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Model Rocketry Technical Manual

Welcome to the Exciting World of Estes Model Rocketry!

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INTRODUCTION

Welcome to the exciting world of Estes® model rocketry! This technical manual was written to provide both an easy-to-follow guide for the beginner and a reference for the experienced rocket enthusiast. Here you'll find the answers to the most frequently asked questions. More complete technical information on all the subjects can be found on the Estes® website (www.estesrockets.com) and the Estes Educator™ website (www.esteseducator.com)

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WHY ESTES MODEL ROCKETRY?

The hobby of model rocketry originated at the dawn of the space age in the late 1950's. Seeing space boosters carry the first artificial satellites into Earth's orbit inspired many enthusiastic young people to try to emulate the rocket pioneers by building their own rockets. Unfortunately, these homemade "rockets" usually involved stuffing flammable chemicals into metal pipes, very often with tragic results. Newspapers told of fingers and eyes lost – and all too frequently of lives lost. What was needed was a safe alternative that would allow young people to experience the thrill of constructing and launching their own rockets and provide them with the opportunity to explore the fascinating science of rocketry. Estes model rocketry is the answer.

A SAFE PROGRAM

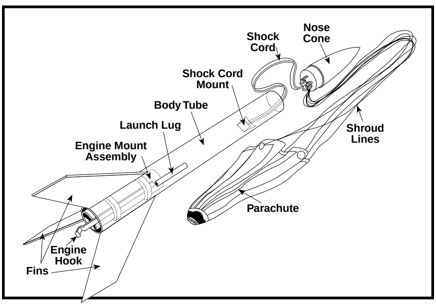
Estes model rocketry is a safe activity because it incorporates three important features. The first is the model rocket engine, a professionally manufactured, low cost, solid-fuel rocket engine. This frees the rocket builder from the inherently dangerous procedures of mixing chemicals and packing propellant.

The second feature is the use of safe materials for constructing the rockets. All model rockets are built using only lightweight materials such as paper, plastic, and wood. Metal parts are never used for the main structural components of the model.

The third feature is the incorporation of the Model Rocket Safety Code into all our flying activities. The safety code provides guidelines for the safe operation of model rockets, such as launching the rockets electrically from a safe distance, and using recovery systems to gently return the model to Earth. When the safety code is followed, model rocketry is an extremely safe activity, safer than baseball, soccer, or swimming. Our hobby's excellent safety record spans over 45 years and 300 million rocket launches.

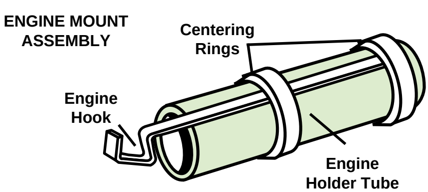
YOUR FIRST MODEL ROCKET

The Estes Alpha® is shown here to illustrate the parts of a typical model rocket for the beginning rocket builder. The construction techniques used in this and other model rockets are explained in greater detail in this manual.



For your first model rocket we recommend one of the Estes E2X® series. No modeling experience is needed to build an E2X® model. Construction involves almost no cutting or sanding, and the models do not need painting.

The Skill Level 1 models are an excellent choice for your second or third model. These models are also a good starting point if you have previous model building experience.



As your knowledge of rocketry and your modeling skills increase you can move up to building higher skill level models, and eventually to building your own custom designs from parts available in the Estes catalog.

CONSTRUCTION TECHNIQUES

In the construction of your Estes model rockets you will typically need the following tools and supplies (see kit instructions for specific requirements):

- Modeling knife
- Ruler
- Spray paint
- Masking tape
- White glue or carpenter's glue
- Scissors
- Spray Primer
- Tube-type plastic cement
- Fine and extra fine sandpaper

Always exercise care when using a modeling knife (they are very sharp!) and don't leave the knife laying around after you finish with it. Use some sort of cutting board under the knife. A smooth, flat piece of board is great; an old phone book or thick catalog also works well on a hard surface. Use newspaper to protect your work surface from accidental glue spills.

TYPES OF GLUE

Several types of glues and adhesives are commonly used in the construction of model rockets; the proper glue to use depends on the application.

1. White Glue: This glue works on porous materials such as paper and balsa. It is a good choice for engine mounts, balsa and fiber fins, launch lugs, paper parts, and for applying fillets to fin-body joints.
2. Aliphatic Glue: Also known as "wood glue" or "carpenter's glue"; it is usually yellow or tan in color. It is used just like white glue, but it is stronger and dries faster.
3. Tube-type Plastic Cement: This thick, clear liquid is used to glue styrene plastic parts to porous materials such as paper. It is typically used to glue plastic parts to body tubes. Some E2X series kits use this glue for assembly.
4. Liquid Styrene Cement: This thin, clear liquid is used to bond styrene parts together. The cement comes in a bottle and is applied with a small brush.
5. Cyanoacrylate: Commonly known as "super" or "instant" glues, these adhesives are available in both thin and thick formulations. Because this type of glue can instantly bond skin, it should never be used by unsupervised children. Eye protection and gloves are recommended. These adhesives are useful for quick assembly or field repairs. They work well for gluing plastic parts to balsa or body tubes.
6. Epoxies: These two-part adhesives are also recommended for the advanced modeler. Epoxy provides extra strength for the engine mounts and fins of high-thrust rocket kits. It also makes excellent fin fillets in one step.

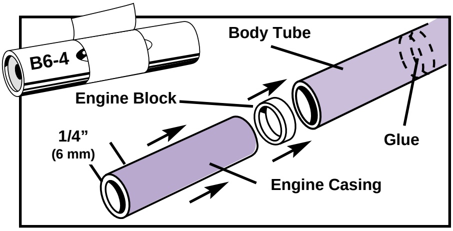
1. ENGINE MOUNTING METHODS

It is important to have a strong engine mount. This secures the engine, allowing it to "push" your rocket into the air.

Engine Block Installation

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

When building a model, use an engine casing (or the special spacer tube supplied in some kits) to push the engine block into position. First, mark the engine casing 1/4 inch from the end. Apply glue to the inside of the tube using a cotton swab or small dowel. Place the engine block just inside the rear of the body tube, then 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.



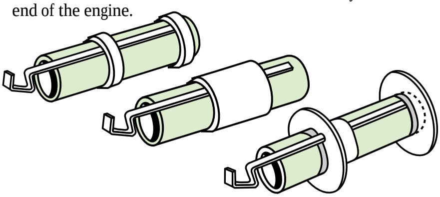
When mounting the engine in a model with an engine block, wrap the engine with masking tape until it makes a tight friction fit in the tube, then slide the engine into place. If the fit is too loose, the engine will kick out at ejection and may not deploy the recovery system. If the fit is too tight, you may damage the model trying to push the engine in place. Adjust the amount of tape as needed.

If the arrangement of the engine mount tube and fins allows enough space, a wrap of tape around the tube and engine joint can help hold the engine in the model.

Engine Holders

In many models a quick release engine holder (also called an engine hook) is the best device to use for mounting an engine. The forward end of the engine holder is inserted through a 1/8 inch wide slit in the tube, and prevents forward movement of the engine. Apply glue fillets where the engine mount spacer rings attach to the engine mount tube for extra strength.

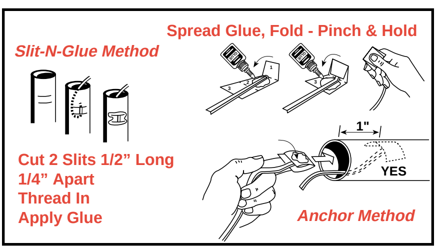
To mount an engine in a model with an engine holder, spring the end of the holder up and slide the engine into place. Check to make sure the end of the holder latches securely over the end of the engine.



