,960. Other pat. pending.

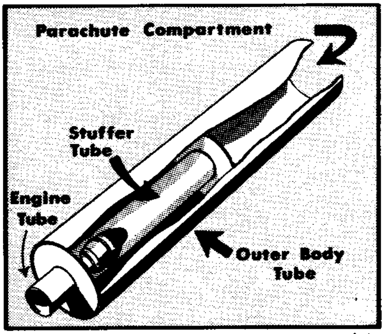
Reliable Recovery

No rocketeer likes to see the product of many hours' labor broken because the recovery system didn't work properly. Recovery failures are almost always due to an error in building the model or in preparing it for flight.

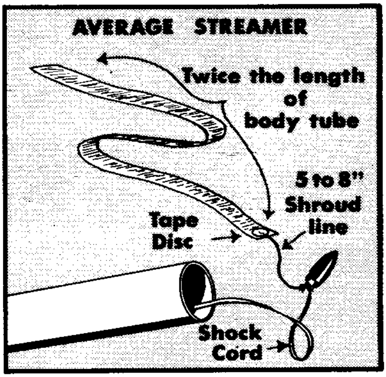
The most common error on parachute and streamer models is failing to install the engine properly. If the engine is not held securely, it will be ejected instead of the streamer or parachute. On models with engine holder hooks, make sure the hook latches properly over the end of the engine. If the model relies on a friction fit to hold the engine, wrap enough masking tape around the engine to make it fit *tightly*.



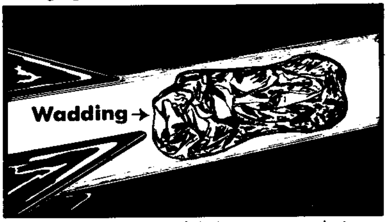
A second error is leaving a hole that ejection gasses can leak through. Incorrect engine mount design or construction is often the villain. For reliable recovery the rear of the rocket *must* be air tight when an engine is in place.



Recovery reliability on extra-large models can be improved by using a stuffer tube. This reduces the volume that the ejection charge must pressurize, resulting in more force to eject the nose cone and 'chute. A stuffer usually is made from BT-20 or BT-50 body tube, centered inside the model's body, with paper rings glued on each end. The rings should also be glued to the inside of the body so there is no gas leakage into the space between the stuffer and outer body tube.



For high altitude models parachute recovery is often too good; the bird can be miles away by the time it finally touches down. Streamer recovery is often the answer. A strip of 1" wide flameproof crepe paper, usually at least twice as long as the rocket itself, will supply enough drag at the nose to make the rocket fall sideways. In this condition it falls enough faster than with a parachute to bring it back close to the launch area. It falls slow enough, however, to avoid damaging the model.



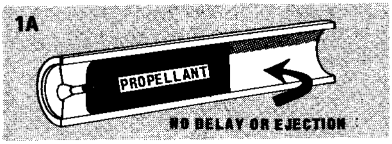
Whether the model has a parachute or streamer, always be sure to use enough flameproof wadding. The wadding not only serves as an insulating layer between the hot ejection gases and the 'chute or streamer; it also works as a gas seal and piston to insure that the ejection charge works evenly against the recovery device. Wadding should be *loosely* packed, filling the entire area of the tube for a distance equal to twice its diameter.

By following these suggestions, you'll find you get many more successful flights. Not only will your models last longer, but you'll also find that reliable recovery makes model rocketry more enjoyable.

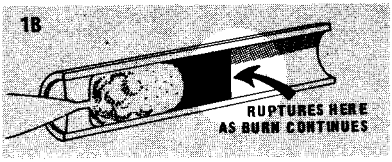
MULTI-STAGING

Ignition

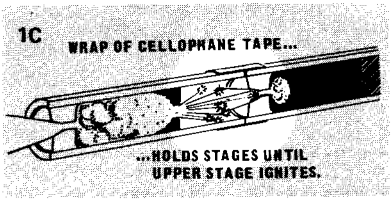
The first stage of a multi-stage rocket is always ignited by standard electrical means. Second stage ignition occurs automatically upon burnout of the first stage. Figure 1A



shows that the first stage engine has no delay or ejection charge. This gives instant ignition of the next stage at burnout.



In figure 1B the propellant is partially burned, leaving a large combustion chamber. As the propellant continues to burn, the wall of propellant becomes thinner until it cannot withstand the high pressure inside the chamber. At this point the remaining propellant wall ruptures, and the high pressure exhausts forward toward the nozzle of the next stage, carrying hot gases and small pieces of burning propellant into the nozzle of the second stage engine. This action is illustrated in figure 1C.



For this system to work, the stages must be held together until the upper stage engine has ignited. When this happens, the stages must then separate in a straight line. This is accomplished by wrapping one layer of cellophane tape around the joint between engines and then recessing this joint 1/2" rearward in the booster body tube, as in fig. 2. Recessing the joint forces the stages to separate in a straight line.

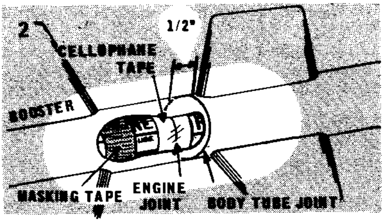
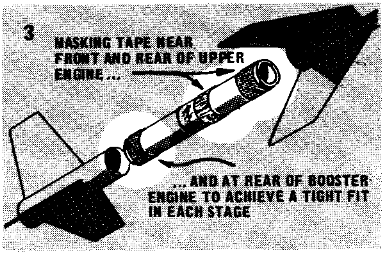
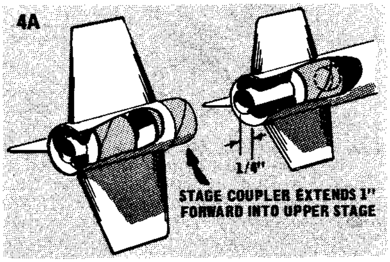


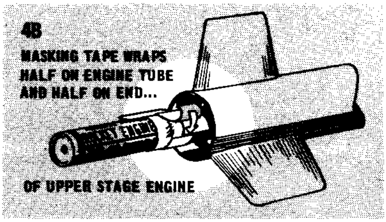
Figure 2 shows the engine installation in a typical two-stage model. Always tape the engines together before inserting them into the rocket. Check carefully before and after taping to be sure the engines are in their proper positions (nozzle of upper stage engine against top end of booster engine). Failure to check carefully can be highly embarrassing as well as damaging to the rocket.



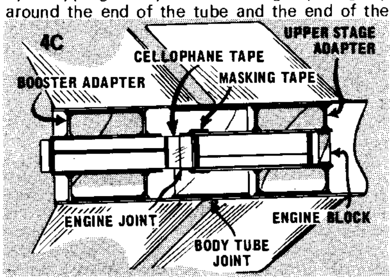
After taping the engines together, wrap masking tape around the upper stage engine at the front and near the rear as in fig. 3 to give it a *tight* fit in the body. Push it into place. Wrap the booster engine and push it into position. Failure to get the upper stage engine in place tightly enough will result in the recovery system misfunctioning; failure to secure the booster stage tightly can result in its dropping off under acceleration.



Rockets using large diameter tubes (BT-50 and BT-60) require somewhat different methods, but the same principles of tight coupling and straight line separation must be followed. The recommended coupling method for large diameter tubes is illustrated in fig. 4. The stage coupler is glued to the booster body tube, with the adapter for the upper stage engine mount positioned forward to allow the stage coupler to fit into the upper stage, while the tube adapter in the booster is positioned to the rear.

