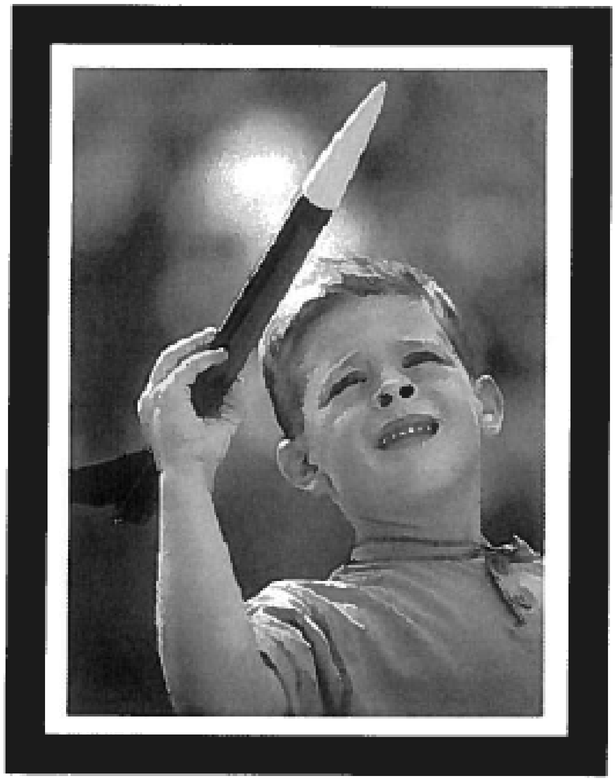
MC1302A
Member's Manual



4-H Basic Model Rocketry Units 1 & 2

Acknowledgements

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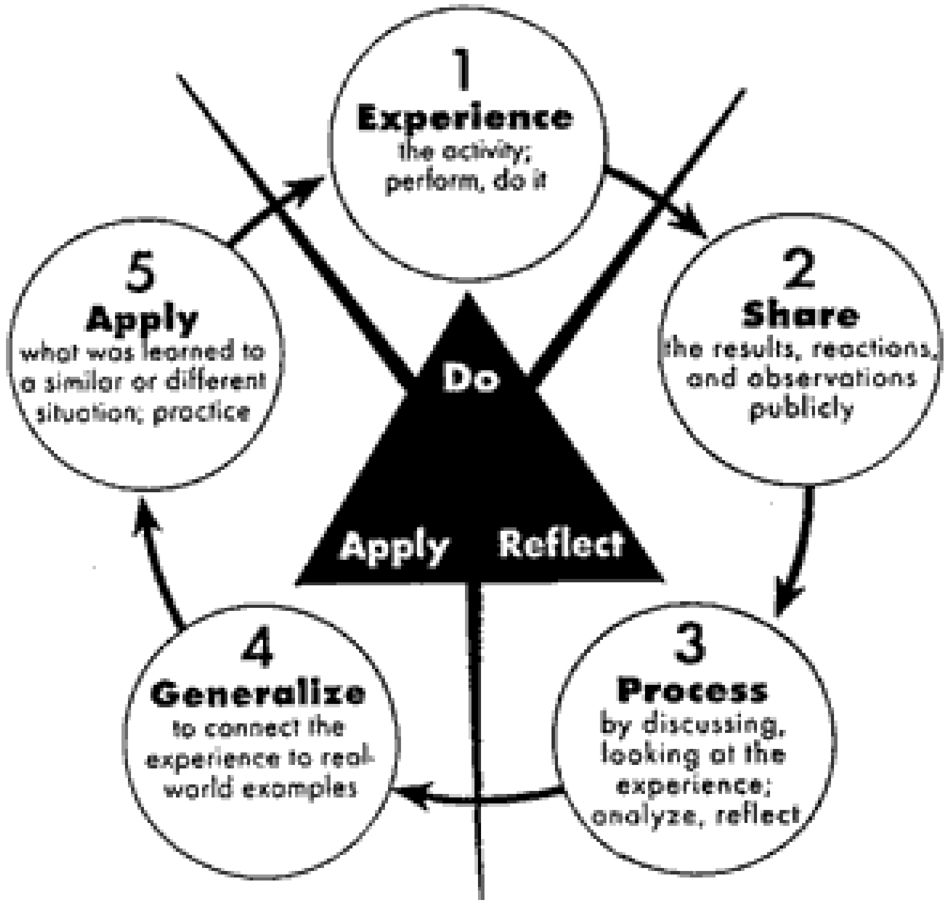
EXPERIENTIAL LEARNING PROCESS

The 4-H program has adopted a process that allows youth to first learn by doing before being told or shown how and then process the experience. The experiential learning model developed by Pfieffer and Jones (1985) and modified by 4-H includes five specific steps:



The Experiential Learning Process allows an individual to go through the process of discovery with very little guidance from another individual. A situation, project or activity is presented that allows for individual thought and problem solving. Outside assistance is provided at a minimum and supports the individual throughout the process by questioning at each stage. Individuals participate in an activity, reflect on what they did, and then assess how what they learned can be applied to a life situation.

1) Experience Questions: How is it working? What else might you try? What might make it easier?
2) Share Questions: What happened? How did you feel? What was the most difficult?
3) Process Questions: What problems seemed to reoccur? What similar experiences have you had?
4) Generalize Questions: What did you learn about yourself? What did you learn about the activity? How does this relate to something else in life? How did you decide what to do?
5) Apply Questions: Where else can this skill be used? How will you use this in the future? What will you do differently after this experience?

INTRODUCTION

Congratulations! By taking this project, you are taking steps to becoming the next astronaut or scientist who will change space travel and exploration in the future.

Model Rocketry Fundamentals (written for Units 1 and 2) is designed for the 4-H member who has little to no experience in building or launching model rockets. As a 4-H member, leader, or parent, you will learn about the history of rocketry and about the scientific principles of rocketry, range safety and launching aspects of model rocketry.

Unit 1 consists of Skill Level 1 rockets with simple, one-piece balsa or basswood fins only. Unit 2 consists of Skill Level 2 rocket kits with balsa or basswood fins only.

ROCKETRY

Rocketry Categories

There are four categories of rocketry that are recognized: Model Rocketry (MR) aka Low Power Rocketry (LPR), High Power Rocketry (HPR), Research Rocketry and Professional Rocketry.

Model Rocketry (MR) or Low Power Rocketry (LPR) —

Consists of model rockets constructed of safe materials—e.g. cardboard, plastic, and wood—and are fueled by single-use motors, composite motors, or reloadable motors, which are commercially manufactured. These rockets may be flown over and over simply by replacing the used motor with a fresh one. They typically contain a parachute, streamer, or other recovery device that allows them to land gently for later re-flight. The modeler need never mix, pack, or work with explosives or propellants. The maximum weight for a MR is 3.3 pounds. Motors use 4.4 ounces (125 grams) or less of propellant. As a rule, motors for model rockets are sized A-G class up to 320 N-sec of total impulse. Model rocketry is regulated by the National Fire Protection Association (NFPA) Code 1122.

High Power Rocketry (HPR)—

Consists of model rockets also constructed of safe materials but tend to use stronger materials and techniques such as plywood for fins and fiberglass techniques. HPR can be any size rocket using commercially available APCP or hybrid motors ranging from “G” to “O” power. To launch high power rockets, you must be a member of NAR or Tripoli, have a HPR level certification and be a minimum age of 18 years old to purchase high power rocket motors. Youth ages 14-17 may obtain a Junior HPR Level One certification in order to launch “H” and “I” motors. All high power rockets must be flown in compliance with their own separate High Power Safety Code. HPR is regulated by the NFPA Code 1127 and the FAA (Federal Aviation Administration)

Research Rocketry (aka Amateur and Experimental Rocketry)—

Rocketeers who uses any commercially made rocket motor or builds their own APCP or Hybrid motors. Most research rocketeers make their own motors, design their own rockets and use very expensive electronic devices to track their data and recover their rockets with. This is not an option for children.

Professional Rocketry—

People who work in the field of rocketry come from all types such as engineers, scientists, mathematicians, chemists, technicians and astronauts. Jobs stem from the private and commercial sectors, as well as from the government. Would you like to get paid to work with rockets?

MR (aka LPR) and HPR—
Both hobby crafts are for those who simply enjoy the building and launching of rockets. This type of rocketry is considered sport rocketry including public launches, creation of clubs and competitions. You do not have to be a member of NAR or Tripoli to participate in MR, but by participating in MR and HPR you are required to follow the NAR Safety Codes.

Brief History of Rocketry

Modern rocketry is the culmination of over 2,000 years of human imagination, experimentation, invention, warfare and scientific discovery. There were many scientists over millennia that influenced rocketry. Archytas, a Greek philosopher, used thrust for motion. Sir Isaac Newton published the “Three Laws of Motion,” the basis for all modern rocket science. Konstantin Tsiolkovsky (the *Father of Modern Astronautics*) researched the possibilities of earth satellites and space stations, and Robert Goddard (the *Father of Modern Rocketry*) created and launched the first liquid propellant rocket motor. These advances paved the way for the Soviet Union’s “Sputnik,” mankind’s first satellite, and American astronauts completing the first manned landing on the moon.

Rocketry has advanced tremendously since the beginning and will continue with future missions of space exploration and the advancement of rocket science.

MODEL ROCKETRY

History of Model Rocketry

With the end of World War II, the sky no longer held limits for individual imaginations, and reaching for the stars was no longer a dream but a possibility. Young rocket enthusiasts started designing and building their own model rockets and rocket motors—involving metallic body tubes and the mixing of dangerous propellants—that was responsible for injuring and even killing numerous young scientific experimenters. A licensed pyrotechnics expert, Orville Carlisle, and his brother Robert designed a model rocket and model rocket motors for Robert to use in his lectures on the principles of rocket-powered flight. G. Harry Stine, an engineer and author, wrote articles published in Popular Mechanics about young people attempting to make their own rocket motors with disastrous results. The Carlisle brothers sent samples of their designs to Mr. Stine, resulting in Mr. Stine and Orville Carlisle forming the first model rocket company. Model Missiles Incorporated, in Denver, Colorado. Mr. Stine, who is widely known as the *“Father of Model Rocketry*,” also authored “The Handbook of Model Rocketry” (now in its seventh edition), and founded the National Association of Rocketry (NAR) in 1958 to promote model rocketry and safety within the hobby. Orville Carlisle became the first member of NAR. The NAR publishes the standard which governs all model rocketry enthusiasts today, the NAR “Model Rocketry Safety Code.”

For Adult and Volunteer Leaders:

Visit the 4-H website at www.colorado4h.org for information on governing agencies and model rocketry organizations and clubs.

Types of Model Rockets

Rockets are classified by complexity (skill levels), style, ability to carry a payload and motor type.

Skill Levels—

Model rockets are generally placed into six levels of skills, ranging from SL-0 ready-to-fly models to SL-5 extremely challenging rockets to build.

Single Motor Rockets—

Rockets which contain only one motor.

Cluster Motor Rockets—

Rockets having two or more motors in a single body tube. All motors are ignited at the same time.

Multi-Stage Rockets—

Rockets having two or more body tubes stacked end on end with a motor in each section. The tubes' motors are coupled together, one on top of the other. This type of rocket uses a sequential ignition method, meaning that first the booster stage ignites, then prior to burnout ignites the intermediate stage (if any), and finally the sustainer (or upper stage) ignites. Each lower stage upon burnout stumbles to the ground.   No more than three stages are considered stable for model rockets.

Payload Rockets—

Rockets that carry cargo when they are launched. Payload sections can be either a clear plastic tube or an additional body tube and are usually affixed between the middle of the rocket and the nosecone. They can carry simple items like toy action figures, flowers, glow sticks, marbles, or eggs to more complicated items like altitude measuring devices or cameras. Never place live animals or any living thing with a vertebra in a payload. Finally, never put anything that is destructive, flammable, explosive or otherwise harmful in a model rocket.

Scale Rockets (includes scale-like and semi-scale)—

Model rockets which are modeled after a real rocket. Scale model rockets should always be painted and decaled according to their actual counterpart rocket.

Novelty Rockets—

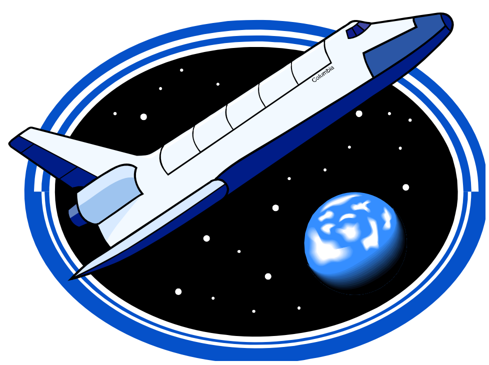
Unusual shaped rockets or futuristic styled, or rockets that take the appearance of a real non-rocket object. Examples are port-a-potty, police box, cones, pyramids, spools, saucers, etc.

Helicopter—

This rocket uses a revolving or spinning motion to help break its fall. Helicopter recovery systems generally consist of rotary blades of some type.

Gliders—

A recovery system consisting of wide sings to glide and slow the air-born vehicle's descent. Rockets may be recovered by a glider recovery system or carry (boost) a glider vehicle into the air releasing the glider vehicle at apogee and then descend on its own parachute or streamer recovery system.



NAR Model Rocket Safety Code

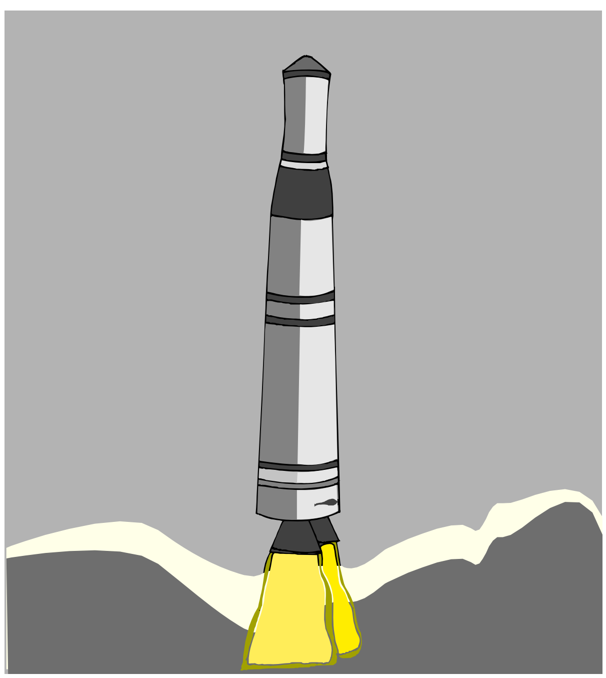
1. **Materials.** I will use only lightweight, non-metal parts for the nose, body, and fins of my rocket.
2. **Motors.** I will use only certified, commercially made model rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.
3. **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 away when I launch rockets with D motors or smaller, and 30 feet 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 1,500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320 N-sec (71.9 pound-seconds) of total impulse.
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 table below and in safe weather conditions with wind speeds no greater than 20 miles per hour. 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.
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.

A fire extinguisher and First Aid Kit should be available.

LAUNCH SITE DIMENSIONS

Installed Total Impulse (N-sec)	Equivalent Motor Type	Minimum Site Dimensions (ft.)
0.00--1.25	1/4A, 1/2A	50
1.26--2.50	A	100
2.51--5.00	B	200
5.01--10.00	C	400
10.01--20.00	D	500
20.01--40.00	E	1,000
40.01--80.00	F	1,000
80.01--160.00	G	1,000
160.01--320.00	Two Gs	1,500

Revised March 2009 taken from the NAR website: http://www.nar.org/NARmrsc.html



SCIENCE PRINCIPLES OF ROCKETRY

What makes a rocket launch into the air? How can you predict the flight of a rocket? The science of physics, developed after centuries of observations, predictions, and experiments, helps explain rocket science and was instrumental to its development. To understand the science of rocketry, it is important to first understand the concept of a force.

Concept of Force

What is a force? A force is simply a push or a pull. Sometimes, you can feel a force. For example, when you kick a soccer ball, you are giving the ball a *push* force. In football, when the defensive player misses his tackle and he grabs onto the jersey of his opponent and tries to pull him to the ground, the opponent is feeling a *pull* force.

However, there are many forces that you cannot see or feel that are working all of the time. For example, when you are standing, the force of gravity is pulling you down while the force of the ground is pushing you up. Because the force of gravity pulling you down is the same as the force of the ground pushing you up, scientists say that the forces are balanced. When forces are balanced, they cancel each other out and you do not notice anything; you remain standing. However, if someone comes along and gives you a shove, your body has just sustained an unbalanced force and you may fall to the ground; in this case, the forces are not balanced. Therefore, if one force is greater than another, scientists say that the forces are unbalanced and then something happens.

From these ideas, Newton discovered and developed the Three Laws of Motion. The Three Laws of Motion explain how a rocket performs.

First Law of Motion: The Law of Inertia

Galileo's discovery of *inertia* is especially important for rocketry. Galileo rolled balls down ramps, across flat surfaces and threw them around a room. He discovered that falling objects fall increasingly faster because gravity is pulling them to the ground. However, he noticed that objects rolling along a flat surface kept the same speed. Galileo called this concept inertia. Inertia describes why a spacecraft keeps moving forever in space at the same speed unless it uses its engine to speed up or slow down or until it bumps into something.

Activity #1: Explore Inertia

Prep time: 20 seconds

Experiment time: 10 seconds

Materials: Mug

One playing card

Nickel or quarter

Procedure:

1. Place the mug upside down on a flat surface, preferably a table or a counter.
2. Place the playing card on top of the bottom of the mug so that the ends of the playing card stick over the edge of the mug.
3. Place the coin on top of the card at the center of the mug.
4. Using your thumb and forefinger, snap the card away from you. Be sure to snap level with the card.
4. Next time try it with the mug right side up.

What happened? The coin should slightly drop onto the bottom of the mug in the same position as before, in the center of the mug.

Why? This activity illustrates inertia. Before you snap the card, the force of gravity is pulling down on the coin and the force of the card is pushing up on the coin; the forces are balanced. When you snap the card away, the coin stays in the same relative position in the center of the mug because of inertia; the coin is at rest and remains at rest until a force is acted upon it. (The coin falls slightly onto the bottom of the mug because the force of gravity is no longer countered by the force of the card.)

You may have seen several different versions of this trick. In one version, a person pulls the tablecloth out from under a table setting of china dishes and crystal glasses. All of these different versions illustrate the concept of inertia!

Isaac Newton used Galileo's discovery of inertia to develop his first law of motion. Newton's first law says that an object at rest will remain at rest and an object in motion will remain in motion unless acted upon by an unbalanced force.

Activity #2: Explore Unbalanced Forces

Prep time: 5 seconds

Experiment time: 5 seconds

Material: Drinking straw with paper wrapper on it

Procedure:

1. Carefully tear off one end of the paper wrapper on a drinking straw. Slide the paper wrapper about ½" away from the end, so that when you put your mouth on the drinking straw, the paper is not in your mouth.
2. Blow into the straw.

