HEAD HEART HANDS HEALTH

Introduction to Model Rocketry

UNIT 1 4-H MANUAL

COLORADO STATE UNIVERSITY
EXTENSION

Acknowledgements

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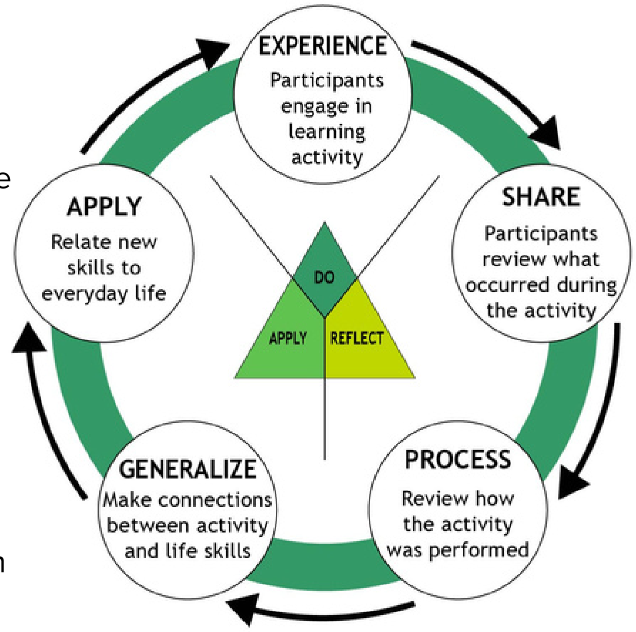
Experiential Learning Process



The 4-H program utilizes a process where adult leaders ask open-ended questions that challenge youth to think. Through this inquiry, youth can propose hypotheses and determine their own solutions. The Experiential Learning Model developed by Pfieffer and Jones (1985) and modified by 4-H includes five specific steps that can be summarized into three main processes: Do, Reflect, and Apply.

The Experiential Learning Model encourages discovery with minimal guidance from others. A situation, project or activity is undertaken for individual thought and problem solving. Minimum outside assistance is provided, but support is offered to the individual by questioning at each stage. The youth participating in an activity reflect on what they did and then assess how what they learned can be applied to a life situation. Below are questions that might help during each stage of learning.

1) Experience (Doing)
Questions: What sources of information are available? What is possible? What do you expect to see? How is it working? What else might you try?

2) Share (Reflecting on what occurred)
Questions: What was your goal for this project/activity when you began? What happened? What were the results? What was most difficult? How do you know? What did you learn? What surprised you? How did you share this project/activity with others?

3) Process (Reflecting on what's important)
Questions: What problems seemed to reoccur? How did you solve them? What similar experiences have you had? How was the experience like or unlike experiences others had? Would you do anything differently? What did you learn about making decisions? What suggestions would you have for someone else who wanted to do a similar project/activity? What life skills were you developing through your project? Why are life skills important? What new questions do you have about yourself, others, and future goals?

4) Generalize (So what?)
Questions: What did you learn about yourself or about the activity? What key points have you learned? How did you decide what to do? What else could you have done? How does this relate to something else in life? Where have you faced similar challenges in your life? Where might this situation occur in the future? Why is it important to have plenty of information before making decisions? What did you learn about your own skill in communicating with others?

5) Apply (Now what?)
Questions: How does this project/activity relate to your everyday life? Why is this project/activity important to you? Where else can this skill be used? How will you use this in the future? What will you do differently after this experience? How can I make an impact? What will I create next? In what ways do people help each other learn new things? What are qualities you think are important in a leader? If someone helped or mentored you in this project, what would you tell them you learned and what difference it has made in your life? How would you express your appreciation?

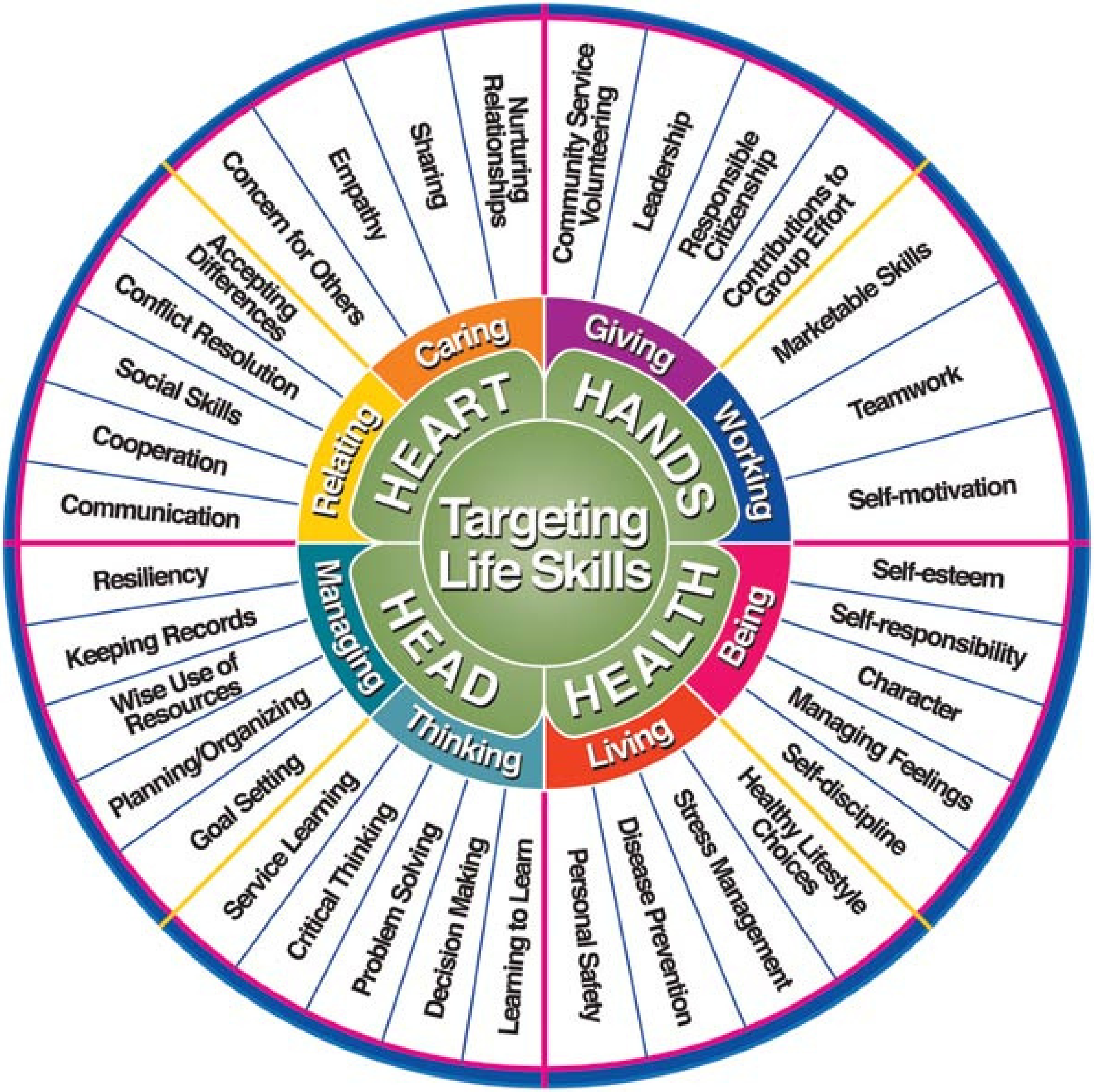


Image: Hendricks, P. (1998) “Developing Youth Curriculum Using the Targeting Life Skills Model” http://www.extension.iastate.edu/4H/skls.eval.htm

Targeting Life Skills

A skill is a learned ability. Life skills are those abilities that assist individuals to lead successful, productive, and satisfying lives. In 4-H, we use the Targeting Life Skills Model to help youth become competent and prepared for adulthood. The Targeting Life Skills Model categories are based on the four H’s from the 4-H clover (Head, Heart, Hands, and Health). Under each of these main categories, there are four categories and eight subcategories listing specific skills youth learn in 4-H. The main goal in 4-H positive youth development is to provide developmentally appropriate opportunities for youth to experience life skills and to be able to use them throughout a lifetime. By understanding the importance of the 4-H framework and its structure, 4-H members, parents, professionals, and leaders will know the expectations and will be able to effectively use 4-H delivery methods to help youth learn these life skills.

About the 4-H Thriving Model

The 4-H Program Leaders' Working Group developed the 4-H Thriving Model to advance and support the accomplishment of the 4-H Youth Development 2025 National Strategic Plan. They describe the 4-H Thriving Model as follows:

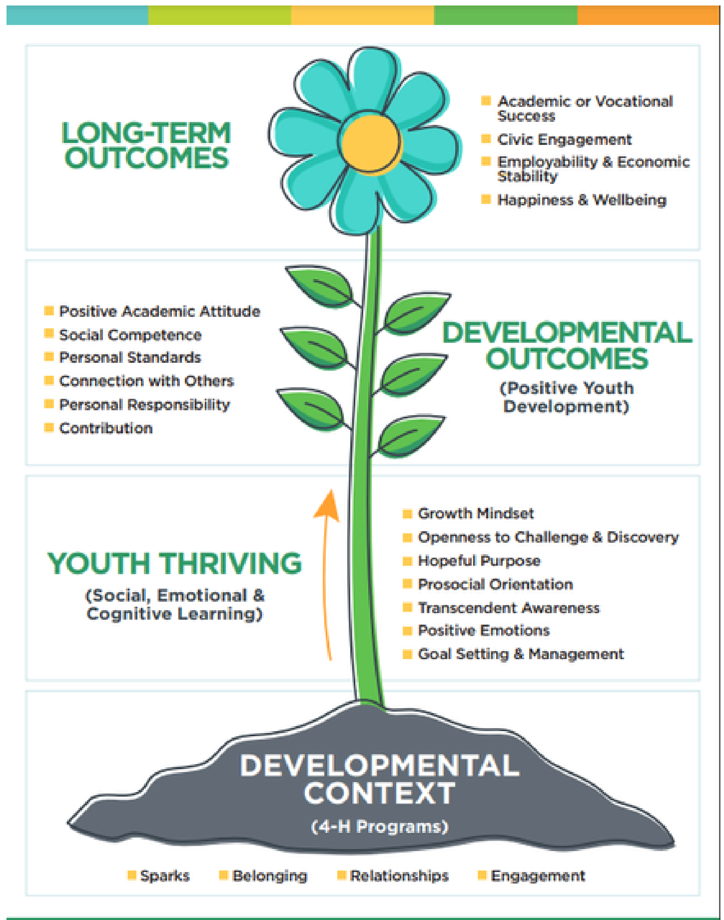
The 4-H Thriving Model illustrates the process of positive youth development in 4-H programs by connecting high quality program settings to the promotion of youth thriving.

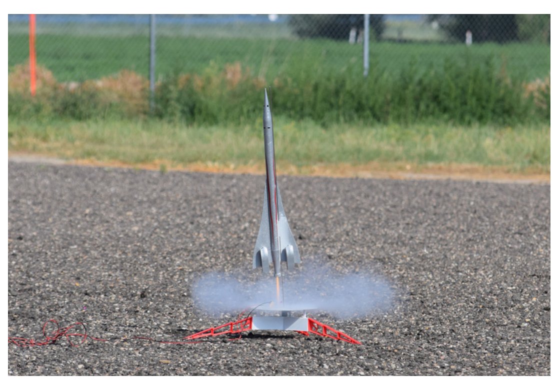
High quality 4-H program settings provide youth a place to belong, matter and explore their personal spark. High quality settings foster developmental relationships with youth, relationships that express care, challenge growth, and share power. These components help ensure that 4-H programs provide a nourishing developmental context – a place where youth can belong and grow.

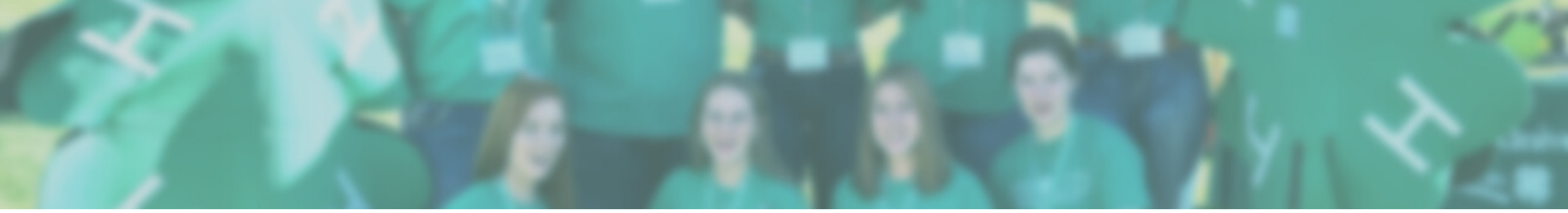
High quality 4-H programs contribute to Positive Youth Development (PYD) through the intentional promotion of social, emotional, cognitive, and behavioral habits of mind. In the 4-H Thriving Model this process of PYD is described by seven indicators of thriving: Openness to challenge and discover, growth mindset, hopeful purpose, pro-social orientation, transcendent awareness, positive emotionality and self-regulation through goal setting and management.

Youth who experience high quality developmental settings in 4-H with an emphasis on these key social-emotional skills achieve key positive youth development outcomes, including academic motivation and success, social competence, high personal standards, connection with others, personal responsibility, and contribution to others through leadership and civic engagement.

Youth who achieve positive developmental outcomes are more likely to also achieve long-term outcomes marked by vocational or academic success, civic engagement, employability and economic stability and happiness and well-being. (Learn more at https://helping-youth-thrive.extension.org/.)







Chapter 1: Introduction To Model Rocketry

Congratulations! By taking this project, you are on your way to becoming the next astronaut or scientist who will change space travel and exploration in the future. Opportunities for careers in aerospace have never been more abundant as we are exploring spaces near and far. As you go through this unit, be thinking about these opportunities that are interesting to you. Be sure to pay attention to the Safety Tips and Activity Guide highlights to support your learning.

Unit 1 Introduction to Model Rocketry 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 basics of rocketry, range safety, and launching aspects of model rocketry.

Model Rocketry has been a popular hobby, sport, and educational tool for over 60 years. Millions of people from all over the world have safely built and flown a wide variety of model rockets that have captured the imagination and inspired many.

SAFETY TIP: Be sure to check out the safety tips throughout this unit to make sure you have a safe and successful rocketry experience.

Built with inexpensive, lightweight materials and commercially available solid-propellant rocket engines, model rocketry is a safe activity that is fun and exciting. Model rockets can be flown over and over with new engines and repaired when damaged with a little patience and ingenuity.

The types of model rockets you can build are almost limitless. Options range from simple rockets that are just a nose cone and three fins to highly detailed and complex models from science fiction or accurate scale models of real world rockets used in space flight to oddities that appear unlike anything you've ever seen. In higher units, members can explore many of these different types of model rockets.

There are principally four categories of rocketry that are recognized nationally and internationally: Low Power Rocketry (LPR) commonly referred to as Model Rocketry, High Power Rocketry (HPR), Experimental Rocketry, and Professional Rocketry.

Model Rocketry or Low Power Rocketry (LPR)

Low Power Model Rockets are model rockets constructed of safe light-weight materials—e.g. cardboard, plastic, and wood. Low power rockets weigh less than 3.3 pounds and are fueled by black powder motors or single-use composite motors, which are commercially manufactured. Motors are also known as engines. These rockets typically contain a recovery system (example: parachute or streamer) that allows them to land gently for later re-flight. Low power rockets use motor sizes "A" through "G." These motors have less than 125 grams (4.4 ounces) of propellant and have less than 160 Newton Seconds of total impulse. (We will learn more about this in higher units.)

High Power Rocketry (HPR)

High Power Model Rockets are also constructed of safe, light-weight materials, and may also use stronger materials such as plywood for fins, fiberglass rubes, and epoxies. High Power Rockets can be any size rocket using commercially available Ammonium Perchlorate (APCP) or hybrid motors ranging from "H" to "O" power. These engines can have 160 all the way up to 40,960 Newton Seconds of total impulse.

To fly high power rockets, you must be a member of The National Association of Rocketry (NAR) or Tripoli Rocketry Association and have a High Power Rocketry certification. There are three Levels of HPR certification, Level 1 allows for “H” and “I” engines, Level 2 allows you to fly “J”, “K”, and “L” engines, and Level 3 is for “M” and higher engines. Buying high power engines requires the appropriate certification level and the buyer must be at least 18 years old. Youth ages 14-17 can obtain a Junior HPR Level One certification in order to launch “H” and “I” engines.

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).

Experimental Rocketry

Most experimental rocketry is done for research purposes and includes rocketeers designing and making their own propellant for custom engines. These rockets often use expensive and exotic materials that are engineered and designed for high performance. More advanced math and computer simulations are done to calculate the aerodynamic forces of their rockets. These rockets also launch expensive payloads and electronic devices to track their data and recover their rockets. This is done by some amateur rocketry enthusiasts and college teams that have advanced understanding in chemistry and engineering. This is not an option for children or adults without extensive training and experience in these fields.

Professional Rocketry

People who work in the field of rocketry come from all types of backgrounds such as engineers, scientists, mathematicians, chemists, technicians, and astronauts. Jobs stem from the private and commercial sectors, as well as the government. Until recently, the National Aeronautical and Space Administration, or NASA, was the only place in the United States that was really building and launching rockets into space professionally.