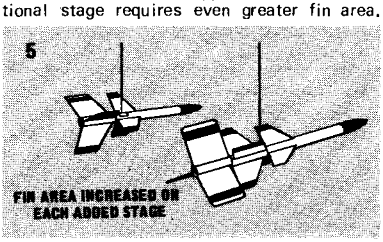


The upper stage engine holder tube projects 1/4" rearward from the end of the upper body tube. The engine is held in place by wrapping a layer of masking tape *tightly* around the end of the tube and the end of the engine as in fig. 4B. The engine mount in the booster must be built to leave space for this system (see fig. 4C).



Stability

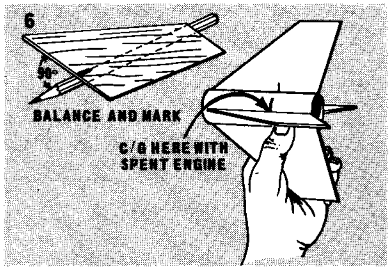
Since two or more engines are mounted near the rear of a multi-stage rocket, it has a tendency to be tail-heavy. To compensate for this, extra large fins are used on lower stage. Generally, the lower set of fins on a two-stage rocket should have two to three times the area of the upper set. Each additional stage requires even greater fin area.



When checking for stability, test first the upper stage alone, then add the next lower stage and test, and so on. In this way you can be sure that the rocket will be stable in each step of its flight, and you can locate any stage which does not have sufficient fin area. Always check for stability with the largest engines to be used in place.

Booster Recovery

Most lower stages are designed to be unstable after separation. The booster should be built so that the center of the area of the fin (its balance point) matches or is up to 1/4" ahead of the booster's balance point with an expended engine casing in place. Thus, boosters will require no parachute or streamer, but will normally tumble, flutter or glide back to the ground. If the booster is to be used again, it should be painted an especially bright color, as it does not have a parachute or streamer to aid in spotting it once it is on the ground.



Types of Engines

Lower and intermediate stages always use engines which have no delay and tracking charge, and no parachute ejection charge. There is no delay so that the next stage will receive the maximum velocity from its booster. The engines which are suitable are those which have designations ending in zero, such as the A8-0, B6-0, 1/2A6-0S, and B14-0.

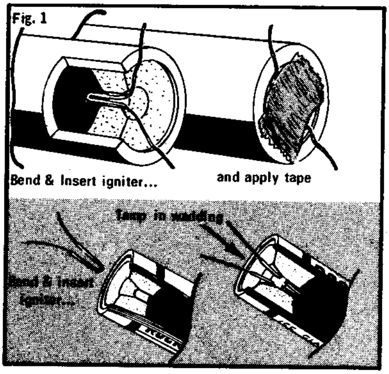
In the upper stage an engine with a delay and tracking charge and parachute ejection charge is used. As a general rule the longest possible delay should be used. Engines suitable for upper stage use are those with long delays such as the B6-6, A8-5, C6-7, etc.

LAUNCHING

Model rockets, like professional rockets, are launched electrically. This provides both safety and realism. Each engine sold by Estes Industries is supplied with an igniter and complete instructions; still more information is supplied with launcher kits. However, the basic information needed to launch models successfully is included in these pages.

Igniter Installation

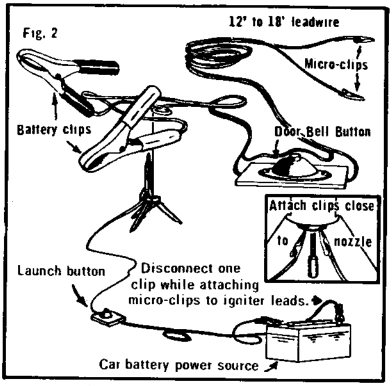
Estes igniters are supplied in strips of three. Cut the igniters apart (scissors will work) midway between the coated sections. Bend the igniter at the middle as shown and push it into the engine as far as it will go. To operate properly the igniter must touch the propellant grain. Spread the leads and apply a square of masking tape to the nozzle and leads as shown in Fig. 1. The eraser on the end of a pencil is good for pressing the tape securely into place.



An igniter can also be held in place by rolling a 1" square of flameproof wadding into a ball and inserting it into the nozzle with a pen or pencil to hold the igniter firmly in place.

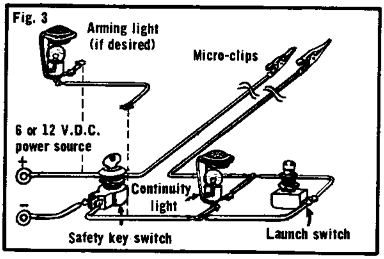
Electrical Systems

The electrical system which operates the igniter can be made in many ways. It can be a simple home-made unit, as the one shown in Fig. 2, or it can be one of the more complete systems sold by Estes Industries.

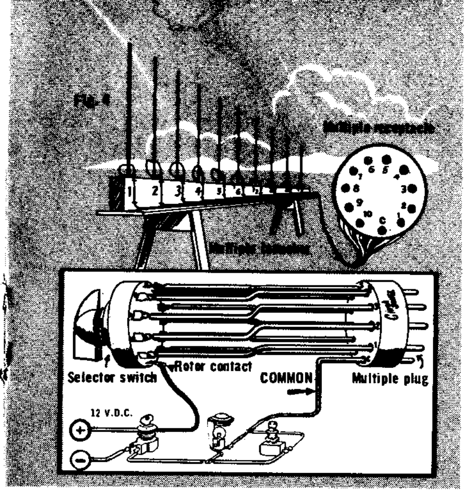


All of these systems work by passing enough electrical current through the high-resistance igniter to heat it to 1100°F. This ignites the coating on the igniter which in turn ignites the engine. The system is attached to the igniter with micro-clips as shown. When connecting the micro-clips to the igniter make sure the clips do not touch each other or the rod or blast deflector. If they do touch, the current from the battery will "short" through the clips, rod or deflector and not reach the igniter.

Any electrical system *must* have a spring-return launch switch so the current turns off automatically when the button is released. In addition a safety disconnect must be provided. On simple systems the battery clips should be disconnected when the micro-clips are being attached to the igniter. More complete systems may have safety key switches or safety plugs to do the same job.



The circuit shown in Fig. 3 also includes a continuity check pilot light. This is a small bulb (no more than ¼ ampere for safety) which lights when the safety interlock is closed *if* the clips make good connections at both the battery and the igniter. When lit, it indicates that the rocket can be launched.

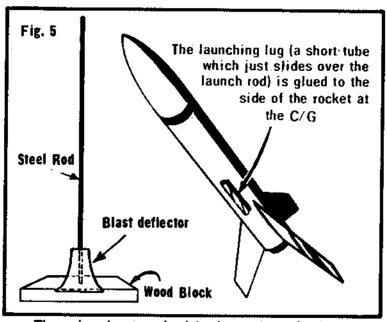


Most rocket clubs prefer a multiple launcher system for group launchings. The basic electrical circuit can be adapted by adding a rotary "pad selector" switch as shown in Fig. 4. Each launch pad then has *one* micro-clip which is connected to the "common" line to the battery and *one* micro-clip which is connected to one of the individual terminals on the selector switch.

Launcher Design

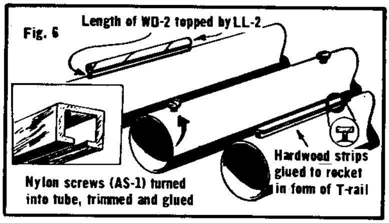
A rocket cannot be simply set on its fins and launched; some method of holding it in position before ignition and guiding it during the first few feet of its flight is necessary. The launcher must perform these functions.

Fig. 5



The simplest suitable launcher design uses a wood block to support a 36" long, 1/8" diameter steel rod. A short tube, slightly larger than the rod, is glued to the side of the rocket near its balance point. This tube slips easily over the rod and keeps the rocket pointed in the right direction. Fig. 5 shows a rod launching system.