What happens? The paper wrapper on the drinking straw shoots off the straw.

Why? When air is blown into the straw with the paper wrapper, the paper wrapper moves away from you

An object at rest will stay at rest until a force is exerted on it. This means that when you put your rocket on the launch pad, it will stay there until you launch the rocket. The surface of the launch pad pushes the rocket up while gravity pulls the rocket down. Because these forces are equal, the rocket remains on the launch pad. When the motor is ignited, the force from the motor is an unbalanced force applied to the rocket, which causes the rocket to lift off from the launch pad.

A Type of Force—

An object will keep moving in a straight line at a constant speed until a force acts on it. For example, if you kick a soccer ball, it will keep rolling. However, you know that the soccer ball will eventually stop rolling and Newton's law explains why. The force from the friction of the grass and the air acts on the soccer ball, slowing it down until the soccer ball eventually stops. However, in outer space, friction is very small. In rocketry, Newton's first law says that a space rocket will move in a straight line at the same speed until other forces change the flight path of the rocket. When you watch the movement of a puck on an air hockey table, you are observing a system with almost no friction, similar to outer space. The puck keeps moving in a straight line until it bumps into the side of the table, hits the goal, or until a player hits the puck. What causes friction? Tiny grooves and ridges on the surface of objects cause friction. Many times, you cannot even see these grooves and bumps. However, the grooves and ridges snag on each other, slowing down the object. The rougher the surface, the bigger the grooves and the ridges are, making it easier to snag and slow down the object.

A Type of Friction—
Drag is a type of friction that occurs when objects move through liquids such as water or gases such as air. Drag slows down runners, swimmers, and racecars. That is why many swimmers in the Olympics wear specially designed swim suits to make the grooves and ridges in the swim suit fabric smaller, or in other words, to minimize the drag of a swimmer in the water; these specially designed swim suits can make a person swim a fraction of a second faster, enough to help that person win a race. Drag is also why racecars have a more streamlined shape than a van.

Drag also affects model rockets. If the surface of your model rocket is not smooth, your rocket will not accelerate as much and will not soar as high as predicted with a certain rocket engine. Therefore, you might need to sand your rocket fins. When you participate in an advanced model rocketry project, you will have the opportunity to design your own rocket. In that project, you may want to design a streamlined rocket to minimize drag.

Second Law of Motion: The Law of Acceleration

Newton's second law describes what happens when a force acts on something. If the force acts on an object that is not moving (at rest) and the force is big enough, then the object will start moving (accelerating) in the direction of the force. If the object is moving, then the force can make the object move faster (accelerate), slow it down (decelerate), or change its direction.

Newton expressed these ideas in a simple mathematical equation:

F=ma

Force (f) = mass (m) multiplied by (X) acceleration (a).

According to his equation, if the object keeps the same mass, the bigger the force that is applied, the larger the acceleration will be. The more powerful the rocket engine that you use to launch your rocket, the greater the acceleration of your model rocket will be.

However, Newton's equation also says that if the force stays the same, a lighter object that has less mass will accelerate or decelerate faster than a heavier object with more mass. What does this mean? For example, if you are racing on a bicycle, it is easier to go faster on a lighter weight bicycle than on a heavier one. Similarly, this law explains why it takes longer for a freight train to come to a stop than a car or a person on a bicycle; a freight train loaded down with coal is a much heavier object with much more mass.

Newton's second law explains why there are different types of rocket engines for model rockets. A model rocket with less mass will have a greater acceleration than a rocket with more mass using the same type of rocket engine. Therefore, the acceleration of a model rocket depends upon the mass of the rocket and the force of the rocket engine. If you are attempting to launch a model rocket with more mass, you will need to use a more powerful engine to overcome the force of gravity.

Mass and Weight/Acceleration and Speed—
By now, you have probably noticed that we have used the words mass and weight. Many people use weight and mass interchangeably,

but that is not technically correct. So, what is the difference between mass and weight? Pretend that you weigh 100 pounds when you step onto a scale on Earth. However, if you step onto a scale on the moon you will weigh less than 17 pounds and on Jupiter, you will weigh a whopping 264 pounds. What happened? After all, you are the same person; the amount of material that you contain, called your mass, is the same. No matter whether you are standing on the Earth, on the moon, or on Jupiter, your mass remains the same. When you weigh yourself on Earth, the scale records your mass plus the force of Earth's gravity, and the number on the scale that you see is called your weight.

However, the force of gravity on the moon is one-sixth the force of gravity on Earth; thus, you weigh much less on the moon than you do on Earth. In contrast, the force of gravity on Jupiter is 2.64 greater. Therefore, you weigh much more on Jupiter than you do on Earth. Thus, mass is the amount of material that an object contains and remains the same regardless of its location. In contrast, weight depends upon the force of gravity on an object's mass; thus, an object's weight will change depending upon its location.

Why is this important? Newton's equation uses mass instead of weight. Thus, the equation says that the force necessary to move an object is the same on the Earth, the moon, Jupiter, or in space.

There is also a difference between acceleration and velocity (speed). Let us say that you are running at the pace of 9 miles per hour. After a while, you get tired and start to slow down. Then as you are reaching the finish line, you see that your competitor is just in front of you. By speeding up or increasing your velocity, you cross the finish line before your opponent and win the race! Thus, speed is how fast you are traveling. Acceleration describes any change in speed, whether it is positive or negative. A decrease in speed is called deceleration.

Third Law of Motion: Law of Reaction

Newton's third law states that for every action, there is an equal and opposite reaction. This law explains why a rocket launches into space. When the rocket motor pushes gas downward (the action in Newton's law), the gas pushes back on the rocket (the reaction in Newton's law), pushing the rocket upward, and liftoff occurs.

On the next pages are several activities to do with your members that show Newton's Third Law of Motion.

Subject Background—

Do you know who Sir Isaac Newton is? He was born in 1643 and discovered the three laws of motion. Thrust is the force which moves a rocket through the air and through space. This demonstrates Newton's third law of motion—for every action there is an equal and opposite reaction. In order to have an action-reaction you need to have a pair of things. Let's think of jumping up in the air. Your "action" is pushing up off the ground and the "reaction" is your body going up into the air.

Activity #3: Air Pressure Straw Rockets

Suggested Group Size: 8-10 Youth

Recommended Ages: 5-18

Activity Time Estimate: 1 ½ hours

Materials:

- Paper
- Drinking Straws (no bends)
- Scotch Tape
- Sample Straw Rocket
- Modeling Clay
- Card Stock
- Scissors
- Straw Rocket Launcher*

Purposes:

- To understand air resistance
- To learn about air pressure
- To learn laws of motion
- To identify parts of a rocket
- To encourage creativity

*Go to www.colorado4h.org to obtain reference material to build a straw rocket launcher for approximately $10 or contact your local Extension office to see if they have one.

Procedure:

1. Show youth an example of an air pressure rocket and have them name the parts: body, tube, fins, and nosecone.

2. Discuss all the possible variable when building an air pressure rocket:

   a. Size of fins

   b. Location of fins

   c. Fin material

   d. Shape of fins

3. Have youth build their straw rocket. They can decide on the length of their body tube. Have them cut the length they wish, then use their thumb-tip ball size of clay to “plug up” one side of the rocket and shape it into a nosecone. Have them smooth the clay down along the sides to seal any air holes.

4. Have them then cut three identical fins to attach to the other side of the rocket with tape.

5. Gently load the straw onto the launching tube, making sure the youth **do not jam it on,** as this can cause clay to get into the tube and cause launch failure.

6. You can either have youth launch for altitude or aim for a target by rotating the launching tube gently to an angle.

7. When the youth are ready to launch the rocket, have them pull the rod up and just let it go. **Do not allow them to slam it down,** as it makes no difference in the rocket performance and only compress the spring and damages the launcher.

Variation: Point out the different designs and discuss which went further/higher.

Activity #4: Balloon

Prep time: 30 seconds

Experiment time: 20 seconds

Material: Balloons

Procedure: Blow up a balloon. Release.

What happens? The balloon "flies" around the room.

Why? When air is released from the balloon (the action in Newton's third law), the balloon moves away (the reaction in Newton's third law). Why doesn't the balloon move straight forward? That is because the air is not released evenly from the balloon, causing the balloon to vibrate and move unpredictably around the room.

Activity #5: Rocket Balloons

Prep time: 3 – 5 minutes

Experiment time: 30 seconds

This is a fun activity. However, it is a little more difficult than the previous activities because it is tricky to attach the balloon properly to the straw.

Materials:
- Balloons
- Drinking straw
- Smooth string or fishing line (at least 10 feet)
- Tape
- Helpers

Procedure:

1. Thread the string through the drinking straw. Have a helper hold each end of the string, pulling the string taut. The straw should be close to one end of the string.
2. Blow up the balloon.
3. Have another helper carefully tape the balloon to the drinking straw. (Do not tape the balloon to the straw at the end of the balloon where you blew in the air.)
4. Release the balloon.

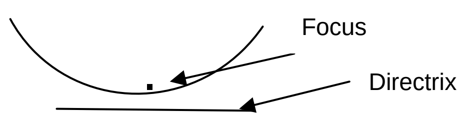
What happened? The balloon moved along the string, away from its starting location.

Why? When the balloon is released, air escapes from the balloon (the action in Newton's third law). The balloon then moves away (the equal and opposite reaction in Newton's third law).

Try repeating this activity using different sizes and types of balloons and by blowing up the balloons using different amounts of air (partially blowing up the balloon, blowing up the balloon to its maximum capacity, etc.). Observe.

If you have seen a rocket launched, you may have noticed that the rocket did not go straight into the air and return straight back down to land on top of the launch pad. In fact, the flight path of a model rocket –or its trajectory--usually has the shape of a parabola. The path is governed by projectile motion equations which break down the movement of the rocket into horizontal and vertical components. Whereas the upward or horizontal motion is constantly decelerating due to the force of gravity, the cross motion or vertical component is unchanged throughout the flight. (Newton's first law!) Both components are affected by the angle of launch and wind conditions. This leads to a parabolic trajectory which is illustrated below.

Below is an example of a parabola. A parabola is the set of all points (x, y) that are the same distance from a fixed line (called the directrix) and a fixed point (focus) not on the directix.



How can you predict the flight path of your model rocket? How can you predict the apogee, or total height, of your rocket that you have designed? To answer those questions requires more complicated mathematical calculations than addition, subtraction, multiplication, and division. In fact, Newton developed a completely new type of mathematics called calculus so that he could make those predictions.

As you participate in more advanced rocketry projects, you will study Newton's laws and the science and mathematics of rocketry in more detail. You will then be on your way to becoming an aeronautical engineer, or a real "rocket scientist".

ELEMENTS AND FLIGHT PRINCIPLES OF MODEL ROCKETRY

Anatomy of a Model Rocket

Basic Parts of a Model Rocket—In order to build and launch model rockets, it is important to learn the names and functions of the parts.

External Parts of a Model Rocket—

Nose Cone: The leading part of the rocket. LPR nosecones consist of molded plastic or shaped balsa wood. Nosecones usually come in one of the following shapes: parabola, hemisphere, ogive, cone, blunt cone or blunt. The shape of the nosecone is determining factor as to how fast and how high the rocket will travel.

Body Tube (aka Airframe): Encases motor, wadding, and the recovery device

Fins: Stabilizes rocket during flight.

Launch Lug: Fits over launch rod, guides rocket straight until rocket is going fast enough for the fins to stabilize the flight

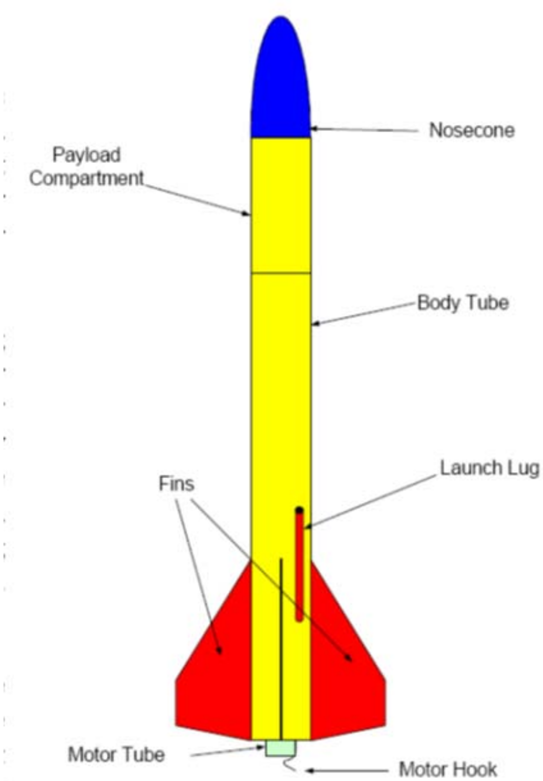
Motor Mount Assembly Parts---
A unit to hold the rocket motor in place within the end of the rocket's body tube. The motor mount assembly consists of:

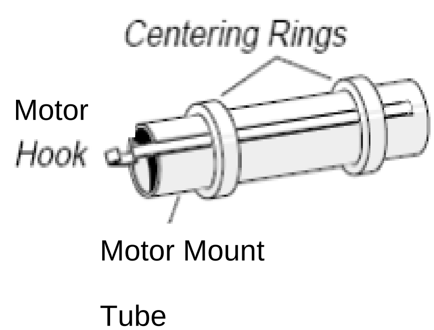
Motor Mount Tube: Where the motor fits into.

Centering Ring (s): Centers the motor mount assembly in the body tube.

Motor Hook or Motor Retainer Clip: Secures the motor in the motor tube.

Thrust Ring: Prevents motor from being forced into the upper body tube. Not all models contain a thrust ring.





Internal Recovery Parts of a Model Rocket —

Parachute: Parachutes consist of a circular piece of material, shroud lines and adhesive dots or tabs. Parachutes vary according to size of model rocket, 8 inches to 35 inches or larger in diameter. They are used to return the rocket safely to earth after its flight. Parachute shroud lines are a series of thing strings attached to the parachute enabling the parachute to billow out catching the air, to slow the flight descent.

Eyelet or Screw Eye: A connection point on a nosecone where the top of the shock cord and the parachute shroud lines connect to, to ensure the nosecone and parachute stays attached to the rocket's body tube after deployment of the parachute. *Eyelet*---is a molded part on a plastic nosecone. *Screw Eye*---is used primarily on balsa nosecones, which is screwed and glued into the balsa.

Shock Cord Mount: A system used to connect the shock cord to the body tube.

Shock Cord: The shock cord connects the body tube to the nose cone eyelet so they do not become completely separated upon deployment of the parachute. The shock cord also transfers the "shock" of extreme force received during ejection of the parachute and nosecone. This lessens the chance of any damage done to the rocket.

Recovery Wadding: A flame resistant material (paper) used to protect the internal parts of the rocket from the ejection charge. However, if packed too tightly the gases and flames could cause damage to the rocket.

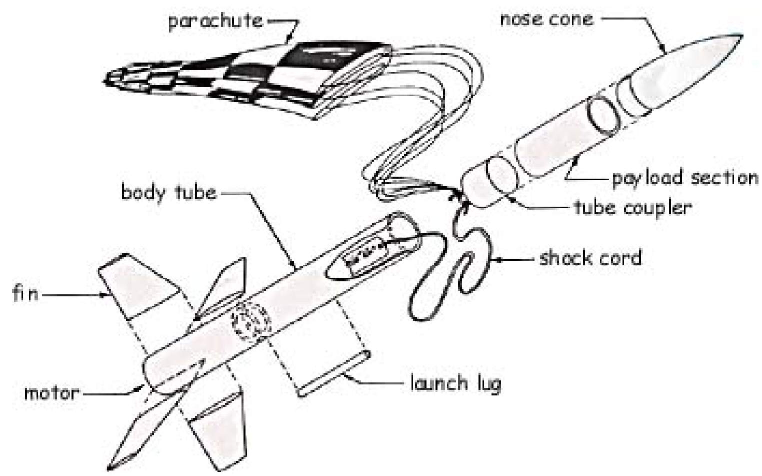


Figure 1: Taken from Model Rocketry Unit 2 Manual

Model Rocket Motors

Black Powder Motors —

Under the “Model Rocketry History” section of this manual, you learned that Orville Carlisle and G. Harry Stine formed the first model rocket company, Model Missiles Incorporated, in Denver, Colorado. By 1959, though, the demand for single-use rocket motors exceeded their capabilities to produce. The Estes family owned a fireworks company in Denver. Their son, Vern, found a way to mechanize the production of rocket motors. He patented the production of rocket motors. He patented a machine which he named “Mabel”. It was capable of producing a rocket motor in 5.5 seconds by using compressed air. Vern Estes formed his own company, Estes Industries, and in 1961 moved his company to Penrose, Colorado.

Parts of a Black Powder (Solid Fuel) Rocket Motor:

- Paper Casing
- Ceramic Nozzle
- Nozzle Throat
- Black Powder Solid Propellant
- Delay Element & Tracking Smoke
- Ejection Charge
- Clay Retainer Cap

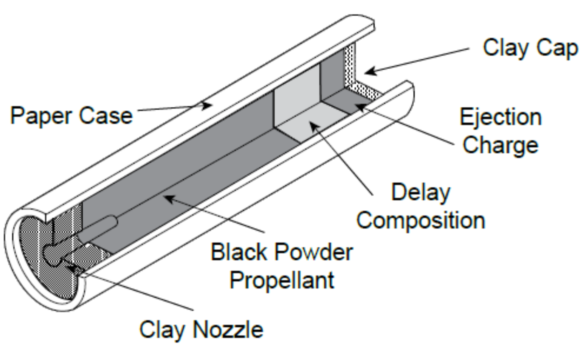


Figure 2: Apogee Components: A Rocketry Reservior; www.ApogeeRockets.com

Composite Motors —

Composite motors consist of primarily two major components: an oxidizer—Ammonium Perchlorate (AP), and a fuel-binder—which is usually made up of one or two types of materials. Both components are then mixed wet and then cured into a rubbery-solid form. Composite motors come in two types: single-use motors and reloadable motors. Composite motors are rapidly changing the market for rocket motors primarily starting with high power rockets, but more and more are being made for the smaller model rockets.

Parts of a Composite Motor:

- Casing (Single Use or Reloadable Casing)
- Nozzle
- Composite Propellant
- Delay Grain
- Delay Holder
- Ejection Charge
- Paper Cap

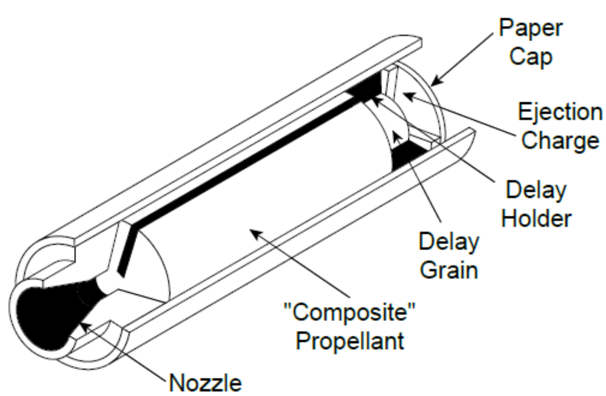


Figure 3 Apogee Components: A Rocketry Reservoir: www.ApogeeRockets.com

Standard Motor Classifications —

In the classifications of motors for model rocketry, we can begin with the power of the motor. The power of the motor is called "Total Impulse." Impulse is the product of "force" and the "time" over which the force is applied. The product of the force and the duration over which it was applied is called "Total Impulse." In rocketry, the force is the "thrust" produced by the motor, and the time is the duration over which the rocket motor is producing thrust.