2. SHOCK CORD MOUNTS

Attach the shock cord securely. Both methods shown yield good results. The slit-n-glue method is good for body tubes too small for an anchor mount.

The anchor is cut from paper or index card stock. Be sure to glue the anchor far enough into the tube or it will interfere with the proper fit of the nose cone.



3. SECURING A SCREW EYE

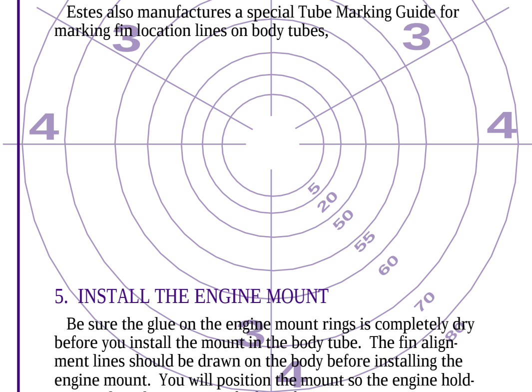
If your model uses a screw eye to attach the shock cord to a balsa nose cone or adapter, make sure the screw eye is securely attached. Make a hole by inserting and removing the eye; then squirt glue into the hole and replace the eye.

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.

Mark the body tube for fin alignment using the "V" notch of a drawer sill or door frame. Match the edge of the notch with a spacing mark; run a pencil along the edge to draw your guide line. Gluing the fins to the body on these lines will insure that they are straight.

Estes also manufactures a special Tube Marking Guide for marking fin location lines on body tubes,

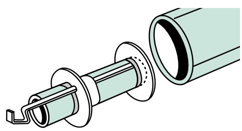


5. INSTALL THE ENGINE MOUNT

Be sure the glue on the engine mount rings is completely dry before you install the mount in the body tube. The fin alignment lines should be drawn on the body before installing the engine mount. You will position the mount so the engine holder is midway between two fin lines for easier operation.

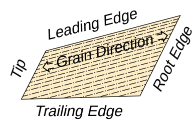
Before gluing, make sure the mount slides easily in the body tube. If it's tight, sand it until it slides easily.

Smear a liberal amount of glue around the inside of the body tube over the area where the mount's ring or coupler will fit. Insert the mount into position in one smooth motion. DON'T pause, or the glue will "grab" it in the wrong place! Support the tube "nose-up" while the glue dries.



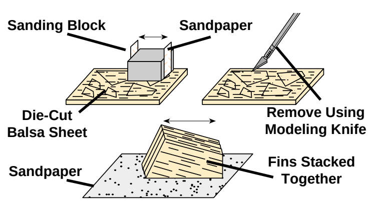
6. BALSA FINS

Fins are used to aerodynamically guide your rocket. Some model rockets use fins made from thin sheets of balsa wood. In many kits the fins are pre-cut for you by a punch die. In other kits, or to make custom fins, you must use a pattern to mark and cut a blank sheet of balsa. All balsa fins must be cut so that the grain of the wood runs parallel with the leading edge of the fin for maximum strength.



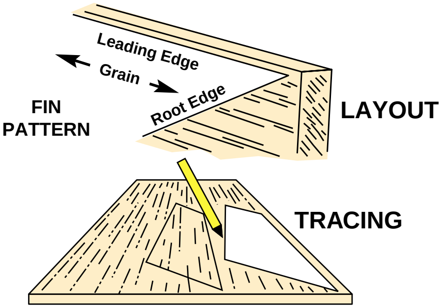
Die-Cut Balsa Fins

Before removing the die-cut fins from their sheet, use extra fine sandpaper to sand both surfaces of the sheet of balsa (a sanding block is helpful here). Use a modeling knife to carefully cut through the points where the fins are still attached to the die-cut sheet, then remove the fins. Stack the fins together and sand all edges square.

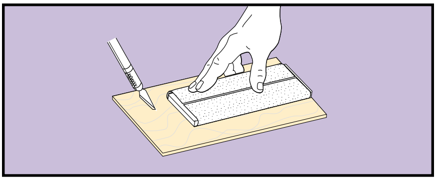


Balsa Fins From Patterns

To make fins from an un-cut sheet of balsa, start with a full-size fin pattern cut from stiff paper or thin cardboard. When laying out the fins on the sheet of balsa be sure to position the pattern so that the leading edge of the fin runs parallel to the grain direction! Trace around the pattern with a pencil or ball point pen to mark the balsa for each fin.



Use a metal straightedge whenever possible. Hold the knife blade at a 90° angle to surface being cut, and handle at about 45° for clean cut. If blade is dull or held too high, balsa tends to tear. A razor saw blade may be required to cut thicker balsa.



Shaping Balsa Fins

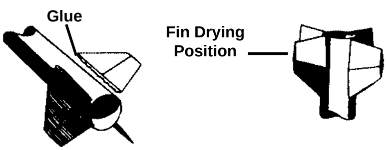
The instruction sheets in many kits tell you to sand all edges of the fins square. This is fine, and it is the easiest method, but you can reduce drag and increase the altitude performance of your rocket by proper shaping of the fin edges.

For general purposes, sand all fin edges round except the root edge (the edge that glues to the body). Make the root edges straight and square, never rounded! The sides of the fins should be sanded smooth.

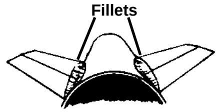
On high performance models sand the fins to the streamlined shape shown for minimum drag. The front (leading) edge of the fin should be rounded; the back (trailing) edge should come to a sharp edge.

7. ATTACHING THE FINS

After marking the tube and sanding the fins, you are ready to attach them to the body. The best way to attach balsa or fiber fins to a rocket with white glue is by using a "double glue joint". Apply a layer of glue to the root edge of a fin and a thin layer of glue to the body tube where the fin will be attached. Do this for all fins and allow this glue to dry. Then apply a second line of glue to the root edge and press the fin in place onto the body, holding it in place until the glue begins to set. Before the glue sets completely, sight down along the body tube to make sure that the fin is aligned parallel with the tube, and oriented straight away from the surface of the tube. Adjust the fin alignment as needed. Support the rocket body in a vertical position while the glue on the fins dries.



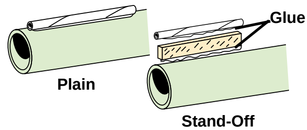
Sometime after the fin joints have dried completely, they should be reinforced. Do this by applying a "fillet" of glue as shown. Always support the body in a horizontal position while fillets are drying so that the glue does not run. Build up the fillets in several thin layers, allowing each layer to dry between applications (this is much faster than waiting for a single thick fillet layer to dry).



8. ATTACHING LAUNCH LUGS

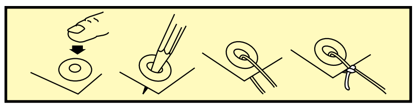
The launch lugs are used to position the rocket on the launch rod. The lugs and rod help guide the rocket in its first few feet of flight. The model must be guided until it is going fast enough for the fins to guide it. Launch lugs are attached in much the same way as fins. If a stand-off is used to 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. Sight along the tube to be sure the lug is parallel to the body tube before the glue sets. Apply glue fillets to the lug after the initial glue joint has dried.

Read "LAUNCHER DESIGN" starting on page 9 for launch lug placement.

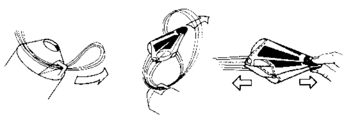


9. PARACHUTE ASSEMBLY

The most common model rocket recovery system is the parachute. On page 11 you will find alternate recovery systems. Estes parachutes are now fully assembled. To assemble an unassembled parachute, cut out the plastic parachute along the dotted lines. Apply the six vinyl tape rings to the corners of the parachute and punch holes through the parachute material in the center of the tape rings using a sharp pencil. Cut three equal length shroud lines that are twice as long as the parachute diameter. Tie both ends of the shroud lines through the holes in the tape rings, as shown.