Fig. 6



Some launching guides are designed to fit around the lug instead of inside it. The "C" rail is typical of these. Rails generally have the advantage of being stronger and more rigid than rods. However, most model rockets will fly very well with either system. Fig. 6 illustrates a rail and some lugs to fit.

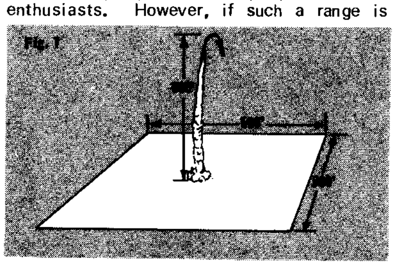
When building a launcher be sure to use a base that is big enough and heavy enough to provide a secure foundation. A piece of 3/4" plywood a foot square works well for most rockets. Bricks or rocks can be used to weight the base when extra-large models are being launched.

Safety

Make sure the area around the launcher is clear and has no dry weeds or highly flammable materials. When approaching the launcher to mount a rocket or check it, put your hand on the end of the rod before leaning over. This helps protect you against the possibility of eye injury from the rod.

Launch Areas

The best place to fly models is on a model rocket range. Many such ranges have been set up by organized groups of rocket enthusiasts. However, if such a range is

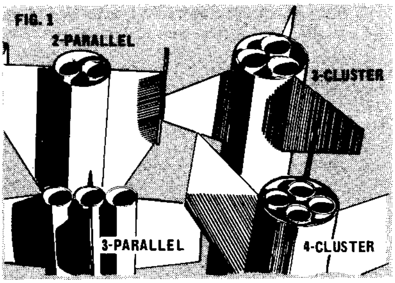


not available, it is best to select a place, free of trees and houses, large enough to recover the rocket within the area. Generally the field should be at least 300 to 500 feet on a side. Set the launcher at the center of the area as shown in Fig. 7.

CLUSTERING

When large models and heavy payloads have to be launched, one engine often cannot supply enough power. A cluster of several engines is generally the answer to this problem.

ENGINE ARRANGEMENTS



In designing a clustered model the first rule to remember is that thrust must be balanced around the centerline of the rocket. Figure 1 shows several engine arrangements that satisfy this requirement. All engines should be located close together to keep unbalanced thrust from forcing the model off course.

ENGINE MOUNTING

The engine mounting system serves three purposes: First, it holds the engines securely in place throughout the flight. Second, it aligns the engines so they work together as a unit and give a straight flight. Finally, it must seal the rear of the rocket so that recovery system ejection gases cannot leak out through cracks and holes in the back of the model.

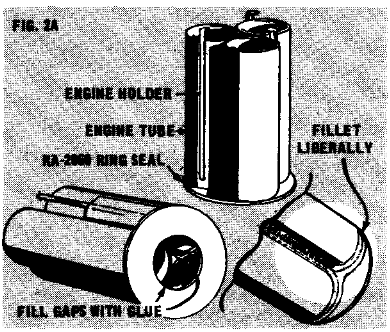
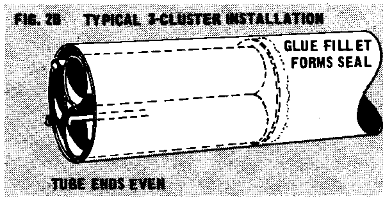
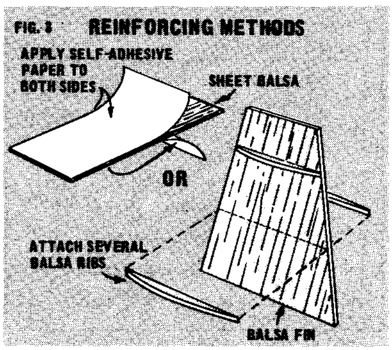


Figure 2 shows a typical engine mounting system for a three-engine model. The spaces between tubes are sealed at the front of the engine mounting tubes by gluing an adapter ring which fits the inside of the body in place as shown. To install the engine mount, smear a liberal amount of glue around the inside of the rear of the body tube. Immediately slide the engine mount unit into place so the rear of the engine mount tubes is even with the rear of the body and the engine retainer hooks project from the tube. Do not pause while inserting the engine mount or the glue may stick with the mount in the wrong place. Set the unit on its *rear* end while the glue dries.

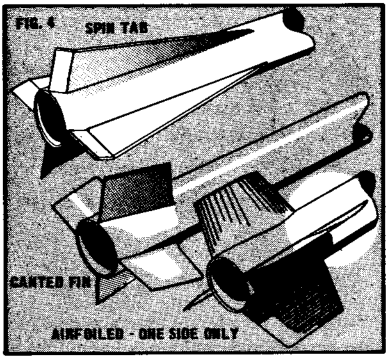


STABILITY

Because the weight of several engines is concentrated in the rear of a cluster rocket, extra attention should be given to designing the rocket so it is stable. Since the engines will not always all be producing exactly the same amount of thrust at the same time, an extra margin of stability is needed. Pay extra attention to the rules in the stability chapter.



The extra load on a cluster model's fins requires that they be made extra strong. One-eighth inch thick balsa sheet is the most popular fin material for cluster birds. Thinner fin stock can be used, but it should be reinforced for best results.



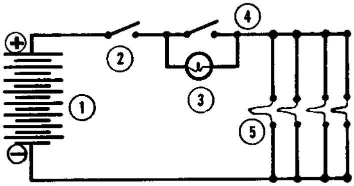
A small amount of spin helps give straighter flights by averaging out uneven thrust. (Too much spin increases drag and reduces performance.) Three methods of providing spin are illustrated. With any system, make sure that all fins or tabs are made to spin the rocket in the same direction.

IGNITION

Ignition is the most important part of successful clustering. All engines must be ignited at the same time. To do this, always use a 12 volt car battery for the power supply and a heavy duty electrical system (such as the Estes FS-5 Launch Control System). Install the igniters carefully and connect them in parallel.

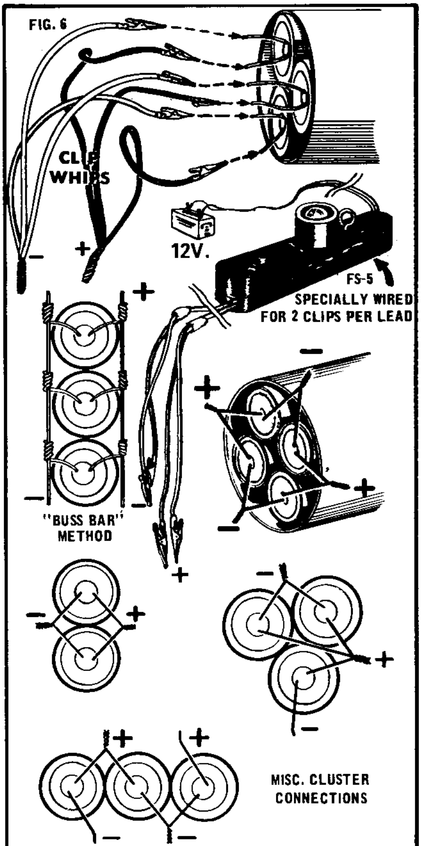
Several typical methods of connecting ingiters are shown in figures 5 and 6. Make connections carefully to get good contact and to avoid pulling the igniters from the engines. Always connect igniters in parallel--*never* in series.