Estes Inc. Black Powder Motor Coding System:

1. *Casing Color Code:* Estes' Industries color code their motors to provide easy identification of the four primary applications of black powder motors:

    a. Green—Single motor
    b. Purple---Upper Stage (on multi-staged rockets)
    c. Red---Booster Stage
    d. Black---Plugged for special applications

2. *Alpha-Numeric Code:* All commercially produced, black-powder motors will be labeled with an alpha-numeric code which depicts the motor's performance information:

    a. Total Impulse ("C")—The letter on the motor refers to the total impulse (total power in Newton seconds) produced by the motor. Each letter has up to double the total power as the previous letter.
    b. Average Thrust ("6")—The first number in the motor code shows the motors average thrust (average push) in newtons. [4.45 newtons = 1 lb.]
    c. Delay ("3")—The last number in the motor code is the number of seconds from burnout to ejection charge. The delay element consists of a slow burning matter which releases a smoke trail for easy rocket location in flight.

In a typical hobby store you will be able to find motors in power classes form 1/8A to F.

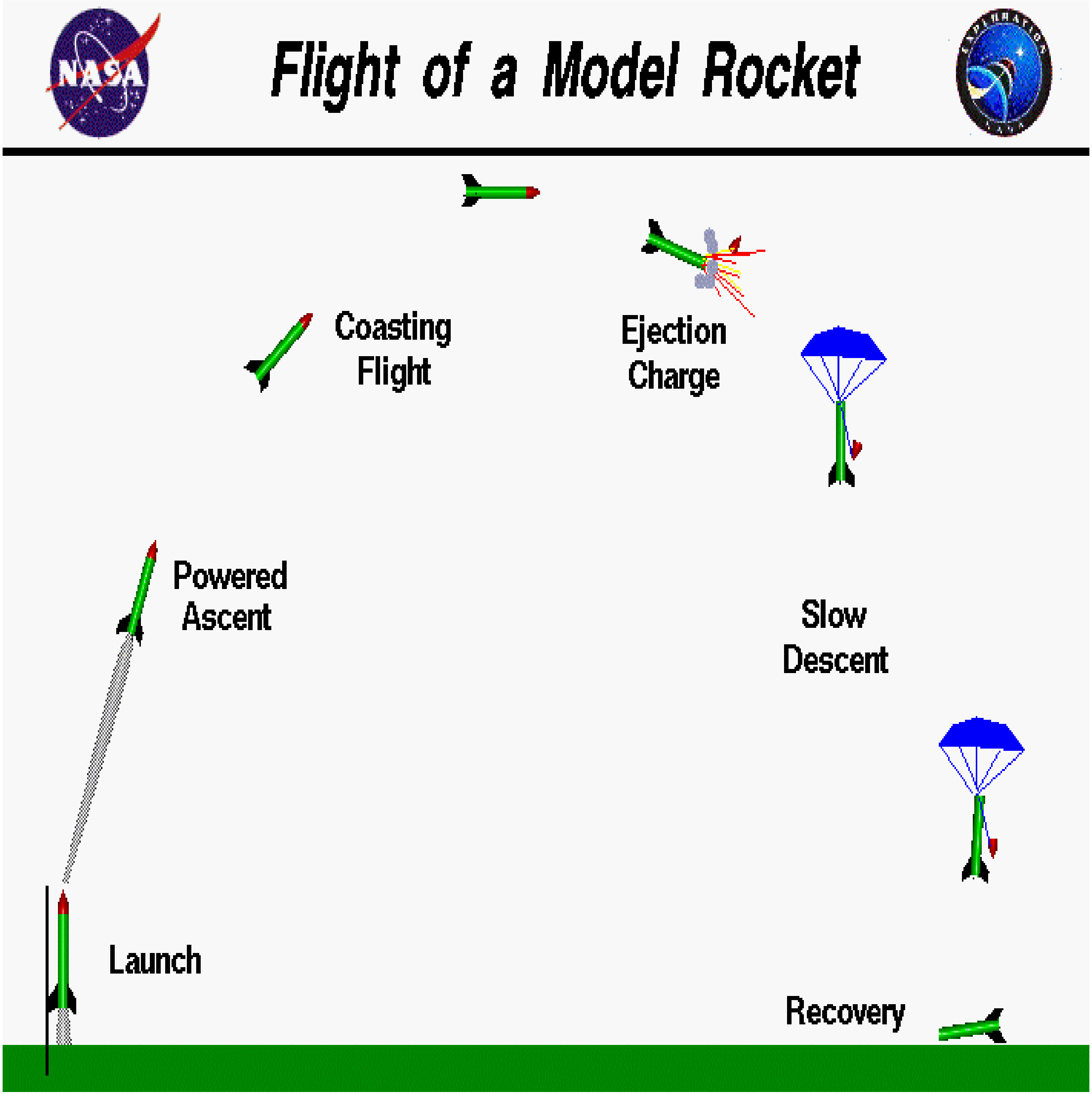
Hobby Rocket Motor Information

Classification	Motor Type	Total Impulse	Category
Model Rocket	1/8 A	0.3125	Micro
	1/4 A	0.625	Low Power
	1/2 A	1.25	
	A	2.5	
	B	5	
	C	10	
	D	20	

Information adapted from NAR website on Standard Motor Codes:
http://www.nar.org/NARmotors.html

Proper Care of Motors—

Motor propellant can separate from its casing. Motors can develop hairline cracks in either the propellant or the casing which may not be visible to the naked eye. Mishandling of motors can be disastrous to your rocket and could do potential harm to yourself, spectators or surrounding property. Avoid dropping the motors on hard surfaces and avoid uncontrolled temperature environments such as freezing and thawing. It is recommended that you store your motors in a hard plastic container at room temperature. Always inspect your motors prior to use.



This figure is from the NASA website at: http://exploration.grc.nasa.gov/education/rocket/rkftlgiht.html

At this website you can enter the mass, angle of launch and initial velocity of your rocket and it will give you the flight path:
http://galileoandeinstein.physics.virginia.edu/more_stuff/Applets/ProjecticleMotion/jarapplet.html

Rocket Stability—Understanding Stability

Center of Gravity (CG) —

If, for any reason, a force is applied to a stable flying rocket that causes it to rotate, the rotation will always be around its center of gravity. The center of gravity of any object is the one small point that represents the intersection of all the possible balance points of that object. CG is represented by the symbol:

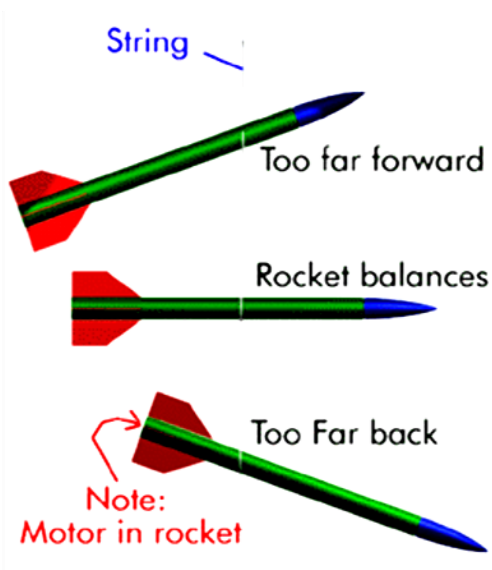


Figure 4

The center of gravity is always determined with the motor in place. The rocket to be tested (with the motor in flight position) is suspended from a string, as illustrated. The string is attached around the rocket body by using a loop. Slide the loop to the proper position so that the rocket is balanced, hanging perpendicular to the string. Apply a small piece of tape to hold the string in place. If the rocket's center of gravity (balance point) falls in the fin area, it may be balanced by hooking the string diagonally around the fins and body tube. A common straight pin may be necessary at the forward edge of the fins to hold the string in place. If the rocket is stable, it will point forward into the wind created by its own motion. Some stable rockets will not point forward unless they are started straight

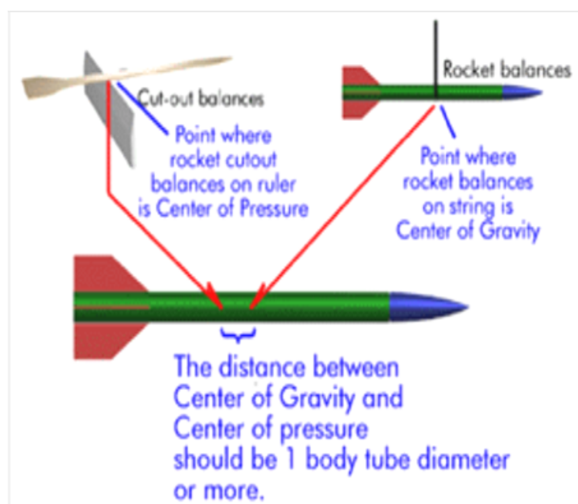


Figure 5

Activity #6 Center of Gravity

Prep time: 5 seconds

Experiment time: 30 seconds

Procedure:

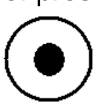
1. Take a stainless steel spoon and try to balance it on one finger.

2. Keep changing the location of your finger along the spoon until you discover the one spot that will keep the spoon balanced.

That location is not halfway down the stem of the spoon; it is closer to the bowl portion of the spoon. When the spoon is balanced, the forces pulling down on one side equal the forces pulling down on the other side, this balancing point is the center. Gravity is the force. The balancing point is called the center of gravity.

The center of gravity is important to make sure that an object remains stable. For example, car manufacturers need to determine the center of gravity of cars to determine how easy it is for a car to rollover during an accident. A vehicle such as a dune buggy has a low center of gravity so that it does not usually tip over when making a turn.

Center of Pressure (CP) —
As a model rocket flies through the air, aerodynamic forces act on all parts of the rocket. In the same way that the weight of all the rocket components acts through the center of gravity, the aerodynamic forces act through a single point called the center of pressure. CP is represented by the symbol:



One method to find the center of pressure of your rocket is:

Step 1: Cut out a profile of your rocket in cardboard. It does not have to be the same size, but it does need to be accurate in shape and scale.

Step 2: Balance the cutout on the edge of a ruler. Mark the rocket where it balances. This spot marks the center of pressure of your rocket.

For the rocket to be stable, the CG must always be forward of the CP, with a minimum distance of the diameter of the rocket's body tube between each.

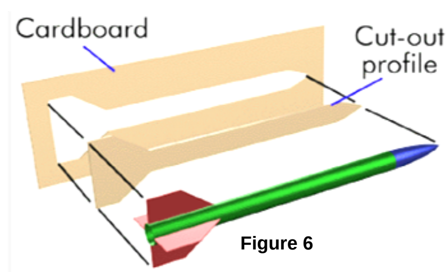


Figure 6

A good way to keep the CP and CG symbols straight is CP is the one with the dot or "point" in the center. Think center of pressure = pressure *point*.

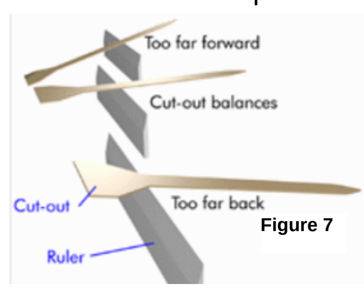


Figure 7

Figures 4-7 were taken from:
http://www.rockets4schools.com/education/Basci_Rocket_Stability.pdf

The following was taken from "Why Do Rockets Go Unstable?" by Tim Van Milligan; excerpt from "Apogee's Rocketry E-zine," Issue #42 (03/04/01) www.ApogeeRockets.com

Other Factors that Affect Stability—

Numerous factors can cause a model rocket to become unstable in flight. A few of those factors are listed below.

"Crooked or Canted Fins: If you have fins on your rocket that are not perfectly straight, they have the potential to cause unexpected lift forces to be generated.

Fins Where the Airfoils Are Different: If each fin on your rocket has a different airfoil, this would have the same effect as crooked or canted fins.

It generates non-uniform lift forces. The best airfoil on all the fins would be the teardrop shape (symmetrical); but if it is not uniform on both sides, you have what is called a "cambered" airfoil. This type of airfoil is similar to those on the wing of an airplane, whose purpose is specifically to generate lift.

Forward Fins: These are any fins placed on the model in front of the Center-of-Gravity (CG). They are always destabilizing if they generate lift. Therefore, it is critically important that they be made as small as possible, and that they are "perfectly straight" on the model. If they are not, the model is probably going to be unstable. *(Forward fins are also known as "canard" fins.)*

Asymmetrical Fin Arrangements: The word asymmetrical means "not" symmetrical; in other words, fins that are not placed or spaced equal distances around the tube. It would also include having some fins on the rocket being bigger than others are. In either case, what happens is that the lift force on one side of the rocket can be bigger than on the other side. This can cause the model to do loop if it is hit by a sudden gust of wind (on the wrong side of the model).

Fins That Pop Off During Flight: When this happens, the result is that the lift forces around the rocket are not uniform. This makes the rocket do loops, and it is easy to figure out after the flight, if you are fortunate to find the parts afterward.

Loose Fins: Even if the fins do not pop off during flight, the reason we do not tolerate loose fins on the rocket is that they can vibrate back and forth. This disrupts the airflow on one side of the model, and can cause it to go unstable. So never, tape a fin onto a rocket or permit someone else to do so. This is just asking for trouble.

Loose Nose Cones That Are Canted in the Tube: This is similar to the Number 8 above, because a canted nose cone can generate more lift forces on one side of the rocket than the other can.

Rocket Binding on the Launch Rod: This is similar to the one above. The rocket hangs up for just a moment, decreasing its speed. When it lets go, now, it is not traveling fast enough.

Getting entangled in the igniter clips, preventing it from lifting off smoothly: This would be anything that slows the rocket while it is on the rod may be a detriment to the stability of the flight."

Loose or Constricted Launch Lug: The sudden force of pressure applied to a loose launch lug after the motor is ignited can cause the launch lug to snap off. The rocket will respond by twisting, causing it to cant or turn horizontal before even leaving the distance of the launch rod.

Constricted Launch Lug: Launch lugs that are not completely straight in line with the body tube, or has decals placed in front or behind it, are factors that can cause the launch lug to bind against the launch rod. The results can cause the rocket to decrease in speed prior to leaving the pad, hang up on the rod and not leave the pad, or cause the flight to become unstable.

Types of Recovery Systems

As part of a successful launch, the rocket must return to ground level safely. Several types of recovery systems are used to slow the speed of the rocket, allowing for the safe return of the rocket.

Typical Recovery Systems—

Parachute: The most common method of recovery used to bring your rocket down safely.

Streamer: Long narrow strips of plastic that help break the fall of the rocket.

Featherweight: Is a small lightweight rocket that floats back to earth.

Tumble: Is similar to a featherweight except the rocket uses tumbling motion to help break its fall.

Glider: Some rockets have gliders that ride "piggy-back", attached to a rocket's tube. The glider separates from the rocket (or booster stage) after apogee, and glides down while the rocket (or booster stages), is recovered by a parachute or streamer. Another example of a glider is one with "wings: that expand out from the rocket body tube. The glider starts a gliding circular pattern to reach the ground.

Helicopter: The entire rocket uses a revolving or spinning motion to help break its fall. Helicopter recovery systems generally consist of rotary blades of some type.

Unusual Recovery Systems—

Nose-Blow or Break-Apart Recovery: Similar to the streamer only it uses the nosecone to create enough drag and flutters to the ground.

Aerobrake or Drag: Instead of "deploying" a recovery system from within the body of the rocket, the entire rocket serves as its own recovery system by using its large but lightweight mass to slow its descent down. Many Styrofoam rockets and saucer/UFO rockets use air drag to slow their descent rate.

Horizontal Spin: Can be used with LP as well as HP rockets and typically the rockets are very long and slender. The nosecone will separate from the main body of the rocket and come down on its own recovery system. The rest of the rocket will use a horizontal spinning action which creates a lift and allows the rocket to return to the ground at a safe speed.

Magnus-Rotor: Similar to the helicopter but only the blades rotate.

Unicopter: Uses a similar rotation action as the helicopter, but its spin method is based on the flutter of a maple seed.

LAUNCH SYSTEMS AND FIELD OPERATIONS

Parts of a Model Rocket Launch System

Motor—

There are mini-motors, single stage motors (A-B-C-D), and booster motors for multi-stages. The A series contains all of the mini-motors which are used in the smaller rockets. The motor gives the rocket the energy it needs throughout the flight.

Igniter—

Used to ignite the rocket motor(s).

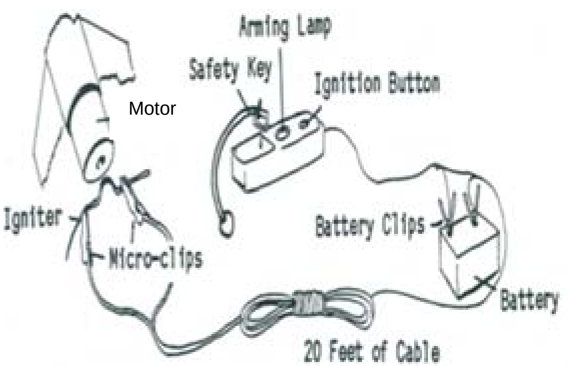


Figure 8: Taken from Model Rocketry Unit 2 Manual

Launch Control—

The launch control allows control over the launch for safety reasons, ensuring a safe flight. It comes with safety interlock key, arming lamp, ignition button, micro-clips, and 20 feet of launch cable. The cable should be a minimum of 15 feet (min. required by the NAR Model Rocketry Safety Code).

Batteries—

Batteries provide electricity to create the heat source to energize the igniter. Use the size and number of batteries recommended by the manufacturer of the launch controller.

Launch Pad—

The launch pad holds the rocket in place during the launch for safety reasons. The launch pad includes safety cap, launch rod, blast deflector plate and launch base.

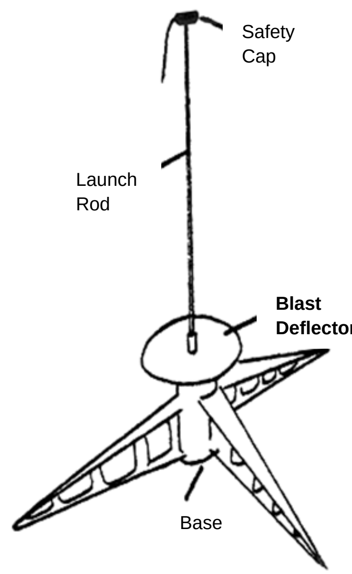


Figure 9: Taken from Model Rocketry Unit 2 Manual

Selection and Preparation of a Launch Field

You have your rocket built, you have your launch system ready, now where do you launch?