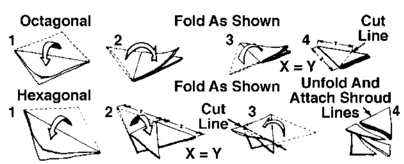
To attach the parachute to the nose cone or adapter eyelet, thread the shroud lines through the eyelet, pass the parachute through the loop of shroud lines as shown, then pull the lines tight.



In addition to regular, pre-printed model rocket parachutes, you can assemble custom parachutes using a wide variety of thin plastic sheeting. When making a chute from scratch, cut the plastic sheet to shape, then attach shroud lines as shown previously. Carpet thread makes excellent shroud lines.

Parachute Shape

The most common parachute shapes are square, round, hexagonal and octagonal. While square parachutes are the easiest to make, they are not very efficient and allow a considerable amount of sway during descent. Round parachutes are very stable in descent, but are more difficult to make. Hexagonal and octagonal parachutes are stable and reasonably easy to make. The accompanying drawings illustrate methods for making these shapes.

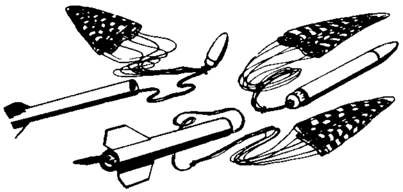


Snap Swivel Assembly

It's often worthwhile to attach your parachute to a snap swivel to allow the 'chute to be easily removed. This lets you change parachute size in response to different wind conditions, or swap 'chutes between models. A snap swivel has an eyelet on one end and a wire snap hook on the other. The swivel connection in between helps keep your parachute lines from tangling up if the 'chute rotates on descent. Snap swivels are available where fishing supplies are sold.

10. CONNECT IT TOGETHER

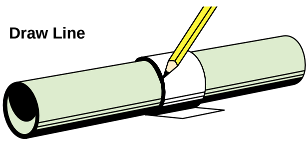
The first illustration shows how nose cone, parachute and rocket are connected on most models. If the rocket has a heavy payload section, it's a good idea to use two chutes as shown in the second picture.



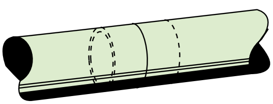
11. CUTTING TUBES

When building custom design rockets or replacing damaged tubes on your models, you will often need to cut a specific length body tube. Here's how to get a neat cut every time.

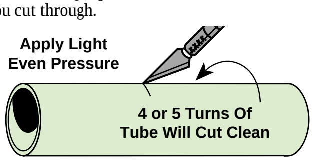
(1) Mark the tube at the point where the cut is to be made. Wrap a straight strip of paper around the tube and align the edge with the mark. Draw a line completely around the tube. You can also use the pencil holder on the Estes Tube Marking Guide to draw the line.



(2) Slide a stage coupler or expended engine casing into the tube – center it under the cut position to support the tube.



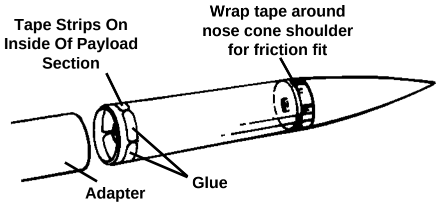
(3) Using a sharp blade, cut lightly along the line, rotating the tube as you cut. Don't try to cut all the way through on the first turn. Use a light pressure on the knife for several turns until you cut through.



(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, to remove burrs and rough edges.

12. CLEAR PAYLOAD SECTIONS

Models that have a clear plastic payload section present a special problem: White glue will not bond the plastic to a balsa nose block. To overcome this, apply tape strips to the inside of the payload tube, then glue the balsa nose block to the tape strips using white glue.



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. A model with a smooth finish not only looks more professional, it experiences less drag in flight, so it flies higher.

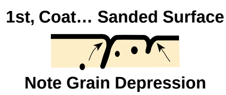
The degree of difficulty in finishing a model rocket depends on the materials used in its construction. Models with plastic nose cones and fins are the easiest to finish. Some come with all pre-colored parts and require no finishing at all. Models built with balsa parts require extra steps to produce a smooth, shiny finish.

1. SANDING AND SEALING BALSA PARTS

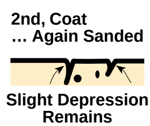
To get a smooth finish, the wood grain of the balsa must be filled. Many suitable types of spray primers and wood fillers are available at hobby shops and hardware stores. Spray primers are widely available and work great. Water-based wood fillers have no noxious fumes; you may need to add water to thin them to a brushable consistency.

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 spray primer to the balsa. Let this dry completely, then sand with 320 grit (or finer) sandpaper, until the surface is smooth again. Apply more primer, repeating the procedure until all the pores in the balsa are filled.



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



2. SPRAY PAINTING THE MODEL

Using a good enamel spray paint is the easiest way for a novice to get a smooth, uniform finish on a model rocket. Other types of paints can be used, but be wary of mixing different types of paint on the same model; paint compatibility problems may cause the model's finish to wrinkle or "craze". If in doubt, test the compatibility of different paints on a piece of scrap material. Paint fumes can be harmful; only paint outdoors or in a well-ventilated area.

To hold the model during painting, make a "painting wand" by rolling a sheet of newspaper into a very long, narrow cone and inserting it into the rocket's engine mount. An expended engine casing glued onto a wooden dowel also makes a great painting wand, especially for heavier models. Before painting, wipe the model with a clean, slightly damp cloth to remove any dust from its surface.

3. PRIMER COAT (Optional)

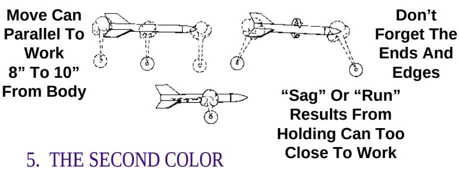
While not necessary, a coat of sandable primer provides a uniform base color and a better bonding surface for the paint layers; it also helps fill any remaining minor surface imperfections. Spray on the primer in thin coats until the model is a uniform color. When the primer is completely dry, lightly sand the surface with 400 grit (or finer) sandpaper.

4. 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.

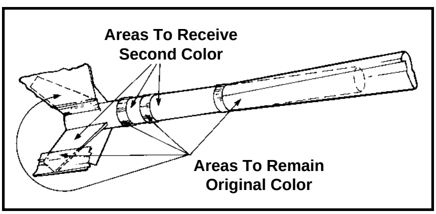
Always spray on the paint in light, even coats, allowing the model to dry between each coat. Trying to cover the model with one thick coat of paint will only result in paint runs. Several thin coats will also dry faster than a single thick coat. When the first coat has dried completely, sand lightly with extremely fine sandpaper. Wipe off any dust 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 in a warm, dust-free area. Allow the model to dry a full day if it is to be masked for additional colors.



5. THE SECOND COLOR

When the base color has dried completely, 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. Masking tape that is too sticky may pull up the base color paint when removed; if you have this problem, you can stick the tape to you skin before applying it to the model to remove some of its tackiness.

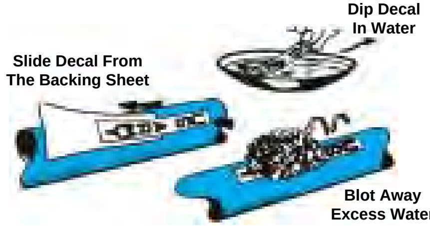


With the model masked, apply an additional thin coat of the first color to finish sealing the edges of the tape. When this is dry, apply the second color in several thin coats. Use just enough paint to get good color. After the last coat is dry, remove the masking carefully to avoid peeling the paint.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

6. FINAL TOUCHES

For best results, let the paint dry overnight before applying decals. Some models have self adhesive decals; these must be positioned very carefully before pressing into place, since they can not be moved once they are stuck down.