FIG. 5 TYPICAL SYSTEM TO IGNITE UP TO 4-ENGINE CLUSTER



1. 12 V. CAR BATTERY
2. SYSTEM ARMING SWITCH
3. CONTINUITY CHECK LIGHT
4. FIRING SWITCH
5. IGNITERS CONNECTED IN PARALLEL

FIG. 6

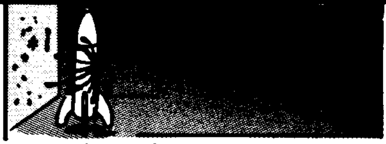


GENERAL INFORMATION

Use a heavy-duty launcher such as the Tilt-a-Pad with cluster models. When heavy rockets are being flown, the launcher should be anchored to the ground with rocks or bricks.

Before installing the engines in your cluster rocket, pack the front of each engine above the ejection end cap with flame-proof wadding. This eliminates the possibility of one engine's ejection charge igniting the ejection charge of another engine and damaging the rocket when one engine in a cluster fails to ignite at lift-off. For more complete information on clustering, see Estes Technical Report #TR-6.

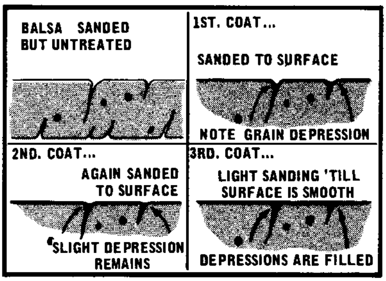
FINISHING



The finish of a rocket starts with the very first steps of assembly. Sloppy gluing and other messy habits will ruin the appearance of a rocket so that nothing can be done to get the perfect appearance which is desired. On the other hand, careful construction will make a model look good even before the paint is applied.

SANDING and SEALING

Paint cannot replace sandpaper. If a balsa surface is not sanded and sealed carefully, it will be impossible to get a smooth paint job. Begin by sanding all balsa surfaces with extra-fine sandpaper until smooth.

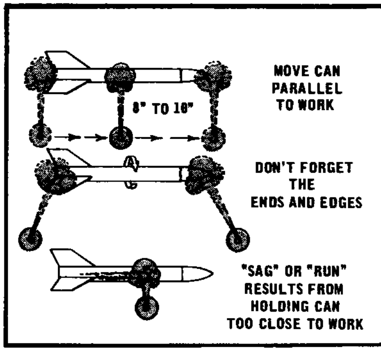


Next, apply a coat of sanding sealer to the balsa. Let this dry completely, then sand with 320 grit (or finer) sandpaper until the surface is smooth again. Apply more sealer, repeating the procedure until all the pores in the balsa are filled.

Practically all of the sealer should be sanded off after each coat. This is because the purpose of the sander is to fill the holes, not the smooth areas of the balsa.

BASE COLOR

Once you feel the balsa surfaces are prepared, it's time to apply the base color. The base color is the lightest of the colors to be used on the model. Usually this will be white. If the model is to be painted with fluorescent colors, the base coat *must be white.*

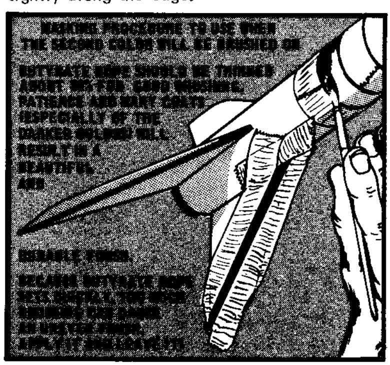


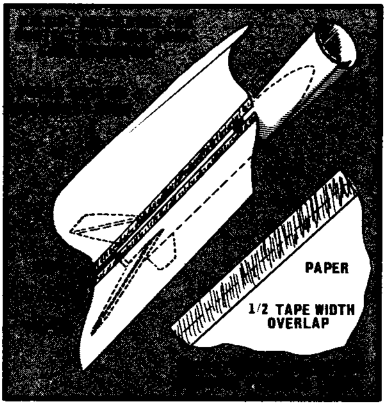
Apply a light, even coat of the base color and set the model aside to dry. Always spray or brush thin coats; thick ones dry slow and tend to "sag". When the first coat has dried completely, sand lightly with extremely fine sandpaper. Wipe any dust off with a clean, slightly damp cloth and apply another coat. Let this dry, then follow with additional light coats until the model has a clear, pure color.

Let the base coat dry completely. Allow at least four hours in a warm, dust-free area (a day is better when possible). Don't let the temperature get over 120° while the model is drying.

THE SECOND COLOR

When the base color has dried, cover all areas on the model which are to remain this color. Cover small areas with masking tape. Large areas should be covered with typing paper, held down at the edges with masking tape. It's important to seal the tape down tightly along the edge.

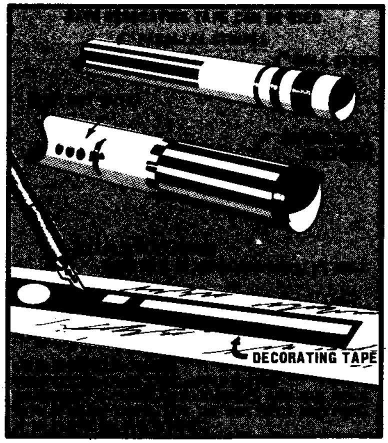




With the model masked, apply an additional thin coat of the first color to finish sealing the edges of the tape. When this is dry, apply the second color in several thin coats. Use just enough paint to get good color. After the last coat is dry, remove the masking carefully to avoid peeling the paint. A third color would be applied in the same way as the second.

For best results let the paint dry overnight before applying decals. Most decals should be soaked in lukewarm water for

30 seconds or until they slide on their backing sheets. The decal is then slid so one edge is off the backing. This edge is positioned and held in place on the rocket and the backing pulled out from under. Smooth the decal down with a damp finger and blot away any excess water with a rag.

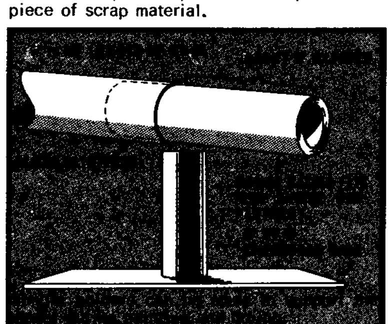


Stripes and bands may be made of either decal material or decorating tape. The pieces should be cut to size before application.

When a model has been finished with fluorescent paint, apply a light coat of clear spray before applying tape or decals. With any paint finish, it is best to apply several coats of clear after the decals have dried to protect them.

Wax may be applied over most enamel or butyrate finishes, but never directly over fluorescent paints. Test the finish to be waxed by applying the wax to an inconspicuous corner of the model or a scrap of tubing with the same paint finish. Some paints will rub off when wax is applied.

NOTE: Enamel paint may be applied over butyrate dope, but NEVER APPLY BUTYRATE DOPE OVER ENAMEL PAINT. If in doubt, test the compatibility of different paints on a piece of scrap material.



TRACKING

Every rocketeer wants to know how high his models fly. Many methods of determining a model's peak altitude have been tried, but only one method has proven itself. This method is known as triangulation.

The simplest form of triangulation uses only one very simple tracking device. With it, the rocketeer measures the angle between the ground and the line of sight to the rocket at its peak altitude. When this angle and the distance from tracker to launcher are known, it is very easy to determine the altitude.

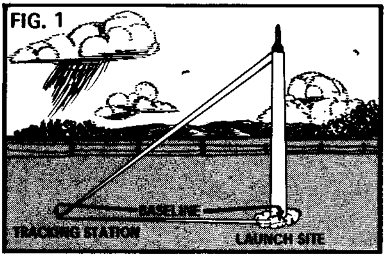


FIG. 1

TRACKERS

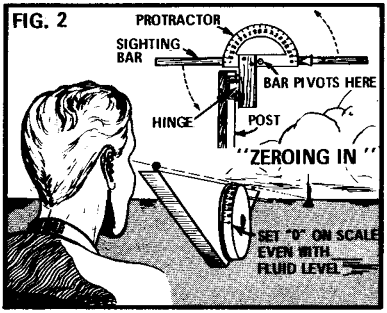


FIG. 2

The Estes Altiscope is one of the best all-around basic tracking devices. However, the rocketeer can also easily make his own tracker. An inexpensive plastic protractor, mounted securely on a post set in the ground, with a sighting stick pivoted at the "center" of the protractor, will do the job. The tracking device must be set so that it reads 0° when aimed at the rocket on the launcher and 90° when aimed straight up. If the tracker is not "zeroed in" on the launcher, it will give incorrect information.