Refer back to the NAR Model Rocketry Safety Code to ensure you are following all the required rules related to launching your rocket. In selecting your launch site, also check with your local law enforcement for park restrictions relating to model rockets. It is also recommended and considerate to contact your local fire department to inform them that you will be performing a model rocket launch. If a fire ban is in place, there may be a no-cost permit you can obtain from the Fire Marshall in order to launch rockets.

The launch field should be devoid of power lines, trees, buildings and other obstructions. Prevent rockets from flying over spectators' heads, including yours, by setting up the launch pad at an angle of 90° in relationship to the wind. Rope or mark off the launch range to prevent spectators from roaming into the range. Set up a field table for rocket preparation, and if you are conducting a multiple flight event, set up a range table for the launch ignition system and data recording. Having a flag posted near the launch site is also helpful in tracking direction of the wind.

Setting up the Launch Pad System

If you are using a single portable launch systems (e.g. Estes Port-a-Pad or Quest's Lift Off Model Rocket Launch Pad) to launch rockets with, be sure to set the pad up in an area free from dry grass or other easily burnable material at a minimum distance of 15 feet for D motors or smaller and 30 feet for rockets with larger motors. Remember to place the safety cap on the launch rod to avoid eye or other type of injuries. Tie the ignition key to the string attached to the safety cap. This will prevent an accidental launch from happening while you are working with your on the pad.

Do a simple tie with the power cord (micro-clip end) around one of the pad's legs, looping it through the opening in the leg closest to the blast deflector. Be sure to leave enough length for the micro clips to reach up to the rocket's igniter. This will help to prevent someone from pulling the igniter clips off or the igniter out of the motor when picking up the launch controller unit on the other end of the power cord.

Tip #1: *Tie the ignition key to the other end of the safety cap string. With the ignition key tied to the safety cap, an accidental launch of the rocket may be avoided while you are working with your rocket at the pad.*

Tip #2: Sometimes a slight wind gust on heavier rockets can tip the launch pad system over. Either stake the legs down or strengthen it with some large rocks.

Flight Operation and Safety Check Procedures

Whether you launch your rocket by yourself or with a group, you always need to prepare for the unexpected. Always have near you the following range safety equipment: rakes or flapper rakes, shovel, jugs of water and a water-pressurized fire extinguisher. In addition, always have on you a cell phone for calling for emergency assistance if needed.

Organized rocket club launches will usually set up a multiple pad launch system, sometimes set up for both model rockets and high power rockets, with the range roped off. Many will use a speaker system so all spectators can always hear what is going on, especially for "heads-up" flights. Organized rocket club launches will also appoint a minimum of two officers, a range safety officer (RSO) and a Launch Control Officer (LCO). If you launch your rocket by yourself, you are responsible for following the NAR Safety Code and responsible for alerting any spectators who may be present.

Range Safety Officer (RSO) Responsibilities—

- Responsible for the safe operation of the rocket launch range.
- Has the final authority to approve or deny launch of any rocket.
- May also act as the rocket check-in officer.
- May also act as the person in charge of assigning the rockets to the launch pads.

Launch Control Officer (LCO) Responsibilities—

- Keeps the launch range running smoothly.
- Assists RSO in maintaining safe range operations.
- Operates the launch controller(s).
- Controls whether a launch range is "open" or "closed."
- May act to assign rockets to launch pads.
- Makes announcements over the PA system.

Terms Used on the Flight Range

Range is Open: means the LCO has removed the safety key from the launch control system, possible misfires have sat for at least one minute, and it is safe for you to approach the launch pads.

*Range is Closed***:** means the LCO has closed the launch pads for any further activity, and prepares to launch the rockets currently on the pads. No one is permitted to approach the launch pads for any reason.

Spectators are permitted to sit on chairs, but never on the ground, primarily for their safety. Trying to quickly get up off the ground when a rocket is coming in "ballistic" or to get out of the way of a rocket that "CATO" is nearly impossible to do.

Ballistic: means the rocket's recovery system has failed and the rocket is returning to earth at a very high rate of speed.

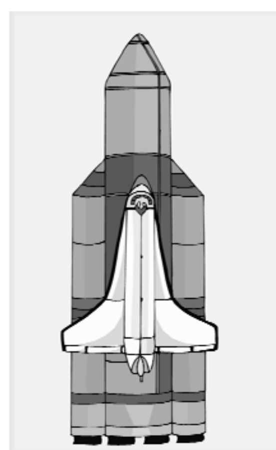
CATO: means a catastrophic failure or a "catastrophe at take-off". Most CATOs are due to mishandling of motors: dropping them onto a hard surface, or storing them in uncontrolled temperature environments (freezing and thawing).

Heads-Up Flight: means the rocket on the pad about to be launched has either never been flown before or its stability may be undetermined. A heads-up flight requires all spectators to be standing.

Heads-Up: means a rocket may be coming in ballistic, has CATO'ed or may be landing in proximity of where the spectators are.

Maiden Flight: means the rocket on the pad has never flown before.

Event: means something has occurred to the rocket in flight, i.e. drogue chute has deployed or the main parachute has deployed.



Activity 7: Experimenting with Parachute

Prep time: 20 minutes

Experiment time: 5-10 minutes

Note: This experiment can be a tricky one to perform correctly. It is important to use the same toy figure or toy figures that are similar in shape and weight. If the toy figure does not weigh enough, then the differences between the drop times for the various sized parachutes will be negligible. The height for the drop also makes a difference. If you are standing on a kitchen chair, the differences in drop times for the various sized parachutes may not be significant; thus, it is important to drop the toy figures from at least eight feet above the ground. Finally, it is important to let go of the toy figure as opposed to tossing the toy figure.

Materials:		
	Plastic trash bags	Strong thread
	Small toy figures of the same weight	Scissors
	Ruler	Stopwatch
	Tape	Helper

Procedure:

1. Make three different sized parachutes by cutting three squares from the trash bags: 3 inches on each side, 4 inches on each side, and 6 inches on each side.
2. Cut 12--12" lengths of thread and tape each piece to every corner of each square.
3. On each parachute, tie the four loose ends of a thread together, and then tape to the toy figure.
4. Predict which parachute will drop the fastest, and which will drop the slowest.
5. Stand at the top of the stairs, the top of a slide, or on a balcony and let go of the figure. Have a helper use a stopwatch to time how long the parachute takes to land.

What happens? The figure with the larger parachute will take longer to reach the ground if the figures are all the same.

Why? The larger parachute has a greater surface that is exposed to the air and thus encounters greater drag. The force of the air friction or drag slows the descent of the figure with the large parachute.

The concept of drag is important for the recovery system of your rocket. You will notice that a bigger parachute will float in the air and will take longer to land. This is especially critical if it is windy. The wind will catch your rocket and carry it farther away from your launch site. In addition, the size of your parachute and the weight of your rocket are critical. If you borrow a parachute from a rocket kit and that rocket weighs much less than your rocket, you may have a problem with rocket recovery; your rocket will return to the ground much faster and the harder landing may damage the rocket.

Sometimes, rocket kits will provide a parachute and will then have you cut a hole in the middle of the parachute. The hole is to decrease the force of drag and to increase the speed of the falling rocket so that it returns to the ground much faster and is not carried farther away in a breeze so that it lands closer to the launch site. However, if you cut too large of a hole, the rocket will fall too quickly and become damaged

PREPARING YOUR ROCKET FOR FLIGHT

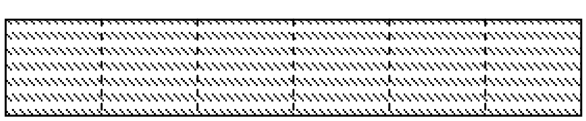
You have built your rocket, your launch site is properly set up, and now you want to launch your rocket into the sky. Here are five key steps you need to perform to prepare your rocket for flight.

Recovery Wadding

Recovery wadding is material used to protect your rocket's recovery system. Wadding must be both flameproof (flame retardant) and biodegradable. Two common types of wadding are flameproof tissue wadding and cellulose fiber, commonly known as "Dog Barf." Estes Industries, Inc. first developed the tissue wadding from common toilet paper, coating it with a flame retardant agent. Dog Barf is actually cellulose insulation, composed of 75-85% recycled paper filler (usually newspaper material) and 15% fire retardant such as boric acid or ammonium sulphate. Tissue wadding may be purchased at most hobby stores and online web stores**.** Cellulose insulation can easily be obtained at a local hardware store, usually under $10 a bail, which will last you a lifetime of rocketry.

Wadding is used to seal off any vents (air holes) above the motor. This prevents the hot gasses from the ejection charge reaching the recovery system. If the hot cases were able to reach the recovery system, they would melt the recovery system and burn through the shock cord.

When using tissue wadding, the number of sheets to use depends on the size of the rocket's body tube (body tube). Your kit instructions will usually tell you how many sheets to use. Generally, you will use from 3 to 6 sheets per rocket flight.



Steps To Follow When Using Tissue Wadding—

- Gently "crumble" each sheet of wadding, individually. Do not wad into a tight ball.

- Insert each sheet, individually, into the body tube, pushing it down as far as possible.
- Blow the wadding to the top of the motor mount (or as far into the body tube as possible).

Steps To Follow When Using Dog Barf Wadding—

- Use about twice the amount of cellulose in inches as the diameter of your rocket, e.g. 1" rocket tube = 2" of cellulose.
- Insert the wadding into the tube and then blow the wadding down as far as it will go.
- Never hard-pack wadding into the body tube as it could prevent the recovery system from deploying properly, if at all.

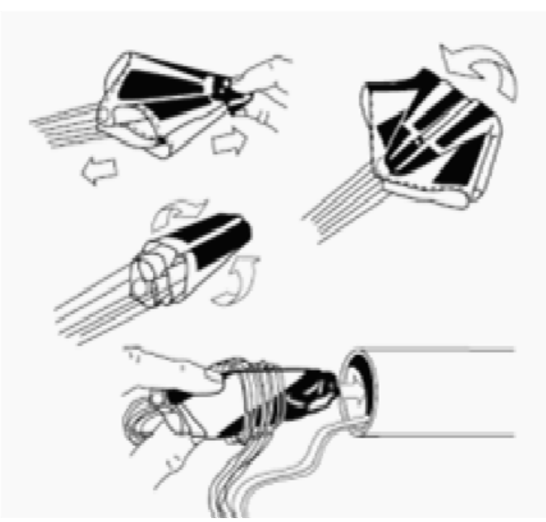
Preparation of a Parachute or Streamer Recovery System

Spread the plastic streamer or parachute flat and rub talcum powder onto both sides of the parachute. Be sure to cover each side thoroughly from edge to edge.

Never wad and stuff your parachute or streamer into the rocket as this may cause them to jam and then not deploy properly from the rocket. You may follow your kit instructions on how to fold your parachute or streamer or follow the steps below.

For a streamer, start by folding it end to end in half several times, depending on the size of the streamer. When you get to about 2- to 3-inches in length, roll the streamer the rest of the way, tight enough that it will slide easily into the rocket's body tube.

For a parachute, start by folding the parachute in half, making a half circle. Continue folding the chute into triangles by taking one outside edge corner, bring it into the center bottom edge of the chute, and repeat with the opposite side. Continue folding the chute in by triangles until you have a size small enough to fit your rocket's body tube.



Make sure the parachute shroud lines are straight. Place the shroud lines inside the folds of the parachute or gently wrap them in a neat row around the parachute. Do not pull the shroud lines too tight or allow them to hang too loose, which can cause tangles or hang-ups.

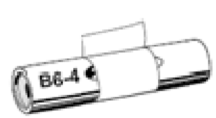
First insert as much of the shock cord into the rocket as possible first, followed by the streamer or parachute and the rest of the shock cord. Do not stuff the recovery system too tightly into rocket. The parachute or streamer should easily slide in and out of the body tube. Make sure the recovery system is placed below the "neckline" of the nose cone.

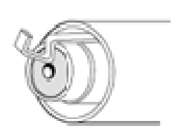
The rocket's nosecone should be loose fitting, but tight enough not to fall out when held upside down and lightly shaken. Add small amount of masking tape to the shoulder of the nosecone until you get a proper fit. Make sure the shroud lines and the shock cord are not sticking out of the rocket or stuck between the nose cone and the body tube, which can cause the nose cone to bind and not deploy properly, if at all.

Motor Installation

Insert the motor into the rear of the rocket, nozzle end pointing out.

For friction fit motor mounts, wrap masking tape around the motor casing. The motor should fit tightly into the motor casing. The motor should be tight enough that needle nose pliers would be needed to pull it out.





NOTE: Usually, once the motor has been spent and the casing has cooled, you should be able to pull the motor casing out without pliers just by twisting and pulling on it.

Installation of an Igniter

To ensure proper handling:

- Do not tear
- Do not cut
- Do not remove the tape between the two lead wires of the same igniter.

This tape holds the lead wires in place to prevent shorts and to provide strength to hold the igniter's shape. You may cut the tape to separate igniters on the same strip.

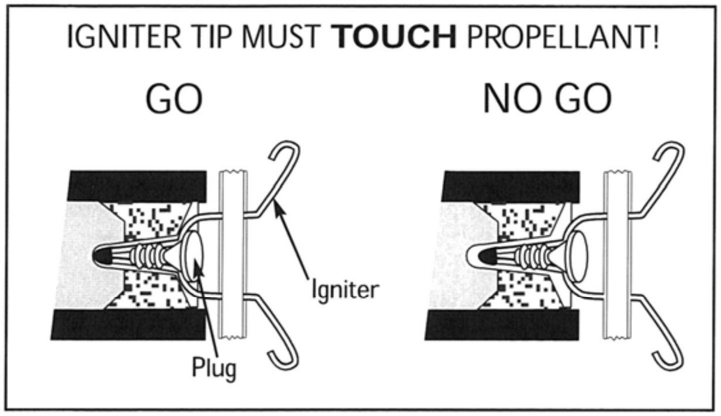
The keys to successful igniter installation are to insert the igniter all the way to the bottom of the nozzle and to secure the igniter firmly in place with the appropriate igniter "plug." All motors will come with a set of igniter plugs that will fit the motor's nozzle. The larger the motor the larger the igniter plug for that motor, so be sure you have the proper size plug for the motor you are using. If the igniter tip does not actually touch the propellant the igniter will "burn," but the propellant will not be heated enough to initiate combustion. If the igniter is not firmly secured in the correct position, the small weight of a micro-clip and its lead wire may be enough to pull the igniter slightly away from the propellant.

After the igniter is properly inserted, push an igniter plug into the nozzle. This will bend the lead wires to one side a little. However, do not bend the lead wires before inserting the plug. Bending the wire before inserting the plug will pull the tip of the igniter away from the propellant.

After inserting the igniter and igniter plug in your model rocket motor, carefully bend igniter wires back and form leads into a "U-shape". This provides two points to which each micro-clip is attached instead of one and will give you a better chance of having a successful ignition.

Refer to the "Ignition Installation" diagram on the next page.

Igniter Installation



About 90% of all problems with engine ignition are caused by the igniter not being properly and securely held in place in the engine.

The igniter must **touch** the propellant at the moment the igniter is heated for ignition.

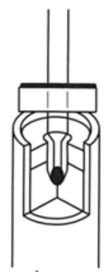
Attach micro-clips to igniter leads as close as possible to nozzle.

MODEL ROCKET IGNITER INSTALLATION

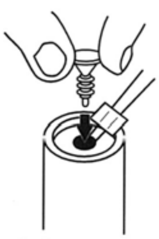
Always use electrical model rocket igniters with a model rocket launch controller.

1. Cut tape separating igniters. Do not remove tape.

2. Separate plug from strip of plugs.

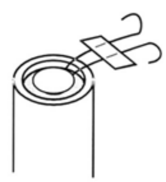


3. Insert igniter into engine. Igniter <u>must</u> touch propellant.

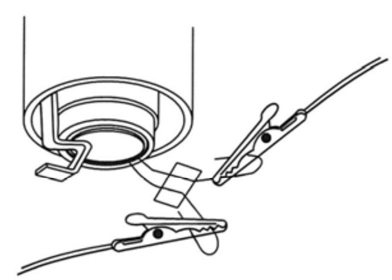


4. Insert plug into engine nozzle.

5. Push plug firmly into engine.



6. Bend igniter wires.



7. Attach one micro-clip to each lead of igniter. Clips must not touch each other or blast deflector and igniter leads must not cross.

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Placing the Rocket on the Launch Pad

Remove the safety cap (with ignition key attached) from the launch rod. Place the model rocket on the launch pad by placing the launch rod through the launch lugs. If you are using a portable pad system that sits on the ground, be sure to replace the safety cap onto the launch rod.

It is important to note here that all model rockets, including high power rockets, require electricity to ignite the rocket motors. Electricity travels from the control box, through the wire, and into the two wires of the igniter. The heat of the electricity will burn the small amount of pyrogen at the end of the igniter, which in turn starts the motor propellant to burn. When wires touch each other or touch other metal parts before the electricity can reach the igniter pyrogen, a short in the electrical current will occur, preventing the igniter from lighting the motor. Therefore, you do not want your ignition wires to touch each other or any other metal on the launch pad.

Some rockets will require a "standoff clip" to prevent the igniter wires from touching the blast deflector. Examples of standoff clips: clothes pins, spent motor casings, heat resistant hard plastic tubing, and a small flat rock. If it is necessary for you to prop up your rocket from the blast deflector, check to see that the motor retention clip will not hang up on the standoff clip, preventing the rocket from leaving the launch pad.

The next step is to attach the micro-clips. Check to see that the micro-clips are clean. Dirty micro-clips can prevent electricity from flowing through the igniter. If they are dirty, use nonabrasive scouring pad or find sandpaper to clean them. In attaching the micro-clips, make sure they do not touch each other, the blast deflector or the launch rod. Attach the clips so they are facing away from each other. (Refer back to the igniter installation drawing on page 34)

LAUNCHING YOUR ROCKET

Launch Procedures

Whether you launch by yourself, as a family, with friends or with a rocket club there are procedures you should follow as you prepare to launch your rocket.

Perform these procedures in the order stated:

#1 Close the range—
If you are launching with an organized rocket club, the LCO will ultimately be the one who will close the rocket range. However, if you are launching as a family or with a group of friends, you need to announce to all spectators that the range has been closed. Be sure you have everyone's attention when you prepare to launch your rocket.

#*2* Verify Electrical Continuity—
The LCO (or you) will announce if you have continuity. If you are using a portable pad, you perform this task by inserting the launch key into the launch control box. If the light turns on, then you continuity and you are ready for the next step. If not, you may want to check your batteries.

#3 Perform Range Safety Check—
Make sure the launch area is clear of any obstructions or people. Check the sky for planes, parachutists, ultralites, etc. This is also the responsibility of the RSO. Ultimately, anyone can stop a launch at any point in the launch count. As you are focus on your countdown procedures, you may not be aware of an interference approaching your launch range, and you should advise your

spectators to keep an eye and ear open to any possible interference.