We are now entering a new golden age of rocketry with private businesses such as SpaceX, Blue Origin, Boeing, Sierra Nevada Corporation, Copenhagen Suborbitals, Virgin Galactic, United Launch Alliance, and many others developing new ways to travel through space. There are many opportunities for careers in the aerospace field, and many of the pilots, astronauts, engineers, and scientists today started with model rocketry as kids. Careers in the aerospace industry also go beyond science including finance, business, design, and marketing. Would you like to get paid to work with rockets?

ACTIVITY GUIDE: After you have read the manual and built and launched at least one model rocket, complete the Careers activity in the Activity Guide section of this manual.

Model Rocket Safety

> *SAFETY TIP: Be sure to review each of these regulations from the National Association of Rocketry and check off each box to show that everyone understands it.*

Model Rocketry is an incredibly safe activity, especially if you follow the National Association of Rocketry (NAR) Model Rocket Safety Code. Model Rocketry is legal in all 50 states and is regulated by the Federal Aviation Administration (FAA) and the National Fire Protection Association (NFPA) Code 1122 "Code for Model Rocketry." Following the Model Rocket Safety Code along with the instructions included with your model rocket kits makes this hobby very safe.

The National Association of Rocketry 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. When conducting a simultaneous launch of more than ten rockets, I will observe a safe distance of 1.5 times the maximum expected altitude of any launched rocket.

☐ 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.

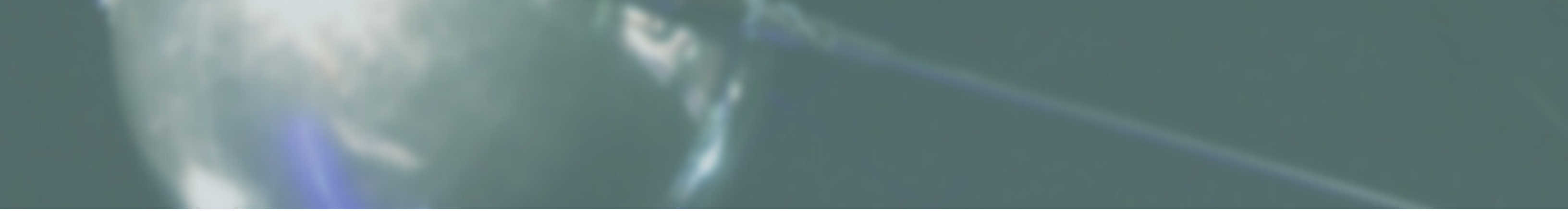
☐ 7. Size. My model rocket will not weigh more than 1,500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320 N-sec (71.9 pound-seconds) of total impulse.

☐ 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.

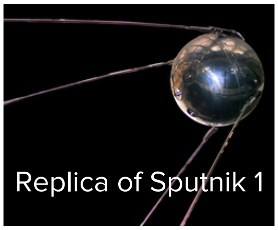


History of Rocketry

Since the beginning of time humans have looked up to the night sky in wonder. Cultures from all over the world have stories of how the moon and stars came to be. Observations of the night sky became Astronomy, one of the oldest natural sciences. Ancient people of Mesopotamia, India, Greece, China, Egypt, Mesoamerica, and others developed mathematics, calendars, charts, and the basis of science by observing the movement of the stars in the sky.

Black powder was invented in China sometime in the 9th Century. Nobody knows when the first rocket was invented, but it did not take long for the people of ancient China to discover that they could put their newly discovered gunpowder into bamboo tubes and tie them to arrows to make what they called "divine engine arrows" or “Fire Arrows,” which became the first rockets.

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 engine. 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.


Replica of Sputnik 1

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 engines—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 engines 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 engines 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.

It soon became clear that Model Missiles was falling behind in the production of the now popular and safe black powder motors. With the help of Mr. Vern Estes and his invention, known as "Mabel", model rocket engines were mass-produced safely and reliably. More information regarding the Estes family and "Mabel" may be found on page 15 under Black Powder Motors. 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.

Since 1958, millions of children and adults have successfully built and flown their own model rockets. What had been science fiction became the space age, and model rocketry continues to influence young people, teaching the principles of science, and leading the way for the future of space flight and exploration.

Getting Started with Model Rocketry

Getting started in model rocketry is as simple as purchasing a model rocket kit. Local craft and hobby stores as well as online companies will stock a variety of model rocket kits that start at $10 to $20. To fly the model you built you will need an appropriate sized engine (which traditionally comes with igniters, also known as starters or initiators, and engine/motor plugs), an electronic launch controller, and a launch pad. You can find these accessories at the same craft and hobby stores, and they often come in complete packages with one or two model rocket kits included for around $50.

Launch pads and controllers can be used over and over again for years and are a one time cost. Your local 4-H club or project leader may have their own launch system. Check with your county 4-H agent or specialist. Another option would be to go to NAR.org and click on 'Local Clubs' for rocketry. NAR chartered Sections are locally-organized rocket clubs, which include three Section types: Public Sections (open to anyone); Organizational Sections, e.g., the American Rocketry Challenge (ARC), school, scouts, even 4-H (which limits participants to their specific organization's membership); and Private Sections (families, friends, etc.). All Sections require at least one NAR senior member and qualifies for Landowner Site Insurance. Never launch a model rocket without a launch pad or an electric controller, because it is unsafe. However, many people choose to build their own launch pads and controllers, which will be discussed in a later unit.

SAFETY TIP: A commercially-made or NAR club built launch system is the safest option for those new to model rocketry.

Chapter 2: Elements and Flight Principles of Model Rocketry

Anatomy of a Model Rocket

In order to build and launch model rockets, it is important to learn the names and functions of the parts.

Model Rocket Parts

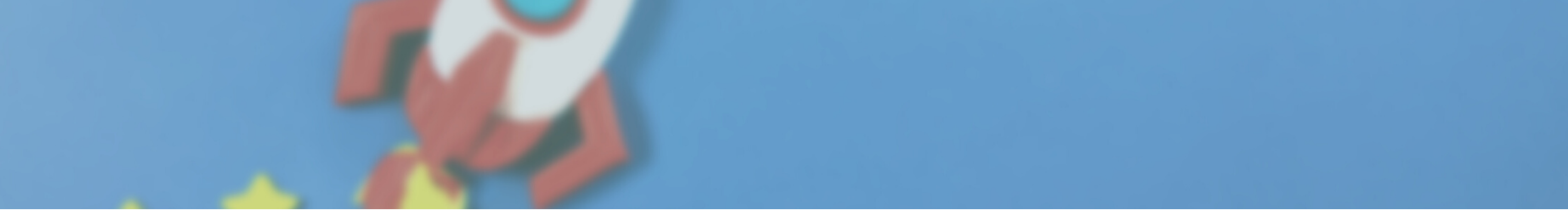
Basic model rockets are made up of a nose cone, body tube, and fins. A rocket requires a guidance system called a launch lug to keep it standing upright on the launch pad and stable until the rocket reaches full power. There is also a recovery system that will include a shock cord that attaches the nose cone to the body tube and the recovery system. Model rockets require a power mechanism (a motor, also called an engine) and a way to hold that mechanism in. One method is called friction fit, where tape is placed around the motor to create a tight fit directly in the rocket's body tube. The other method is called an engine mount system, which is made up of several parts, described later in this manual.

External Parts of a Model Rocket

NOSE CONE:
The nose cone (sometimes referred to as the 'nose' of a rocket) sits at the top of the airframe (body tube). The nose cone has distinguishing parts: the ‘tip’ of the nose cone which is the very top of the rocket, and the ‘shoulder’ which fits into the body tube. Above the shoulder is an ‘edge’ which is wider than the shoulder. This is referred to as the ‘lip’ of the nose cone and keeps the nose cone in place during the rocket flight. One more part which relates only to plastic nose cones is called the ‘seam’ edge, which is caused by the molding process. This edge can easily be sanded down to create a more aerodynamic nose cone. Nose cones may come with a small screw-in eye bolt or have a fabricated “eyelet” built in during the molding process. (Refer to page 11, Eyelet or Screw Eye.) Nose cones come in many shapes and sizes and are usually made from plastic or balsa wood. Nose cones are not always cone shaped, but are commonly made of the following shapes: ogive, parabola, hemisphere, cone, or a combination of those shapes. The shape of the nose cone is an important factor as to how fast and how high the rocket will travel. It is important when building a model rocket for the nose cone to fit in the body tube correctly - too tight and the recovery system may not deploy and too loose and the recovery system may deploy too soon.

BODY TUBE (AKA AIRFRAME OR FUSELAGE):
A long round tube made of spiral cardboard or paper. The body tube holds the rocket's exterior rocket parts (fins, nose cone, and launch lug) and interior parts (motor mount assembly and motor, and the recovery system including protective wadding).

FINS:
Model rockets can have three or more fins placed along the body tube and fins can vary greatly in size and shape. Many model rocketeers will experiment with the size, shape, and placement of fins in order to test which ones will fly higher and faster. The primary function of fins is to stabilize the rocket during flight, keeping the rocket flying straight. For any particular rocket, fins are generally uniform in size and shape. How well the fins are finished (sealed, sanded and painted) will also determine how well the rocket will perform. Fins generally have three to four edges. The part of the fin that attaches to the body tube is called the 'root edge,' and the opposite side is called the 'tip' or the 'outboard/outward edge.'

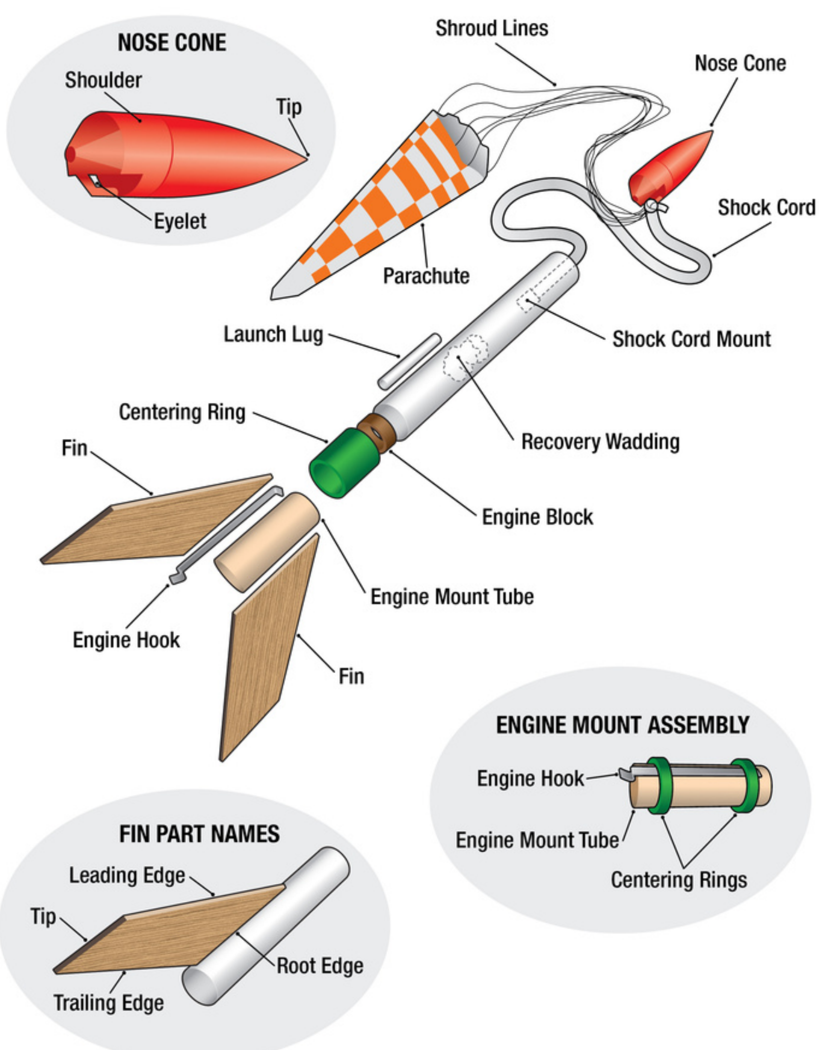


The top of the fin is the 'leading edge,' and the bottom is called the 'trailing edge.' The 'grain lines' of wood fins should always be parallel to the leading edge of the fin. Small fins near the nose cone are called 'canards.' Most canard fins in the beginner levels (Skill Levels -1, -2) are just for show; but for larger, more complicated rockets canard fins can and will affect the stability of a rocket.

It is important to attach fins to the body tube so they are evenly spaced around and also straight (perpendicular to or near the bottom of the body tube). The cross-section of the fins can be
square but also rounded or curved, also known as airfoiling. Airfoiling fins will streamline the leading and trailing edges and greatly improve the performance of the rocket. Balsa wood fins can be sanded so the leading and trailing edges are rounded, wedged shape, or combination of the leading edge round and the trailing edge wedged.

LAUNCH LUG:
Launch lugs provide the initial guidance for the rocket as it comes off the launch pad. Model rockets have launch lugs glued to the side of the body tube. It is important to make sure that your launch lug is properly aligned when building your rocket and is wide enough to fit onto your launch rod.

This diagram shows the basic components found in most model rockets.



Engine Mount Assembly Parts

Rocket engines (also known as rocket motors) can be held directly in the body tube, known as a 'friction fit,' or placed in a 'motor mount.' The motor mount assembly is a unit which holds the rocket motor in place within the end of the rocket's body tube. The motor mount assembly consists of:

MOTOR MOUNT TUBE:
The motor mount tube is where the motor fits into.

CENTERING RING(S):
Centering rings center the motor mount assembly in the body tube.

MOTOR HOOK OR MOTOR RETAINER CLIP:
These secure the motor in the motor tube and prevents it from falling out.

THRUST RING OR ENGINE BLOCK:
These prevent the motor from being forced into the upper body tube. Not all models contain a thrust ring.

Internal Recovery Parts of a Model Rocket

PARACHUTE:
A parachute isn't just a parachute, but a system of parts that are used to return the rocket safely to earth after its flight. Parachutes systems consist of: a circular piece of material called a 'shroud' or 'canopy,' shroud lines, and adhesive dots or tabs. Parachutes vary according to the size of the model rocket, six inches to 35 inches or larger in diameter. Parachute shroud lines are a series of thin strings attached to the parachute enabling the parachute to billow out, catching the air to slow the flight descent. (There are other forms of recovery systems outlined later in this unit.)

EYELET OR SCREW EYE:
These are mechanisms that serve as a connection point on a nose cone where the top of the shock cord and the recovery system attaches, ensuring the nose cone and recovery system stay attached to the rocket's body tube after deployment of the recovery system.
Eyelet: a molded part on a plastic nose cone
Screw Eye: primarily used on balsa nose cones, which is screwed in and glued into the balsa

ACTIVITY GUIDE: Now that you have learned about the anatomy of a model rocket, test your knowledge by labeling the diagram in the Name the Parts of a Model Rocket activity in the Activity Guide section of this manual.

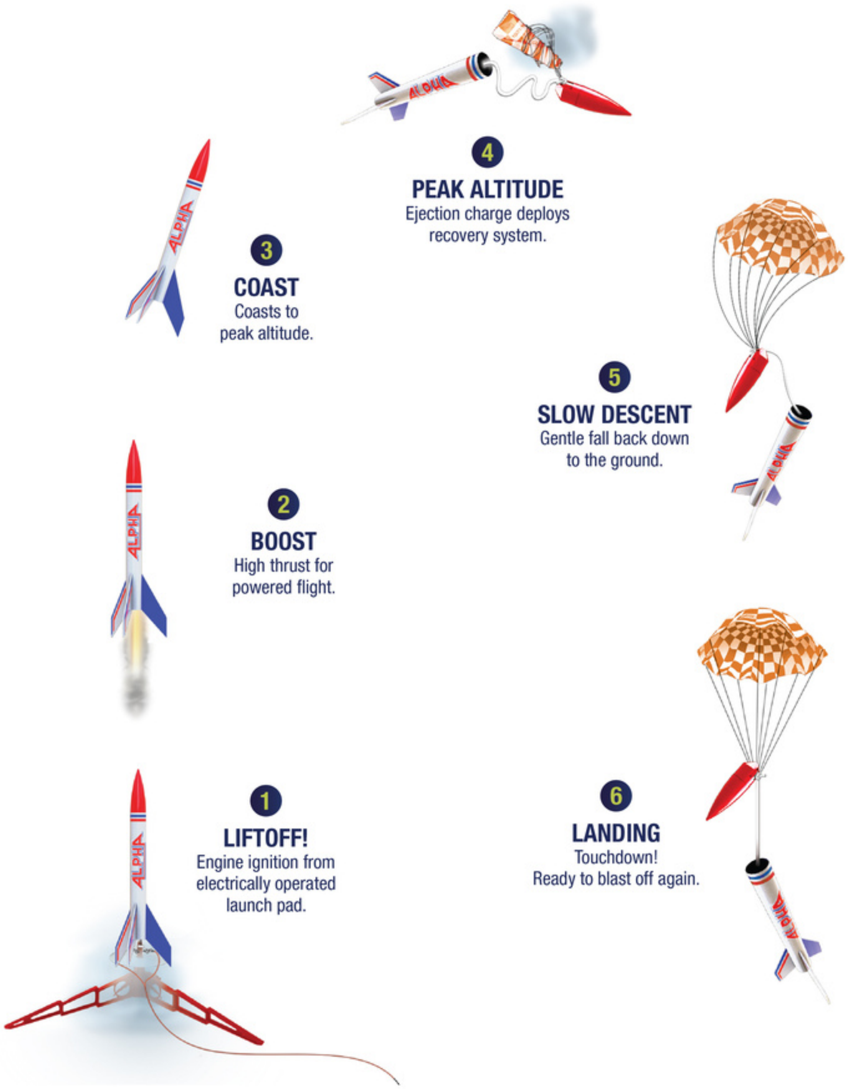
SHOCK CORD MOUNT:
This is a method of attaching the shock cord to the rocket's airframe. There are three methods commonly used: 1) a paper mounting method, 2) a motor mount attachment method, and 3) a through-the-wall method.