To apply a water-transferable decal, first cut it out of the decal sheet, then soak it in lukewarm water for 60 seconds or until it begins to slide on the backing sheet. Slide the decal so that one edge is off the backing. Position this edge on the model and hold it in place while pulling the backing out from under. Smooth the decal down with a damp finger, then blot away any excess water with a rag or paper towel.

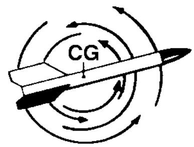


After the decals have dried completely, spray the model with clear acrylic coating to protect the finish. Apply the clear spray in several thin coats, allowing time for each coat to dry. If the model was finished with fluorescent paint, apply a light coat of clear spray before applying decals.

STABILITY

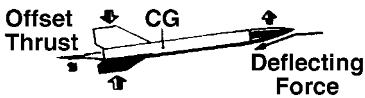
One of the first things a model rocket designer learns is that a vehicle will not fly unless it is aerodynamically stable. By stable we mean that it will tend to keep its nose pointed in the same direction throughout its upward flight. Good aerodynamic stability will keep the rocket on a true flight 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.



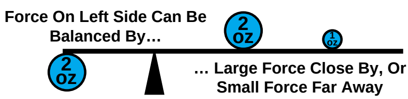
When a free-flying object rotates, it always rotates around its balance point. The proper term for the balance point is the center of gravity, abbreviated as CG. Thus the balance point (CG) is the pivot for all forces trying to turn the rocket.

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 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.

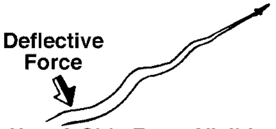


Force Acting On Fins Opposes Other Forces

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.



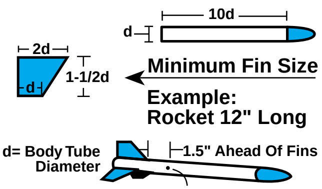
The side forces on the nose and fins of a rocket that is flying straight are very small. When something disturbs the rocket and it starts to rotate sideways, the side forces on both nose and fins increase. (There is some aerodynamic force on the body; however, it is small and can usually be ignored.) 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.



How A Side Force Visibly Affects Course Of Normally Stable Rocket

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 rocket modeler 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.



Rocket Should Balance Here

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!

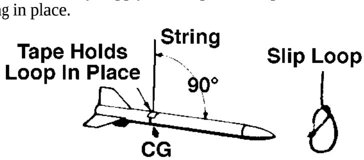
Finally, the rocket should balance at least 1/8 its length ahead of the front of the fins. This gives the fins the leverage they will need to counteract the force on the nose.

Remember that these rules are general; they are based on experience rather than precise mathematical analysis. Always remember to test your model for stability before you launch it.

SWING TESTING FOR STABILITY

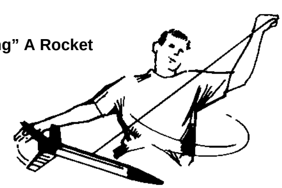
The easiest way to test the stability of a model is to fly it – without launching it. Do this by attaching a string to the model and swinging it through the air. If the string is attached at the rocket's CG, its behavior as it is swung through the air will indicate what it will do in powered flight.

Test your model by forming a loop in the end of a six to ten foot long string. Install an engine in the rocket; use the heaviest engine you expect to fly in the model. (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.



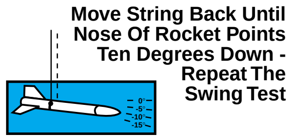
With the rocket suspended at its center of gravity, swing it overhead in a circular path. If the rocket is very stable, it will point forward into the wind created by its own motion. Some rockets which are stable will not point forward of their own accord unless they are started straight. This is done 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.

"Starting" A Rocket



If it is necessary to hold the rocket to start it, an additional test should be made to determine when 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.

Double Check A Rocket With Questionable Stability As Follows:

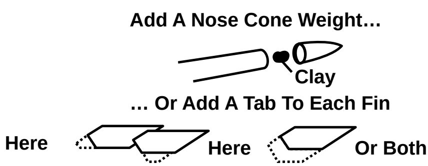


Rocket Should Still "Fly" Nose Forward

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 a CG shift as the propellant burns. When this happens, the model can crash into the ground at high speed.

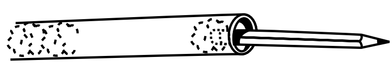
If your rocket does not pass the stability test, it can usually be made stable. Two methods can be used: The balance point can be moved forward, or the fin area can be enlarged. To move the balance point forward, add weight to the nose cone. For models with hollow plastic nose cones, pack some clay into the tip of the nose. To add weight to balsa nose cones, attach washers to the base of the cone. The CG can also be moved forward by adding a payload section to the model. Fins can either be replaced with larger ones or extra tabs can be glued to the rear or tip edges of the fins. Additional fins could also be added to the model. Some scale models use supplementary clear plastic fins. After making your changes, swing test the model again to be sure it is now stable.



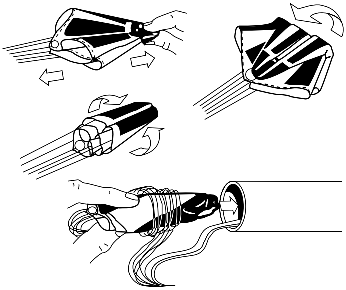
PREPARING FOR FLIGHT

Parachutes and streamers must be protected from the heat of the ejection charge by using flame-resistant recovery wadding. NEVER use regular tissue paper in place of flame-resistant wadding! Ordinary tissue paper will continue to smolder after ejection and can cause dangerous grass fires.

Loosely pack enough flame-resistant 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 into several sections as shown. Pack shroud lines and shock cord in on top of the wadding. Push the folded 'chute down into the tube on top of the shroud lines and shock cord, then slide the nose cone into place.

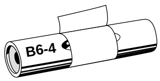


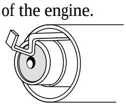
If the parachute has been packed in the model for an extended period, re-pack the 'chute just prior to launch. Dusting the parachute with talcum powder before packing will also increase the chances of a successful deployment. It is especially important to follow these precautions on cold days because the low temperature makes the plastic parachute material less flexible.

Check the fit of the nose cone on the model: If it is too tight, see if the shock cord or shroud lines were trapped between the nose cone shoulder and the body tube. If the nose is still too tight, sand the shoulder of the nose cone or the inside of the body tube with fine sandpaper. If the nose cone fit is too loose, wrap tape on the shoulder to adjust the fit. The nose cone should separate easily, but should not fall off if the rocket is inverted.

To deploy the streamer or parachute recovery gear correctly, the engine MUST be held in place SECURELY. This may be done by wrapping 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.

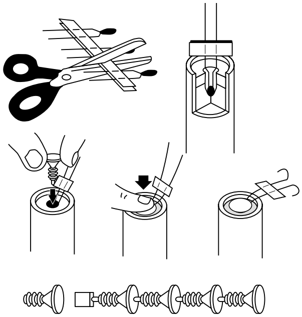




IGNITER INSTALLATION

For safety reasons, do not install igniters in model rocket engines until you are ready to fly the rocket. Never connect a launch control system to an igniter installed in a rocket engine unless the model is on a launch pad. Never ignite a rocket engine indoors.

Use scissors to separate the igniters; leave the paper strip attached to the igniter wires. Hold the engine nozzle end up, then insert the igniter into the nozzle as far as it will go. To operate properly, the tip of the igniter MUST touch the propellant. Insert the igniter plug into the nozzle and firmly push it all the way in. Be sure to use the correct color-coded igniter plug for the engine to insure proper fit. Bend the ends of the igniter wires back; this provides a larger area for attaching the micro-clips.