#4 Proceed with Launch Countdown— Most rocket clubs' LCO will perform the countdown for you. Some will even perform the actual launch. However, if you are performing this duty yourself, make sure the spectators are aware that you are in the process of launching by counting down in a loud voice. If you have someone tracking or spotting your rocket for you, be sure, you have his or her attention. Again, at any point during the countdown, a halt to the launch can be called by the RSO, the LCO, a spectator, and yourself. For both LPR and HPR launches, countdowns usually start at five (5), giving spectators time to become alert to the launch which is about to occur. Perform your countdown and launch. If your rocket for any reason misfires, remember to wait one minute before approaching your rocket or get permission from the LCO to approach the launch pads.

Ignition Misfires

Ignition misfires mean the motor failed to ignite. This can be caused by a broken igniter, a break in the electrical circuit, or an igniter pulled away from contact with the motor propellant. NEVER approach a rocket immediately following a misfire, as it is possible that the ignition is just delayed. According to the NAR Model Rocketry Safety Code, wait one full minute prior to approaching a rocket that misfired.

Rocket Recovery

When recovering your rocket, you must first find out if the range is "open," if your rocket is still on the launch pad or if it landed within the rocket launch range. If there are still rockets waiting to be launched on other launch pads, do not approach your rocket until the LCO has given you permission. If your rocket has landed outside of the range site, and you do not have to cross into the range site to retrieve your rocket, than it will be safe for you to recover the rocket. When you have permission to recover your rocket, never run to retrieve the rocket. When running, it is very easy to stumble, trip or run over your rocket.

Checklists and Rocket Flight Log Sheet

The following two pages are checklists for you to use when you plan to launch your rocket. The checklists include what you look for in a launch site, what you need to set up a launch range and the procedures to follow for launching your rocket. To ensure you have a safe and fun launch, make a copy of the following checklists and complete them each time you set out to launch your rocket.

To record your rocket's flight information, attached is a Rocket Flight Log Sheet. Did you build the rocket yourself? What skill level was it? Was it a Ready-to-Fly kit or a SL-1 kit? Did someone loan you a rocket to launch? Make several copies of the Rocket Flight Log and complete one log sheet for each rocket you built or flew. You may record up to two flights per rocket per log sheet. Complete as much information as you can and add the completed log sheets to your project Model Rocketry e-record.

The checklist and the Rocket Flight Log can also be found on the 4-H website at: www.colorado4h.org

LAUNCH SETUP AND RANGE EQUIPMENT CHECKLIST

Launch Flight Permission:

- ☐ No Fire Bans
- ☐ Obtained Fire Marshall Permission

Launch Site Permission:

- ☐ Land Owner's Permission OR ☐ City, State or National Parks (Local Authorities') okay

Launch Site Needs:

- ☐ Review the NAR Model Rocketry Safety Code
- ☐ Site free from power lines, trees, buildings, etc.
- ☐ Launch Surface—asphalt, cement, gravel, bare ground, green grass, or covered with a flameproof platform.

Individual Field Safety Preparations (Launching without Spectators or an Organized Rocket Club):

- ☐ Leaf Rake or Flapper Rake
- ☐ Shovel
- ☐ Fire Extinguisher
- ☐ Jugs of Water
- ☐ Cell Phone with fire department number on speed dial
- ☐ Field Table for preparing your rocket for flight
- ☐ Launch Pad System—
- ☐ Electronic Control Unit ☐ Fresh Batteries ☐ Launch Pad Stand Unit
- ☐ Blast Deflector ☐ Launch Rod ☐ Safety Key
- ☐ Safety Cap, if applicable, in place on launch rod
- ☐ Standoff Clip, i.e. clothespin or other device

Group/Club Field Safety Preparations (Launching with Spectators)

- ☐ Checked off prior list
- ☐ Ropes to mark off range site
- ☐ Flag(s) for wind direction
- ☐ Launch System Control Table
- ☐ Data Recording Table (Registration Sign In)
- ☐ PA System, if applicable
- ☐ Appoint LCO Name: ______________________________
- ☐ Appoint RSO Name: ______________________________

Range Box Equipment and Supplies:

- ☐ Masking Tape
- ☐ Baby Powder
- ☐ Needle-nose Pliers
- ☐ Long Thin Dowel Rod or Probe (for pushing down wadding or pushing out motor)
- ☐ Motors
- ☐ Motor Plugs
- ☐ Igniters
- ☐ Parachutes and Streamers (different sizes)
- ☐ Fishing Swivel Hooks (for quick recovery system changes)
- ☐ Wadding or Dog Barf
- ☐ CA or Super Glue (for quick fixes)
- ☐ Acetone (to unstuck fingers)

Use with adult supervision only! (applies to the two items above)

- ☐ Hobby Craft Sticks (for applying glue)
- ☐ Small Cup Container (for quick fixes)
- ☐ Tin Can for spent motors, igniters and plugs

Individual Self:

- ☐ Hat
- ☐ Sturdy Shoes or Hiking Boots
- ☐ Plenty of Drinking Water
- ☐ Sunscreen Lotion

Other Suggestions:

- ☐ Camera
- ☐ Lawn Chairs
- ☐ Light Snacks

FLIGHT PREPARATION CHECKLIST

Rocket—Fins and Launch Lug(s):
- ☐ Aligned straight
- ☐ Securely attached with fillets

Rocket Stability:
- ☐ Center of Gravity (CG) is ahead of Center of Pressure (CP)
- ☐ No loose, cracked or broken parts

Rocket Recovery Preparation:
- ☐ Wadding properly placed into the rocket (No wad balls)
- ☐ Shock cord secured and in good condition
- ☐ Baby powder on plastic parachute or streamer
- ☐ Parachute or streamer properly folded and inserted into the body tube
- ☐ Parachute, streamer and shock cord properly attached to the nose cone
- ☐ Nose cone slides into body tube easily, not too tight and not too loose

Rocket Motor Preparation:
- ☐ Check the size of motor for rocket and weather conditions
- ☐ Properly fit motor into motor mount assembly (friction fit may require masking tape)
- ☐ Check condition of igniter (wires not crossed or broken, filament not broken)
- ☐ Insert igniter (top of igniter must touch the propellant)
- ☐ Insert motor plug (motor plug color correct for size of motor being used)
- ☐ Lightly shake rocket right side up to see if the motor and igniter are securely attached

Field Flight Preparation:
- ☐ Remove safety cap (with safety key attached) from launch rod
- ☐ Slide rocket onto launch rod via the launch lug(s)
- ☐ Replace safety cap (with safety key attached) onto launch rod
- ☐ Secure igniter clips onto the igniter (one per igniter wire)
- ☐ Check to verify igniter clips are not touching each other, the launch rod or blast deflector
- ☐ Remove safety cap (with safety key attached) from launch rod and return to launch control box

Flight Procedure:
- ☐ Close the range
- ☐ Insert safety key (with safety cap attached) into launch control box—check for continuity
- ☐ Receive permission for launch from LCO and RSO, if launching with an organized club
- ☐ Advise spectators you are about to conduct a launch (if no LCO or RSO is present)
- ☐ Check field range for obstructions
- ☐ Check air space for obstacles
- ☐ Perform countdown (5 – 4 – 3 – 2 – 1 – Launch!)
- ☐ Remove the safety key from the control box

Misfires:
- ☐ Wait until the range is open or a minimum of one minute before approaching the rocket
- ☐ Replace safety cap onto launch rod before looking at your rocket
- ☐ Check for short in electrical current (igniter clips touching blast deflector, each other or launch rod)
- ☐ Check for damaged or spent igniter and replace, if needed
- ☐ Remove safety cap and repeat “Flight Procedure”

Rocket Recovery:
- ☐ Obtain permission from the RSO to retrieve your rocket (if it landed within the rocket range site)
- ☐ Do not attempt to recover your rocket yourself if it landed high in a tree, on a power line or building
- ☐ Do not run towards your rocket
- ☐ For long-range recoveries, take a friend with you and bring plenty of water
- ☐ Re-pack your recovery system into the rocket at point of recovery (preventing cord and line tangles and tears)

ROCKET FLIGHT LOG SHEET

(Use one Rocket Flight Log Sheet for each rocket built or launched.)

MEMBER ACTIVITIES:

Did you build this rocket? (Y or N) ____________________________ Did you paint this rocket? (Y or N) _______________

Did you launch this rocket? (Y or N) ___________________________ Total times this rocket was launched: ______________

ROCKET DESCRIPTION PER KIT PACKAGING (Must meet your unit's rocket criteria.):

Name of Rocket Kit: ___________________________________ Manufacturer's Name: ____________________________________

Rocket Skill Level *(check one)*: ☐ SL-1 Kit ☐ SL-2 Kit ☐ SL-3 Kit ☐ SL-4 Kit ☐ SL-5 Kit

Rocket Weight without Motor: _________________________ Rocket Length: _______________ Number of Fins: _______________

Fin Type: ☐ Plastic Fins ☐ Balsa /Basswood Fins ☐ Plywood Fins ☐Other______________

Recommended Motors: ____

Recovery System: ☐ Parachute ☐ Streamer ☐ Glider ☐Other_____________________

FLIGHT #1—LAUNCH INFORMATION (if launched):

Date: ___________________ Launch Site: ____

Launch Conditions:

Approx. Temperature: ______ Humidity/Precipitation: ______________________________________ Wind Direction: ____________

Approx. Wind Speed: ____________________________ Cloud Cover: ____

Rocket Information:

Motor Used: ______________________________________ Recovery System Used: ____

Launch Pad Information:

System Used *(check one)*: ☐ Single-Pad System ☐ Multi-Pad System

No. of Misfires (if any): _______

Lift-Off Information *(check one)*:

☐ Successful Lift-Off ☐ Hung-up on Rod or Stand-Off Support ☐ Caught on Igniter Clips

☐ Motor Failure ☐ Other: ____

Flight Information *(check one)*:

☐ Straight-Up Flight ☐ Spinning but Straight ☐ Corkscrew Ascent ☐ Unstable

☐ Horizontal Flight ☐ Weather Cocked Into the Wind ☐ Other: ____

Recovery Information *(check all that applies)*:

☐ Did Not Deploy ☐ Partially Deploy ☐ Deployed Fully ☐ Nosecone Separation

☐ Stable Descent ☐ Tangled Shroud Lines ☐ Motor Ejected ☐ Motor Mount Ejected

Landing Information *(check one)*:

☐ Soft Landing ☐ Hard Landing ☐ Non-Deployment (Nose Dive) ☐ Water Landing ☐ Landed in Tree

☐ Landed on Building ☐ Caught on Power Line ☐ Drifted Out-of-Sight ☐ Other: _______________

#1 POST-FLIGHT INFORMATION *(describe any damage to rocket)*: ____

____

____

FLIGHT #2—LAUNCH INFORMATION (if launched twice):

Date: ___________________ Launch Site: ____

Launch Conditions:

Approx. Temperature: ______ Humidity/Precipitation: ______________________________________ Wind Direction: ____________

Approx. Wind Speed: ____________________________ Cloud Cover: ____

Rocket Information:

Motor Used: ______________________________________ Recovery System Used: ____

Launch Pad Information:

System Used *(check one)*: ☐ Single-Pad System ☐ Multi-Pad System

No. of Misfires (if any): _______

Lift-Off Information *(check one)*:

☐ Successful Lift-Off ☐ Hung-up on Rod or Stand-Off Support ☐ Caught on Igniter Clips

☐ Motor Failure ☐ Other: ____

Flight Information *(check one)*:

☐ Straight-Up Flight ☐ Spinning but Straight ☐ Corkscrew Ascent ☐ Unstable

☐ Horizontal Flight ☐ Weather Cocked Into the Wind ☐ Other: ____

Recovery Information *(check all that applies)*:

☐ Did Not Deploy ☐ Partially Deploy ☐ Deployed Fully ☐ Nosecone Separation

☐ Stable Descent ☐ Tangled Shroud Lines ☐ Motor Ejected ☐ Motor Mount Ejected

Landing Information *(check one)*:

☐ Soft Landing ☐ Hard Landing ☐ Non-Deployment (Nose Dive) ☐ Water Landing ☐ Landed in Tree

☐ Landed on Building ☐ Caught on Power Line ☐ Drifted Out-of-Sight ☐Other: ___________________________

#1 POST-FLIGHT INFORMATION *(describe any damage to rocket)*: ____

____

GLOSSARY OF TERMS

Acceleration—The rate of change in velocity (speeds up or slows down).

Aerodynamic Force—The resulting force applied to an object by air and gases, and the resulting motion of those forces.

Airfoil—The shape of an object which travels through air or water, designed to provide the maximum advantage for flight, i.e. wings, propellers, rotor blades, sails, and rocket fins.

Airframe—The main body of a rocket or aircraft, in which all other parts of the rocket or aircraft are attached to or placed within (Also see "Body Tube").

Apogee—The highest point in a rocket's flight.

At Rest—At a standstill, motionless, unmoving.

Balsa Wood—A very light, strong wood grown in Ecuador and used in the structure of model airplanes and model rockets.

Basswood—A light-weight and easily worked wood with very little grain.

Blast Deflector—A flat, circular plate made of metal used to deflect the exhaust (flame) of the rocket's motor when fired.

Body Tube—A rocket kit can be comprised of two or more body tubes, but the longest tube—where all parts are attached to or instead within—is also called the "airframe." (Also see "Airframes").

CATO—Means a "catastrophe-at-take-off," an eruption of uncontrolled forces, which ultimately destroys the rocket. CATO are generally caused by damaged motors.

Center of Gravity (CG)—The point on an object around which its weight is evenly balanced; the point at which a model rocket will balance on a knife edge.

Center of Pressure (CP)—The center where all external outside forces (air pressure, wind, thrust, etc.) are equal on the complete object (a rocket's nosecone, airframe and fins).

Cluster Motors—A grouping of two or more motors in a single-stage rocket.

Coming in Ballistic—Means a rocket is returning to the ground at a high rate of speed, without deploying its recovery system.

Coupler—An object used to join two objects (body tubes) of the same or different sizes together.

Decelerate—To decrease in velocity (slow down).

Dog Barf—A type of wadding used in model rockets made of flameproof, biodegradable cellulose fiber.

Drag—A type of friction which causes an object to slow down.

Electrical Continuity—The presence of electrical flow from the battery to the launch control device to igniter.

Engines—The same as motors. See "Model Rocket Motors."

Featherweight Recovery—A system of recovery where a rocket is so light that it floats down.

Fillets—Concave beads of glue used to strengthen parts of the rocket attached to the airframe.

Fins—See "Rocket Fins".

Flashing—Leftover plastic from the molding process of plastic parts (e.g. nosecone and fins).

Force—A push or a pull motion.

Friction—A type of force which resists motion, causing an object to slow down.

Fuselage (aka Airframe or Body Tube)—The main body of a rocket or aircraft, in which all other parts of the rocket or aircraft are attached to or placed within.

Glider Recovery—A method of rocket recovery consisting of wide wings to glide and slow the rocket's descent.

Heads-Up Flight—A rocket flight where spectators and participants need to be watchful; generally consists of first-flight (maiden flight) rockets, or rockets of questionable stability.

Helicopter Recovery—A method of rocket recovery which uses a spinning motion to slow its descent; most helicopter recovery systems consist of rotary blades of some type.

HPR—High Power Rocketry.

Inertia—A type of force on an object which remains constant until another force changes the velocity or direction of the object.

Ignition Key—See "Safety Key."

Ignition Misfire—An action which prevents the rocket's motor from igniting.

Launch Lug—A device attached to the rocket's airframe to guide the rocket along the launch rod on the launch pad during lift-off.

LCO—Launch Control Officer.

LPR—Low Power Rocketry.

Maiden Flight—The first flight of an aircraft or rocket.

Masking—A method used in painting when applying two or more colors of paint.

Mass—The amount of matter within an object.

Micro-Clips —Small clips used to connect the igniter to the electrical wire from the launch control system.

Model Rocket Motors—Thick paper casings containing propellant used to launch model rockets (e.g. black-powder solid propellant and composite motors).

Model Rocket Propellant—Fuel used in model rocket motors.

Model Rocket—A rocket made of safe materials such as cardboard, plastic, and balsa wood; equipped with a recovery system; uses black powder solid propellant or composite fuel; and are designed to be launched several times.

Motor Hook (aka—Motor Retention Clip)—A metal clip built into the motor mount to hold the rocket motor in the motor tube.

Motor Mount—A small tube, usually consisting of a thrust ring, centering ring and a motor hook, which fits into the rear of a model rocket and holds the rocket motor in place.

Motors—See Model Rocket Motors.

NFPA—National Fire Protection Agency. Authority on fire, electrical and building safety, and along with NAR, helped to develop the NAR Model Rocketry Safety Code.

NAR—National Association of Rocketry. The governing organization for model and sport rocketry nationwide.

Newton's Three Laws of Motion

1. Law of Inertia—A body at rest will remain at rest or a body in motion will remain in motion in a straight line with constant velocity unless acted upon by an exterior force.
2. Law of Acceleration—Change in a body's motion is proportional to the magnitude of any force acting upon it and in the exact direction of the applied force.
3. Law of Reaction—Every acting force is always opposed by an equal and opposite reacting force.

Nosecone—The leading end of the rocket, which is connected to the rocket's airframe by the shock cord.

Parachute Recovery—The most common of model rocket recovery systems, consisting of a plastic or nylon rip stop cloth cover (shroud) and shroud lines; made in various sizes and shapes.

Payload Section—A tube connected to the rocket's airframe, which holds scientific experiments, non-vertebrate live animals or electronics.

Portable Pad Launch System—A one-pad, easy to carry portable launch system, consisting of the launch stand, blast deflector, launch rod, safety cap and key, and launch control box.

Pyrogen—A composition which produces flame when heated.

Range Box—A box used to carry tools and supplies needed to launch a rocket.

Range is Closed—What is said on the launch field when there is a rocket flight about to take place to prevent anyone from approaching the launch pad area.

Range is Open—What is said when the launch control system is shut down, the safety (ignition) key is removed, and it is okay to approach the launch pads.

Recovery Systems—Methods used to slow a rocket's descent safely to the ground.

Rocket Fin Edges—Rocket fins consist of three to four outer edges—

1. Leading Edge—Forward edge of the fin, the edge which travels first into air.
2. Outboard Edge—The outside edge of a fin, which neither leads nor trails. Not all rockets have an outboard edge.
3. Root Edge—The edge of the fin which joins with the rocket's fuselage.
4. Trailing Edge—The bottom edge of a fin, which is the last edge of the fin to enter the air.

Rocket Fins—Fins provide stability to the rocket so the flight will be straight and forward. The larger primary fins are located at the rear of the rocket. Much smaller fins may be found closer to the nosecone of the rocket in combination with the larger fins. They are referred to as "canard" fins. Both types of fins provide flight stability and also affect the location of the CG and CP of the rocket. Fins are generally made up of wood, plastic or fiberglass.