When the operator at the tracking station is ready, the rocket is launched. He follows the rocket with his tracker as it rises. When it reaches its peak altitude he stops or locks the tracker. The indicated angle is then read from the protractor scale.

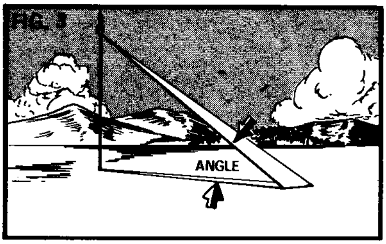
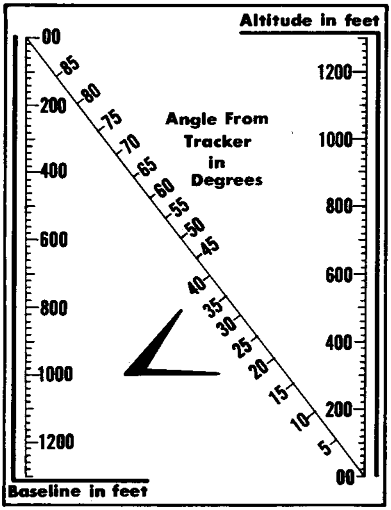


FIG. 3

The <u>tangent</u> of this angle is found by checking the table on the next page. Multiply the tangent by the distance from tracker to launcher (baseline distance) to find the altitude.



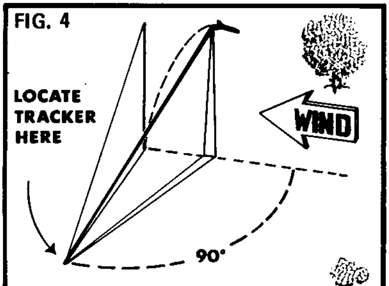
The chart above, called a <u>nomogram</u>, provides a simpler, quicker but less precise

TABLE OF TANGENTS

Angle	Tan.	Angle	Tan.	Angle	Tan.
1°	.02	28°	.53	54°	1.38
2	.03	29	.55	55	1.43
3	.05	30	.58	56	1.48
4	.07	31	.60	57	1.54
5	.09	32	.62	58	1.60
6	.11	33	.65	59	1.66
7	.12	34	.67	60	1.73
8	.14	35	.70	61	1.80
9	.16	36	.73	62	1.88
10	.18	37	.75	63	1.96
11	.19	38	.78	64	2.05
12	.21	39	.81	65	2.14
13	.23	40	.84	66	2.25
14	.25	41	.87	67	2.36
15	.27	42	.90	68	2.48
16	.29	43	.93	69	2.61
17	.31	44	.97	70	2.75
18	.32	45	1.00	71	2.90
19	.34	46	1.04	72	3.08
20	.36	47	1.07	73	3.27
21	.38	48	1.11	74	3.49
22	.40	49	1.15	75	3.73
23	.42	50	1.19	76	4.01
24	.45	51	1.23	77	4.33
25	.47	52	1.28	78	4.70
26	.49	53	1.33	79	5.14
27	.51			80	5.67

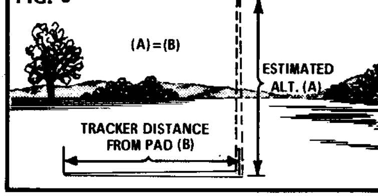
method for performing the altitude calculation. Draw a straight line from the correct baseline point on the chart, through the measured angle and on across the altitude scale. The correct altitude is the point at which the line crosses the altitude scale.

FIG. 4



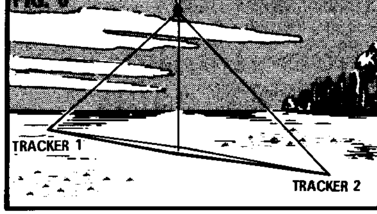
A single tracker will give best results on calm days. Wind interferes with accuracy since models tend to tilt over into the wind as they fly. The result is that the rocket will not be straight over the launch site at peak altitude, but instead will be some distance over in the direction of the wind. To keep error due to wind drift to a minimum, locate the tracker at a 90° angle to the wind direction as shown.

FIG. 5



In determining where to locate a tracking station, estimate the altitude your model will reach. The tracking station should be approximately this distance from the launcher (usually 500 to 1000 feet). Measure the distance from launcher to tracker carefully to insure accurate altitude calculations.

FIG. 6



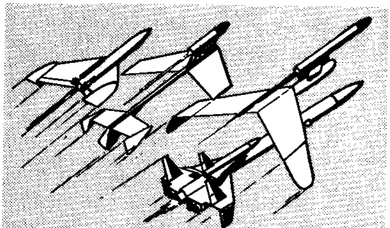
For more precision, use two trackers on opposite sides of the launcher. The easiest way of calculating rocket height using two trackers is to find the altitude for each tracking station and then take the average of these two altitude figures.

More elaborate tracking systems and more elaborate mathematics can be used to gain greater accuracy when the rocket doesn't fly straight up. However, a simple tracking system will do the job very well when good models are flown on calm days. More complete information on basic altitude tracking is contained in Estes Industries Technical Report TR-3.

BOOST-GLIDE

Boost-gliders are models which fly straight up like any other rocket. However, they glide back to earth instead of coming down suspended from a parachute.

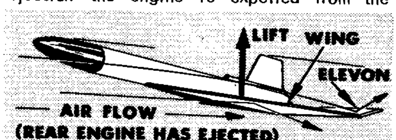
There are four main types of boost-gliders: Conventional front engine, conventional rear engine, pop-pod and parasite. Although these types appear very different, many of the same principles apply to all.



A boost-glider, as any other rocket, must be stable to fly upward. For this reason, most boost-gliders are designed with their engine mounts as far forward as possible. During glide a model must still be stable, but not by nearly so great a margin. If most or all of the engine is positioned ahead of the model's balance point, it will help make the model fly correctly.

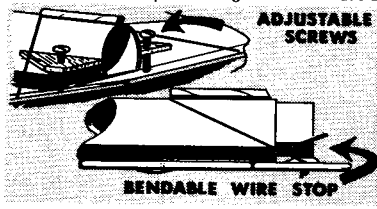
Rear-Engine Models

Based on conventional model rockets, the rear-engine boost-glider was the first type developed. Two fins are made extra-large to form wings. Control surfaces, called elevons, are mounted on these wings. The elevons are held straight by the engine during powered flight and coasting. At ejection the engine is expelled from the



rear of the rocket, and the elevons swing up as shown. This forces the rear of the model down slightly so the wing meets the air at an angle, providing lift to support the model.

Many rear engine models are made with extra empty engine casings mounted to the front of the engine to provide extra weight up forward for better stability. With all rear engine models it is important to remember that all control surfaces must be perfectly straight for the upward flight. The illustration

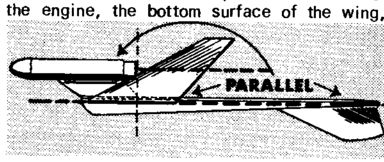


above shows the control systems of a typical model. Estes Industries Technical Report TR-4 contains more information on rear engine boost-gliders.