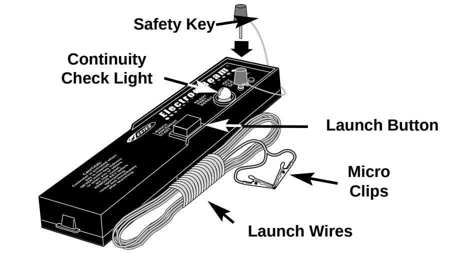
If an igniter plug is not available, roll a 1" square of flame-proof recovery wadding into a ball and insert it into the nozzle alongside the igniter wires using the point of a pen or pencil. Press the wadding ball firmly in place.

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, igniter plug, 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.

1 LAUNCH CONTROL SYSTEMS

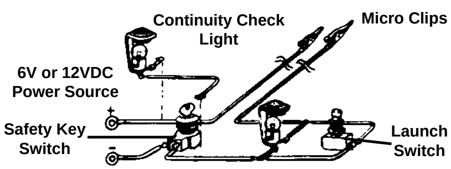
The electrical launch system controls the flow of electrical current to the igniter. Safety features built into the controller insure that current does not reach the igniter until it is time to launch. An Estes launch controller is shown below:



All launch control systems work by passing electrical current through the high-resistance wire in the tip of the igniter; this current heats the wire, which ignites the coating on the igniter, which in turn ignites the engine. The launch system is attached to the igniter with micro-clips, one clip on each igniter wire. 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. Micro-clips become corroded with use; use sandpaper to clean the inside of the clip jaws to insure good electrical contact.

All launch control systems must have a spring return launch button so the current turns off automatically when the button is released. In addition, a removable safety interlock ("safety key") must be provided; this could be an electrical key-switch or an insertable metal pin. Estes' launch controllers have a removable spring-return safety key also. Both the key and launch button must be pressed down for launch. When the safety key is removed or not held down, the launch controller cannot complete the electrical circuit to send current to the igniter. **ALWAYS remove the safety key and carry it with you when you go hook up the igniter!** This insures that no one could activate the launch controller while your hands are near the rocket nozzle.

Any homemade electrical launch control system must include all the safety features outlined above. See the Estes publication "Model Rocket Launch Systems" for more details. A typical launch controller circuit is shown below:

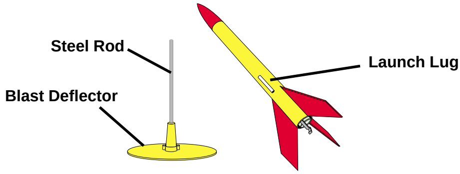


This circuit includes a continuity check light. This is a small bulb (no more than 1/4 amp for safety) that lights when a complete circuit exists between battery and igniter; this indicates that the rocket can be launched. If the continuity check bulb does not light when the safety interlock is closed, remove safety key and check to see if the micro-clips are properly connected to the igniter. ALWAYS remove safety key before approaching the rocket.

2. LAUNCHER DESIGN

A model rocket cannot be simply set on its fins and launched since the rocket requires a fast airflow over its fins for stability. The model must be guided until it is moving fast enough for the fins to operate; the launcher provides this initial guidance.

Most model rockets are guided during launch by an 1/8” diameter, 32” long launch rod (heavier models require thicker rods for extra strength). A short tube, called the launch lug, is glued to the side of the rocket. This tube slips easily over the rod and keeps the rocket pointed in the right direction during launch. A single launch lug should be mounted near the balance point of the rocket; two lugs located either side of the CG provide better support for longer models.



The blast deflector is a metal plate that prevents the engine exhaust from hitting the launch pad or ground, preventing fires. Heavier rockets will require thicker launch rods and a launcher with a heavier base. Bricks or rocks can be used to weight the base when extra-large models are being launched.

When building a launch pad 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; a larger base made from two-by-fours easily handles one pound models.

3. LAUNCH SAFETY

Only launch model rockets from a large open area. Make sure the ground around the launcher is clear and has no dry weeds or highly flammable materials. Always cover the launch rod with the launch rod caps! After sliding the rocket onto the launch rod, replace the cap on the rod before hooking up the igniter. The cap protects you from accidental eye injury from the rod. If the cap is not available, put your hand on the end of the rod before leaning over. Remove cap for launching.

Immediately before launching a rocket, check for low-flying aircraft. If there are other people in the launch area, announce the launch loudly to get their attention, followed by an audible five-second countdown.

After a successful launch, remember to remove the safety key from the controller and replace the cap on the launch rod. If the rocket becomes entangled in a power line or other dangerous place, to avoid injury DO NOT attempt to retrieve the model!

4. LAUNCH AREAS

Choose a large field away from power lines, tall trees, and low-flying aircraft. It should be free of easy-to-burn materials. The length of the smallest side of the field should be at least one fourth of the rocket’s expected maximum altitude. The Model Rocket Safety Code contains a table of minimum field dimensions for each engine size.

COUNTDOWN CHECKLIST

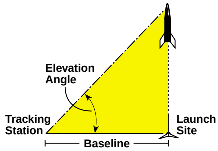
Use a countdown check list when you launch your models. You’ll find it makes your rocket flights more successful and enjoyable. The following procedure is recommended for most parachute or streamer models. For other types of rockets, try to develop your own complete check list.

12) Pack flame-resistant recovery wadding into the body tube. Insert the parachute or streamer.
11) Install the nose cone or payload section, checking for proper fit. 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 (if required for this model). 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(s) in the rocket. If the rocket uses engine holders, check that the holder proper hooks the rear end of the engine.
9) Install an igniter in each engine.
8) Be certain the safety key is not in the launch controller! Place the rocket on the launcher. Clean and attach the micro-clips.
7) Clear the area, check for low flying aircraft, alert the recovery crew, trackers, and spectators.
6) Insert the safety key into the launch controller and hold down. Give an audible count down: 5) 4) 3) 2) 1)
5) Push launch button while safety key is held down. LAUNCH!

TRACKING

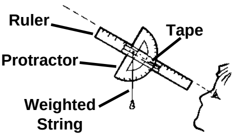
The easiest way to measure how high a rocket flies is to visually “track” the model using a tracking instrument, then “triangulation” is used to determine the altitude. The tracking instrument is used to measure the angle between the ground and the line of sight to the rocket at its peak altitude.

This angle is called the “elevation” angle. When the elevation angle and the distance from tracker to launcher are known, it is very easy to determine the altitude.



TRACKERS

The Estes® Altitrak is one of the best all-around basic tracking devices. However, it is easy to construct a simple tracker: A plastic protractor is attached to a ruler as shown. Tie a weighted string through the small hole at the “center” of the protractor. When sighting along the edge of the ruler toward the horizon, the string should hang by the 0 mark on the protractor; when sighting at a point in the sky, the position of the string will indicate the elevation angle.

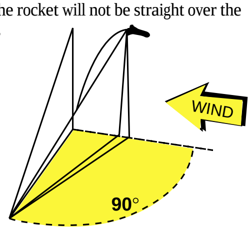


The distance from the launch area to the tracking station should be approximately equal to the altitude expected for an average rocket flight to be tracked. This distance is called the “baseline” and its length should be carefully measured. The tracker should have a clear view of the launch area and should not be looking into the sun.

Before launch, alert the person at the tracking station. When the tracker signals readiness, the rocket can be launched. The tracker sights along the tracking instrument and follows the rocket as it rises. When the rocket reaches its peak altitude, the tracker “locks” the tracking instrument. An Altitrak is locked by releasing the trigger. To lock the homemade tracker, the operator uses a finger to clamp the string in place before moving the instrument (this takes practice!). The elevation angle is then read from the tracker.