Rocketry Fundamentals—The essential and primary principles of rocketry.

RSO—Range Safety Officer.

Safety Cap—A device used to cover the end of the launch rod on the portable pad launch system in order to avoid possible injury.

Safety Key (Ignition Key)—The key for the launch control box, which allows electrical current to flow from the control box into the igniter.

Sanding Sealer—A chemical-based substance used to fill in the tiny grain lines in balsa and basswood fins and nosecones.

Shock Cord Mount—A means to hold the rocket's shock cord within the rocket's airframe.

Shock Cord—A cord (made of rubber, elastic or Kevlar) which connects the rocket's airframe to the nosecone, and absorbs the shock of force emitted by the rocket motor's ejection charge.

Shroud Lines—Thin, long strings which connect the parachute's shroud (cover) to the nosecone.

Standoff Clip—An object used to raise the rocket off the blast deflector, i.e. clothespin, spent motor casing, small heat-resistant tubing.

Streamer Recovery—The second most common recovery system used in model rockets, consisting of a thin narrow strip of material (nylon, Mylar or plastic) of various sizes and shapes.

Tack Cloth—A sticky material used to remove dust and sanding particles from a rocket's surface prior to painting.

Thrust—A reaction force; i.e. the force expelled by the burn of propellant in the rocket motor, which causes the rocket to lift off the pad.

Tripoli—A non-profit rocket organization developed for the advancement and operation of non-professional research high power rocketry.

Tumble Recovery—A system of recovery where the rocket, after reaching apogee, tumbles end-over-end, creating drag and thus slowing its descent.

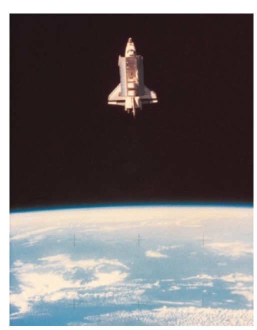
Velocity—A measurement of change of position over time.

Wadding—A flame-proof and biodegradable material used to protect the rocket's shock cord and recovery system from the heated gases emitted by the ejection charge of a rocket motor.

Weight—The amount of mass plus the force of gravity.

Wood Filler—A non-chemical wood-based or latex-based filler used to fill in cracks, pits and groves of balsa and basswood fins and nosecones.

Wood Grain—The orientation of the direction of the grain (growth) in a piece of wood.



EDUCATIONAL AND ROCKET RESOURCES

4-H Websites:

For County, State, and National 4-H Information and resources search:

www.colorado4h.org

For information on the numerous 4-H projects, go to the above website and search:

Project Selection Guide

For information regarding 4-H project exhibit rules, go to the above website and search:

State Fair Exhibit Requirements

Books:

50 Model Rocket Projects for the Evil Genius by Gavin D.J. Harper

Apogee Video Books by Timothy S. Van Milligan

Handbook of Model Rocketry, 7th Edition by G. Harry Stine and Bill Stine

Model Rocket Design and Construction by Timothy S. Van Milligan

Governing Sites for Model Rocketry:

www.nar.org

www.tripoli.org

www.canadianrocketry.org

Rocket Manufacturer and Supplier Websites: Note: Sites continue to change through the years. Do a search for "Model Rocketry" to discover new sites.

apogeerockets.com
asp-rocketry.com
BRSHobbies.com
discountrocketry.com
customrocketcompany.com
dynastar-rockets.com
estesrockets.com
fliskits.com/products
hobbylinc.com
jonrocket.com
leadingedgerocketry.com
pratthobbies.com
prestomart.com
qmodeling.com
questaerospace.com
redarrowhobbies.com
rocketryonline.com
semroc.com
siriusrocketry.com
starlightrockets.com
sunward1.com
therocketgarden.com
wildmanrocketry.com

Hobby Stores:
Hobby Lobby

Hobby Town USA

Local NAR & Tripoli Sponsored Clubs:

COSROCS (Colorado Springs Rocket Society), Colorado Springs: www.cosrocs.org

C.R.A.S.H. (Colorado Rocketry Association of Space Hobbyists), Denver: www.crashonline.org

NCR (Northern Colorado Rocketry), Ault: www.ncrocketry.org

SCORE (Southern Colorado Rocketeers), Pueblo: www.scronline.net

Tripoli-Colorado, Denver: www.tripolicolorado.org

UNIT 1 & 2 SUPPLEMENT BOOKLET FOR BALSA & BASSWOOD FINS —MODEL ROCKET CONSTRUCTION

Select a Rocket Kit and Get Organized

Model rocket kits and launch supplies can be purchased in almost any hobby shop and toy store. Some carry an assortment of rocket kits designed for all ages and levels of skill, from simple starter kits to complicated scale models, but the selection of rocket manufacturers and kits may be limited.

Where to Look—

Coupons: Watch for store coupons via local coupon fliers, booklets, newspaper or the Internet.

Catalogs: Manufacturer catalogs usually can be found free in hobby stores, or you may want to write to a manufacturer and request a copy of their catalog. (See List of Manufacturers under Resources.)

Internet: The Internet is another source for purchasing model rocket kits. There are many Internet stores that sell brand name rocket kits, so if a particular kit is not available locally, look for it online. There are also many manufacturers that specialize in types of rockets: SL-0 through SL-3 kits, SL-2 through SL-5 LPR and HPR kits, novelty type rockets, rocket gliders and even research rocket kits. You may even look for vintage rockets on Internet auction sites such as eBay©. Refer to Resources prior to this Supplement for website information.

Selecting Your Rocket Kit—

Unit 1 members are required to build a simple 3 to 5 finned Skill Level 1 rocket. All kits built in Unit 1 must have balsa or basswood fins. Be sure the rocket kit you choose meets the requirements as stated in the State Fair Requirements located at the 4-H website: www.colorado4h.org.

Unit 2 members are required to build a simple 3 to 8 finned Skill Level 2 rocket with balsa or basswood fins. Be sure the rocket kit you choose meets the requirements as stated in the State Fair Requirements located at the 4-H website: www.colorado4h.org.

Check Condition: When purchasing your rocket kit, verify that the body tube(s), nosecone and fins are in good condition. Body tubes are easily crushed or crinkled before the package is opened.

Skills and Knowledge, Not Size: Members are not judged on the size of the rocket, but rather on the skills and knowledge learned, and the quality of the construction and finishing of the rocket.

Inventory Your Rocket Kit—

Carefully Open the Kit Package: Most kits contain one or two very small parts, so be careful when opening your kit package.

Look for Missing Parts: Refer to the list of items in your kit instructions and check for missing or badly damaged parts. If you have missing or damaged parts, consider returning the kit to the store for a replacement kit.

Determine What Supplies Are Needed: Check your kit instructions for supplies you will need to construct your rocket. Also refer to the section "A Well-Equipped Rocketry Tool and Range Box" for suggestions and hints.

Find an Appropriate Work Area—

Your work area should include plenty of workspace, good lighting, and proper ventilation. For rocket construction, you can safely perform the work inside the house or inside a garage with good ventilation. If any painting is necessary or desired, it will be necessary to set up a protected area in a well-ventilated garage or an area outdoors, blocked from the wind.

Safety First! Working with glue and paints require good ventilation!

Protect Your Work Area: Cover your work area with a protective plastic sheet, white or brown paper such as butcher paper or flattened paper bags. Do not use newspaper to cover your work area as the newsprint can transfer to your rocket parts and yourself.

Working with Glues: Work with water-soluble glues if possible for easy cleanup. Wear protective gloves to avoid getting glue on your hands, and refrain from touching your face when working with glue.

Practice Patience—

The old saying goes: "Patience is a virtue." You can avoid many unnecessary mistakes, repairs and cleanups by taking your time and not "rushing" into a task.

Read Your Kit Instructions Entirely Before You Start—

Another way to avoid mistakes is to read the instructions prior to starting any construction on your rocket kit. After reading the kit's instructions, review the construction techniques listed in this booklet for each phase of your build process.

A Well-Equipped Rocketry Tool and Range Box

Construction Supplies and Tools—

Applicators (Toothpicks, Hobby Sticks, etc.): Use for performing application tasks such as applying glues, adhesives, fillers, decals, etc.

Cardboard Box (Oversized): Use a paint box for your rocket.

Cloth (Tack Cloth, Microfiber Cloth, or Lint-Free Towels): Removes residue from parts of the rocket during the sanding and painting.

Containers with Lids (Small Plastic): Use to mix wood filler with water in to form a workable paste, or when working with glues.

Glue for Cardboard and Wood: Use to glue paper shock cord mounts, shock cord knots, motor mounts, and for fillets (a thin line of glue along fins and launch lugs). Recommend water-based glue, such as clear drying white glue or yellow carpenter's wood glue (preferred). You may purchase wood glue at most hobby stores and home improvement stores. Glues come in many container sizes. One brand of wood glue comes in a small, "pen-shaped" container with a small nozzle end and easy to refill.

Glue for Plastic onto Cardboard: Use to glue plastic fin units to the rocket's cardboard body tube. Suggested glues: E6000, epoxy or a general-purpose adhesive. Check the label on the glue to see if it is compatible for plastic and cardboard. NOTE: Adult supervision is required for most of these gules, as well as proper ventilation.

Hobby Knife: A soft grip hobby knife with a protective blade cap and extra blades. Use to remove flashing on nosecones or other plastic parts and the inner mold from the nosecone eyelet.

Masking Tape (Automotive Grade): For masking off areas of the rocket you do not want to paint.

Pencil: Use for marking fin and launch lug guide lines, etc. Mechanical pencils are preferred for a sharper line. Never use a pen as the ink will bleed through paint.

Ruler: Use for measuring where the launch lug, the motor mount and other parts of the rocket may fit together. A small 6-inch or 12-inch hard plastic or metal ruler is recommended.

Sandpaper (280-, 320-, 400-, 600-Grit): Use for sanding and air foiling the fins.

Sandpaper (320- and 400-Grit): Use for sanding wood filler placed in the grooves of the body tube's body and removing the waxy coating on the body tubes.

Sandpaper (600-Grit to Micro-Fine, optional): Use for sanding plastic edges or smoothing out the seams lines of a plastic nosecone.

Sanding Block: Use to sand the flat sides of fins.

Scissors: For cutting out patterns, decals, and shock cord mounts, shroud lines, etc., as needed.

Sealer/Finishing Clear Coats: Use to secure decals and for providing a nice flat, matt or glossy finish to your rocket (An optional technique.)

Spray Paint Gun (Plastic): A plastic spray gun, which uses a trigger device, that can be attached directly to the spray paint can, making it easier to hold, control, and guide the flow of paint. Easily found at hardware stores.

Spray Paints for Top Coats: Use to paint your rocket. Mixing different brands of paint for your primer, top and finishing coats could cause what is known as an "orange-peel" or bubbling reaction to the paint. Until you know for certain what works well together, it is recommended that you use the same brand name for all the various stages of coats of paint. If you choose to paint your rocket in bright colors –yellow, red, orange—a first coat of white paint is recommended.

Spray Primer (Sandable): Use a sandable primer paint prior to spraying on any top coats! Gray, white or rust sandable primer paint is acceptable.

Wood Filler (Water-based): Fills in the grove lines on the rocket's body tube. Look for fillers that are water cleanup, have no chemical odors, and are easy to sand and paint. Recommended examples: Elmer's Carpenter's or ProBond Wood Fillers or Zar's Latex Wood Patch.

Wood Fillers and Sealers (Chemical-based): Use to fill in the tiny pits in the wood grain. Creates a very smooth surface, but requires good ventilation when working with it. Suggested chemical-based fillers are Aero Gloss Sanding Sealer and Aero Gloss Balsa Fillercoat Primer. **NOTE:** Adult Supervision recommended.

Optional Build Equipment and Supplies—

Acetone: Use for CA (e.g. Super Glue©) removal from exposed skin. NOTE: Adult supervision required.

Airbrushes: If you are skilled in using airbrushes, they can be an excellent tool when painting a rocket.

Crafter Gloves: Use to protect your hands from glues, chemicals and paints, keeps the oils of your hands from transferring to your rocket causing some paints to not adhere well to the rockets, etc.

Cyanacrylate (CA) Glue (e.g. Super Glue©): Use for reinforcing the ends of body tubes (an optional technique.) Note: Adult supervision is required.

Elastic Binding Cord (1/16", 1/8" or ½"): Use instead of the rubber-band shock cord. The rubber band shock cords tend to become dried out and brittle, breaking after a few flights.

Face Mask or Scarf: Safety prevention tool to keep from breathing in sanding particles or fumes from glues and paint.

Glue Application Tips: Small tips that can be connected to plastic cement tubes to provide a thin line of glue.

Hobby Syringe or Eyedropper---Use to apply two or three drops of water at a time to wood fillers.

Modeling Plastic Putty: Fills in dips, seam lines, and scratches on external plastic parts.

Paint Drapes or Newspapers: Use to line and protect the floor and cabinetry when painting.

Paint Supports or Stands: A means to prop the rocket nosecone and/or rocket for painting. See suggestions given under "Painting Techniques."

Paper Towels or Soft White Cloth: Use for quick cleanups.

Right-Angle Metal Bar: Use to assist in drawing straight lines along the body tubes. NOTE: Door frames or any right-angle object can be used for this technique.

Safety Goggles: May be used when painting to protect the eyes from overspray.

Transfer or Decal Paper: May be used to create your own decals.

Tweezers: Use for parts that are too small to be readily picked up with your fingers.

Range Box Tools and Supplies—

Acetone: Use for CA Glue (e.g. Super Glue© removal from exposed skin. Tip: Finger Nail Polish Remover contains acetone and works well to remove CA from skin. NOTE: Adult supervision required.

Container (Small): Good to have on hand when working with glues.

Cyanacrylate (CA) Glue (e.g. Super Glue©): Use for quick fixes when on the launch site. NOTE: Adult supervision is required.

Dowel Rod (Long/Thin) or Probe: Helps to push down recovery wading towards the motor mount, and sometimes to help push out a motor that may have jammed up inside the airframe.

Hobby Craft Sticks: Good to have on hand when applying glues while at the launch site.

Masking Tape: Use to create a better friction fit for nose cones and rocket motors.

Motor Plugs: Holds the igniter in the rocket motor. Motor plugs come in different sizes to match the size of the different motors.

Needle- Nose Pliers: -Helps to pull out hot, spent motor, and for opening and closing swivel snap hooks.

Parachutes: The most common recovery system. Having several sizes available, some with holes and some without, makes it easy to do a quick change out for range and launch conditions.

Scouring Pad: Use to remove any residue on the launch rod to prevent the launch lugs from hanging up on the rod. Recommend a heavy-duty commercial scouring pad made from synthetic fibers.

Streamers: Use for quicker rocket descents. Especially useful for smaller launch fields, colder days, and higher winds. Be sure to have a variety of sizes available to choose from.

Swivel Snap Hooks: Use to attach parachutes or streamers for quick-change outs, and helps to reduce shroud line tangles.

Talcum Powder: Use on plastic parachutes and streamers to make the surface slick, making it easier for the parachutes and streamers to unfurl (open up). Also aids in locating the rocket in the sky when the recovery system deploys.

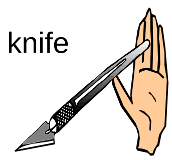
Balsa and Basswood Model Rocket Construction Techniques

Each model rocket kit is unique in its design and construction, even though many use the same techniques. Be sure to read the kit instructions completely prior to starting any work. The sections below suggest methods and techniques towards the building process of rockets in general. The following sections are listed in the order of recommended procedures and may not necessarily follow the same order of steps in your kit instructions. Be sure to review and compare each of the following sections with your kit instructions so you may apply the best technique or application for your rocket.

NOTE: Your model rocket kit may or may not require some of the following construction techniques. Read each section to see if it would apply to your kit build. If it does not, then proceed to the next section.

Preparation of All Plastic Parts—

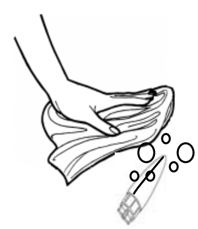
Removing Plastic Flashing: Flashing is leftover plastic from the molding process. With a sharp blade (hobby knife), trim all excess flashing off each part.



Safety First! Hold and guide your knife blade away from your body; use a scraping method rather than a cutting method to remove the flashing. Remember to replace the safety cap when you are done with the hobby knife.

Tip: Be sure to not scrape off any tabs or pegs used to connect pieces together.

Wash Off Chemicals: During the molding process, chemical agents are used to coat the molds so the plastic parts will not adhere to the molds themselves when formed. When the plastic parts are removed from the molds, an unseen residue of those chemicals can transfer to those parts, making it difficult for paints to adhere to them.



Use warm water with a couple drops of dishwashing detergent to wash off any residue chemicals (also referred to as “film”) from any exterior plastic parts including the nosecone.

Gluing Plastic Parts—

Safety First! Always work in a well-ventilated area when working with any type of chemical-based compound or glue.

Test Fit Parts Prior to Gluing: Make sure you are working with the correct parts, and that they fit together snuggly prior to gluing.

Application of Glue: Use applicator tips, toothpicks, etc., something that will allow you to apply a thin line of glue. Do not use your fingers!

Safety First! Use protective gloves to keep the glue off your hands, especially when working with any type of plastic cement.

Apply Glue Sparingly: Use glue sparingly and work quickly. Plastic cement heats up the plastic, effectively softening it (melting it) so both pieces join together to form one piece.

Tip: Do not use CA (e.g. Super Glue©) or any type of quick repair glue for general construction. Sometimes, kit instructions will recommend a type of glue to use. Tester's Plastic Cement generally works well for most plastic modeling construction.

Nosecone Techniques—

If you rocket kits comes with a plastic nosecone, be sure to follow the steps stated in the above section about removing the flashing and washing off the nosecone. Balsa nosecones require sanding and filling in of the wood grain to make it smooth. A sleek, smooth nosecone will enable your rocket to fly straighter and faster into the air. Also, with less drag on your rocket, your rocket will soar higher into the sky. (Refer to Newton's Three Laws of Motion, the Law of Inertia.)

Plastic Nosecones: Filling in Dips, Grooves and Scratches on the Nosecone: You can use modeling plastic putty to fill in any dips, grooves or scratches you may find on your nosecone, particularly along the mold seam lines. Once the putty has hardened, start with 400-grit sandpaper to smooth the filler down even with the body of the nosecone.

Safety First! Many types of plastic putty used for model craft have toxic and flammable vapors. Be sure to follow the product's instructions for use and storage and use only in a well-ventilated area.

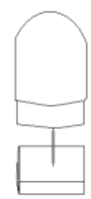
Tip: Check with your local hobby stores or do an Internet search for plastic putty.

Balsa Nosecones: Filling in Wood Grain, Grooves and Scratches on the Nosecone: Use either a wood filler paste or a balsa sealer to fill in the grain and any gouges or scratches the balsa nosecone may have.

Safety First! Proper ventilation is required when working with any chemical fillers and sealers.