SHOCK CORD:
The shock cord connects the body tube to the nose cone 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 nose cone. This lessens the chance of any damage done to the rocket.

RECOVERY WADDING:
Recovery wadding is a flame resistant material (traditionally paper) used to protect the internal parts of the rocket from the ejection charge. However, if packed too tightly the gasses and flames could cause damage to the rocket.

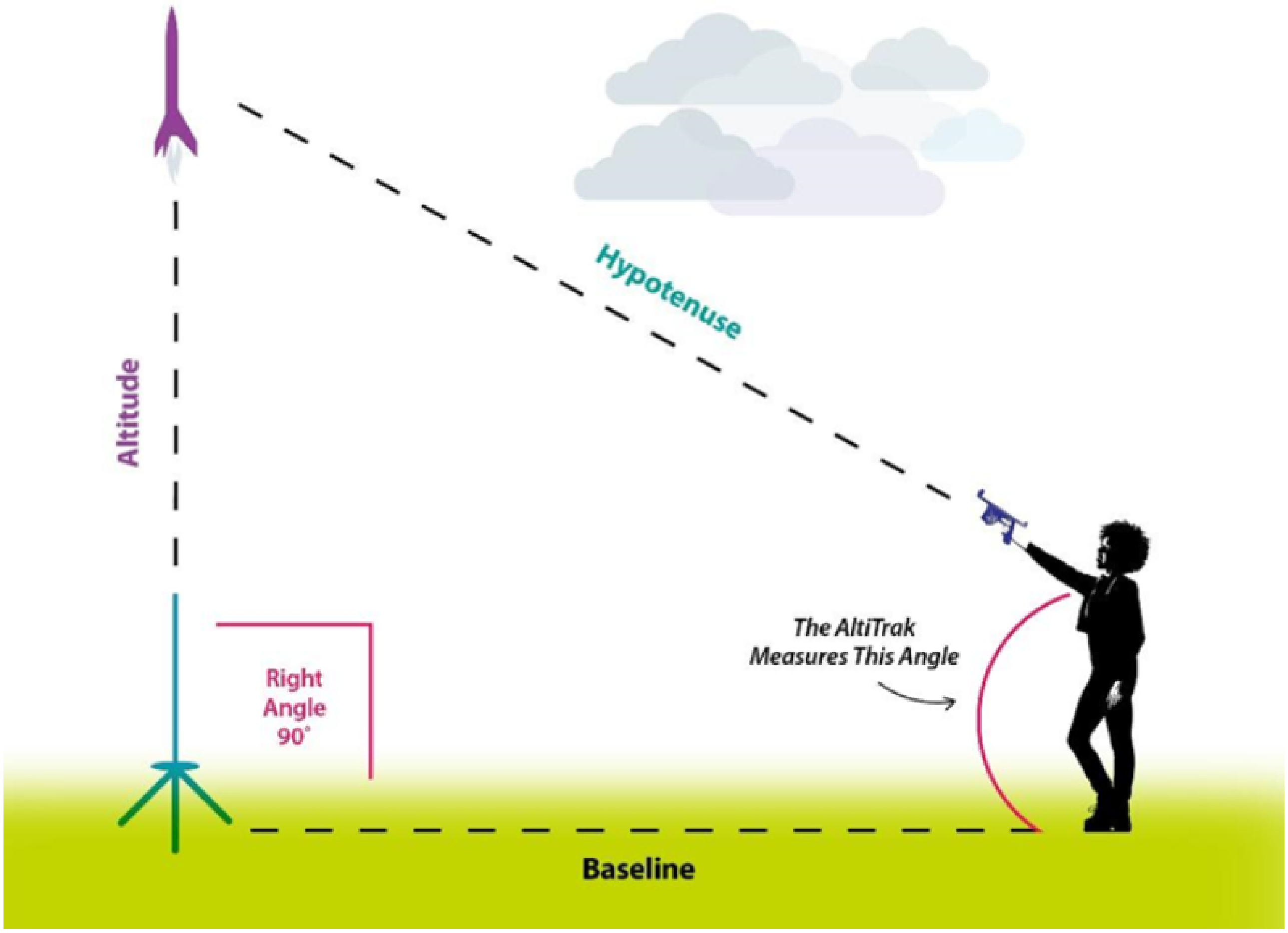
Model Rocket Flight

Model Rocket Flight profiles are used to predict the actual characteristics of a real rocket launch. After the rocket is properly built and prepared for launch, it will be placed on the launch pad for flight. The rocket engine is started by using an electric controller which heats up an 'igniter' or 'starter' that has been inserted into the nozzle of the rocket engine. The rocket engine is ignited with an electric controller. The rocket engine builds pressure very quickly as the propellant burns and gasses coming out of the engine nozzle propel the rocket into the sky in what is called the boost phase. When the propellant in the engine burns out, the rocket continues to climb higher in the coast phase. As the model rocket reaches the peak altitude, called apogee, a delayed ejection charge at the top of the engine pushes the nose cone out of the body tube deploying the recovery system. The parachute that is attached to the recovery system unfurls and the model rocket safely returns back to earth.



Altitude Tracking Methods

How high did your rocket fly? There are few simple ways to determine the altitude of your rocket at apogee, or peak altitude. The first approach uses a protractor-like device and basic geometry to give a fairly accurate measurement. This tool can be created (instructions can be found online to build with a washer, string, and paper) or purchased (Estes AltiTrak™ or MiniAltiTrak™). These devices provide the angle between the baseline and the triangle's hypotenuse (or distance from the observer and the rocket). Using the baseline measurement and tangent of the determined angle, the height the rocket traveled can be calculated. A more accurate approach to tracking rocket height is using an electronic altimeter. Altimeters measure the rocket's altitude along with additional variables such as flight time, speed, and acceleration. These electronic devices can vary in price and capability. If purchasing an altimeter, make sure it fits in your rocket's body. Altitude tracking will be covered in more detail in future units.



ACTIVITY GUIDE: Now that you know about altitude, learn how to determine your rocket's altitude by completing the How High Did Your Rocket Go? activity in the Activity Guide section.

Types of Model Rockets

There are many types of model rockets that are classified by style, engine size, engine types, and recovery system. Rocket kits can then be further classified into skill level based on how simple, complex, or difficult the kit is to assemble.

Skill Levels

Model rockets are generally placed into six levels of skills, ranging from Skill Level 0 ready-to-fly models that come already assembled to Skill Level 5 that are extremely challenging rockets to build. Newer model kits have simplified the skill levels to Beginner, Intermediate, Advanced, Expert, and Master. The skill level on a kit is subjective and can vary depending on the manufacturer.

Rocket Engine Configuration Types

Single engine rockets are rockets which contain only one engine and are the most common and easiest to build and fly.

Cluster engine rockets are rockets having two or more engines in a single body tube. All engines are ignited at the same time.

Multistage rockets are rockets having two or more body tubes stacked end on end with an engine in each section. The tubes' engines 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 the intermediate stage (if any) ignites, and finally the sustainer (or upper stage) ignites. Each lower stage upon burnout tumbles to the ground. No more than three stages are considered stable for model rockets.

Rocket Styles

Payload rockets are 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 any living thing (animals, insects) in a payload. Use only inanimate objects as payloads, such as M&M's or Skittles or two colors of chalk or sand to see what might happen. Will it mix up or stay the same? Finally, never put anything that is destructive, flammable, explosive or otherwise harmful in a model rocket.

Scale rockets (includes scale-like and semi-scale) are model rockets which are modeled after a professional rocket. Scale model rockets should always be painted and decaled according to their actual counterpart rocket.

Novelty rockets ("oddrocs") are unusual shaped rockets, 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.

Recovery Systems

There are numerous types of recovery systems and recovery methods for model rockets. On some types of rockets that are light-weight and small, the rocket design serves as its own recovery method. The two primary types of recovery systems are the parachute and streamer systems. A nose-blow recovery system has exactly two parts, the nose cone and a shock cord. This type of a safe recovery is less common. The rocket's nose cone and airframe have to be very light, the rocket will probably eject its spent motor casing, which will allow it to flutter down safely. Missing any one part of a recovery system could be disastrous to your rocket. Below are examples of recovery methods and recovery systems that are usually found in LPR rocketry.

FEATHERWEIGHT RECOVERY METHOD
This is a type of low-mass rocket that is its own recovery system. These rockets are made of lightweight paper, cardstock or Styrofoam and are usually very small. The rocket will eject its spent motor casing prior to apogee, complete its coasting stage, and then simply float or flutter down similar to a feather. Examples: Styrofoam cup rockets, paper geometric-shaped rockets, etc.

TUMBLE RECOVERY METHOD
This is a type of loss-mass rocket that can generally hold-up to a hard landing. The rockets will eject the spent motor casing and then use the method of turning end-over-end (tumbling to the ground). Examples: Small lightweight spool rockets or multi-stage rockets (the 1st and 2nd stages), etc.

DRAG RECOVERY METHOD
Once again, this type of rocket is generally low mass but has a large frontal area, meaning a very wide surface area. This surface area increases the air resistance when it descends (comes down) through the sky. The rockets are generally made of lightweight materials such as paper, cardboard, Styrofoam, plastic, and balsa or basswood materials. Most of these rockets tend to have a larger bottom end like, pyramids, cones, saucers, or umbrella shaped rockets. The rocket flips over at apogee and drags through the air down to the ground.

STREAMERS
For small, light model rockets streamers are a length of ribbon attached to a shock cord to create air resistance and slow the rocket down.

PARACHUTE
A common recovery system for model rockets is a circular piece of cloth or plastic attached to the shock chord with shroud lines that creates a canopy that fills with air to allow the model rocket to float gently back to earth.

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
Gliders are a recovery system consisting of wide wings 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.

There are many other less common types of recovery systems including: Parawing Recovery, Horizontal-Spin Recovery, and Aerobrake Recovery, just to name a few.

ACTIVITY GUIDE: Now that you know about recovery systems, complete the Testing Recovery Systems activity in the Activity Guide section.

Model Rocket Motors

Is it a rocket engine or a rocket motor? Strictly speaking an engine is a type of motor. NASA calls solid-fuel rockets, like the boosters alongside of the space shuttle, motors while liquid-fuel rockets with moving parts, like a turbo-pump, an engine. When model rocketry took roots in 1959 G. Harry Stine decided to call them motors when he started his business, but later Vern Estes called them engines when he started making them for Harry. Wernher Von Braun, a famous aerospace engineer responsible for the Saturn V rocket that took men to the moon, would call them both motors and engines. These terms are used interchangeably within model rocketry.

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 and a machine, which he named "Mabel," that 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 where it is still located today. Estes Industries is currently the only manufacturer of NAR certified black powder rocket engines.

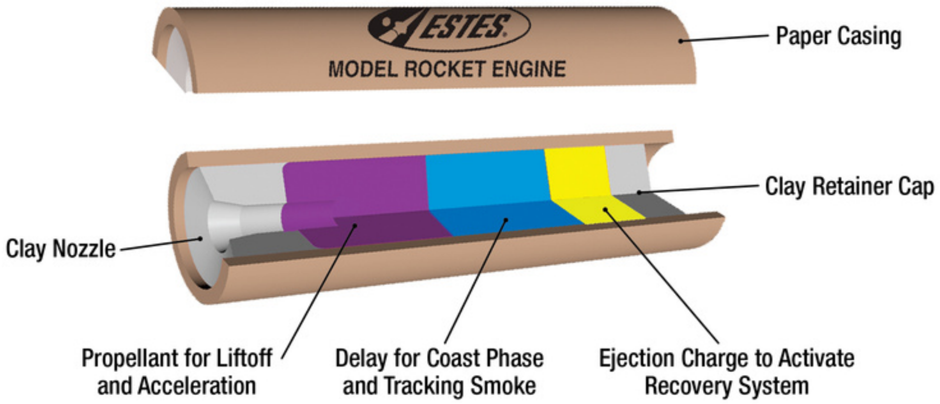
Parts of a black powder (solid fuel) rocket motor:

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

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. Quest, Aerotech, and Cesaroni are current manufacturers of single use and reloadable composite model rocket motors.

SAFETY TIP: Reloadable motors are not meant to be used by younger members.



B

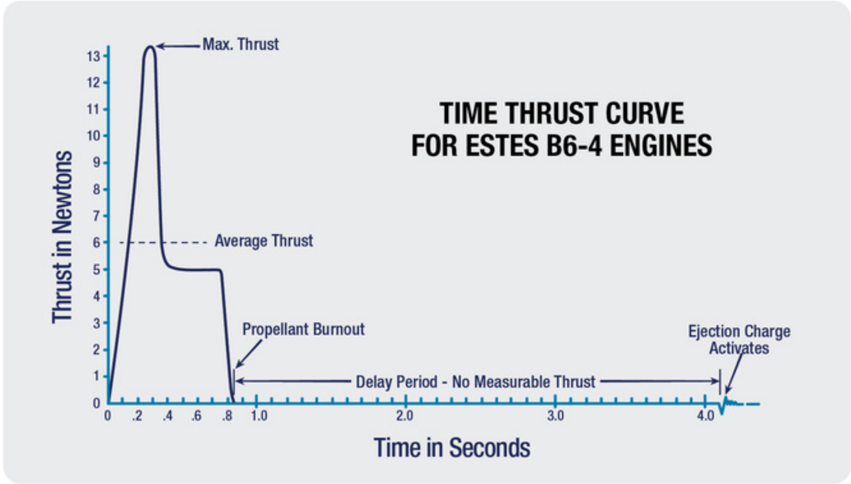
Letter indicates total impulse or total power produced by the engine. Each succeeding "letter" has twice the power of the previous letter.

6

Number shows the engine's average thrust in Newtons or the average push exerted by the engine. (4.45 Newtons = 1 lb.)

4

Number of seconds between the end of thrusting and the ejection charge.

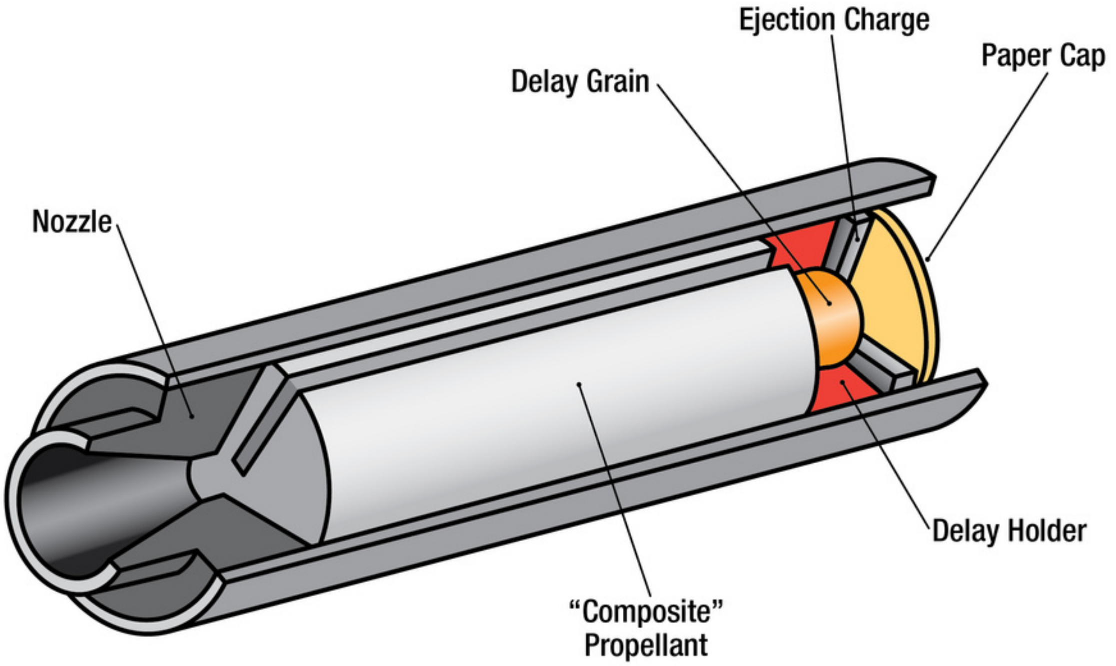


Estes model rocket engines have been proven consistent and reliable in more than 300 million launches.

ESTES education

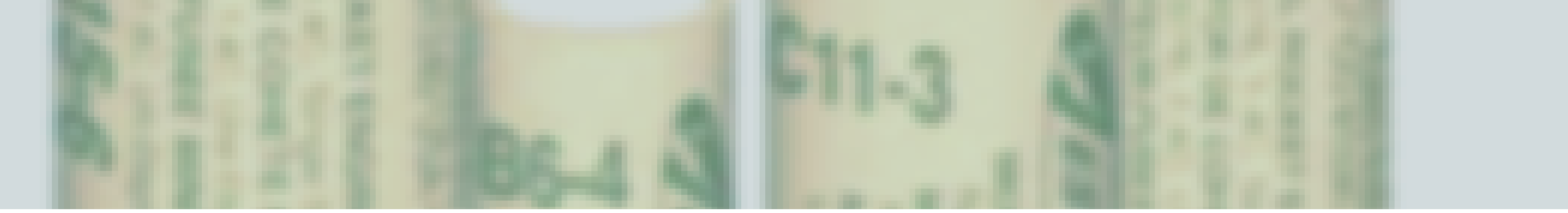
Parts of a composite motor:

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



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. Force is measured in Newtons and time in seconds. You will see the total impulse listed in Newton-seconds (N-sec) which is how much power a motor has. 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. See the diagram on the Time Thrust Curve on the previous page for an example of total impulse.