Find the tangent of the elevation angle from the table at the end of this section, or using a scientific calculator (enter the angle, then press the TAN key). Multiply this tangent by the baseline length (the distance from the tracker to launcher) to find the rocket’s altitude. The Altitrak gives a direct readout of the altitude, assuming the tracker is located 150 meters from the launch pad.

A single tracker gives 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.



For better accuracy, use two tracking stations on opposite sides of the launch pad, or place more than one tracker at each station. The easiest way of calculating rocket height using multiple

TABLE OF TANGENTS

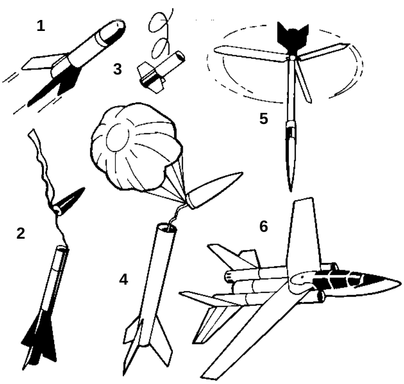
Angle	Tan	Angle	Tan	Angle	Tan	Angle	Tan	Angle	Tan
1	.02	17	.31	33	.65	49	1.15	65	2.14
2	.03	18	.32	34	.67	50	1.19	66	2.25
3	.05	19	.34	35	.70	51	1.23	67	2.36
4	.07	20	.36	36	.73	52	1.28	68	2.48
5	.09	21	.38	37	.75	53	1.33	69	2.61
6	.11	22	.40	38	.78	54	1.38	70	2.75
7	.12	23	.42	39	.81	55	1.43	71	2.90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

trackers is to find the altitude for each tracker and then take the average of these altitude figures. More complete information on basic altitude tracking is contained in Estes Industries Technical Report TR-3.

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 it or presenting a hazard to persons on the ground. Also, the recovery system provides an area for competition when rocket flyers hold contests to see whose rocket can remain aloft the longest. In addition, rocket recovery is an area for valuable experimentation and research as modelers develop new and better methods of returning their rockets to earth.

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:



1. Featherweight Recovery, 2. Streamer Recovery, 3. Tumble Recovery, 4. Parachute Recovery, 5. Helicopter Recovery, 6. Glide Recovery.

Some of the most common errors causing recovery system failures are listed below with their solution.

PROBLEM (1) Engine not held securely and ejects, instead of recovery device being deployed.

SOLUTION: On models with engine holder hooks, make sure hook latches properly over end of engine. If engine is held by friction fit, wrap enough masking tape around engine to hold it tightly.

PROBLEM (2) Parachute or streamer is melted or scorched by hot ejection gases.

SOLUTION: Be sure you have used sufficient recovery wadding to fill a length of two body diameters.

PROBLEM (3) Nose cone fails to separate from body tube.

SOLUTION: Check fit of nose cone in the body tube; be sure no shroud lines are trapped by nose shoulder. Parts should separate easily, but not be loose. If fit is too tight, sand inside of body tube or nose cone shoulder with fine sandpaper.

PROBLEM (4) Nose cone falls off before ejection.

SOLUTION: Fit is too loose. Wrap masking tape on shoulder of nose cone for a snug but not tight fit.

PROBLEM(5) Parachute deploys, but wind carries rocket away.

SOLUTION: In windy conditions replace the parachute with smaller 'chute or streamer. Or, "reef" the 'chute by applying a wrap of tape around the parachute shroud lines, half-way up; this prevents the 'chute from opening fully so the model falls faster. Or, cut a spill hole in the center of the parachute.

PROBLEM (6) Hole or crack in rocket allowing ejection gases to leak through.

SOLUTION: Construction at rear of rocket must be air tight when engine is in place.

PROBLEM (7) Failure to deploy recovery device because body tube is too large for proper pressurization.

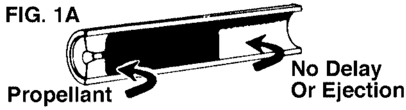
SOLUTION: Add a stuffer tube, usually made from BT-20 or BT-50. Center stuffer tube inside rocket with paper rings and glue securely in place. Stuffer tube reduces area to be pressurized.

MULTI-STAGING

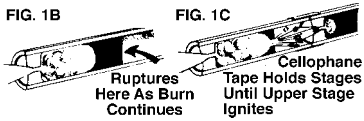
1. IGNITION

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.

FIG. 1A



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 blows 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 figure 2. Recessing the joint forces the stages to separate in a straight line.

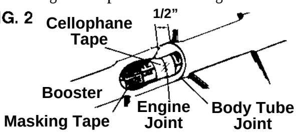
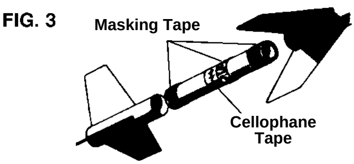
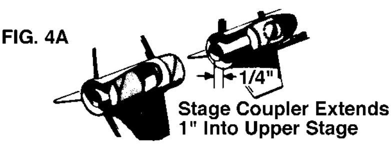


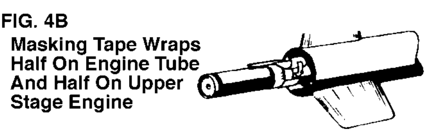
Figure 2 shows the engine installation in a typical two-stage model. Always tape the engines together before inserting them into the rocket. IMPORTANT: Check carefully before and after taping to be sure the engines are in the in proper positions (nozzle of upper stage engine against top end of booster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



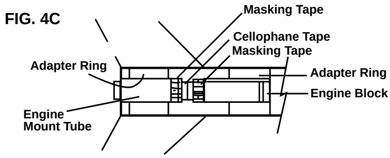
After taping the engines together, wrap masking tape around the upper stage engine at the front and near the rear as in figure 3 to give it a tight fit in the body. Push it into place. Wrap the booster engine and push it into position. Failure to get the upper stage engine in place tightly enough will result in the recovery system malfunctioning; 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 figure 4A. The stage coupler is glued to the booster body tube, with the motor adapter for the upper stage engine mount positioned forward to allow the stage coupler to fit into the upper stage, while the motor adapter of the booster engine mount 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 figure 4B. The engine mount in the booster must be built to leave space for this system (see figure 4C). The booster engine is held in place with a wrap of masking tape in the same manner as the upper stage engine.



In some multi-stage models the engines cannot be coupled directly together with cellophane tape, such as the case where a D12 is staged to a standard size engine. In this case, use masking tape on the stage couplers as needed to achieve a tight fit between stages, to prevent separation before upper stage ignition.

2. STABILITY

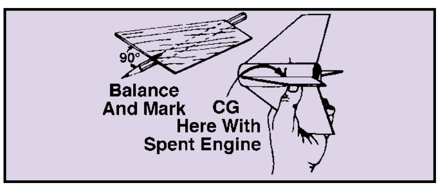
Since two or more engines are mounted near the rear of a multi-stage rocket, it has a tendency to be tail-heavy. To compensate for this, larger fins are often used on the lower stage. Each additional stage requires even greater fin areas. This effect can be minimized if the upper stage is fairly long, increasing the stability of the model.

Fin Area Increased On Each Added Stage

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 heaviest engines to be used in place.

3. 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. A booster stage should be painted an especially bright color because it does not have parachute or streamer to aid in spotting it once it is on the ground.



4. TYPES OF ENGINES

Lower and intermediate stages always use engines which have no delay element, and no parachute ejection charge. No delay is used so that the next stage will receive the maximum velocity from its booster. Suitable engines have designations with a "0" delay, such as the B6-0, C6-0, D12-0, and A10-0T.

In the upper stage an engine with a delay and a 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 A8-5, B4-6, C6-7, D12-7, etc.

CLUSTERING

When large models and heavy payloads have to be launched, one engine often cannot supply enough power. A cluster of several engines can be used in this case.