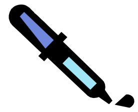
If Using a Chemical-Based Balsa Filler Primer or Sealer: Carefully (but vigorously) shake the jar of filler primer of sealer. Then with an applicator stick, thoroughly stir the filler primer or sealer, making sure the mixture is mixed well. With a large bristle brush, tickly coat the entire nosecone and let dry.

Tip: Use a straight pin pressed into the bottom of the nosecone as a holder, placing the other end of the pin into a cardboard box or Styrofoam block.



If Using a Water-Based Wood Filler: Put a small amount of wood filler into a small container and mix in just enough water to make it into a toothpaste-like consistency. Too much water could cause the balsa nosecone to lose its pre-formed shaped.

Tip: Use an eyedropper or plastic syringe to apply two or three drops of water at a time.



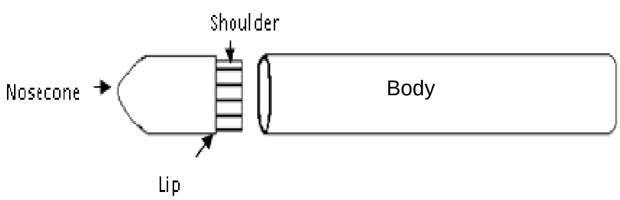
Thinly coat entire nosecone and allow to dry.

Sanding and Filling: After your nosecone is dry, starting with 320- or 400-grit sandpaper and going to 600- or 800-grit, lightly sand the nosecone. Repeat sanding and filling until you achieve a nice smooth finish.

Safety First! Wear a face mask if you are sensitive to dust particles.

Tip: Remember! Do not sand too far down on the "lip "of the nosecone.

Test Fit Nosecone: Test the fit of the nosecone "shoulder" into the rocket's body tube. The lip of the nosecone should match the outside edge of the body tube. See illustration below.



The nosecone should fit snug enough that when you tip the rocket upside down, the nosecone will not fall out, but not so tight that it is difficult to pull out.

Tip: If the nosecone easily fails out, take a small piece of masking tape and attach it to one side of the nosecone's shoulder. Re-test fit the nosecone to the body tube. If the nosecone still falls out when the rocket is tipped upside down, add a little more masking tape to the nosecone's shoulder until it fits properly.

Body Tube Preparation—

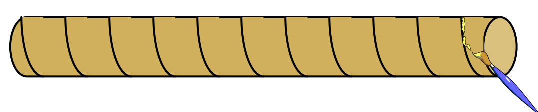
The main body tube of the rocket, the one where all the parts fit onto or into, is the "airframe" of the rocket. Some rockets have more than one body tube to create either or longer or a wider airframe, or to serve as accessory parts to the rocket.

Model rocket body tubes are made up of several layers of paper/cardboard material and rolled to create a tube. Many have narrow or large "roll" grooves in them. These grooves will cause drag on your rocket and paint will not hide the grooves. To eliminate the additional drag on your rocket and to give your rocket a sleeker look, you will need to fill in the grooves. Follow the steps below to prep your body tube (s).

Fill in Groves: Put a small amount of wood filler into a small container and mix in just enough water to make it into a toothpaste-like consistency. Too much water can cause the cardboard to bubble, so use sparingly.

Tip: Use an eyedropper or hobby syringe to apply two or three drops of water at a time.

With a small applicator (toothpick, hobby stir stick, or even your finger), pat the wood filler into the groves along the body tube. Try to keep it mostly in just the groves, for whatever excess is on the body tube will need to be sanded away later. Let dry completely.



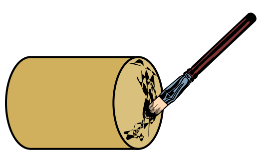
Sand the wood filler smooth and even with the body tube. Start with 320 grit, wipe off residue, and repeat the steps with 400 and then 600 grit sandpaper.

Tip: Use a tack cloth, a microfiber cloth, or dust-free towel to wipe off residue.

Remove Glossy Coating: Even if your rocket's body tube does not need to have any groves filled in, you may still want to paint it. Most body tubes have a glossy coating to them, which should be remove prior to painting, making it easier for the primer paint to adhere to the body tube. Use 400 to 600--grit sandpaper to sand lightly away the glossy coating and to smooth out any bumps in the body tube.

Strengthen the Top End of the Body Tube (Optional): The end of body tube where the recovery system deploys tends to start raveling or breaking down after a few flights. Strengthening the inside edge of the tube with a little CA (e.g. Super Glue©) helps to keep the end from deteriorating too fast.

Safety First! Be sure to have adult supervision whenever using CA and to always read the warning labels. Work in a well-ventilated area and have acetone nearby in case fingers get stuck. Nail polish remover has acetone in it and works well to removing CA.



Depending on which end of the rocket the recovery system is deployed—front or rear ejection—paint on a thin layer of CA inside the tube, from the top edge to about ¾" down. Let dry.

Take a small piece of 320- or 400-grit sandpaper and lightly sand smooth.

Re-test fit your nosecone to the body tube. If necessary, remove either excess masking tape or lightly sand the shoulder of the nosecone to obtain a smooth, but snug fit. Remember: the nosecone should come out easily when tugged, but not fall out when tipped upside down.

About Shock Cords—

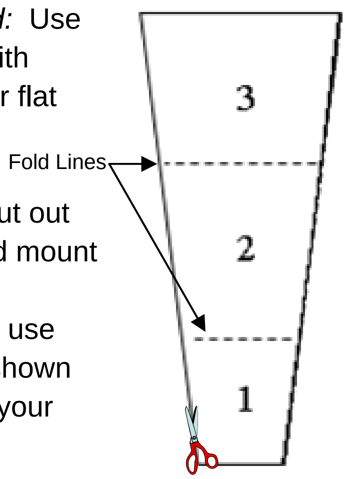
Shock cords serve two main purposes for the rocket. First, they are used to connect the nosecone to the rocket's body tube. Second, shock cords absorb the shock of force produced by the ejection charge of the rocket motor. The "force" is the result of the hot gasses created and released by the ejection charge.

Most Skill Level 1 and 2 rocket kits contain a shock cord made out of rubber band type material. Two other common types of shock cords for model rockets are elastic band material commonly used in sewing projects, and Kevlar cord. Rubber band shock cords will quickly dry out and become brittle. Elastic band shock cords, the type used for sewing, will generally last longer than the rubber band shock cords. However, these too will become charred from the hot gasses and will burn through or break over time. Kevlar cord is a flame resistant material, but it has no elastic material in it. Being flame and heat resistant, though, Kevlar shock cords will last longer than the other materials.

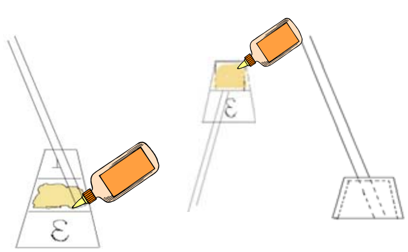
Shock cord length is also important. Shock cords need to be long enough to keep the nosecone from bouncing back into the rocket, which could cause damage. The "bounce back" is referred to as "recoil." When you stretch a rubber band and release it, it recoils back to its original shape. Since Kevlar cord is not elastic, it needs to be long enough to absorb the shock of force applied to it, as well as long enough to keep the nosecone from damaging the rocket. A general rule to follow is to make your shock cord at least three times as long as your rocket, especially if you are using Kevlar.

Methods of Attaching the Shock Cord— There are numerous ways to secure the shock cord to a rocket. One of the methods is by attaching the shock cord to your motor mount. Read your kit instructions on how to connect the shock cord to your rocket and how to build your motor mount (also see "Motor Mount Assembly" in this supplement). Consider where you would like to place your shock cord to your rocket. You can always follow your kit instructions, or try one of these three methods:

Paper Shock Cord Mount Method: Use this method with rubber band or flat elastic shock cords only. Cut out the shock cord mount from the kit instructions or use the template shown here to make your own.



Follow your kit instructions on how to glue the shock cord to the shock cord mount. It is important that the shock cord is coming out at the top of the folds at a slight angle on the shock cord mount after all the folds are completed. Refer to the picture shown below.

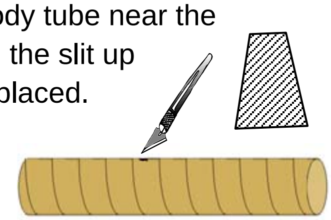


While the glue is still wet, curve the shock cord mount around your finger with the smooth side next to your finger.

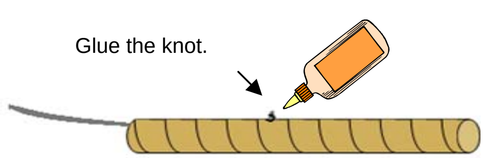
Place glue to completely cover the folded side of the shock cord mount and insert into the body tube. The top of the shock cord should be below the shoulder length of the nosecone, approximately 1 ½ "from the top of the tube. Press the shock cord mount against the interior of the body tube, making it as smooth as possible. Remove any excess glue from inside the tube. Bumps in the shock cord mount or rough dried glue on the inside of the tube could cause the parachute or streamer recovery system to snag and not deploy properly.

Through-The-Wall Method: This method is best used with rubber band or flat elastic shock cords. Some kits use the through-the-wall method and use a small plastic cover to place over the knot.

Cut a small slit in the body tube near the center of the tube. Line the slit up with where a fin will be placed. This prevents the shock cord from getting in the way of the launch lug and launch rod.

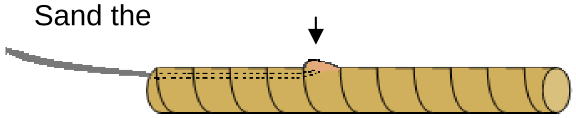


Slip one end of the shock cord through the slit and secure the end with a double knot. Add a drop or two of white glue to the knot to secure it. Let dry.



Take some wood putty or filler and mold a small mound over the knot and onto the body tube. Round and smooth the mound towards the rear of the body tube to allow the airflow to glide over the mound, creating less drag on the rocket. Let dry.

Sand the

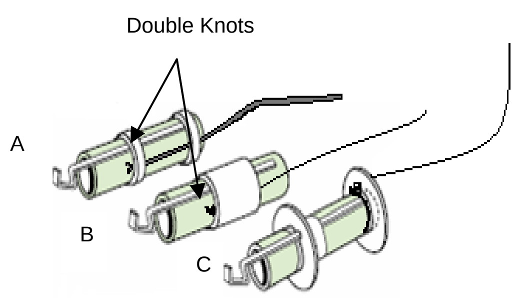


mound smooth, but do not sand down to the knot.

Onto the Motor Mount Assembly Method: This method works best with Kevlar shock cords. Read your kit instructions on how to build your motor mount assembly completely through prior to adding the shock cord. If you decide to connect your shock cord to the motor mount assembly and your kit requires you to build a motor mount, follow the steps below.

There are several ways to connect the shock cord to a motor mount. However you choose to connect the cord to the motor assembly, remember the following steps:

Step 1: Secure the end of the shock cord with a tight double knot.



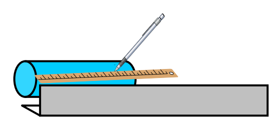
(See Figures A and B.)

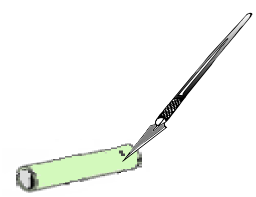
Tip: File or cut a small groove inside the centering ring for the shock cord to rest into. This makes it easier for the centering ring to slide over the motor tube, motor hook and shock cord.

Step 2: Tie the shock cord around the motor casing on the far side of the centering ring to give added security. (See C Above.)

Motor Mount Assembly—

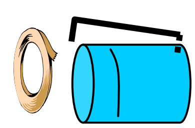
Building the Motor Mount Assembly: Make a mare where the centering ring (s) go and where the motor hook inserts into the motor tube. Most kit instructions will have you cut a 1/8 inch slot about 1/4 inch from the top of the motor tube.





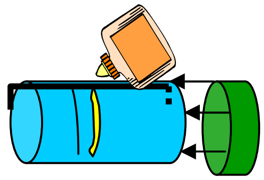
Tip: Slightly pinch the motor tube end with your thumb and forefinger as you "gently" press down with the tip of the hobby knife. This will help you to avoid crushing the tube as you cut the slot.

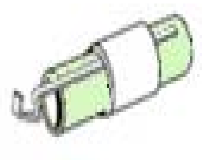
Safety First! Be careful when applying pressure with the hobby knife. Less pressure will help avoid slips and possibly cutting your hand.



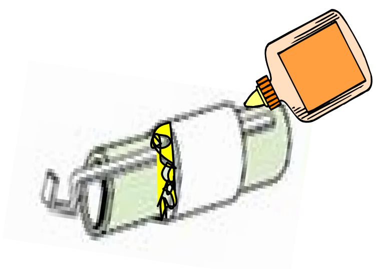
Secure the motor hook in place (in a straight line down the tube). With a piece of cellophane tape, secure the motor hook on the motor tube. This will help to prevent it from shifting or sliding out of position while you are placing on your centering ring.

Always test fit parts prior to gluing.





Apply enough glue to the motor tube about ½ inch from the centering ring line to allow you to slide and position the centering ring into the proper place. Wipe of the excess glue from the end of the centering ring with your finger. Leave some glue on the joint.
Let dry.

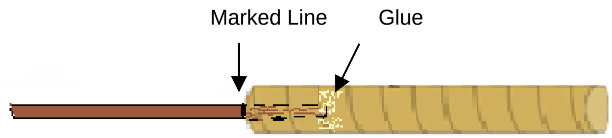


Apply another line of glue on the other end of the centering ring. Stand on end and let dry. Glue applied to a joint is called “fillet”. Fillets are used to strengthen parts together.

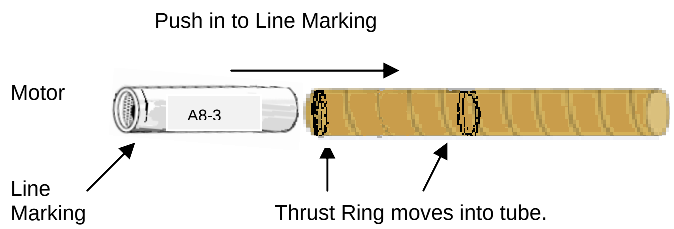
Tip: Wipe off any excess glue that may be on top of the centering ring(s) (the body of the centering ring) as it will interfere when you put the motor mount assembly into the body tube.

Securing the Thrust Ring: If your rocket kit comes with a thrust ring, follow your kit instructions in the placement of the thrust ring. Either it may go directly into the rocket’s body tube, or it may be placed into the motor tube. Some basic steps to follow when gluing the thrust ring into the motor tube or body tube are as follows:

- Make a mark on a motor (preferably a spent motor) about ¼” from nozzle end.
- Mark an applicator stick about ¼ “shorter than the size of the motor.
- Apply glue to the marked end of the applicator stick.



- Insert the applicator stick into the body tube (or motor tube, per your kit instructions) up to the line you marked.
- Apply the glue to the inside of the body tube (or motor tube). Be sure to spread glue all the way around the inside of the tube.



- Place the thrust ring into the tube.
- Using the pre-marked motor, push the thrust ring up into the body tube (or motor tube).
- Continue to push up to the line marking the motor. Quickly remove the mot

Inserting the Motor Mount into the Body Tube: Again, read your kit instructions prior to inserting your motor mount into the body tube or your rocket. Some kits will have you insert the motor mounts even with the bottom of the body tube. Others will have you leave about ¼ “ to ½” of the motor assembly to extend beyond the outside of the body tube.

The kit instructions should tell you how far down inside the body tube to apply the glue for the motor mount assembly. In general, you will apply glue into the body tube just short of where the centering ring will be placed. The glue will spread forward into the body tube as the motor assembly is pushed into the body tube. The general steps to securing the motor mount into the body tube are similar to the steps used in gluing the thrust ring into the body tube (or motor tube).

- Mark an applicator stick to the depth indicated in your kit instructions
- Apply glue to the same marked end of the applicator stick.
- Insert the applicator stick into the body tube up to the line you marked.
- Apply glue to the inside of the body tube. Be sure to spread glue all the way around the inside of the body tube.

Tip: This is a case where more glue is preferred to less glue. Too little glue could cause the motor mount to "freeze" in place before getting it all the way into the body tube. However, too much glue can cause excess glue to run down the inside of your body tube and onto the shock cord.

- In one quick motion, slide the motor mount into the body tube.

Tip: If you have already placed lines for your fins and launch lug onto your body tube, be sure to place the motor hook between two of those lines. Lining the motor hook along one of the fin lines could make it possible to put a motor into the motor mount. Lining the motor hook along the launch lug can cause interference with the launch rod and cause a short in the electrical current.

- Once you have the motor mount into position, prop the body tube up with the motor mount end down, to help prevent excess glue from running down the inside of the tube. Let dry.
- Apply a glue fillet to the outside joint of the motor mount to the body tube. Let dry.

Couplers and Payload Sections—

Couplers: Some model rocket kits include one or more couplers. Couplers are used to join two body tubes together to make a longer body tube. Sometimes, the body tubes are the same size in diameter, and sometimes they are not. So couples will also be used to change the body tube's tube diameter from one section to another. Couplers are made from balsa, plastic or cardboard tubing. Couplers are sometimes glued on both ends, and sometimes just one end is glued.

Payload Sections: Other model rocket kits may include a payload section. For most model rocket kits, the payload section is made from a clear plastic tube. Some common payloads are eggs, scientific experiments, and liquids. (Never put a live animal in a payload.) Payloads sections usually have just one end glued to the body tube.

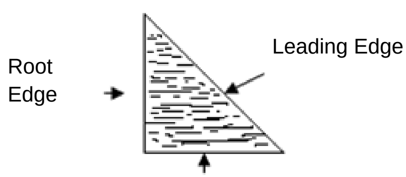
Recommended Glues for Couplers and Payload Sections: Use wood glue when gluing cardboard or balsa parts to a cardboard body tube. To glue a plastic coupler or payload section to a cardboard body tube, it is recommended to use an E6000, epoxy or a general-purpose adhesive. Check the label on the glue to see if it is compatible for plastic and cardboard. NOTE: Adult supervision is required for most of these glues, as well as proper ventilation.

Learning about Fins—

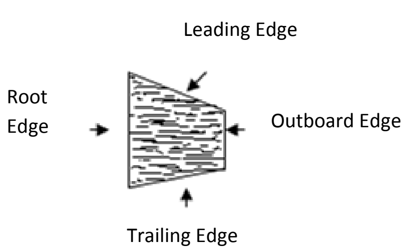
Fins come in all sizes and shapes. They are used to stabilize your rocket while in flight. The center of gravity (CG) and center of pressure (CP) are also determined by the size and placement of fins. Always place your fins as your rocket kit instructions tell you. Commercial rocket kits are tested for proper fin placement and size, so you know that the CG and the CP will be in the right places on the rocket.

Most fins have three or four edges to them. All edges have a name. The "root edge" is the edge that will be glued to the rocket's body tube. Many rocket kits mark the root edge with a small hole. The "leading edge" is the edge that will lead into the sky. The "trailing edge" is the edge last to enter into the sky, and the "outboard edge" is the edge between the leading and trailing edges, also known as the "outside edge". Two typical fin patterns are shown below.