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 multistaged 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 motor's 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		
Motor Type	**Total Impulse**	**Category**
⅛A	0.3125	Micro
¼ A	0.625	Low Power
½ 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

SAFETY TIP: Be sure to follow proper care of motors to keep your rocket from blowing up due to a damaged motor!

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 potentially cause 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 and 'nozzle' end prior to use and do not use motors that appear damaged. You can dispose of black powder motors by soaking them in a bucket of water until cardboard dissolves rendering the motors safe to dispose of in your regular household trash.

Chapter 3: Building Model Rockets

Selecting a Rocket Kit

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. You can request catalogs from many manufacturers by calling or visiting their website to see all the options and order directly. You can source model rocket kits online. There are many companies and distributors that sell brand name rocket kits, which can be a good resource if you are looking for a particular kit. You could potentially also find out-of-production or vintage rocket kits on auction sites.

Unit 1 members are required to build a simple three to four finned Skill Level 1 rocket. Unit 1 kits built for either a judging event or a Fly Day Contest, must have balsa or basswood fins and fly on a single-stage motor. Fly Day rockets are also required to have a parachute recovery system. Be sure the rocket kit you choose meets the requirements as stated in your exhibit requirements. (The Colorado State Fair Exhibit Requirements are located at the 4-H website: www.colorado4h.org.) Remember, members are not judged on the size of the rocket, but rather on the skill and knowledge learned and demonstrated in the quality of the construction, finishing, and flight of the rocket. Bigger is not always better and smaller is not always easier. Try to find a kit that inspires you and is appropriate for the unit you are in.

Building a Rocket Kit

While launching a rocket is a lot of fun, building your model rocket should also be an enjoyable experience. Making the build process fun and having a successful flight both rely on patience, preparation, and following instructions. Manufacturers of model rocket kits spend a lot of time and effort creating instructions that are as detailed and easy to understand as possible. Everything you need to know to successfully build and launch your rocket will be in the included instructions. Every kit has different build techniques, so it is important to always follow the instructions for your kit.

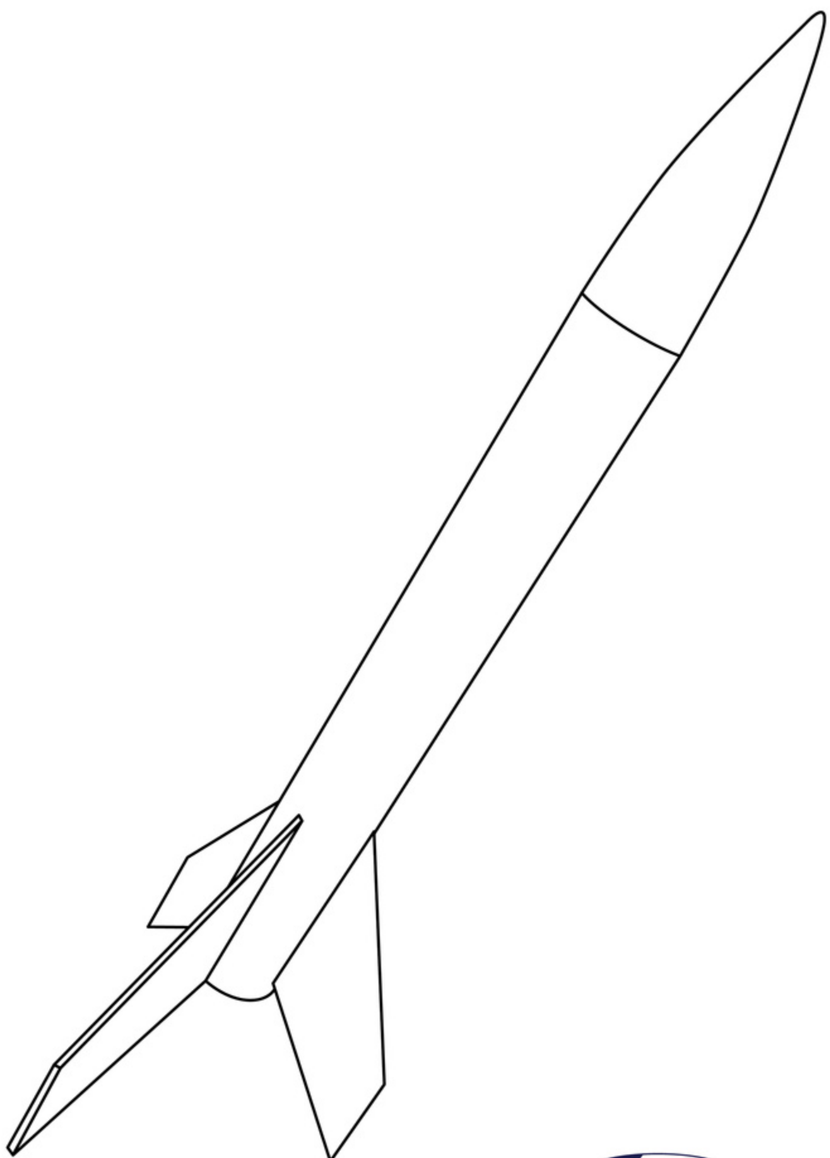
The first step of building should be to check the condition of your kit. When purchasing your rocket kit, verify that the body tube(s), nose cone, and fins are in good condition. Body tubes are easily crushed or crinkled before the package is opened and balsa wood fins can be broken. Sometimes these things can be fixed by experienced builders, but it may be better to return or choose a different kit if it is damaged. Next, carefully open the kit package, most kits contain one or two very small parts, so be careful when opening your kit package. Locate the instructions. There will be a list of items and parts included in the kit. Check for missing or badly damaged parts. The instructions will also tell you what supplies are needed. The most common supplies are wood glue, tape, sand paper, pencil, and a cutting tool.

Read all of the instructions before you start building. A good way to avoid mistakes is to read the instructions prior to starting any construction on your rocket kit. You can often test fit, sometimes called dry-fitting, parts without glue to see how they are assembled and fit together.

To construct model rockets, you will need plenty of space, good lighting, and proper ventilation for working with glue and paint. You can safely perform the work inside the house or a garage as long as there is good ventilation. If any painting is necessary or desired, be sure to set up a protected area in a well ventilated garage or an area outdoors, blocked from the wind. Safety first! You will want to consider covering your work area with a protective plastic sheet, white or brown paper, such as butcher paper, or flattened paper bags.

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.

ACTIVITY GUIDE: Once you have built your rocket, complete the Design Your Rocket Finish activity in the Activity Guide section.



Chapter 4: Launch Systems and Field Operations

Selection and Preparation of a Launch Field

You have your rocket built. You have your launch system ready. Now, where do you launch and what do you need to know ahead of a launch?

Things to consider when deciding if the day is good for a launch:

- Skies need to be clear or partly cloudy with no 'low ceiling' clouds as your rocket should never 'disappear' into the clouds.
- You cannot launch with wind speeds greater than 20 miles per hour (mph). Be prepared for wind gusts and take extra care when launching in wind speeds greater than 10-12 mph, rockets can drift quite far.
- Consider using a streamer instead of a parachute.

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.

The NFPA (National Fire Protection Association), state, county and municipal entities (cities and towns) all have a say in what restrictions go into your local Fire Ban Stages. Always check with your state, county and city or town to know what stage model rockets fall under. Most states put rockets with fireworks, which usually falls under Stage 1. If you have an important launch event coming up, contact your local Fire Marshall to see if the Marshall will approve your launch site, safety equipment, and adult support for a no-cost permit. The Fire Marshall may grant the permit, but may place additional time restraints or equipment improvement, etc., on it. In some cases, local Fire Departments may send a brush truck out to the launch site, just to be prepared.

NO FIREWORKS MEANS NO MODEL ROCKETS!
If a fire ban is announced in your area (no matter what level it is), build rockets, don't launch!

The launch field should be devoid of power lines, trees, buildings, and other obstructions. Select a launch site that does not present the risk of a grass fire. Prevent rockets from flying over spectators' heads, including yours, by placing the launch pad at an angle of 90° in relation to the wind. You can tilt the launch rod into the wind (no more than 30° degrees from vertical). 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. It is helpful to have a flag posted near the launch site to track the wind direction.

SAFETY TIPS: An air-pressurized water (APW) fire extinguisher and First Aid Kit should be available when launching your rocket.

Never run to retrieve your rocket. Tripping onto or running over your rocket could damage your rocket beyond repair.

Spectators should be at least five feet behind the person conducting the launch to avoid accidental bumps.

Launch Site Dimensions

The launch space required for a rocket launch is dependent on the engine in use. View the table below to see how much space is needed for your rocket launch. As a reference, if you are launching a “C” engine or smaller, a football or soccer field has plenty of space.

Engine Type	Installed Total Impulse (N-sec)	Minimum Distance to the Closest Obstacle(ft.)
1/2A	0.00 - 1.25	50
A	1.26 - 2.50	100
B	2.51 - 5.00	200
C	5.01 -10.00	400
D	10.01 - 20.00	500
E	20.01 - 40.00	1,000
F`	40.01 - 80.00	1,000
G	80.01 - 160.00	1,000
2 Gs	160.01 - 320.00	1,500

Keep all spectators away from the LCO officer (or person launching the rocket) a minimum of five feet to avoid launch accidents.

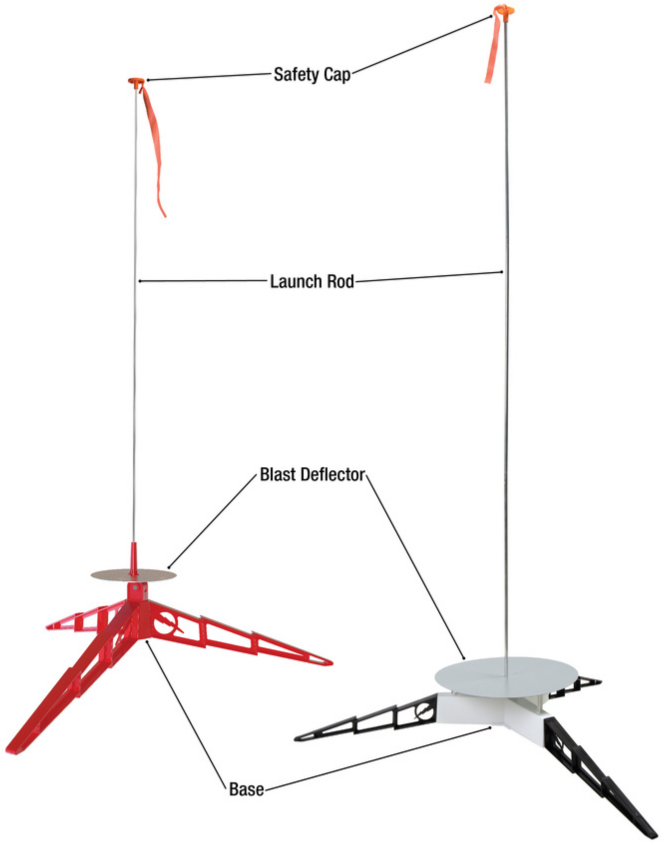
Launch site for professional rockets.

Parts of a Model Rocket Launch System

Model rocket launch systems are made up of three main components: a launch pad, launch controller, and batteries. There are several launch systems you can purchase commercially and plans are available online for building your own with the help of a parent or leader. The launch pad holds the rocket in place during the launch for safety reasons. The launch pad includes a safety cap, launch rod, blast deflector plate and launch base. Having a stable launch pad and straight launch rod is crucial for a stable and safe flight. A launch controller allows control over the launch for safety reasons, ensuring a safe flight. It comes with a safety interlock key, arming lamp, ignition button, micro-clips, and 15 feet of launch cable (15 feet is the minimum required by the NAR Model Rocket Safety Code). The launch controller will need battery power to ignite the starter (igniter) for the motor. Batteries provide electricity to create the heat source to ignite the starter. Use the size and number of batteries recommended by the manufacturer of the launch controller.

Setting up the Launch Pad System

If you are using a single portable launch system (e.g., the 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 A-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 types of injuries.



Wrap or tie the power cord (microclip 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 string attached to the safety cap or, alternatively, the key can also be placed on a lanyard. 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 the launch system and rocket can tip the launch pad over. Either stake the legs down or strengthen it with some large rocks.

Tip #3: Microclips should be kept clean. If you notice discoloration, use an emery board to clean the clip. Keep in your range box.

SAFETY TIPS: The safety cap should be on the launch rod when not in use.

The safety key should be removed from the control box after every launch, especially when approaching the launch pad.

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, shovels, jugs of water, and a pressurized water fire extinguisher. In addition, always have a fully charged cell phone on you for calling 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 you are responsible for alerting any spectators who may be present.

SAFETY TIP: If you are launching in a new location, make sure to familiarize yourself with the safety precautions before setting up for launch.

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.

ACTIVITY GUIDE: To better prepare yourself and others, complete the Create A Safety Brochure activity in the Activity Guide.

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 is preparing 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 is "CATO" is nearly impossible to do.

COMING IN 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 FAILURE: means an event either failed or didn't perform as expected to the rocket in flight, i.e., first stage has deployed or the main parachute has deployed.

Chapter 5: 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 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 sulfate. 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 bale, 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 gases from the ejection charge reaching the recovery system. If the hot gases were able to reach the recovery system, the gases would melt the recovery system and burn through the shock cord.

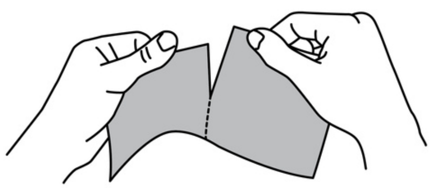
When using tissue wadding, the number of sheets to use depends on the size of the rocket's body tube. Your kit instructions will usually tell you how many sheets to use. Generally, you will use from three to six sheets per rocket flight.

Steps to Follow When Using Tissue Wadding

- Tear the recovery wadding off into individual squares. (See diagram on right.)
- Crumple up recovery wadding into a loose ball.
- Loosely pack recovery wadding into body tube pushing it down to make room for the recovery system. Do not pack too tightly.

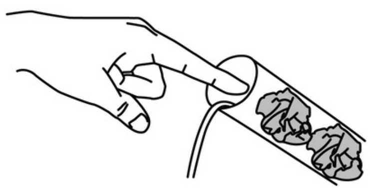
Steps To Follow When Using Dog Barf Wadding

- 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.

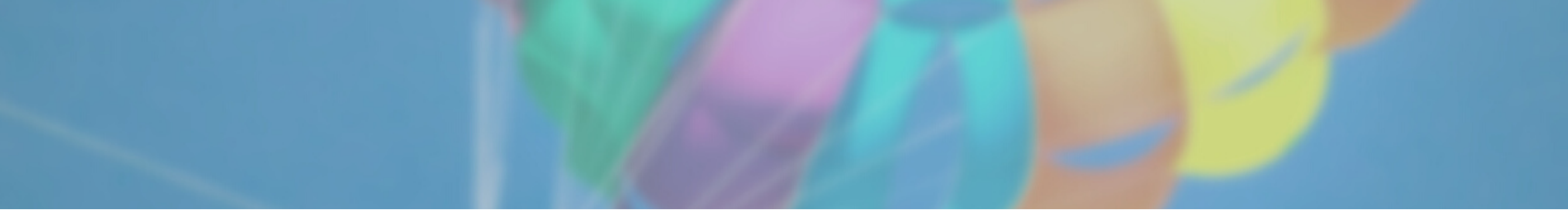


1 Tear the recovery wadding off into individual squares.

2 Crumple up recovery wadding into a loose ball.



3 Loosely pack recovery wadding into body tube pushing it down to make room for the recovery system. Do not pack too tightly.

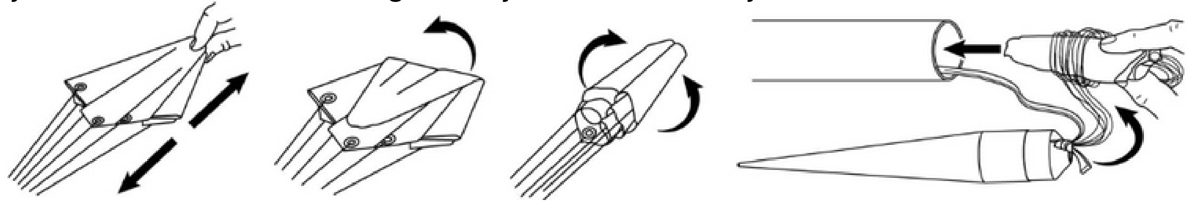


Preparation of a Parachute Recovery System

Spread the parachute flat and rub talcum powder onto both sides of the parachute. Be sure to cover each side thoroughly from edge to edge. Be careful not to inhale the talcum powder.

Never wad, stuff or use a probe (stick, screwdriver, etc.) to push your parachute or streamer below the nose cone shoulder area as this may cause them to jam and not deploy properly from the rocket. The recovery system should slide easily into the body tube. You may follow your kit instructions on how to fold your parachute or streamer or follow the steps below.

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 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.