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.

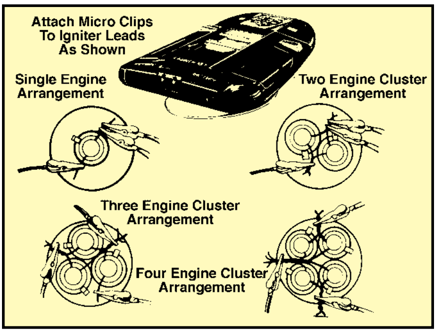
FIG. 1

2 - Parallel **3 - Parallel** **3 - Cluster** **4 - Cluster**

CLUSTER IGNITION METHODS

Reliable ignition is the most important part of successful clustering. All engines must be ignited simultaneously; this requires a heavy-duty launch controller that can supply high current levels. The Estes Command Control launch controller is designed specifically for cluster ignition. A custom designed controller using a 12 volt car battery for the power supply and a heavy gauge wiring is also suitable.

Carefully install igniters in the cluster engines using igniter plugs in the normal way, making sure the tips of the igniters are touching the propellant and are held firmly in place. Igniters must be connected in parallel – not in series! The easiest way to do this is using “clip whips.” Meticulously clean all clips with sandpaper before hooking up the igniters. Every igniter must be connected to one micro-clip from each clip whip. Double-check that one and only one clip from each whip is connected to every engine. At the launcher, check that none of the igniter leads or micro-clips are shorted to each other, to the blast deflector, or to the launch rod. Check one last time that all clips are in place.



GENERAL INFORMATION

Use a heavy-duty launch pad such as the Estes Porta-Pad E™ launch pad with cluster models. When heavy rockets are being flown, the launch pad should be anchored to the ground with stakes or weights.

The Safety Code requires that you stand at least 30 feet away when igniting an engine or cluster of engines totalling more than 30 Newton-seconds of total impulse.

To legally fly rockets weighing more than one pound or using engines containing more than four ounces of propellant, you may need to notify the Federal Aviation Administration, or obtain an FAA waiver, depending on the type of airspace control over your launch area.

Before installing the engines in your cluster rocket, pack the front of each engine above the ejection end cap with flame-resistant wadding. This eliminates the possibility of one engine’s ejection charge igniting the ejection charge of an unignited engine and damaging the rocket. For more complete information on clustering, see Estes Technical Report TR-6 in The Classic Collection.

PAYLOADS

Flying payloads on model rockets is an exciting and challenging activity for both novice and experienced rocket hobbyists. A wide variety of payloads have been flown successfully on model rockets.

Cameras: The Estes SnapShot Camera rocket allows even novice rocket flyers to take aerial photos from 500 feet high. Depending on the engine delay used, the photo can be a vertical shot of the launch area or an oblique view of the nearby landscape. Advanced modelers have adapted and flown auto-sequence 35 mm cameras, movie cameras, and even video cameras and digital cameras on rockets.

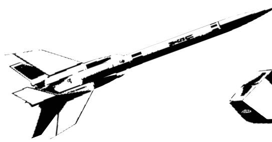
Electronic payloads: These payloads range from simple sonic beacons that aid in recovering rockets that land in tall grass, all the way to radio transmitters and miniature computers that make temperature or altitude measurements during flight.

Eggs: Launching a raw egg and recovering it unbroken can challenge the payload handling skills of any rocket flyer. The egg must be properly padded to survive the flight; you may want to enclose it in a plastic bag just in case!

Biological payloads: Except for insects, you should NEVER launch a live animal in your rocket. The high launch acceleration or a recovery failure could seriously injure or kill the animal. For a similar challenge, try flying a raw egg.

BOOST-GLIDERS

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



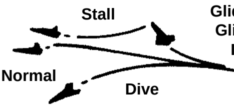
There are several types of boost-gliders, including: 1. Rear engine, 2. Front engine, 3. Pop-pod, 4. Variable geometry, and 5. Parasite. Some boost gliders use radio control to allow the modeler to pilot the glider. Although these types appear very different, many of the same principles apply to all.

A boost-glider, as any other rocket, must be stable to fly upward. During glide a model must still be stable, but not by nearly so great a margin. Boost-gliders can accomplish the transition from boost to glide configuration in several ways. Some use a change in balance point, often by ejecting engine pods; others use a shifting of aerodynamic surfaces; still others use combinations of both methods. See TR-4 and TR-7 in “The Classic Collection” for further discussion on gliders.

GLIDE TESTING

A boost-glider must be “trimmed” to glide correctly before launching. Some models are trimmed by adjusting the positions of elevons or other aerodynamic control surfaces. Other models are trimmed by adding or removing weight, such as clay, to the nose or tail of the glider.

When trimming a model, give it a straight, smooth, level toss into the wind and note how it glides. 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 tip which is on the outside as it turns.



Glide Paths Observed As Glider Is Tossed Lightly Into The Wind From Shoulder Height

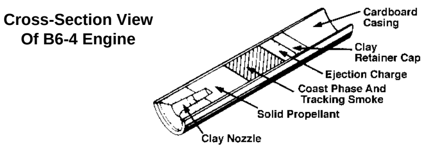
Few models are as spectacular in flight and as enjoyable to watch as a good boost-glider. The modeler looking for a challenge will find that developing improved boost-glide designs is one of the most rewarding areas of research in model rocketry.

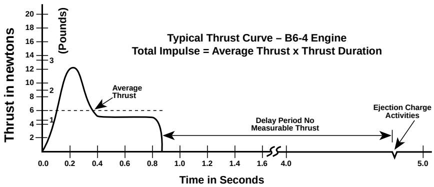
MODEL ROCKET ENGINES

Today's rocket flyers can choose from a large variety of engines to power their models, with an engine available for almost every purpose. NOTE: The rocket engine design and performance information given here is for educational purposes only. We believe that knowing how rocket engines work will increase your understanding of science and help you design better rockets for specific purposes. Manufacturing rocket engines is an inherently dangerous activity that should only be attempted by professionals!

OPERATION

The figures below show the internal structure and thrust curve of a typical model rocket engine.





The combustion of the solid propellant produces high temperature, high pressure gases that are ejected through the nozzle. The reaction to forcing the exhaust out the nozzle is a forward thrust (an example of Newton's Third Law of Motion). During the thrust phase the model rocket accelerates upward, gaining velocity and altitude.

After propellant burnout, the delay element is ignited. The delay material is slow-burning; it produces tracking smoke, but negligible thrust. The delay allows the rocket to coast to peak altitude before igniting the ejection charge.

The rapidly-burning ejection charge produces a burst of gas to pressurize the body tube and activate the recovery system of the model.

ENGINE CODES

Model rocket engines are labeled with a three-part classification code ("B6-4", for example) that describes the performance parameters of the engine. You must understand this code in order to choose the proper engine for your model.

The first part of the engine code is a letter designating the motor's TOTAL IMPULSE class (the "B" in B6-4). You can think of total impulse as the total power the engine produces. Technically, total impulse is a measure of the momentum change the engine can impart to the rocket, measured in Newton-seconds. In practical terms, an engine with greater total impulse can lift a rocket higher and faster, and can lift heavier rockets, than an engine with lower total impulse. The table below gives the total impulse ranges and typical rocket performance for each class.