Example 1



Example 2



In Example 3, notice that the wood grain is going in the same direction as the leading edge. This is very important. If the wood grain is going in any other direction, the airflow around the fin could simply snap the fin apart.

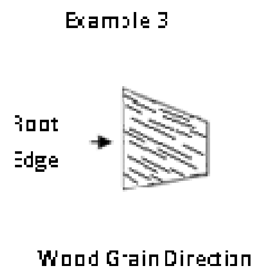
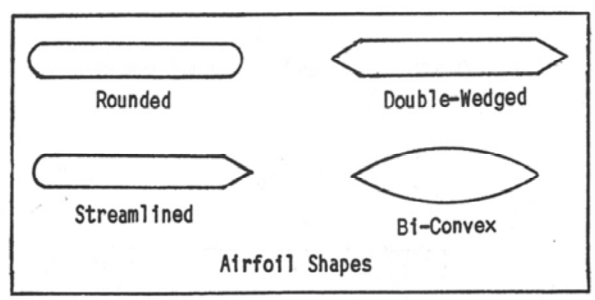


Figure 11: Examples 1-3 Taken from Model Rocketry Unit 2 Manual

Balsa and basswood fins will come out of wood sheets with flat edges. Flat edges on fins will additional drag to your rocket while in flight. To achieve better flight performance, you will want to "airfoil" your fins. Some of the most common types of airfoil shapes are as shown.



Taken from 4-H Basic Model Rocketry, Unit 2 Manual

Balsa and Basswood Fin Preparation—

Cutting, Shaping, and Sailing: When you open your rocket kit, your fins are probably still seated in a balsa or basswood sheet. Most fins are laser cut for easy removal. Before removing the fins from the sheet of balsa or basswood, sand the fins on both sides of the sheet. For initial sanding, start with 280- or 320-grit. To avoid creating "finger" grooves in the soft wood, we recommend using a sand block.

Do not pop the fins out from the sheet. Instead use your hobby knife to cut through the tabs in the wood. Popping the fins out can cause the wood to snag to tear away from your fin, which will require repairing. If necessary, use a metal or sturdy ruler to use as a guide.

Stack fins together and as a single unit, sand the rood edge flat. Sand all remaining edges to make the fins uniform in size and shape, and to remove any tab stubs.

Shape the leading and trailing edges round. If you have an outboard edge on your fin, you may either leave it flat or sand it round as well. Periodically stack the fins together to ensure uniformity in size and shape.

Remove the dust from the fins using a microfiber cloth or tack cloth.

Using Fillers or Sealers and More Sanding:

The grain in the wood consists of lots of tiny pits which, again, causes drag on your rocket. To remove all appearances of wood grain, coat each fin with either wood filler or a balsa sealer (or any other sandable filler medium). When using water-based mediums, you will need to coat both sides at the same time. Wood absorbing water and coating on one side at a time will cause the wood to curl or "warp." The advantage of chemical-based fillers is that they do not warp balsa wood fins. However, chemical-based fillers must be used with adequate ventilation, usually in an open garage or outside. After treating the wood fins with a filler or sealer, let them dry and then sand starting with 320-grit paper. Stack the fins together to ensure uniformity in size and shape.

Remove the excess dust with a microfiber or tack cloth, and repeat the process until the fins have a smooth finish, approximately 2 to 4 times.

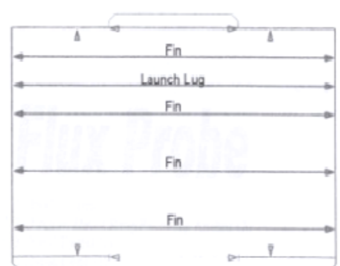
SUGGEST FILLER MEDIUMS:

- AeroGloss 70-4 Balsa Fillercoat Primer-chemical based
- Elmer's Carpenter's Wood Filler—water based (thin wood filler with water to create a toothpaste-like texture)

After the last filler layer has been applied and sanded with 320- or 36-grit paper, increase the sanding paper grit number to 400- to 600-grit, etc., using a tack cloth or microfiber cloth between each sanding. This will achieve an almost glass-like smoothness.

Marking the Body Tube for the Fins and Launch Lug—

If you have not already done so, be sure to lightly sand the body tube to remove the waxy coating. Removing the waxy coating will allow the glue and later, the paint, to adhere to the body tube.

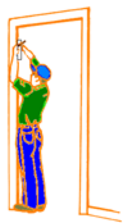


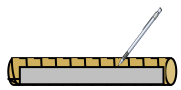
Refer to your kit instructions and cut out the fin alignment guide. Slip the guide over the rocket's body tube on the end where the motor mount is located. The launch lug should be placed where it will not interfere with the fins of the rocket or the motor hook. Line up your guide and mark all lines as your kit instructs.

To mark straight lines along the body tube, you can use a door frame, a fin alignment tool or a right-angle bar. Mark all lines from one end of the body tube to the other end. This will provide you an alignment to "sight" down when attaching your fins and launch lug(s) to ensure the fins and lugs are on straight.

Read your kit instructions for the exact placement of the fins and launch lug(s) and make a little "x" mark on the lines you drew of where the top of each fin and launch lug will sit.

Estes' Photo

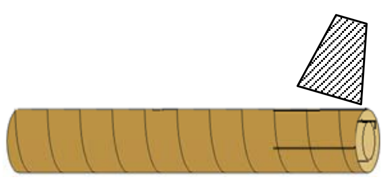




Attaching, Aligning and Filleting the Fins—

Attaching the Fins to the Body Tube: Have a location set up to rest your rocket prior to attaching your fins. Do not allow your rocket to rest on the fins while they are drying as the weight of the rocket may put the fins out of alignment.

Put a thin layer of glue on the fin line (only where the fin will be placed), and again, wipe most of it off; leave just enough glue to make the tube look shinny. Wait about one minute.



Apply a second thin layer of glue to the root edge of the fin, wipe most of it off, and then "walk" the fin onto the body tube, along the glued line.

Tip: This is another case of too much glue is a bad thing. Allowing the glue to "set" on both the fin and the body tube, prior to attaching the pieces together, provides a tacky surface on each piece. This allows the fin to stay in place better. If you applied a line of glue to the fin and then immediately place the fin onto the body tube, you may find that it will tend to slide off or out of alignment.

Aligning All Angles of the Fins: Check the alignment of the fin by sighting down the body tube along the line you drawn with your eye, holding it out at arm's length. The fins should be vertical to the body tube and straight along the fin line from the tip to the tip along the root edge. Adjust if necessary. Let dry.

Repeat the above two steps for all remaining fins and let dry.

Apply Fillets: Apply a thin stream of glue (called a fillet) along both sides of each fin---along the joint with the body tube---and smooth out with your fingertip. Let dry. Sometimes a second application of glue may be needed if bubbles form in the fillets. Fillets add strength to hold the fins onto the rocket.

Attaching, Aligning and Filleting the Launch Lug—

Check Placement of the Launch Lug: Small rockets generally use only one launch lug, but larger rockets may use longer launch lugs, two or even three launch lugs in vertical alignment with each other. Generally, one launch lug is placed near or at the CG (center of gravity). You may discover your instructions will have you place a lug centered between two fins about one inch above the fins, but it may also be placed along the edge of a fin. If using two launch lugs, the second launch lug should be placed about one- to two-inches down from the top of the body tube. **NOTE:** It is recommended to follow your kit instructions as to the proper placement for your launch lug(s).

Alignment and Attachment of the Launch Lug: It is important to align the launch lug vertically along the rocket's body tube. If the launch lug is slanted any, it can bind against the launch rod on takeoff, which can cause the launch lug to tear off or partially tear off, causing the rocket to fly off in any directions.

Lightly sand one side of the launch lug along its entire length. As you did when attaching your fins to the body tube, apply a slight amount of glue to both the body tube line where the launch lug will be placed and let sit for about one minute. Apply a second *slight* amount of glue to the launch lug (in the same spot as before) and attach to the body tube. If you applied too much glue, the launch lug will easily slip off or out of alignment. Raise the rocket to eye level and hold out at arm's length. Sight down the rocket's body tube and launch lug to ensure proper alignment. Let dry.

Apply Fillets: Apply fillets to both edges of the launch lug and smooth out with your fingertip. Be sure the glue does not close up the launch lug holes.

Again, do not use plastic cement for this procedure, as it does not adhere well to cardboard body tubes.

Painting Techniques

Now that you have your rocket built, how should you paint it? Scale, semi-scale, or scale-like rockets should be painted and decaled according to the picture on the kit package. If your rocket is not a scale, semi-scale or scale-like rocket, then you are free to paint it in any color scheme you choose.

NOTE: If your rocket kit comes with decals, choose an appropriate color scheme that will coordinate well with your decals. Some colors of paint will blend in with the decals and the decals will become nearly invisible to the eye.

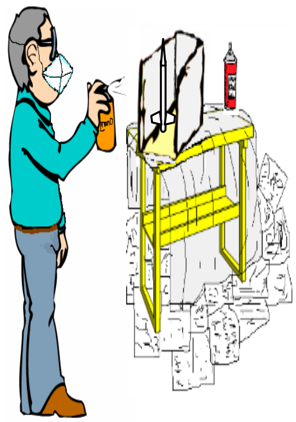
No matter how your rocket is painted, you want to produce a nice smooth surface, and avoid runs or splatters. Spray paints are recommended. A small plastic spray gun, which attaches to the top of spray paint cans, can easily be found in hardware or automotive stores and are easy to work with. If you have experience using airbrushes, those may also be used. Using small paintbrushes to hand paint designs can cause excess paint buildup, causing additional weight and drag to your rocket.

Paint reveals all. If the grooves in the body tube, or notches in the nosecone, etc., were not completely filled in and sanded smooth, they will appear through the paint.

Never paint your rocket's nosecone while attached to the body tube. The paint will seal the nosecone into the rocket and you will have to cut it out, sand and repaint.

Create an Appropriate Environment in Which to Paint—

If you ever had experience working with spray paints, you know that much of the paint spreads out into the air like dust particles. These dust-like particles are the "overspray" of the paint. They can land on surfaces far away, from where you are painting. Select a safe area in which to paint, either in a well-ventilated shop or garage, or outdoors out of the wind. Make sure there are no drafts in the direction of your work area that can blow dirt onto your rocket.



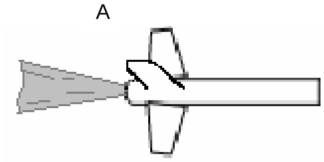
- Wear old clothes that you can afford to get paint stains on.
- Spread out plastic sheets, paint drapes or newspapers to cover the surrounding floor area and cabinetry.
- Use as oversized box with one side cut out as a paint box. It is recommended to cover the box with brown or white paper. As your paper becomes covered with paint residue, you can replace it with new paper, allowing you to use your box repeatedly.

Safety First! If you are sensitive to paint fumes, consider wearing a facemask while you paint. Safety goggles and gloves are also recommended to avoid getting paint in your eyes, on your glasses, or on your hands.

Methods to Hold the Rocket for Painting—

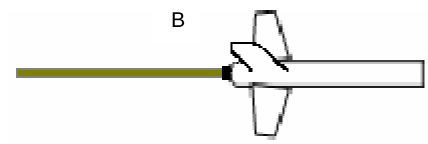
Roll up heavy paper into a cone and insert into the motor mount or the top of the body tube. (See Example A.)

A



Use an extra body tube with a coupler or a dowel rod and insert into the motor mount of your rocket. (See Example B.)

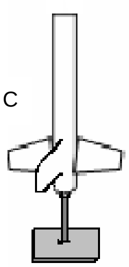
B



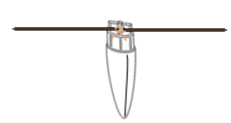
Use a stand to hold the rocket while painting. (See Example C.)

NOTE: Holding the rocket horizontally is the preferred method to hold the rocket when painting as it helps to avoid paint "runs" down the side of the rocket.

C



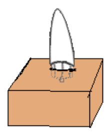
For the nosecone, if it has an eyelet attached to its base, run it through a coat hanger wire or other stiff wire, which you can then lay across the top of the box and rotate as you paint. (See Example D.)



D

You can also brace the nose cone into a foam block or cut a small opening in the top of a box and sit the shoulder of the nosecone through the opening. (See Example E.)

E



Tip. Remember to leave space between the top of the box and the lip of the nosecone so the paint can be smoothly applied clear to the lip's edge.

Primer Paint—

Select a "sandable" primer. Primer and topcoat paints should be the same brand name to avoid any "crazing" damage (dissolving, cracking or bubbling of paint).

<u>Lightly spray</u> in a continual motion parallel to the rocket, about 8 to 10 inches away from the rocket. Be sure to cover all parts of the rocket, but do not paint the inside of the body tube. Do not forget to paint all the fin edges, including the trailing and outboard edges. Allow to dry completely.

Tip: Avoid getting paint inside the launch lug by inserting a small wad of tissue lightly covered with Vaseline just inside each end of the lug. Keep in place until the entire rocket is finished. Afterwards removed with tweezers and clean the Vaseline out using a swab or Q-Tip.

Lightly sand the entire rocket. Remove paint dust with a cloth (microcloth, tack cloth or other lint-free cloth).

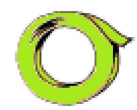
Repeat the painting process with light coats of primer, sanding in between, until all blemishes are gone. Usually 2 to 3 coats of primer will do.

Spray one last light coat of primer and let rocket dry for 24 hours.

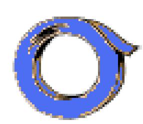
To primer paint the nosecone, follow the same steps as above. NOTE: Usually you can use the same primer paint for plastic nosecones, but there are sandable primer paints specifically made for plastic, as well. Be sure to read the instructions on the primer can.

Tip: Remember to mask off the shoulder of the nosecone. If paint gets onto the shoulder, use paint thinner to remove it or sand it off. Having paint on the shoulder of the nosecone may cause it to stick to the body tube or fit too smugly to the body tube.

Masking—



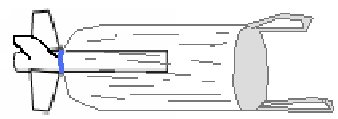
Masking is a method of shielding parts of the rocket you do not want to paint or wish to paint a different color for the rest of the rocket. Regular masking tape, usually a tan or beige color, usually does not seal well and is not recommended. Instead, an alternative would be to purchase a paint masking tape that will give you sharp paint lines. Most home hardware stores carry several brands of tape that will work well. When working with masking tapes, be sure to rub the tape down to form a good seal against the body tube or fins and to whatever material you use to shield the rest of your rocket.



Tip: Plastic automotive masking tape is excellent for multicolor painting and is easy to peel off. It is a much more expensive product, though.

Use plastic bags, white or brown paper to shield the rest of the rocket. Never use newspaper to shield your rocket as the newsprint can rub off onto your hands and onto your rocket.

Tip: Plastic grocery sacks make excellent shielding material. Create a small hole in the bottom of the sack, large enough to place your rocket through. Secure bottom end with the masking tape to the area you want to shield. Drape the rest of the sack over your hand and arm while you are holding the rocket.



Allow your rocket to dry completely prior to removing the tape.

Applying Top Coat Paint—

As noted before, if your model rocket is considered a scale, scale-like or semi-scale model, than you must paint your rocket according to the scale (kit package photo). Otherwise, you may choose your own colors. Be sure to read and follow the recommended process for applying paint listed on the paint cans. If you decide to paint a bright color—yellow, red, orange—do a light undercoat of white paint first. Allow to dry completely before applying the bright color.

Take your time when painting. Do not rush the job. In order to avoid runs, applying several light coats of paint is better than one heavy layer of paint. Again, be sure to read the instructions on the can on how to apply multiple layers. Different paint brands have very different rules for painting.

Let the paint dry completely. Once completely dry, remove the tape and shield.

Multicolor Painting—

The first color applied must be "hardened" (dry for 1 to 2 days) prior to applying additional color to your rocket.
Again, for fine and crisp lines use masking tape appropriate for paint masking and some type of shielding to mask off areas not to be painted.

Apply all additional paint colors the same as your first top coat color, allowing the paint to dry and harden completely between each color.

Finishing Techniques, If Needed

Confirm that the paint is "hardened' before applying decals. It is recommended to wait 36 to 48 hours before applying decals to a painted rocket.

Scale, scale-like, or semi-scale rockets should have all decals applied according to their respective kit photos. Otherwise, you may follow the kit package photo, or decide where to apply the decals yourself. The following are methods of applying different types of decals.

Water Decals—

If you painted your rocket with a dullcote finish, paint the rocket with a clear gloss coate before applying water decals. The decals will stick better and will not form a fog under them. Make sure the clearcote is completely dry prior to applying the water decals.

Soak the decals in warm water, about 30-to 60-seconds, to soften the glue on the backing paper. Once soften, slide the decal onto the surface of the rocket and position it into place. Blot excess water off with a soft cloth or a paper towel. Do not rub, as it may cause the decal to tear. Starting from the center and pressing outward, work bubbles out to the edge of the decal. Let dry.

To return your rocket to a nice dull finish after applying your decals and after the decals have completely dried, spray paint a test sample decal with clear dullcote paint. If successful, no crazing occurs, spray the entire rocket.

Pressure-Sensitive Decals—

Most rocket kits come with adhesive backed decals (pressure-sensitive). Some need to be cut out, while others can be peeled off the backing sheet.

Check to see where the decal is to go before you remove it from its protective backing sheet. For scale models, apply the decals as depicted on your kit photo.

Carefully cut close to the edges of one decal, or peel off one decal. Line the decal up by sight before placing it onto the rocket. Carefully place the center of the decal into place. Smooth the decal from the center out, carefully working out any air bubbles. If you are unable to get all the air bubbles out, use a hobby knife to cut, a small slit and work out the bubbles.

Repeat the process for all your decals.

For placement of large pressure-sensitive decals, draw a line with a pencil along one edge of the decal onto the rocket prior to removing the backing. Gently peel the backing from that edge of the decal only, line up with the pencil marking, and gradually peel and smooth the rest of the decal on.

Tip. Soaking the decal without its backing in one drop of dishwashing detergent to one bowl of water for about 10 seconds. This will help in the placement of the decal. Be sure to remove all access water.

Make Your Own Decals—

Transfer paper for homemade decals is available at most hobby stores or you can purchase decal paper for laser or ink jet printers at most home office stores. Create your own decals and apply the same methods used for pressure-sensitive decals.

Using Finishing Clear Coats—

Some modelers on their rockets use this optional technique. When painting scale models of military missile rockets, many of the rockets are painted with camouflage colors. Adding a dull clearcote over the camouflage provides a more realistic look to the rocket. When using any type of finishing coat, remember to stay with the same brand name of paint that you use for both your primer and top coats to avoid any crazing (bubbling or peeling).

Apply light coats of the clearcote, allowing each to dry completely before applying any additional coats. Usually, though, one coat will be sufficient. Let dry completely before handling.