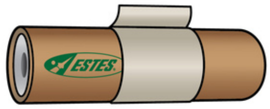
First, insert as much of the shock cord into the rocket as possible, followed by the streamer or parachute and the rest of the shock cord. Do not stuff the recovery system too tightly into the rocket. The parachute or streamer should easily slide in and out of the body tube. Make sure the recovery system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

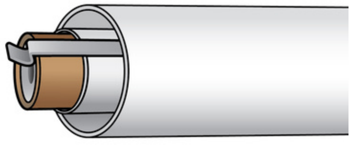
The rocket's nose cone should be loose fitting, but tight enough not to fall out when held upside down and lightly shaken. Add a small amount of masking tape to the shoulder of the nose cone until you get a proper fit. Make sure the shroud lines and the shock cord are not sticking out of the rocket or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

For more information about parachutes and how to fold them, visit https://www.youtube.com/watch?v=H9261CQ0v2E.

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.





ESTES education

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.

Starter Installation

Incorrect handling and installation of the starter is the most common reason for unsuccessful launches!

Igniters generally come in strips of three or more. Each igniter has two separate lead wires. To ensure proper handling:

- Never tear the individual igniters apart.
- Carefully cut the igniters apart between each set.
- Do not remove the tape between the two lead wires of the same igniter.

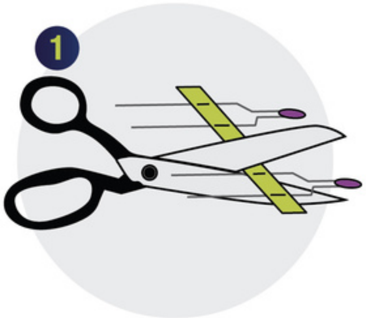
This tape holds the lead wires in place to prevent shorts and to provide strength to hold the igniter's shape. You may cut the tape to separate igniters on the same strip.

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.

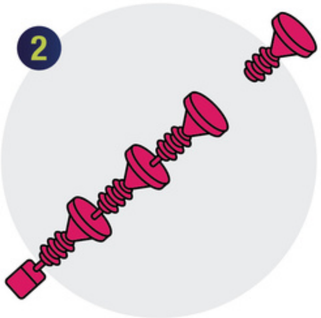
After the igniter is properly inserted, push an igniter plug into the nozzle. This will bend the lead wires to one side a little. However, do not bend the lead wires before inserting the plug. Bending the wire before inserting the plug will pull the tip of the igniter away from the propellant. After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

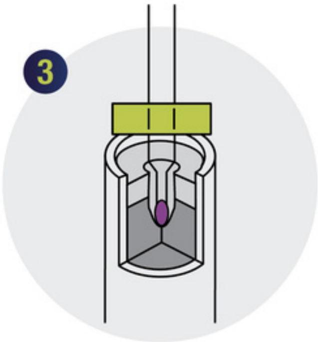
Always use Estes engine starters with an Estes launch controller.



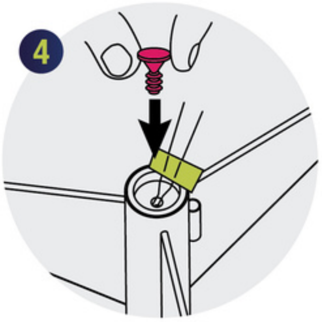
Cut tape separating starters. Do not remove tape.



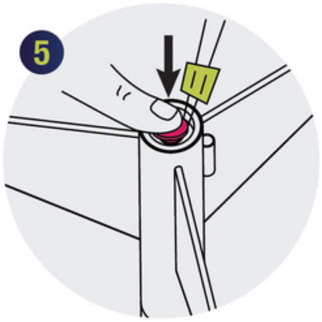
Separate plug from strip of plugs.



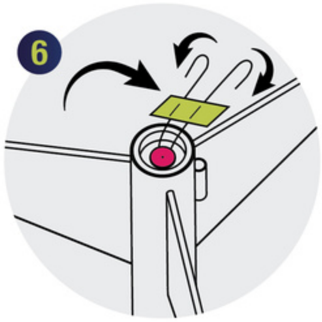
Insert starter into engine. Starter ***must*** touch propellant.



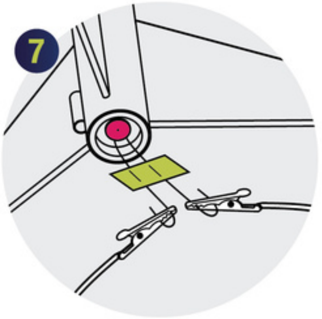
Insert plug into engine nozzle.



Push plug firmly into engine.



Bend starter wires.



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

STARTER TIP ***MUST*** TOUCH PROPELLANT!

About 90% of all problems with engine ignition are caused by the starter not being properly and securely held in place. The starter must touch the propellant at the moment the starter is heated for ignition. Attach micro-clips to starter leads as close as possible to the engine nozzle.

ESTES education

Placing the Rocket on the Launch Pad

Remove the safety cap (with ignition key, if there is one, 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 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 include: 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 a non-abrasive scouring pad, fine sandpaper, or an emery board 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 the previous page.)

Chapter 6: Launching Your Rocket

Launch Procedures

Whether you launch by yourself, as a family, with friends, or with a rocket club there are procedures you must 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 have 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 focused 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.

SAFETY TIP: A safety check should be performed before every launch.

#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, or 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 finishing with the word 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.

LAUNCH!

Ignition Misfires

SAFETY TIP: Wait 60 seconds before approaching a rocket that misfired and NEVER lean directly over the launch rod at any time.

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. Is the rocket range set up with multiple launch systems or just one? If it is just one, you may recover your rocket after confirming or stating the 'range is open'. 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, then 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.

When you are launching your rocket, complete the How High Did You Go? activity in the Activity Guide. Now is a good time to complete the Flight Path Drawing activity as well. The Rocket Launch Debrief activity can be completed at anytime throughout this unit. If you have not done it yet, be sure to complete the Rocket Launch Debrief activity.

Checklists and Rocket Flight Log Sheet

ACTIVITY GUIDE: Once you have launched your rocket, complete the Flight Path Drawing and Rocket Launch Debrief activities in the Activity Guide.

Checklists are an important part of flying. Astronauts, pilots, flight controllers, and other aerospace professionals utilize and rely on checklists to make sure everything is in order and working smoothly. Nothing is more upsetting in model rocketry than watching the beautiful rocket you spent hours building and painting crashing down to earth because you forgot to prepare the recovery system.

The following pages include 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.

Also included in this section is a Rocket Flight Log Sheet to record your rocket's flight information. Did you build the rocket yourself? What skill level was it? 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 record book (e-record).

Launch Checklist

LAUNCH SETUP AND RANGE EQUIPMENT CHECKLIST

Launch Flight Permission:

☐ Obtained Parental Permission ☐ No Fire Bans ☐ Obtained Fire Marshall Permission

Launch Site Permission:

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

Launch Site Needs:

☐ Review the NAR Model Rocket Safety Code
☐ Site free from power Lines, trees, buildings, etc.
☐ Launch Surface— (Circle what applies): asphalt, cement, gravel, bare ground, green grass, or covered with a flameproof platform (i.e., free from burnable matter)

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

☐ Leaf Rake or Flapper Rake (NOTE: Always drag rakes over flames; never "flap"!)
☐ Shovel
☐ Fire Extinguisher (pressurized water)
☐ Jugs of Water
☐ Cell Phone *fully charged* and 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, and in place on launch rod
☐ Standoff clip; i.e., clothespin, spent motor casing, flat rock or another device (if necessary)

Only adults (18+) should approach a fire!

Group/Club Field Safety Preparations (Launching with Spectators):

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

Range Box Equipment and Supplies:

☐ Masking Tape
☐ Baby Powder
☐ Needle-nose Pliers
☐ Long Thin Dowel Rod or Probe (for gently pushing down wadding, or pushing out a spent motor)
☐ Motors (correct sizes for rocket(s))
☐ Motor Plugs (appropriate to motors)
☐ Igniters/Starters/Initiators
☐ Parachutes/Streamers (different sizes)
☐ Fishing Swivel Hooks (for quick recovery system changes)
☐ Flame-Retardant Wadding or Dog Barf
☐ CA (for quick fixes)
☐ Fingernail Polish Remover (for CA mishaps)
☐ Hobby Craft Sticks (for applying CA)
☐ Small Cup Container (for working with CA)
☐ Tin Can for spent motors, igniters and plugs

→ **Use with adult supervision only!**

Individual Self:

☐ Hat
☐ Plenty of drinking water
☐ Sturdy shoes or Hiking Boots
☐ Plenty of Drinking Water
☐ Sunscreen Lotion

Other Suggestions:

☐ Camera ☐ ______________ ☐ ______________
☐ Lawn chairs ☐ ______________ ☐ ______________
☐ Light snacks ☐ ______________ ☐ ______________

Range Box Tools and Supplies

Be prepared when you head to the launch range. Bring additional supplies and materials to help support your launch. Your 4-H leader can help you understand why you need these items in your range box!

SAFETY TIPS: Review your checklists before heading to the launch area.

When working with talcum powder, avoid inhaling it by applying the powder with the wind blowing from either the side or from behind.

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 spent 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 PLUG: 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.

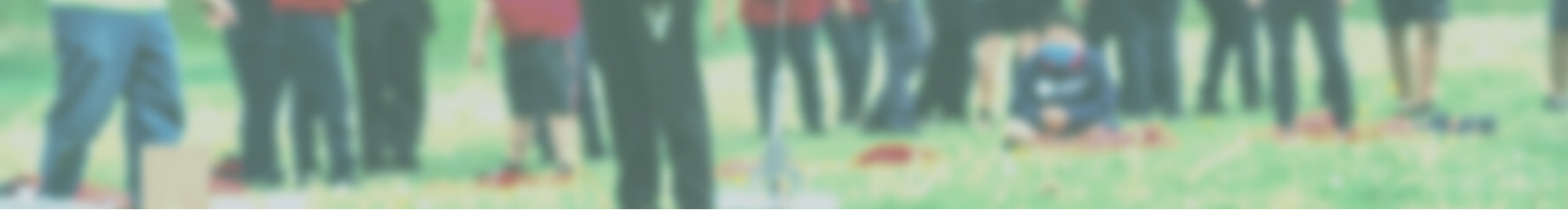
PARACHUTES: The most common recovery system. Having several sizes available, some with holes and some without, makes it easy to do a quick change out for range and launch conditions.

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 (e.g. Baby 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. NOTE: Some baby powder can be made of corn starch, which may become sticky in humidity.



Flight Check

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)

Flight Log

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)*: ______________________

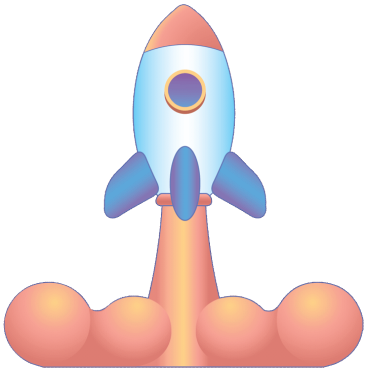
____

Model Rocketry Activity Guide

Now that you have read through the manual, it is time to put your knowledge to the test! Make sure that you show all of your work and bring any extra materials with you to your interview so that the judge can see what you have learned! The following pages include the activities that are referenced in the Introduction to Model Rocketry Unit 1 Manual.

Complete a minimum of four activities. You do not need to complete the activities in order. If you are repeating this unit, do different activities than you did previously.

List of Activities:



CAREERS

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: PLANNING, DECISION MAKING
TIME NEEDED: 20-30 MINUTES
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants will research, evaluate and decide on potential career paths.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

CCSS.ELA-LITERACY.RI.4-5.9
Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

CCSS.ELA-LITERACY.RI.5.7
Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.

TAGS: STEM, CAREER EXPLORATION

LESSON PREPARATION

MATERIALS LIST

- INTERNET OR LIBRARY ACCESS
- SOMETHING TO TAKE NOTES ON (PEN AND PAPER OR WORD PROCESSING SOFTWARE)

Introduction: Through the course of this project, we discussed many aspects of building and designing a model rocket. Each aspect has the potential to be or relate to a career. Think about which part of this project was your favorite, and then think of or research the steps to have that career one day.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THE ENTIRE UNIT 1 MANUAL, COMPLETED 3-4 ACTIVITIES, AND BUILT AND LAUNCHED AT LEAST ONE MODEL ROCKET.

Before the Activity (steps facilitator must take prior to the activity)
Have the meeting in a location where youth can research careers such as the library, or if they are able to bring in a phone, laptop or tablet.

Let's Do It! (steps to conduct the activity)
Get youth thinking about potential careers that could come from this project.
Ask youth to research some of their favorite parts of the model rocketry project, and ask them to identify at least one career that they would be interested in.

VARIATIONS:

If the group of participants is a little older, you can ask them to find information about the career such as salary, hours, etc., and then have them build a budget based on that salary.

CAREERS: TALK IT OVER

OPENING QUESTIONS:

- What has been your favorite part of this project?
- Is there a career that you are currently interested in?
- Are there any connections between the two?

SHARE:

After you have had a chance to research careers, share your discoveries with your 4-H group. Tell them about the career paths that you identified with and why they are or may be of interest to you.

REFLECT:

Have the group discuss which parts of the model rocketry project relates to each of the careers and which parts of the project can help them work towards this career.

GENERALIZE:

Think about the different jobs required to build and launch an actual rocket at NASA. What types of people are involved? What STEM and non-STEM jobs are included?

TERMS:

- CAREER - A job for which you are trained.
- DEGREE - An academic title received after a program of study.
- MENTOR - A trusted counselor or guide.

APPLY:

Have participants consider what steps they need to take to pursue a specific career path. What education or experience is required to have that role? Encourage learners to seek out a mentor to support this path.

Success Indicator:

Connect Model Rocketry with career options.

Learn More:

Discover more about STEM careers using the following link
PBS Nova Labs:
https://www.pbs.org/wgbh/nova/labs/opportunities/resources/

Virtual Fun:

Build your own rocket with United Launch Alliance (ULA) - https://www.rocketbuilder.com

NAME THE PARTS OF A MODEL ROCKET

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: LEARNING TO LEARN, CRITICAL THINKING
TIME NEEDED: 2-10 MINUTES
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants should know, understand, and label each part of a model rocket with correct vocabulary.

NGSS Crosscutting Concepts

Systems and System Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

CCSS.ELA-LITERACY.W.3-5.2.D
Use precise language and domain-specific vocabulary to inform about or explain the topic

CCSS.ELA-LITERACY.L.4.6
Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases, including those that signal precise actions, emotions, or states of being (e.g., quizzed, whined, stammered) and that are basic to a particular topic (e.g., wildlife, conservation, and endangered when discussing animal preservation)

TAGS: MODEL, ROCKET, MODEL ROCKETRY, SCIENCE, PHYSICS

LESSON PREPARATION

MATERIALS LIST

- PRINTED COPY OF DIAGRAM
- PEN/PENCIL OR COMPUTER

Introduction: Model rockets are flying models constructed of lightweight materials such as paper, wood, or plastic. Each model rocket has a similar set of parts that are required to successfully launch, fly, and recover. Understanding what each of these parts of the rocket are will provide you with a better awareness of how model rockets work and how to build them in the coming units.

Before the Activity

If it has been a while since they have read "Anatomy of a Model Rocket," review this section with the participants. Answer any questions that they may have about the location or names of any of the parts of a model rocket.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH "ANATOMY OF A MODEL ROCKET."

Let's Do It!

- This activity can take place individually, or as a group.
- If the participants are completing it individually:
  - Hand out a copy of the diagram to each participant along with a writing utensil, or if they are completing the activity on the computer, make sure they each have a digital copy of the diagram and know how to insert and use text boxes to label.
  - Give them a few minutes to fill out each part of the rocket.
- If you chose to have them complete this activity as a group:
  - Make sure that everyone in the group can see the copy of the diagram. You can use a projector, or if the group is small enough, the group can sit in a circle and look at the diagram together. Point to each part of the diagram and ask the participants what the name of that part is.

NAME THE PARTS OF A MODEL ROCKET: TALK IT OVER

OPENING QUESTIONS:

- Have you seen a rocket before?
- What parts of a model rocket do you know?
- How do those parts apply to a model rocket?

SHARE:

Did you feel you could accurately label the model rocket diagram? What parts did you have a hard time remembering? Why?

If participants have completed the activity individually, go over what each part of the rocket is called. If you did the activity as a group, review some of the parts of the rocket that they did not know immediately.

REFLECT:

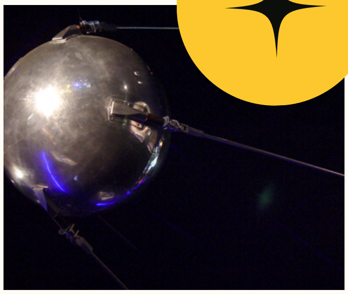
Once you have confirmed all of the parts of the rocket, discuss what their purpose is. What does each part of the model rocket do? What is the role of the parachute? fins? engine? How does the shape of each part relate to its function?

GENERALIZE:

Why is it important to know all the parts of a model rocket? How will it be helpful as you prepare to build/launch/exhibit?

APPLY:

When building and designing a rocket, why is it important to know the parts of a rocket?



Did you know?

The hobby of model rocketry began in 1957 as a response to the launching of the Soviet Sputnik and the start of the Space Age.

Success Indicator:

Label each part of the model rocket accurately.

