THE AMERICAN ROCKETRY CHALLENGE

— A BEGINNER'S GUIDE —

ESTES education

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WELCOME

Welcome to model rocketry and The American Rocketry Challenge! The American Rocketry Challenge, or TARC, is *the* national contest that lets students in grades 6 – 12 exercise real-world engineering skills.

Organized by the Aerospace Industries Association (AIA) and the National Association of Rocketry (NAR), TARC is the largest model rocket contest in the world with thousands of students involved each year. At the commencement of each school year, qualifying flights start to take place at the local level with teams reporting their results to the AIA by mid-spring. The 100 best scoring teams are then invited to a national fly-off in late spring or early summer. At the national contest, teams will have a chance to compete for a share of $100,000 in scholarship grants.

While the rules may seem complex and the task of fielding a competition team may appear daunting, it's really not that difficult with planning and proper organization. As the world leader in model rocketry since 1958, Estes Education is proud to be an educational partner and your ally throughout this school-year long endeavor. ▪

... GETTING STARTED

While you and your students may be eager to build and launch your rocketry challenge rocket, you should spend some time building your students' model rocketry skills, especially if this is a new team.

Official qualifying flights need to be witnessed and verified by a senior member of the NAR, you may also want to consider contacting the NAR for mentorship and guidance. The contest specific NAR page, www.nar.org/team-america, contains lists of NAR Sections and contact info for senior members who have volunteered to mentor teams.

NAR Sections, or clubs, are located throughout the country. NAR Sections may have access to a flying field and launch equipment that your team can utilize throughout your rocketry challenge journey. Even with the help of a NAR Section, you will probably want to locate a flying field of your own. Most NAR Sections fly once a month which may not be sufficient for your needs.

For preliminary launches with smaller rockets, a school athletic field should suffice, with certain considerations. Even for smaller rockets, the flying field should not be adjacent to roads or housing areas so you may need to pick a launch site that is not on school property. If you are launching on public property (like a park) be sure to research any use restrictions. If the launch is for a school-sanctioned educational activity, most jurisdictions will be very cooperative. If you are launching on private property, be sure to have permission of the land owner. Your principal may be able to help you secure a flying field by providing a letter on school letterhead identifying The American Rocketry Challenge as an approved school activity. ▪

GETTING STARTED

THE AMERICAN ROCKETRY CHALLENGE

RULES & DEADLINES

Every year the challenge changes so even if you have competed before, you need to be familiar with the current requirements and timelines.

http://rocketcontest.org

Schedule

There are a few "hard" dates in The American Rocketry Challenge. The first deadline is registration and the second is the deadline when you must submit your qualifying flight results. Check out the challenge website for the most up-to-date information.

The American Rocketry Challenge is challenging and your students should master the fundamentals of model rocketry before progressing to their contest rocket. Start your contest effort as early in the school year as possible. This will give you time to conduct a skill-building program and test your contest model. Refer to our 3-Month Tactical Plan on page 20-22 for an easy-to-follow schedule that will help you educate your team on the necessary engineering principles needed to compete in this competition.

Remember, qualifying flight results are due to the The American Rocketry Challenge by mid-spring, which means you could find yourself conducting test flights in February and March. What is the weather typically like in your area during those months? Build a flight test schedule that takes the weather into account. Be sure to coordinate with your NAR mentor early to make sure he/she is available.

Supply availability is another important consideration. Allow enough time in your schedule to order parts and engines. Be sure to review the regulations and shipping costs for model rocket engines as they can vary based on where you live. Also, be sure to allow enough time for construction as building times will vary based on the complexity of the rocket. ▪

GETTING STARTED

Supplies & Equipment

As your students become proficient with model rocketry, you will need rockets, engines and launch pads. Your team will also need specialized equipment like altimeters and timing devices.

Will your students construct their rockets at home, or will they build them at school? Having students work at school gives you a better opportunity to monitor the construction process and also provides an avenue for group participation. Glues and adhesives take time to dry or cure so it's best if you have an area where models can be left out between building sessions.

Make sure to procure enough parts to allow for mistakes during construction. This should include having extra body tubes, nose cones and parachutes on hand. You will also want to have a portable scale that accurately measures to the nearest gram. During the test flying phase your students may want to add or subtract ballast to adjust for altitude and duration of flight. ▪

GETTING STARTED...

The Engineering Method

As you approach The American Rocketry Challenge, your students should follow the engineering method, a systematic approach used to reach the desired solution to a problem. Because the process seeks a solution to a specific problem, the engineering method is different than the scientific method.

The steps (or phases) of the engineering design process are shown below:

1. **ASK**
   Identify and Define the Problem
2. **IMAGINE**
   Brainstorm Solutions & Research Ideas
3. **PLAN**
   Select & Sketch Ideas
4. **CREATE**
   Build a Model or Prototype
5. **TEST**
   Collect Data & Evaluate Solution
6. **EVALUATE**
   Optimize & Redesign the Solution
7. **COMMUNICATE**
   Share the Results

(Cont. on Page 8)

GETTING STARTED ...