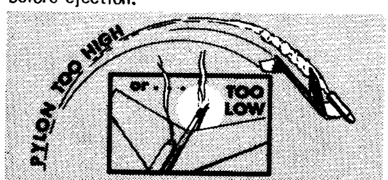
The big problem with rear-engine designs is getting the balance point far enough forward for a good upward flight and still having it far enough rearward for a good glide. The front-engine model solves this by putting the weight of the engine at the extreme front on the way up.

Front-Engine Principles

The engine in a front engine model should be positioned so that its rear is at least as far forward as the middle of the root of the wing. Looking at the model from the side, the centerline of the engine, the bottom surface of the wing,



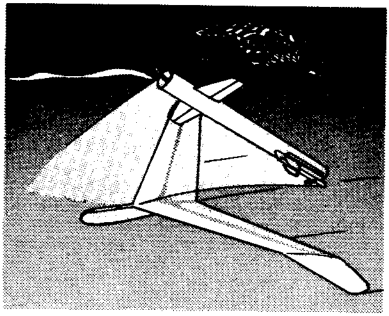
and the horizontal stabilizer must all be perfectly parallel. If any of these is at an angle, the model will tend to travel in one big loop and will probably be on the ground before ejection.



The pylon that supports the engine holder should be about 1/2 inch high. If it is too high, off-center thrust will force the nose of the rocket down. If it is too low, the tail will either be scorched or struck by the ejecting engine. For more information on front-engine models, see Estes Technical Report TR-7.

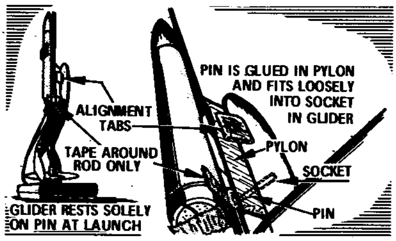
Pop-Pods

For the highest performance from a glider, its weight and drag must be kept to a minimum. The Pop-Pod helps by removing both the weight and drag of the engine



mount. The particular system shown, introduced by Estes Industries, has been adopted by almost every boost-glider designer.

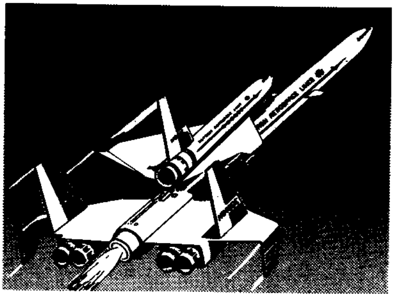
The Estes Pop-Pod (also known as strip pod) can best be explained as a finless parachute or streamer model rocket with a forward-slanting pin on which a glider is hooked. The glider, which fits loosely on the pin, serves to stabilize the whole assembly on the way up. At ejection, the reaction of the nose cone ejecting slows the pod while the inertia of the glider carries it forward and off the hook. (If the pin is a *little* tight, the drag of the parachute will usually pull the pod off.)



For this system the pod must be supported on the launch rod with the glider hanging from it. The pod must be loose enough so it will fall off if the glider is held with its nose up. As with conventional front-engine models, the engine, wing and stabilizer must be parallel.

Parasite Gliders

The first parasite glider systems were built with two gliders fitting on opposite sides of a finless, parachute-recovered core. Since then, a wide variety of models has been built on this principle.

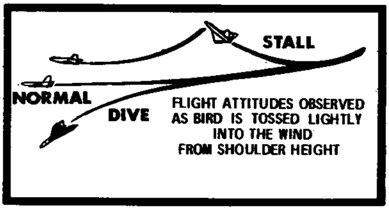


For best results, a parasite model should be built with a long, very stable core vehicle. The glider should be mounted close to the center of gravity of the core. One loose pin at the front of the glider is enough to hold it in place on the way up.

Glide Testing

A boost-glider must be "trimmed" to glide correctly before launching. Most rear engine models are trimmed by adjusting the elevons until a straight flat glide is achieved. Other models are trimmed by adding or removing weight at the nose.

When trimming a model, give it a straight, smooth, level toss into the wind and note how it performs. If it stalls, add weight to the nose. If it dives, remove weight from the nose. If it turns too much, place a *very small* weight on the wing which is on the *outside as it turns.*



Few models are as spectacular in flight and as enjoyable to watch as a good boost-glider. The rocketeer looking for a challenge will find that developing improved boost-glide designs is one of the most rewarding areas of research in model rocketry.

SAFETY

THE DANGEROUS PAST

Most of today's model rocketeers were not concerned with rockets during the "dangerous years" of youth rocketry. These years, from 1957 to 1965, were the years between the time Russia launched the first earth satellite, Sputnik, and the time model rocketry became well known.

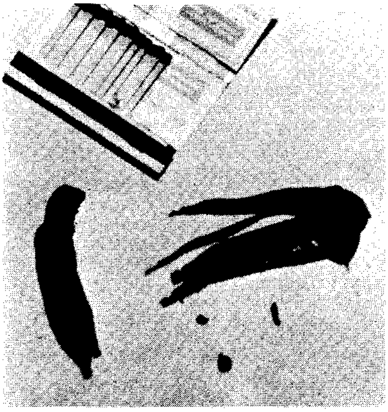
In those "early days" when a newspaper article told about a young rocket experimenter, it was usually a tragic story . . . like the boy in California who loaded a metal pipe with match heads which exploded, killing him instantly and crippling his friend for life . . or the teacher who was killed, and seven of his students injured, when he filled an improvised rocket with explosive chemicals. Still another case was of a young man losing an eye using zinc dust and sulphur in a CO_2 cartridge.

These unfortunate incidents happened to thousands of America's young rocketeers. Why? Because the space age had started and practically every science-oriented young man wanted to build a rocket. However, no safe way was readily available for him to do so. The situation was so bad that the Institute of Aeronautics and Astronautics estimated that a "basement bomber" experimenter had a 1 in 7 chance of being seriously injured or killed for each year he participated. A careful

Dean Bisbee of 5272 E. Dartmouth ave. tries to comfort his son, Lynn, 16, as the youth receives emergency treatment at Denver General Hospital after a homemade rocket exploded and blew off part of his right hand Wednesday. "Just tell the other kids to be more careful when they're working with explosives," the science student asked.

—*Rocky Mountain News Photo by Harry M. Rhoads.*

A "ROCKET" THAT KILLS



The most frequent killer in "basement bomber" tragedies has been a combination of match heads and metallic CO_2 cartridges. Match heads, when confined, are a powerful, sensitive and highly dangerous explosive--wholly unsuitable for rocket experiments.

analysis pointed to the following contributing factors as the major reasons for these rocketeer accidents:

1. A strong desire to build and launch a rocket.
2. A plentiful supply of low cost, (readily available) dangerous materials for use in rocket experiments.
3. A lack of knowledge of the dangers involved.
4. The unavailability of safe materials for the experimenter.

The Solution..

The Estes approach to safety for American rocketeers has taken three directions. First--we've tried to make every potential rocket builder aware of the disastrous results of "basement bomber" type activities by telling him of the dangers of home-compounded fuels and metal rockets. Secondly--we've marketed a line of rocket products which can be flown with a high degree of safety. Then, to make it a complete program, we've provided, along with these carefully engineered products, a wealth of safety oriented literature and technical information. Thus, the rocketeer is guided through his "rocket career" with little chance of serious injury.

Dear Sirs RECEIVED [illegible] 1966
Recently I was seriously considering building my own rocket with my own home-made fuel system. Tonight I received your paper with the report of injuries in such projects. I didn't know about these dangers and now I have decided to leave my model industry to the manufacturers and not take on any of these home-made projects. I thought I would write this little note just to thank you for maybe saving me own injury, no matter how large or small. Thank you very much
ANSWERED [illegible] 1966 Dick Batten

Over the past few years, we've received a number of letters from young men saying, "Thank you for saving my life." It's the kind of letter which makes us very proud because it may indeed be the case--and we've met the prime objective of our program.