Acknowledgments and References

Estes Art Team and Estes Education

TERMS:

- CENTERING RING(S) - A part of a rocket's motor mount that holds the motor tube and motor hook together, and centers the hook straight along the motor tube; provides the means for attaching the motor mount in the rocket's airframe. (Most motor mounts consist of one wide or two narrow centering rings.)
- ENGINE BLOCK - A small thick ring glued in place within the airframe just ahead of where the engine will sit. The engine block (also known as a motor block) keeps the motor from pushing forward into the rocket's airframe and payload area. Used mostly with friction fit motors.
- ENGINE HOOK - A metal clip built into the motor mount to hold the rocket motor in the motor tube.
- ENGINE MOUNT TUBE - 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.
- FIN - Fins provide stability to the rocket so the flight will be straight and forward. Fins are generally made up of wood or plastic and consist of four outer edges:
  - Leading Edge—Forward edge of the fin, the edge which travels first into air.
  - Outboard Edge—The outside edge of a fin, which neither leads nor trails. Not all rockets have an outboard edge.
  - Root Edge—The edge of the fin which joins with the rocket's fuselage.
  - Trailing Edge—The bottom edge of a fin, which is the last edge of the fin to enter the air.
- LAUNCH LUG - A device attached to the rocket's airframe to guide the rocket along the launch rod from the launch pad during liftoff.
- NOSE CONE - The leading end of the rocket, which is connected to the rocket's airframe by the shock cord.
- PARACHUTE - The most common of model rocket recovery systems. it consists of the canopy/shroud, shroud lines, shroud line reinforcement tabs, shock cord, shock cord mount, and an eyelet or screw eye.
- SHROUD (also known as Canopy) - The uppermost part of a parachute system, made from lightweight plastic or ripstop cloth, that opens and catches the air flow allowing the rocket to float down safely to earth.
- SHROUD LINES - Thin, long strings which connect the parachute's shroud (canopy) to the nose cone.
- RECOVERY 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.
- 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 nose cone, and absorbs the shock of force emitted by the rocket motor's ejection charge.
- TIP - 1) The very top point of the rocket's nose cone or, 2) the very outboard/trailing 'point' of a rocket fin. Specifically, for rocket fins that hang lower than the airframe of the rocket, it is the point of a fin in which a rocket rests on when placed on the launch pad. (Not all rockets are made to stand on their fins.)

VARIATIONS:

Participants can also be tasked with drawing their own model rockets with all the parts. They can swap their drawings with a partner, and they are asked to label each other's model rockets.

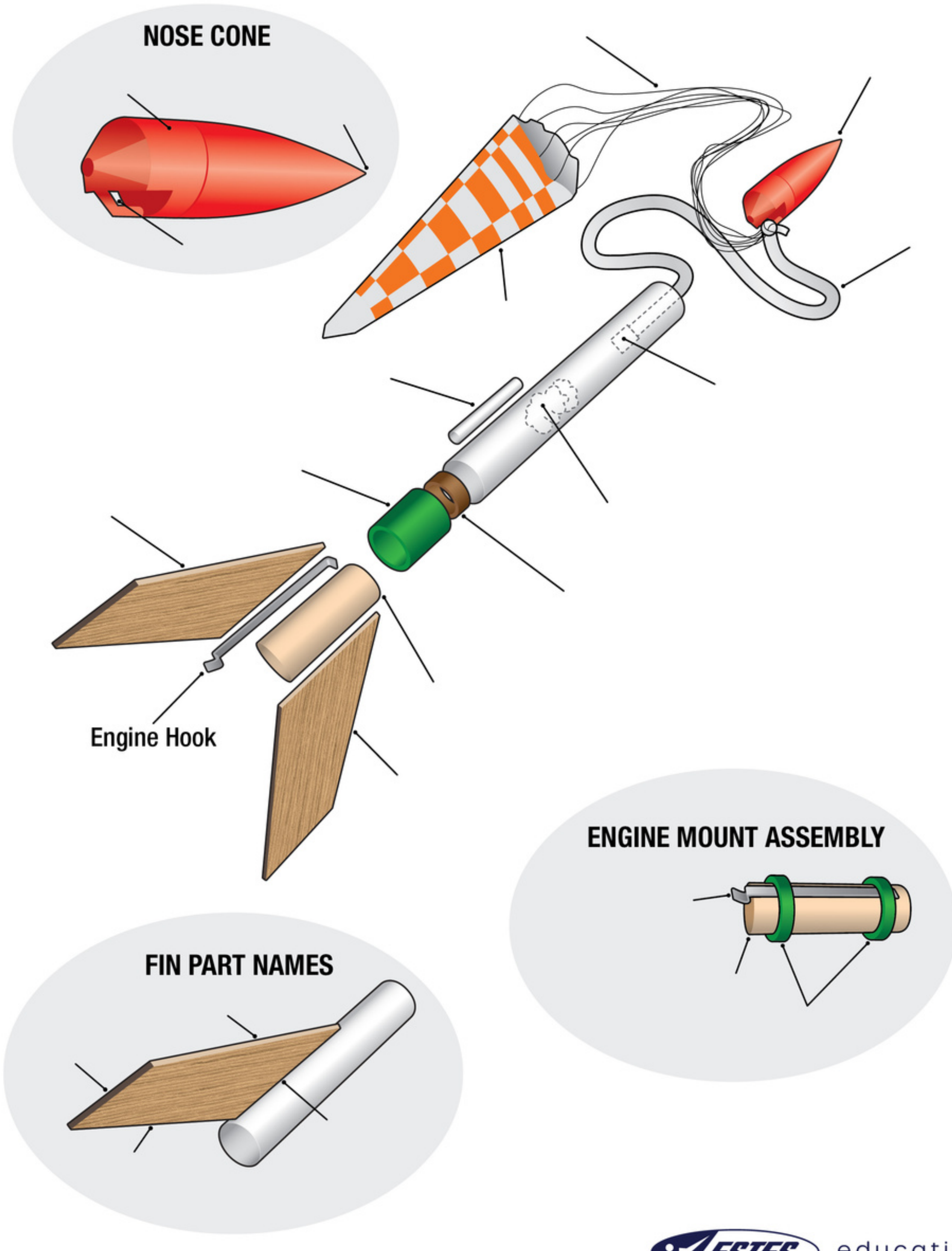
To supplement the activity or in replace of the diagram labeling, have participants act out the parts of the model rocket. Students become the various components: the fins, engine, recovery wadding, recovery system, nose cone, and body tube. (If a larger group, 2 students can represent a part of the rocket). Participants should stand up and form the model rocket. When the students are ready, the instructor will 'ignite' the engine by tapping their shoulder. That should start a cascade of movement and actions by the other students. An example of the cascade of movements includes:

- The engine will react and ignite
- The fins will guide the rocket forward
- The recovery wadding will protect the recovery system from the engine's explosion
- The body tube will keep everything together
- The recovery system (parachute) will open up
- The nose cone stays connected to the parachute and pops off with the parachute

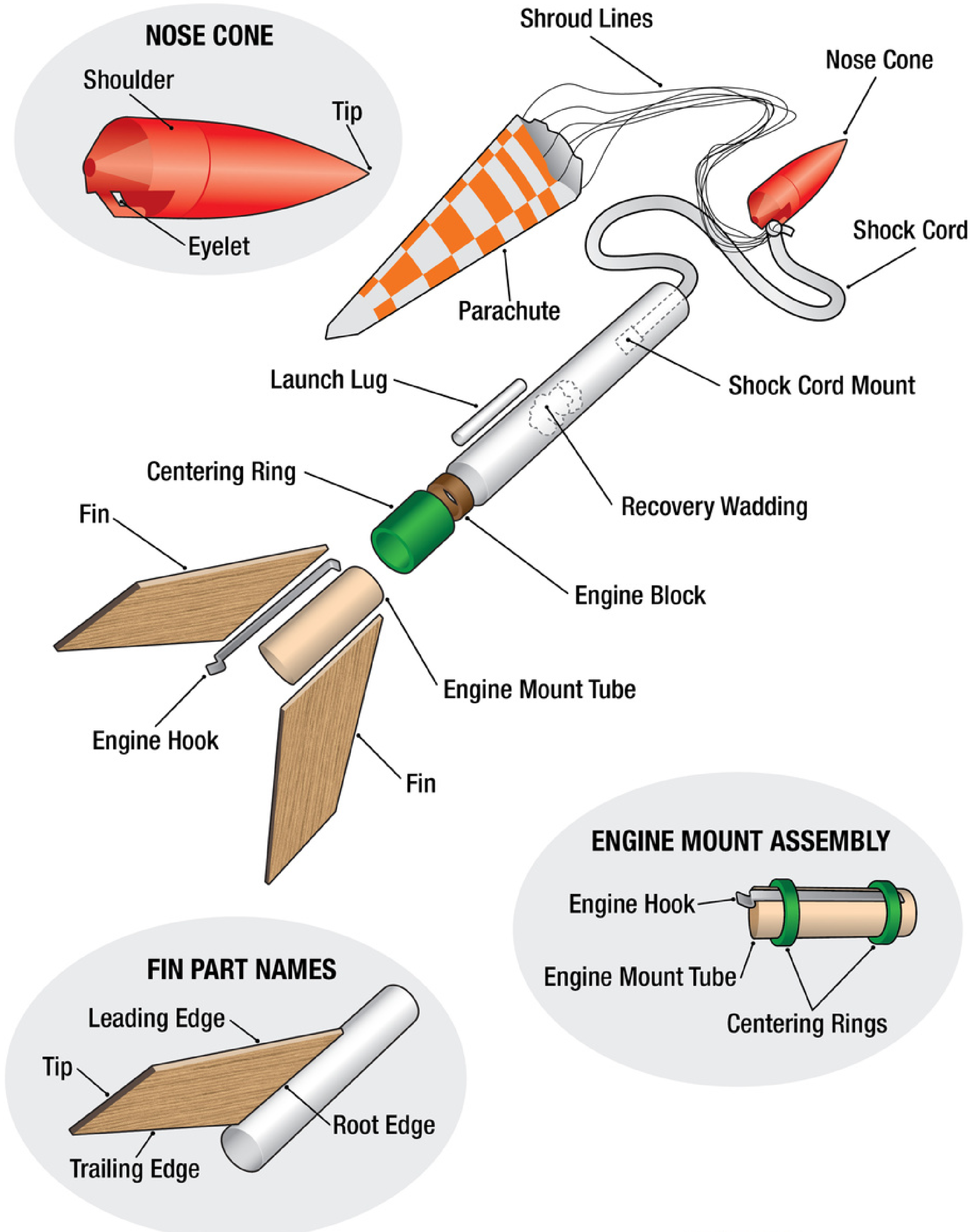
HANDOUTS AND ANSWER KEY

The handout for this activity and the answer key are on the following two pages.

This diagram shows the basic components found in most model rockets.



This diagram shows the basic components found in most model rockets.



HOW HIGH DID YOUR ROCKET GO?

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 12-18)
LIFE SKILLS: CRITICAL THINKING, PROBLEM SOLVING
TIME NEEDED: 30-45 MINUTES
SPACE: AN OUTDOOR AREA IS REQUIRED
SUGGESTED GROUP SIZE: ANY, BUT PARTICIPANTS WILL BE WORKING IN PAIRS

LEARNER OUTCOMES:

Participants will follow the steps to calculate their rocket's altitude.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

Common Core Math
GRADE 6
CCSS.MATH.CONTENT.6.SP.B.5.: Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered

GRADE 7
CCSS.MATH.CONTENT.7.EE.B.3: Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically.

HIGH SCHOOL
CCSS.Math.Content.HSG.SRT.C.8: Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

Common Core ELA
CCSS.ELA-LITERACY.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

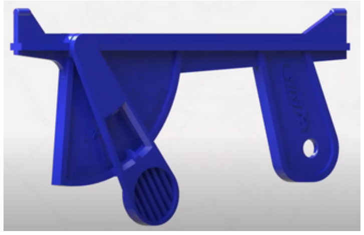
TAGS: ALTITUDE, APOGEE, MODEL ROCKETRY

LESSON PREPARATION

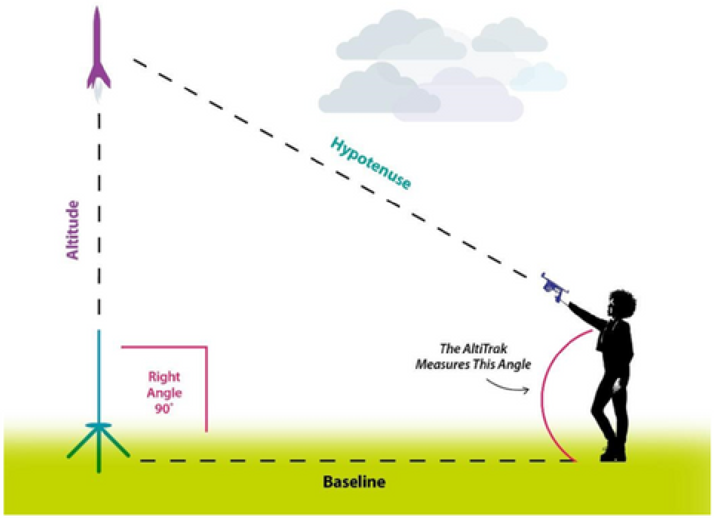
MATERIALS LIST

- PAPER
- PENS/PENCILS
- CALCULATOR
- MANUAL
- TENNIS BALL
- ESTES MINI ALTITRAK (OR CONSIDER BUILDING YOUR OWN DEVICE - SEE VARIATIONS SECTION)
- MEASURING TAPE
- LAUNCH MATERIALS
  - ROCKET
  - ENGINE
  - RECOVERY WADDING
  - STARTERS & PLUGS
  - LAUNCH SYSTEM

Introduction: There are a few ways to determine the altitude of a rocket at apogee, or peak altitude. The approach in this activity utilizes a protractor-like device and basic geometry to give a fairly accurate measurement. These devices provide the angle between the baseline and the triangle's hypotenuse (or distance from the observer and the rocket). Using the baseline measurement and tangent of the determined angle, the height the rocket traveled can be calculated. Technology has also advanced to create electronic altimeters, which do the work for you!



Estes Mini AltiTrak



LESSON PREPARATION

Before the Activity

- Gather all materials for the participants.
- Demonstrate how to hold and use an Estes Mini AltiTrak.
- Group students in pairs for this activity.

Success Indicator:
Participants are able to determine their rocket's altitude.

Acknowledgements:
Estes Education

Learn More:
Learn how to use the Estes Mini AltiTrak with this video: https://www.youtube.com/watch?v=gCKtjqbzPQM .

Virtual Fun:
Check out this virtual simulator to see how the angle impacts the trajectory of objects. https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_en.html

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH THE "ALTITUDE TRACKING METHODS" SECTION IN THE MANUAL.

Let's Do It!

- Identify nearby buildings, flag poles, trees, roofs, etc. Predict how high each of them are and record in the table below.
- Measure and mark 150ft. from the object to be measured. The tracker (using the Mini AltiTrak) will stand here.
- The tracker will hold the Mini AltiTrak with their arms straight out, focusing on the object. Align the front and rear sites at the top of the object.
- Quickly place your finger on the swingarm to hold it in place.
- Partners will record the angle in degrees from the Angle Scale on the Mini AltiTrak.
- Switch places and repeat! Record the heights of at least 4 objects.
- Now practice with a moving target. One partner will throw the tennis ball up into the air and the other will track it with the Mini AltiTrak. Hold the Mini AltiTrak at arm's length, pointed at the tennis ball, and signal to your partner to throw it. Follow the tennis ball as it is tossed up. When it reaches the highest point (the maximum altitude is called apogee). Again, QUICKLY put your finger on the swingarm.
- Record the angle in degrees from the Angle Scale on the Mini AltiTrak.
- Switch places and repeat. Record at least 4 tennis ball launches.
- Once complete, calculate the altitudes of all objects. (See example below)
- After you have calculated it for other objects, use it on your rocket!

VARIATIONS:

Try other moving objects to practice with the AltiTrak. Consider testing various engines to compare the altitude differences with your rocket. Try building your own altitude tracker with easy to find materials at home! Follow the steps at this link here: https://www.grc.nasa.gov/www/k-12/rocket/TRCRocket/altitude_tracking2.html

HOW HIGH DID YOUR ROCKET GO?: TALK IT OVER

OPENING QUESTIONS:

- How high did you think your model rocket could travel?
- How can we measure how high it flies?

SHARE:

After the launch of the model rocket, participants should calculate the height the rocket traveled. Learners should consider their results. How high did your rocket go? Are your results surprising?

REFLECT:

Participants should reflect and compare their results. How did your results compare to others? Why do you think it resulted in any differences?

GENERALIZE:

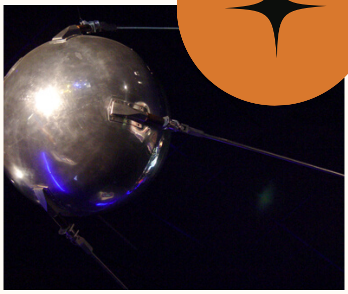
How accurate do you think your results are? Why is it important to know how high your rocket went? How did your results change using different motor sizes/types?

TERMS:

- ALTITUDE - The height of an object.
- APOGEE - The highest point in a rocket's flight.
- TANGENT - A line that intersects a circle at exactly one point.

APPLY:

This simple technique allows learners to calculate apogee for a rocket but can be applied in other ways. How can you use this method in your daily life? Can you use the AltiTrak in other ways?



Did you know?

The hobby of model rocketry began in 1957 as a response to the launching of the Soviet Sputnik and the start of the Space Age.

Acknowledgments and References

Estes Art Team and Estes Education

HOW HIGH DID YOUR ROCKET GO? HAND-OUT

OBJECT	PREDICTION	BASELINE	ANGLE READING	TANGENT	ALTITUDE
EXAMPLE	100 FT	150 FT	30°	0.58	87 FT
TENNIS BALL 1					
TENNIS BALL 2					
TENNIS BALL 3					
TENNIS BALL 4					
ROCKET!					