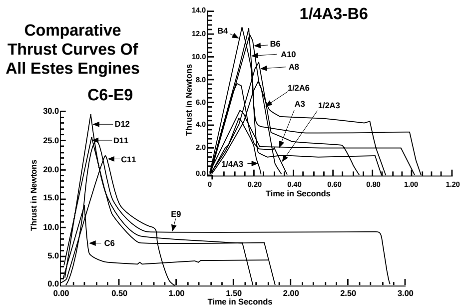
TYPE CODE	TOTAL IMPULSE Newton-Sec	ALTITUDE RANGE OF TYPICAL MODELS meters	APPROX. ALTITUDE OF 60 gram, BT-50 ROCKET meters
1/4 A	0 - 0.625	10 to 75	3 (not rec.)
1/2 A	0.626 - 1.25	20 to 120	10
A	1.26 - 2.50	40 to 250	40
B	2.51 - 5.00	60 to 400	110
C	5.01 - 10.00	80 to 600	260
D	10.01 - 20.00	100 to 700	440
E	20.01 - 40.00	130 to 800	760
F	40.01 - 80.00	160 to 1000	N/A

The second part of the engine code (the "6" in B6-4) gives the AVERAGE THRUST of the engine, measured in Newtons. The Newton is a measure of force; 1 pound equals 4.45 Newtons. The greater the thrust of an engine, the harder it pushes on the rocket and the faster the rocket will accelerate. The B8 and B4 are both B engines (so they have the same total impulse) but the greater thrust of the B8 will cause a rocket to leap into the air much faster.

The third part of the engine code follows the dash (the "4" in B6-4); this number is the TIME DELAY, in seconds, between burnout of the propellant and activation of the ejection charge. This delay allows the rocket to coast to peak altitude before deployment of the recovery system. The proper choice of delay time depends on how long it takes a rocket to reach peak altitude with a particular engine. Engines with codes ending in "-0" are booster engines; they do not contain delay and ejection charges. There is also a special type of "plugged" engine with codes ending in "-P"; these are useful in radio-control gliders where no ejection or booster blow-through is desired.

THRUST CURVES

Estes engines come in different types including end-burning and semi-core-burning. The different thrust curve shapes of these two types are primarily the result of the depth of the "port" formed in the the propellant.



The most common model rocket engine is the end-burner, which has a shallow port. This design is used in many Estes engines and is especially effective with lightweight 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, semi-core-burning engines are available. These engines have deeper ports, producing a very high initial thrust peak due to a larger surface area for propellant burning.

SELECTING THE CORRECT ENGINE

Always use an appropriate engine to fly your rocket. Just because an engine fits in the model does not mean it is a suitable engine! When flying an Estes rocket, consult the Estes catalog or the kit instructions for a list of engines recommended for that model.

If the launch field is small, or if the weather conditions are windy, use a lower total impulse engine to increase your chances of recovering the rocket. If you are launching a heavy payload in a model, it may be necessary to use an engine with a shorter time delay than is recommended for the rocket without a payload.

ENGINEERING AND QUALITY CONTROL

Today the Estes engine represents the result of ever 45 years' effort in engineering, craftsmanship and quality control. The total impulse of Estes engines is closely controlled, which allows us to make our engines very near the maximum permissible size in a given class.

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. 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.

MODEL ROCKET PERFORMANCE

Several factors affect the altitude performance of model rockets.

ENGINE SIZE

The greater the total impulse of an engine, the higher it will boost a model. The approximate altitudes achieved by typical single stage rockets are listed in the table on page 12; high performance models can exceed these values. 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.

WEIGHT

In most cases, the heavier a rocket, the lower the altitude it will reach. A baseball can be tossed higher than an 8 pound bowling 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. Remember to also add the weight of any payload carried in the rocket.

Use high-thrust engines with heavy rockets to insure adequate lift-off speed. The lift-off weight of the rocket must not exceed the Maximum Liftoff Weight for the engine being used (see the engine tables in your Estes catalog).

DRAG

Drag, or wind resistance, is the third item which affects performance. The more drag on a rocket, the lower the 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 performance.

NAR SAFETY CODE

1. MATERIALS. I will use only lightweight, non-metal parts for the nose, body, and fins of my rocket.

2. MOTORS. I will use only certified, commercially-made model rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.

3. IGNITION SYSTEM. I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and will use a launch switch that returns to the "off" position when released.

4. MISFIRES. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

5. LAUNCH SAFETY. I will use a countdown before launch, and will ensure that everyone is paying attention and is a safe distance of at least 15 feet (4.6 m) away when I launch rockets with D motors or smaller, and 30 feet (9 m) when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.

6. LAUNCHER. I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of the rod when it is not in use.

7. SIZE. My model rocket will not weigh more than 53 ounces (1500 grams) at liftoff and will not contain more than 4.4 ounces (125 grams) of propellant or 71.9 pound-seconds (320 N-sec) of total impulse. If my model rocket weighs more than one pound (453 grams) at liftoff or has more than 4 ounces (113 grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

8. FLIGHT SAFETY. I will not launch my rocket at targets, into clouds, or near airplanes, and will not put any flammable or explosive payload in my rocket.

9. LAUNCH SITE. I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour (32 km/h). I will ensure that there is no dry grass close to the launch pad, and that the launch site does not present risk of grass fires.

LAUNCH SITE DIMENSIONS

Installed Total Impulse	Equivalent Motor Type	Minimum Site Dimensions	
		Feet	Meters
.00 - 1.25	1/4A, 1/2A	50	15
1.26 - 2.50	A	100	30
2.51 - 5.00	B	200	60
5.01 - 10.00	C	400	120
10.01 - 20.00	D	500	150
20.01 - 40.00	E	1,000	300
40.01 - 80.00	F	1,000	300
80.01 - 160.00	G	1,000	300
160.01 -320.00	Two G's	1,500	450

10. RECOVERY SYSTEM. I will use a recovery system such as a streamer or parachute in my rocket so that it returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

11. RECOVERY SAFETY. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.

PUBLICATIONS AVAILABLE FROM ESTES WEBSITES

Electronic Model Rocket News
Provides articles of interest, technical tips, information about new products, special offers, and much more. Available at www.estesrocket.com

Newton's Laws of Motion and Model Rocketry - 2821
The three laws of motion are explained in easily understood terms. Simple examples and experiments are included.

Estes Guide for Aerospace Clubs - 2817
The perfect source book for organizing and operating a successful model rocket club or ESP chapter.

Model Rocket Contest Guide - 2815
Use to plan model rocket contests for clubs or schools. Details on competitive events and suggestions on all facets of contest organization.

Projects in Model Rocketry - 2831
Suggestions on how to plan, prepare, and present research projects, ideas for about one hundred projects.

Model Rocket Launch Systems - 2811
Contains a wealth of information. Photographs and clearly-drawn schematics make it easily understood.

The Classic Collection - 2845
A comprehensive collection of technical reports and notes that make a valuable reference tool. Includes TR-1 through TR-7 and TN-1, TN-3, TN-4, and TN-6.

Model Rocketry Study Guide - 2841
A logical program for anyone who wants the most from model rocketry. Guides a beginner on the path to becoming an expert rocketeer.

Altitude Prediction Charts - 2842
A simple system by which aerodynamic drag and other effects can be taken into account in predicting rocket peak altitudes. Technical Report TR-10.

Aerodynamic Drag of Model Rockets - 2843
Gives practical examples of ways to minimize aerodynamic drag and improve performance. Technical Report TR-11.

Elementary Mathematics of Model Rocket Flight - 2844
Information on how to make your own altitude tracker and calculate speeds and accelerations. Technical Note TN-5.

Model Rocketry Technical Manual - 2819
Handy guide for construction and flight of model rockets. Tips on "scratch building", launch systems, tracking, staging, boost-gliders, and more.

Estes Educator News
Interesting technical articles, new product information, plus activities and resources on space and model rocketry subjects suitable for classroom use. Available at www.esteseducator.com.

Guide for Teachers and Youth Group Leaders - 2814
Introduces you to Estes' model rocket technology and the complete services offered in our educational program.

Camp Leader's Model Rocketry Manual - 2822
Proven guide for introducing model rocketry successfully into camp programs.

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