> POSITIVE SAFETY VALUE: These are the words often used to describe the overall safety effect of model rocketry. By using the word POSITIVE we are making reference to a PLUS or ADDITIVE situation. We are, in effect, saying that America's rocketeers will have fewer accidents resulting in personal injury or property loss because model rocketry exists and is widely and freely available.
>
> From YOUTH ROCKET SAFETY REPORT
> by Vern Estes -- March, 1967

A Word on Making Rocket Engines...

At the Estes plant rocket engines are made automatically, under controlled conditions, with limited amounts of propellant being measured by explosion proof metering devices. We've spent many thousands of dollars in engine development work and plant layouts. Only highly-trained personnel are permitted near this operation. We still consider it a dangerous job, but a necessary one if we're to provide you with a safe form of rocketry.

If you would like to someday make rocket engines, we'd recommend you first get a college degree. Then you'll need some expensive special equipment, a safe place to work, and some specialized training.

If you attempt to build rocket engines with less than the above, you may find as some chemistry teachers, students and many others have, that through the rest of your life you will be without a finger, hand, arm, eye, ear, face, or you may be badly burned or even killed. Our country needs live rocket scientists and engineers who have all their fingers and hands. We are looking forward to fellows like you who have a special interest in rocketry to fulfill this need.

ROCKET ENGINE DESIGN

Today's model rocketeer can choose from an amazing variety of engines to power his models. He has an engine available for almost every purpose.

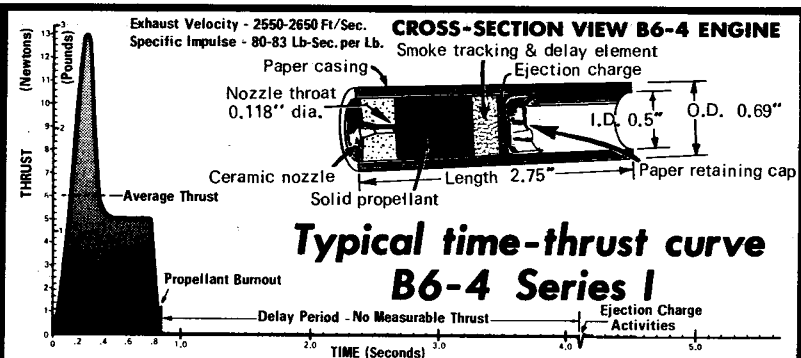
The engines the rocketeer uses come in two main types: end-burning and center-burning. End-burning engines are by far the most popular with model rocketeers. They have a big advantage because they can be built to give a dual level thrust action as shown by the B6-4 thrust curve.

This design is especially effective with light-weight high performance rockets. The high initial thrust boosts the rocket to a suitable flying speed almost immediately; thrust then drops to a lower sustaining level to maintain speed and gain the most distance with the least fuel consumption.

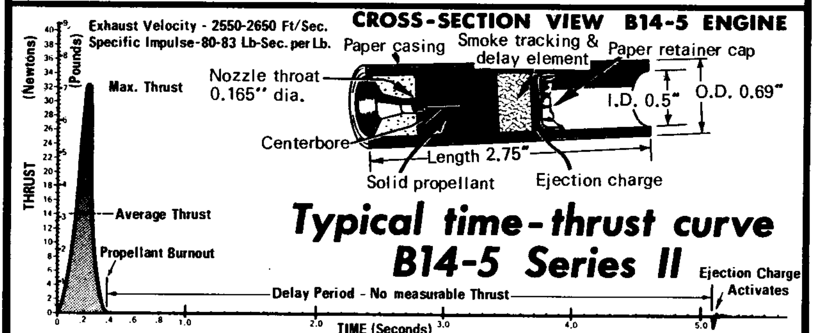
For heavy rockets especially those carrying large payloads, a second type of engine is available. The center-burning engine produces a very high average thrust, but only for a short period of time. This is more efficient for the heavy rocket since it brings the rocket to an adequate flying speed with less fuel than would be used by low thrust engines. The B14-5 thrust curve is typical of center-burning engines.

Single and upper stage model rocket engines of both types operate the same after the propellant has been burned. The end of the propellant ignites a slow-burning smoke tracking/delay element. This "delay charge" produces no thrust, but lets the model coast upward, leaving a smoke trail behind.

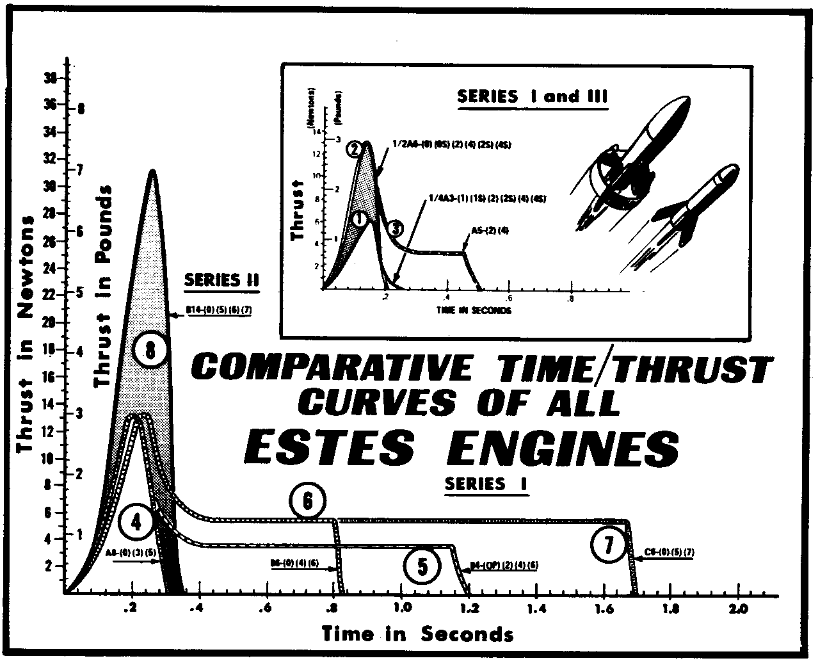
After several seconds the delay charge ignites an ejection charge which pressurizes the forward end of the rocket body to force the parachute out of the tube. (This gas pressure can be used instead to operate many types of recovery system other than para-



Typical time-thrust curve
B6-4 Series I

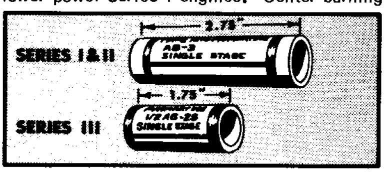


Typical time-thrust curve
B14-5 Series II



chutes.) If the correct engine is selected, ejection should occur at about the time the rocket has reached its peak altitude.

End-burning engines come in two sizes. The most common, known as Series I, is 2.75 inches long and 0.69 inches in diameter. A smaller type, the Series III engine, is 1.75 inches long, and the same diameter. It is simply a shorter version of certain lower power Series I engines. Center-burning



engines are classified as Series II. For more complete information, see the performance graphs and cut-away drawings.

THRUST CURVES

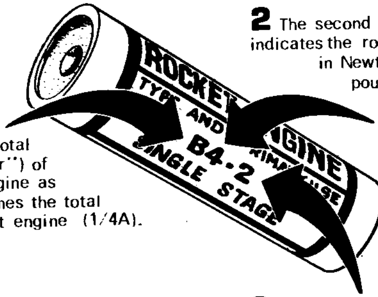
By studying the chart above you can learn much about the expected performance of your model using any type of engine.