HOW HIGH DID YOUR ROCKET GO? HAND-OUT

Table of tan(angle)

Angle	tan(a)	Angle	tan(a)	Angle	tan(a)	Angle	tan(a)
0.0	0.00	25.0	.4663	46.0	1.0355	71.0	2.9042
1.0	.0175	26.0	.4877	47.0	1.0724	72.0	3.0777
2.0	.0349	27.0	.5095	48.0	1.1106	73.0	3.2709
3.0	.0524	28.0	.5317	49.0	1.1504	74.0	3.4874
4.0	.0699	29.0	.5543	50.0	1.1918	75.0	3.7321
5.0	.0875	30.0	.5773	51.0	1.2349	76.0	4.0108
6.0	.1051	31.0	.6009	52.0	1.2799	77.0	4.3315
7.0	.1228	32.0	.6249	53.0	1.3270	78.0	4.7046
8.0	.1405	33.0	.6494	54.0	1.3764	79.0	5.1446
9.0	.1584	34.0	.6745	55.0	1.4281	80.0	5.6713
10.0	.1763	35.0	.7002	56.0	1.4826	81.0	6.3138
11.0	.1944	36.0	.7265	57.0	1.5399	82.0	7.1154
12.0	.2126	37.0	.7535	58.0	1.6003	83.0	8.1443
13.0	.2309	38.0	.7813	59.0	1.6643	84.0	9.5144
14.0	.2493	39.0	.8098	60.0	1.7321	85.0	11.430
15.0	.2679	40.0	.8391	61.0	1.8040	86.0	14.301
16.0	.2867	41.0	.8693	62.0	1.8907	87.0	19.081
17.0	.3057	42.0	.9004	63.0	1.9626	88.0	28.636
18.0	.3249	43.0	.9325	64.0	2.0503	89.0	57.290
19.0	.3443	44.0	.9657	65.0	2.1445	90.0	infinite
20.0	.3640	45.0	1.000	66.0	2.2460		
21.0	.3839			67.0	2.3559		
22.0	.4040			68.0	2.4751		
23.0	.4245			69.0	2.6051		
24.0	.4452			70.0	2.7475		

Calculate Altitude

The formula to use is:

Altitude = **Angle Tangent x Baseline Distance**

Example:

AltiTrak 30° Angle reading:
Tangent = 0.58
Baseline = 150 feet

.58 x 150 ft = 87 feet
The height is 87 feet.

TESTING RECOVERY SYSTEMS

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: PROBLEM SOLVING, CRITICAL THINKING
TIME NEEDED: 1-2 HOURS
SPACE: A TABLE FOR CONSTRUCTION AND A HIGH LOCATION TO TEST YOUR RECOVERY SYSTEM'S DESCENT (LIKE A STAIRWELL)
SUGGESTED GROUP SIZE: INDIVIDUALS OR GROUPS OF FOUR
LEARNER OUTCOMES:

Participants will create, test and compare the different types of recovery systems used in model rocketry.

NGSS Crosscutting Concept

Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

TAGS: DRAG, MODEL ROCKETRY, STEM

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS & NEXT GENERATION SCIENCE STANDARDS

CCSS.MATH.CONTENT.3.MD.A.1
Tell and write time to the nearest minute and measure time intervals in minutes. Solve word problems involving addition and subtraction of time intervals in minutes, e.g., by representing the problem on a number line diagram.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

LESSON PREPARATION

MATERIALS LIST

- SMALL TOY
- 2 PLASTIC GROCERY/TRASH BAGS
- STRING
- SCISSORS
- A FEW PIECES OF PAPER
- 2 PAPER CLIPS
- PEN OR PENCIL
- RULER
- TAPE
- STOP WATCH
- CALCULATOR
- HELPER

Introduction: Many model rockets are able to be reused or launched over and over again thanks to their recovery systems. Recovery systems help rockets safely land to be launched again. There are several different types of recovery systems. In this activity, we will see first hand how each one works, and see why they might be used in different situations.

VARIATION:

Take large trash bags and:
1) cut out circles of different sizes (use lids as a pattern),
2) evenly space an equal number of reinforcement tabs around each circle edge,
3) pass and tie strings through small holes punched through the tabs, and
4) see how the different sizes compare with each other during flight.

Success Indicators:
Identify the differences in recovery systems.

References:
Parachute activity from previous Unit 1 and 2 manual and Helicopter activity

BACKGROUND INFO

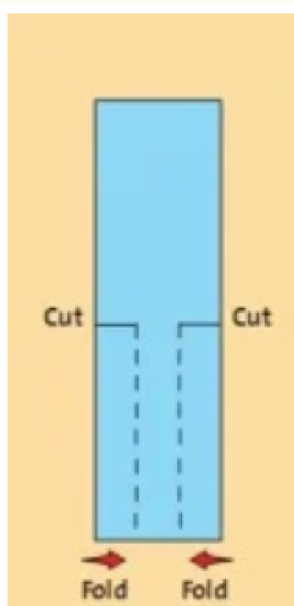
PARTICIPANTS SHOULD HAVE READ THE "RECOVERY SYSTEMS" SECTION OF THE MANUAL. THIS SECTION COVERS THE FOUR TYPES OF RECOVERY SYSTEMS THAT WILL BE TESTED DURING THIS ACTIVITY.

Before the Activity

- Ensure that you have enough materials for the number of participants/groups that you have.
- Select a location where participants can safely drop their toy and measure how long it takes to hit the ground.
- Review the "Recovery Systems" section of the manual with participants so that they understand what type of recovery system they are testing at each step.
- Be ready to take pictures of them completing the activity.
- Participants may need help with the math at the end of this activity.

Let's Do It!
Create/Design Recovery Systems

1. Gather materials. Materials include a small toy, two plastic grocery bags (or small plastic trash bags), some string, scissors, a few pieces of paper, two paper clips, a pen or pencil, a ruler, a stopwatch, and a helper.
2. Make a Parachute System
   a. Start by tying string to the handles of the plastic bag. Three or four parachute lines are likely needed.
   b. Securely attach the toy to the strings.
3. Make a Streamer System
   a. Take another plastic bag. Cut from the bottom of the bag, towards the top. Be sure to leave about an inch of space so that the bag stays in one piece. Repeat this several more times so that the bag looks frayed.
   b. Tie the toy to the bottom of a streamer.
4. Make a Glider System
   a. Create a paper airplane. If learners do not know how to make an airplane, leaders/adults should help guide them.
   b. The toy should be attached to the paper airplane at the bottom using a paperclip or tape.
5. Make a Helicopter System
   a. To create a helicopter, first draw cut lines onto a piece of paper that has been folded in on each side like on the picture of the blue paper below.

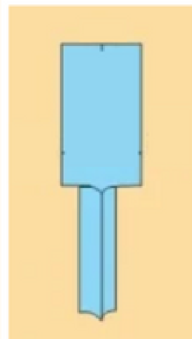


   b. Once completed, cut around the outside of the helicopter.

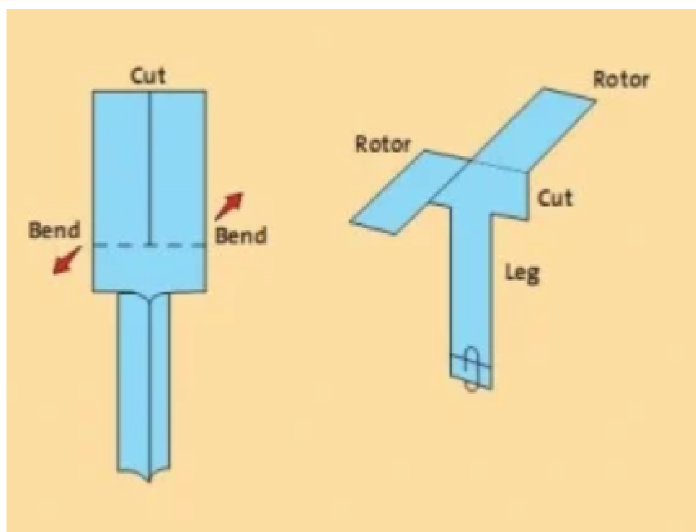
Let's Do It!

Create/Design Recovery Systems Continued

c. Then cut the two solid lines and fold the outside edge over. It should look like this:



d. Next, cut down the middle of the bigger section and fold those wings in opposite directions. Here is a diagram to help explain:



e. Once created, attach a paper clip to the bottom as is shown in the diagram above. Use the paper clip to attach the toy to your helicopter.

7. Once each system is made, go to your tall location and drop the toy off the edge. Make sure to have a partner/helper time how long it takes the toy to hit the ground.
    a. Record this time in the table and repeat the experiment two more times for each system.

8. Once you have completed testing the recovery systems, calculate the average descent time.

Recovery Type	Trial 1 Time	Trial 2 Time	Trial 3 Time	Total (add up all of the times)	Average Time (take the total and divide by 3)	Observations (ex: wind picked up, hit the ground hard, or flew perfectly)
Parachute						
Streamer						
Glider						
Helicopter						

TESTING RECOVERY SYSTEMS: TALK IT OVER

OPENING QUESTIONS:

- What type of recovery systems have you used or seen before?
- What type of recovery system do you think is better for a model rocket?

SHARE:

What were your results? What did you observe about each of the recovery system types?

REFLECT:

Have participants discuss why each type of recovery system might be useful. Have them share the differences between each type and why they could be used in certain situations over the other types. What type of recovery system is better for a model rocket? Why? A model rocket requires a recovery system that slows the descent to prevent damage and can fit inside the body tube.

GENERALIZE:

In what instance would you use each type of recovery system in other applications? How could you have changed your system design to better improve its use?

TERMS:

- GLIDER - A method of rocket recovery consisting of wide wings to glide and slow the rocket's descent.
- HELICOPTER - 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.
- PARACHUTE - The most common of model rocket recovery systems, consisting of a plastic or nylon ripstop cloth cover (shroud) and shroud lines; made in various sizes and shapes.
- RECOVERY SYSTEM - A method used to slow a rocket's descent.
- STREAMER - 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.
- VARIABLE - An element, feature, or factor that is liable to change.

APPLY:

Have participants experiment by varying their streamers and parachutes to suit wind conditions or launch site size. Ideas include cutting out spill holes in the canopies, adding extra folds for streamers or changing out sizes, etc.

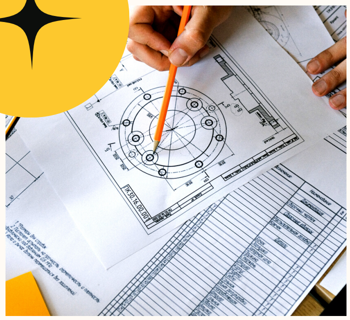
DESIGN YOUR ROCKET FINISH

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: CRITICAL THINKING, PLANNING, ORGANIZING
TIME NEEDED: 10-15 MINUTES
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants will utilize their knowledge of model rocketry to conceptualize and plan their own rocket design.



NGSS Standard

3-5-ETS1-1
Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

EDUCATIONAL STANDARDS

NATIONAL CORE STANDARDS

Anchor Standard 1: Generate and conceptualize artistic ideas and work.

Anchor Standard 2: Organize and develop artistic ideas and work.

Anchor Standard 3: Refine and complete artistic work.

Anchor Standard 10: Synthesize and relate knowledge and personal experiences to make art.

TAGS: PAINT, DECALS, MODEL ROCKETRY, STEAM

LESSON PREPARATION

MATERIALS LIST

- PIECE OF PAPER
- COLORED PENCILS, CRAYONS, OR MARKERS
- STICKERS

Introduction: Before a model rocket is complete, it needs finishing touches! The visual look of a rocket reflects the creators and is a valuable part of any design. Participants draw their model rocket to first solidify their understanding of the parts of a model rocket, but it also enables learners to be creative. Many rockets from large companies like NASA and Blue Origin have specific brands that impact their design. Create your own blueprint and rocket design!

Success Indicators:
Learners will create a drawing of what they would like their rocket to look like with paint and decals or stickers.

VARIATIONS:

Participants can make their diagram digitally if they are familiar with computer software, and would prefer to do so. You could also have them practice painting something other than a model rocket so that they understand how spray paint works in order to better plan their paint job.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ "ANATOMY OF A MODEL ROCKET" THE INFORMATION IN THIS SECTION WILL HELP THEM IDENTIFY WHAT TO DRAW ON THE PICTURE OF THEIR MODEL ROCKET.

Before the Activity

- Be sure to have enough pieces of paper for everyone in the group.
- Ask all participants to bring their rocket or a photo of their rocket.
- Have coloring utensils ready for the whole group.
- Read through the "Anatomy of a Model Rocket" section with participants if you feel it is necessary.

Let's Do It!

- Give each participant a piece of paper. If necessary, use the model rocket line drawing as a template (especially for younger participants).
- Give them time to draw their rocket.
- Once everyone has finished, go through the external parts of the rocket to ensure that each participant has included all of the parts.

DESIGN YOUR ROCKET FINISH: TALK IT OVER

OPENING QUESTIONS:

- What would you like your model rocket to look like?
- Do you want the design to match a well known rocket?
- Do you want to create your own design?

SHARE:

What is your design for your model rocket? What colors, stickers, or imagery did you incorporate in your design?

REFLECT:

Why did you choose those colors/patterns/stickers? How did your design compare to others?

GENERALIZE:

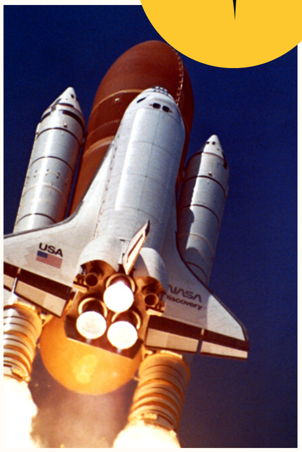
What type of materials do you need to decorate your model rocket in that design? How do you think those colors will look in the sky after it has been launched?

TERMS:

- BLUEPRINT - A design plan or other technical drawing.
- DESIGN - A plan or specification for the construction of an object or system.
- BRAND - A type of product made by a particular company under a particular name.

APPLY:

Why is it important to plan/organize before implementing your design? How can you refine your design before decorating? What tools do you need to decorate?



Did you know?
The iconic orange coloring of the NASA Space Launch System (SLS) fuel tank is more than just a design choice. The SLS was not painted white (and instead left in its original orange) because it saved over 270 kg of weight.

CREATE A SAFETY BROCHURE

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: CONCERN FOR OTHERS, COMMUNICATION, SHARING
TIME NEEDED: 30-60 MINUTES
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants will create a clear and engaging written and visual representation of model rocket safety.

Variations:

Participants can make the brochure digitally if they prefer. They could also make a poster/display board instead of a brochure.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

CCSS.ELA-LITERACY.W.3-6.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

CCSS.ELA-LITERACY.RI.4.1
Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

CCSS.ELA-LITERACY.SL.5-6.5
Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.

TAGS: SAFETY, MODEL ROCKETRY

LESSON PREPARATION

Learn More:

Check out the National Association of Rocketry's Safety Code (https://www.nar.org/safety-information/model-rocket-safety-code/) to see how your safety brochure compares!

Success Indicators:

Students successfully list all safety precautions to take when launching model rockets.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH "LAUNCH SYSTEMS AND FIELD OPERATIONS" AND "LAUNCHING YOUR ROCKET" IN THE MANUAL.

Before the Activity

- Review the safety procedures listed in the manual with the participants.
- Ask if they have any questions on how to safely launch model rockets.
- Be sure to have enough paper for each participant.
- Have coloring utensils for all participants.

Let's Do It!

- Give each participant a piece of paper.
- Direct them to fold it into thirds.
- Let them create their own brochure with all of the necessary safety precautions.

CREATE A SAFETY BROCHURE: TALK IT OVER

TERMS:

- COMING IN BALLISTIC - A phrase heard at a rocket range meaning a rocket did not deploy its recovery system after reaching peak altitude, and has already started returning to the ground with gravity pulling it down at a high rate of acceleration—32 feet per second squared.
- CATO - Means a "catastrophe-at-take-off," an eruption of uncontrolled forces, which ultimately destroys the rocket. CATO are generally caused by damaged motors.
- IGNITION - The spark of an electrical heat source (ignitor) that starts the propellant in a rocket motor burning.
- MISFIRE - When the rocket does not leave the pad.
- RANGE - An appropriately large open space used for launching model rockets.
- SAFETY - The condition of being protected from or unlikely to cause danger, risk, or injury.

CREATE A SAFETY BROCHURE: TALK IT OVER

OPENING QUESTIONS:

- WHAT ARE THE STEPS YOU SHOULD FOLLOW TO SAFELY LAUNCH A MODEL ROCKET?
- WHAT DO YOU DO IF THE ROCKET FAILS TO LAUNCH AFTER PUSHING THE BUTTON?

SHARE:

CONSIDER THE DEVELOPMENT AND DESIGN OF THE BROCHURE. HOW DID YOU FEEL CREATING THIS BROCHURE? HOW DID EVERYONE INTERPRET THE ASSIGNMENT?

REFLECT:

REFLECT ON THE KEY PIECES INCLUDED! WHAT STEPS OR PRECAUTIONS WERE INCLUDED IN MOST OF THE BROCHURES? WHY DO YOU THINK THEY WERE INCLUDED?

GENERALIZE:

HOW DO YOU MAKE SURE EVERYONE AT A LAUNCH REMAINS SAFE? WHAT STEPS DO YOU TAKE BEFORE, DURING, AND AFTER A LAUNCH TO ENSURE SAFETY?

APPLY:

SAFETY IS VITAL TO OUR EVERYDAY LIFE. WHAT PRECAUTIONS CAN BE USED IN OUR DAY-TO-DAY LIFE? WHY IS SAFETY IMPORTANT TO CONSIDER WITH ACTIVITIES LIKE ROCKETRY?

FLIGHT PATH DRAWING

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: LEARNING TO LEARN, CRITICAL THINKING
TIME NEEDED: 10-15 MINUTES
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants will create a model of a model rocket flight path with accurate terminology and visual examples.

NGSS Crosscutting Concepts

Systems and System Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

CCSS.ELA-LITERACY.W.3-5.2.D
Use precise language and domain-specific vocabulary to inform about or explain the topic.

CCSS.ELA-LITERACY.SL.5-6.5
Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.

CCSS.ELA-LITERACY.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

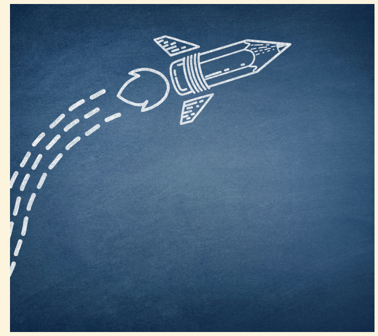
TAGS: LIFTOFF, PEAK ALTITUDE, LANDING, MODEL ROCKETRY

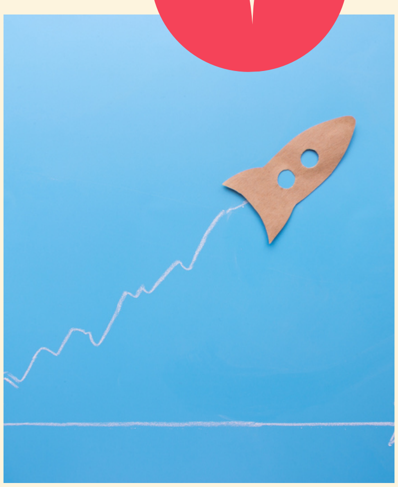
LESSON PREPARATION

MATERIALS LIST

- PAPER
- PENS/PENCILS
- COLORING UTENSILS
- MANUAL

Introduction: Model rockets follow a safe and predictable flight path to ensure safety. This activity ensures learners are able to identify each phase of a model rocket flight pattern and draw what the path should look like.





BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH “MODEL ROCKET FLIGHT” IN THE MANUAL.

Before the Activity

- Review the phases of flight with the participants.
- Review the components of a model rocket engine.
- Have a piece of paper and coloring utensils for each participant.

Let’s Do It!

- Give each participant a piece of paper and some coloring utensils.
- Have them draw each phase of the flight pattern and label them accordingly.

VARIATIONS:

If participants would prefer to do this digitally, they can record a model rocket flight. Then they can insert the names of each of the phases as the model rocket is in that part of its flight.

FLIGHT PATH DRAWING: TALK IT OVER

OPENING QUESTIONS:

- What is it called when a model rocket leaves the launch pad?
- At what phase of flight should the parachute pop out?

SHARE:

If participants have completed the activity individually, go over each step of the flight path. If you did the activity as a group, review some of the steps that they did not know immediately.

REFLECT:

Once you have confirmed all of the steps of the rocket flight path, discuss what their purpose is. How do the parts of the model rocket engine dictate the trajectory of the rocket?

GENERALIZE:

Consider the term “flight path”. Why is it important to understand the flight path of a model rocket? rocket? airplane?

TERMS:

- ACCELERATION - The act or process of moving faster (high thrust for flight).
- COASTING PHASE - The phase of a rocket’s flight where the rocket continues to soar upwards after the burnout of the motor.
- FLIGHT PATTERN - The path in the air made or followed by something in flight.
- LANDING - Touching down after flight.
- Liftoff - a vertical takeoff (engine ignition from the launch pad).
- PEAK ALTITUDE - The greatest degree of height (recovery system is deployed).
- SLOW DESCENT - A gentle fall back to the ground.

APPLY:

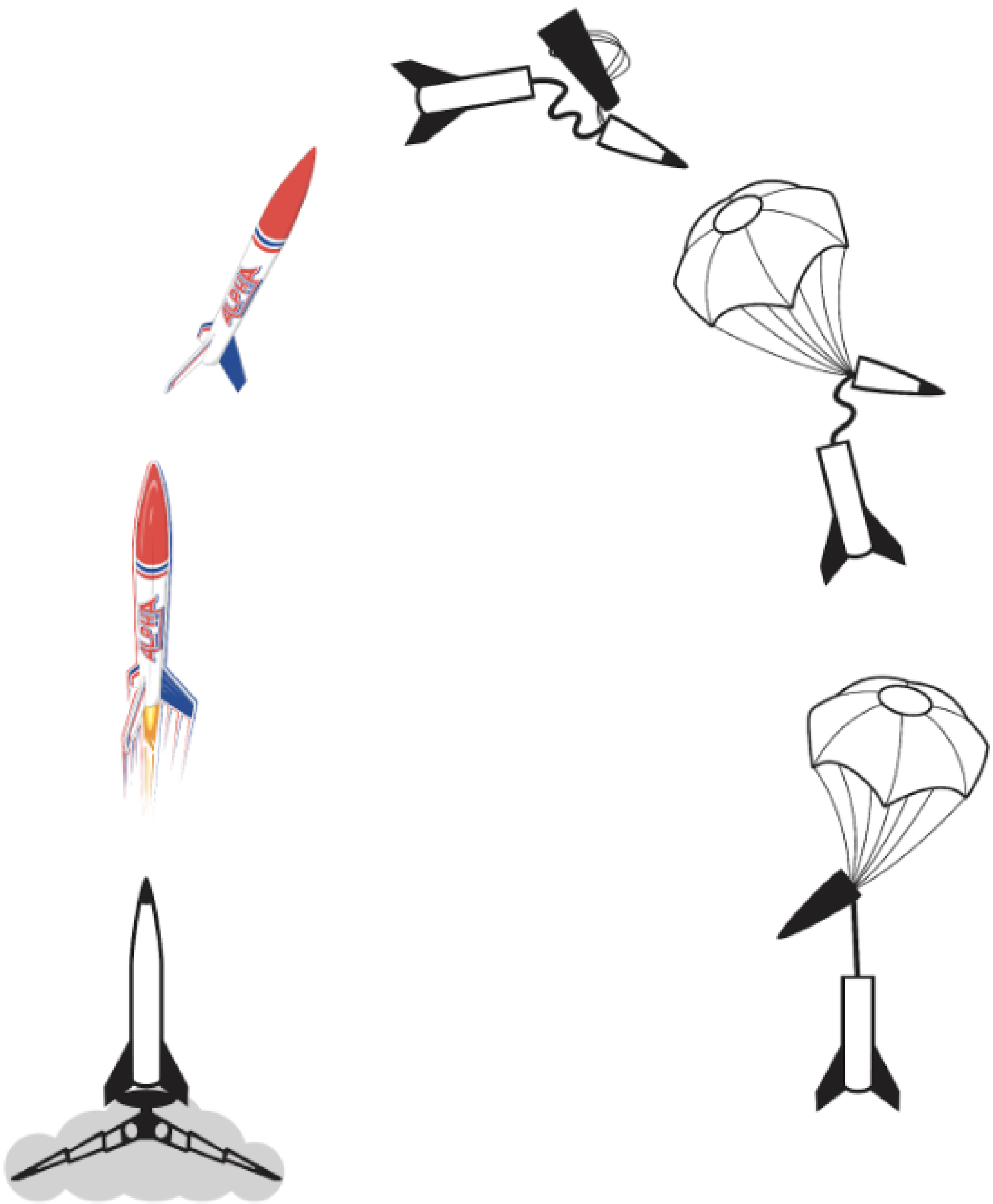
Have participants think about safety. What happens if a flight path changes? How can we ensure a flight path is predictable?

Success Indicator:
Participants are able to identify and label all six phases of a model rocket’s flight.

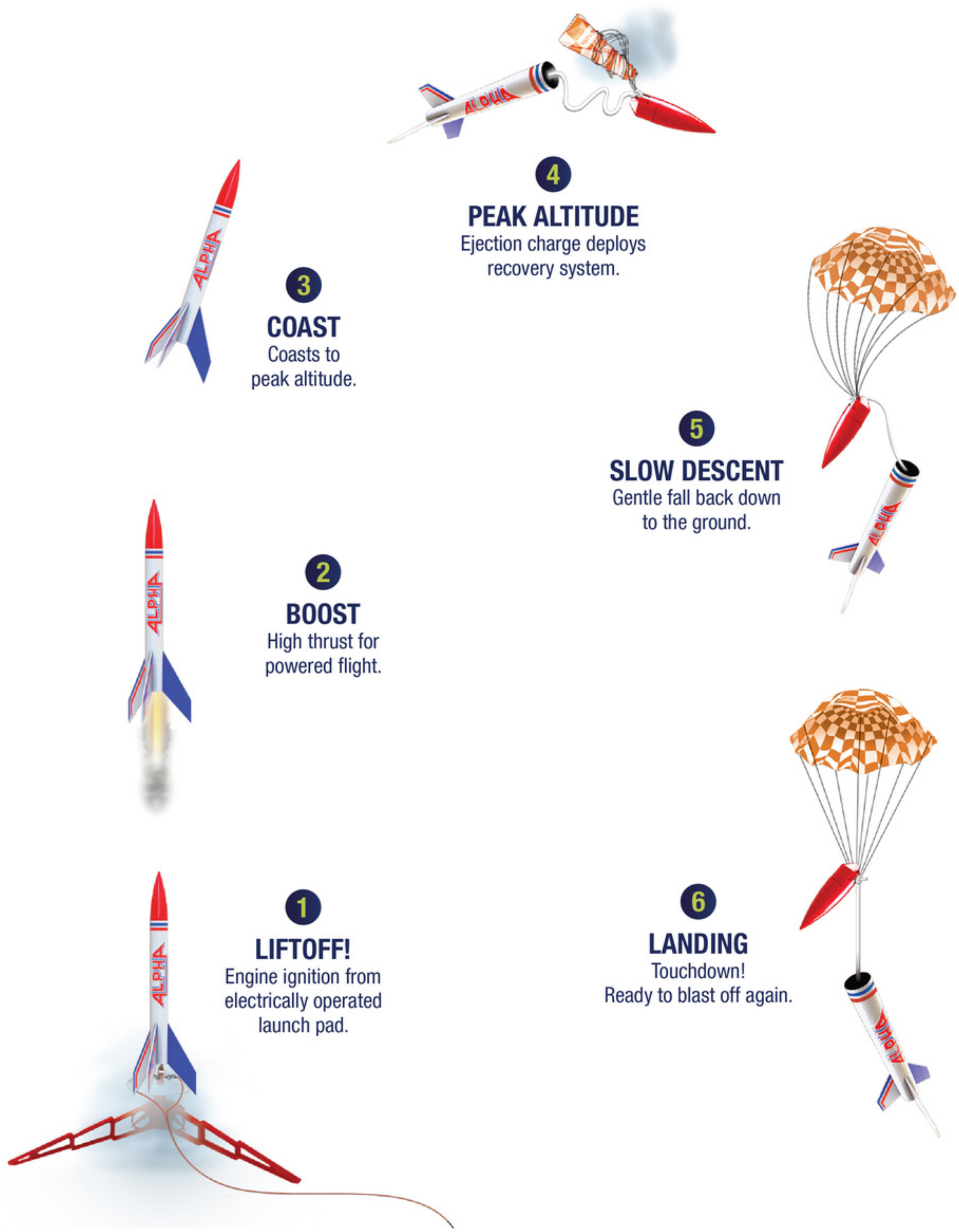
Virtual Fun:
Check out some launch images and results from NASA over the years.
https://www.nasa.gov/content/launch-images

References:
Estes Education

FLIGHT PATH HANDOUT



FLIGHT PATH ANSWER KEY



ESTES education

ROCKET LAUNCH DEBRIEF

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: LEARNING TO LEARN, COMMUNICATION, SHARING
TIME NEEDED: 10-15 MINUTES PER YOUTH
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants will take the appropriate steps to successfully launch their model rocket and discuss outcomes.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

CCSS.ELA-LITERACY.SL.3-5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on topics and texts, building on others' ideas and expressing their own clearly.

CCSS.ELA-LITERACY.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

TAGS: LAUNCH, MODEL ROCKETRY

LESSON PREPARATION

MATERIALS LIST

- WRITING UTENSIL
- LAUNCH MATERIALS
  - ROCKET
  - ENGINE
  - RECOVERY WADDING
  - IGNITERS & PLUGS
  - LAUNCH SYSTEM

Introduction: One of the last steps to completing this unit is to launch a model rocket. We have covered many topics so far in the unit, and now we get to put them all together! Be sure to follow all of the safety guidelines that we have discussed so far, and look for things like the flight path and recovery system. If you are interested in determining how high your rocket flew, check out the altitude tracking activity in this unit.

Success Indicator:
Learners will launch their model rocket and reflect on the outcomes to demonstrate their learning of key concepts.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH “LAUNCHING YOUR ROCKET” IN THE MANUAL.

Before the Activity

- Review the safety procedures with the youth.
- If possible, demonstrate how to safely launch a rocket before youth who have not flown try.
- Make sure that all youth know how to load their rocket for flight.

Let’s Do It!

- Allow each youth to launch their model rocket at least once (depending on time).
- As each youth completes their launch, have them explain the whole process to their friends and family. Encourage the friends and family to ask questions for youth to reflect upon.

ROCKET LAUNCH DEBRIEF: TALK IT OVER

TERMS:

- CHECKLIST - A list of things to be done or collected.
- COUNTDOWN - an audible backward counting to time the last seconds before the launching of a model rocket starting at 5 and ending with the word, "launch!".
- DEBRIEF - To carefully review upon completion for useful information.
- ENGINE PLUG/PEG - A small rolled up piece of paper or plastic forced into the motor nozzle after insertion of the igniter, designed to keep the igniter pressed against the propellant.
- IGNITION SYSTEM - When an electrical current is passed through the igniter by the launch controller, the wire's high resistance causes it to become very hot and ignite the surrounding propellant.
- LAUNCH CONTROLLER - An electrical device used to activate the motor igniter, which in turn ignites the motor. The launch controller should always incorporate a lock-out device such as a key, to prevent accidentally activating the igniter before the rocket is ready to be launched.
- LAUNCH PAD - An assembly containing the launch rod or tower and blast deflector if any, which permits the rocket to remain steady until launched.
- LAUNCH ROD - A stiff rod, whose diameter can be from 1/8" to 1" depending on the size and weight of the rocket, along which a rocket flies for the first few feet of its travel. The launch rod stabilizes the rocket's flight while it builds up air speed.

VARIATIONS:

If participants would prefer to do this digitally, they can record the flight and their description of how it went. They could also journal about their flight experience if they do not have someone to discuss the launch with.

ROCKET LAUNCH DEBRIEF: TALK IT OVER

OPENING QUESTIONS:

- What are the safety guidelines you need to follow as you prepare to launch your model rocket?
- What are the steps to prepare your model rocket for flight?
- What do you do if your starter fails to ignite?

SHARE:

After youth have had a chance to individually discuss their launch with their friend and family, have the youth discuss the launch together. If they were asked any interesting questions, have them share those with the group. If some participants ran across problems throughout the launch, have them explain those to the rest of the group and what they did to solve the problem.

REFLECT:

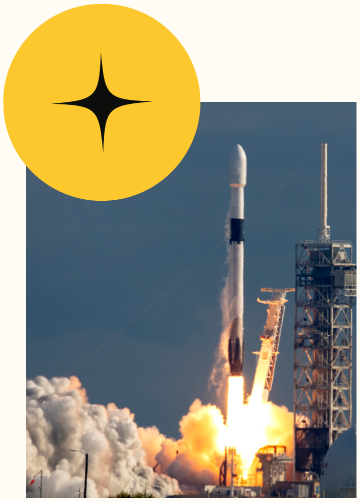
Ask youth what they learned from this launch that will change the way they launch next time. Are they going to bring more supplies with them? Did they learn how much wadding to put in their rocket?

GENERALIZE:

Consider the steps of a model rocket launch. Why is it important to know all of the steps to launching a model rocket? What did you learn that will help you with the Model Rocketry Fly Day Contest?

APPLY:

Transition the participants to think about reflection, evaluation, and communication. When completing a homework assignment, do you typically evaluate or mark it as complete? Why is it important to reflect on a task? When you talk about results, how do you explain them to your parents versus siblings?



Investigate!

Rockets are being launched more often thanks to the advances by NASA, SpaceX, Blue Origin, etc. Check out their social media pages and related news stories to see how they communicated their launch results. Did their rocket take off? Was the launch scrubbed, or postponed to another day? Was their launch successful?

MY MODEL ROCKETRY NOTES

Colorado 4-H Mission
4-H empowers youth to reach their full potential by working and learning in partnership with caring adults.

Colorado 4-H Vision
A world in which youth and adults learn, grow and work together

4-H Pledge
I pledge.....
My head to clearer thinking,
My heart to greater loyalty,
My hands to larger service,
My health to better living
for my club, my community,
my country and my world.

Promesa 4-H
Prometo usar mi mente para pensar con más claridad,
mi corazón para ser más leal,
mis manos para ser más servicial,
mi salud para cuidarme más,
por mi club, mi comunidad, mi país y mi mundo.

4-H Motto
"To Make the Best Better."

COLORADO STATE UNIVERSITY
EXTENSION

Colorado4h.org