For instance, looking at Curve 8 and noting the extremely high thrust of the B14 engine, you'd know your rocket would accelerate quickly to a high velocity. Then, of course, at propellant burn out, it would also slow down quickly due to the high drag of a rocket traveling so fast. The question you'd ask yourself then is...Would my rocket go higher using one of the other B engines which provides less acceleration but keeps pushing for a longer period of time?

NOTE: This rocket engine design and performance information is given for educational purposes only. We believe that if you understand how your rocket engine works you are in a better position to gain scientific knowledge from your activities and to design your rockets for specific purposes such as payload experimentation, altitude studies, drag racing, etc. We **DO NOT** grant permission for you to attempt to copy our design nor do we recommend that you attempt to build your own rocket engines.

ENGINE CLASSIFICATION

All engines sold by Estes Industries are stamped with a code designation which, when understood, will give the rocketeer important and useful data on the engine's performance capabilities. Here's how to read this coding:



1 The first designation in the code indicates the total impulse (total "power") of the engine. The C engine as shown below has 16 times the total impulse of the smallest engine (1/4A).

2 The second designation, a whole number, indicates the rocket engine's *average* thrust in Newtons. (1 Newton equals 0.225 pounds). For normal and most high performance flying an average thrust of 3 to 8 Newtons is best. For high lift off weights and high acceleration studies, the Series II engine with an average thrust of 14 Newtons is recommended.

TOTAL IMPULSE CLASSIFICATION		
Code	Pound-Seconds	Newton-Seconds
1/4A	0.14	0.625
1/2A	0.28	1.25
A	0.56	2.50
B	1.12	5.00
C	2.24	10.00

3 The last number following the dash gives the delay time in seconds from thrust burn out to activation of the recovery system (parachute) ejection charge. Engines with an "O" in this position have no delay or ejection charge and are used only in the bottom stage(s) of multi-stage rockets. Series III engines have an "S" following this designation indicating the engine is shorter.

OTHER ENGINE INFORMATION

ENGINEERING:

Today the Estes engine represents the end result of over 11 years efforts in engineering, craftsmanship and quality control. The total impulse of the Estes engine is closely controlled which allows us to make our engines very near the maximum permissible size in a given class. In addition, the average thrust, peak thrust and delay times are set to give the best overall performance for sport flying and competitive events.

QUALITY CONTROL:

Three out of every hundred engines made by Estes Industries are static tested on a recording type of test stand which graphically records the maximum thrust, thrust variations, minimum thrust, overall thrust duration, length of time delay, and the strength of the ejection charge. Any batch of engines which does not meet rigid standards is discarded. In addition, the engine production machines automatically reject all engines which do not contain the correct amount of propellant. All tolerances are kept as small as possible so that these engines make excellent propulsion units for contests, exhibitions and science studies.

SAFETY:

Rocket engines are not toys, but scientific devices. With common sense and close adherence to safety rules, model rocketry is as safe as any other sport, hobby or scientific study: Carelessness can make it dangerous, as with model airplanes, baseball or swimming. If you are hit by a model rocket traveling 300 or more miles per hour, you will be hurt. Use common sense and follow the safety code. Don't spoil model rocketry's excellent record of safety.

LABEL COLOR:

The label color indicates the recommended use. Green for single stage, purple (or blue) for top stage of multi-stage rockets and red for booster or intermediate stages.

MODEL ROCKET PERFORMANCE

The kits, components and engines produced by Estes Industries have been designed to cover the entire performance range from low altitude sport and demonstration models to high altitude, high performance payload and competition rockets. By choosing his kits, materials and engines carefully, the rocketeer can fill his performance needs exactly. Complete specifications are given on all items to make this selection easy.

HOW HIGH WILL YOUR MODEL GO? The chart below shows the approximate altitudes that can be achieved with single stage rockets.

Engine Size	Altitude Range (depending on rocket size and weight)	Approximate Altitude in a typical 1 oz. model
1/4 A3-2	50' to 250'	100'
1/2A6-2	100' to 400'	190'
A8-3	200' to 650'	450'
B6-4	300' to 1000'	750'
C6-5	350' to 1500'	1000'

(Some high performance models will reach higher altitudes than shown above.)

ENGINE SIZE:

There are several things that affect the performance of a model. The first of these is engine size. The greater the total impulse of an engine, the higher it will boost a model.

WEIGHT:

In most cases, the heavier a rocket, the less altitude it will reach. A baseball can be tossed higher than an 8 pound cannon ball; the same holds true for model rockets. In addition heavier rockets are more apt to tilt at an angle as they leave the launcher, reducing altitude even more.

Weights listed for rocket kits in the catalog do not include engines. To determine the lift-off weight of a model, add the engine weight, shown in the engine selection chart, to the kit weight.

WIND RESISTANCE:

Drag, or wind resistance, is the third item which affects performance. The more drag on a rocket, the less altitude it will reach. A number of factors determine the amount of drag on a rocket. The more frontal area the rocket has, the greater its drag will be. As a result, large diameter model rockets will generally not reach as great an altitude as smaller diameter rockets with the same engine power. Rough surfaces create turbulence in the air as it flows past the rocket, increasing drag. Smooth finishes will increase the capability of the model. The stability of the rocket also affects drag--if it wobbles in flight, it will have greater drag. Careful attention to reducing drag can sometimes double a rocket's altitude capability.

MEASUREMENTS

METRIC and ENGLISH

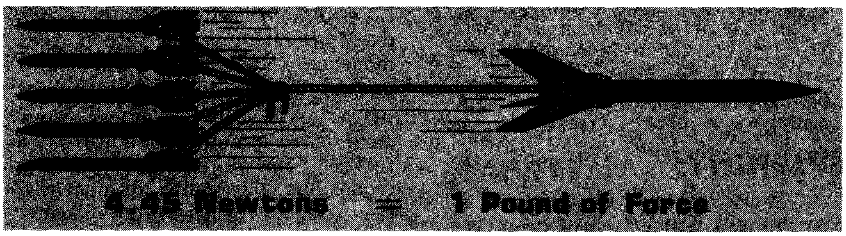
Although model rocketry started in the United States, there are today many thousands of active rocketeers in other countries around the world. Because the metric system is standard in almost every nation in which model rocketeers are active, engine specifications based on the metric system have replaced the former English system specifications.

Since rocketeers in this country use both systems of measure, some information will appear using one system, other items will use the other system. The conversion table below makes it easy to change English measurements to metric and vice versa.

CONVERSION TABLE

English to Metric Measure

MULTIPLY	BY	TO OBTAIN	MULTIPLY	BY	TO OBTAIN
centimeters	0.3937	inches	meters	39.37	inches
feet	0.3048	meters	meters	3.281	feet
feet per second	0.3048	meters per second	meters per second	3.281	feet per second
grams	0.0353	ounces	newtons	0.225	pounds (force)
kilograms	35.3	ounces	newton-seconds	0.225	pound-seconds
kilograms	2.207	pounds	ounces	28.35	grams
inches	25.4	millimeters	pounds (force)	4.45	newtons
millimeters	0.0394	inches	pound-seconds	4.45	newton-seconds



Energy is required to make an object move. This energy which causes motion is applied as a FORCE. Scientists express forces in units of measurement call NEWTONS. A newton is the amount of force needed to move a mass of one kilogram with an acceleration (change in velocity) of one meter per second each second. In other words, a force of one newton will make a mass of one kilogram change speed by one meter per second during every second the force is acting.

ACCELERATION (in meters per second per second) = FORCE IN NEWTONS ÷ MASS IN KILOGRAMS

EXAMPLE:

A Saturn model rocket of 0.36 kilograms (12.54 oz.) mass, acted upon by a force of 24 newtons (5.400 lb.), will be accelerated at the rate of 66.6 meters (218 ft.) per second per second.