The Engineering Method *(Cont. from Page 7)*

If the performance of the prototype is too far off from the challenge requirements, your team may have to drop back to the design phase and try a different approach. Be sure your team keeps detailed documentation of the design process and cycle as they work towards completing their competition rocket. All competitors have the option to submit an engineering notebook for a separate prize, regardless of whether their rocket is selected for the national fly-off or not.

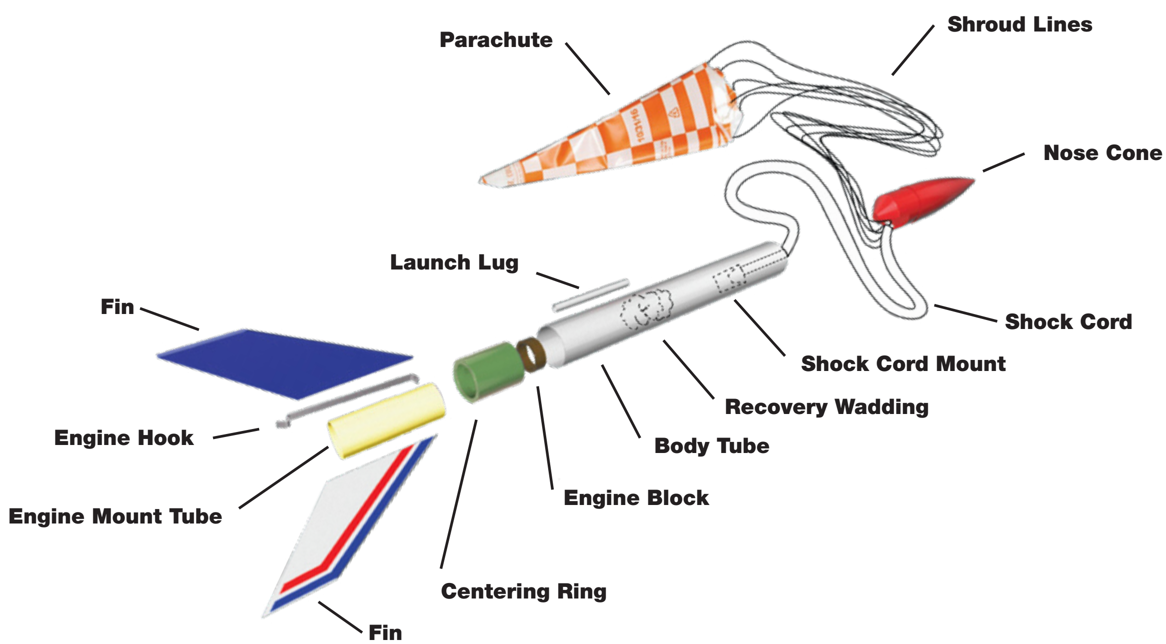
Once you have a satisfactory design that delivers the required performance, your team should build several contest rockets. This way you will have a backup in case something happens to your primary rocket. ▪

WHAT IS A MODEL ROCKET?

Simply described, a model rocket is a reusable flying model of a rocket constructed from lightweight, non-metallic materials that uses pre-manufactured single-use, solid-propellant engines for propulsion.

Regardless of size, most model rockets have the same basic components: a body tube, nose cone (or payload section), fins, engine mount, shock cord and recovery device.

Since the late 1950s, model rocketry has established an excellent safety record due to compliance with the NAR Model Rocket Safety Code made up of easy to follow common sense rules. Refer to pg. 24 for a copy of the code.



Model Rocket Engines

Model rocket engines are manufactured according to exacting standards so their performance is consistent and reliable. Because the engines are manufactured by professionals, the rocket builder does not engage in the inherently dangerous activities of mixing chemicals or packing propellant.

Model rocket engines contain a propellant grain that produces the thrust to propel the rocket. When the propellant is consumed, a slow-burning time delay element ignites.

The time delay element does not produce any thrust to give the rocket time to slow down as it continues to climb. Once the time delay is consumed, there is an ejection charge in the top of the engine to activate the recovery device.

Model rocket engines are rated according to total impulse, which is the product of average thrust times thrust duration.

Model rocket engines use the Metric system of measurement so thrusts are expressed in Newtons. A Newton is the amount of force required to accelerate a 1 kilogram mass at a rate of 1 meter per second per second. For reference, 4.45 Newtons = 1 pound. Total impulse is expressed in Newton-seconds. As the letters progress, the total impulse doubles.

Contest entries are limited to “F” engine power, or 80.00 Newton-seconds. Depending upon the payload requirements for a particular year, contest flights will require rockets in the D – F power ranges.

Challenge rules specify that rockets be single stage, but to reach higher total impulse levels (up to the maximum 80 Newton-seconds allowable) you may cluster two or more engines. Clustering is a technique where multiple engines ignite simultaneously at launch. Examples of full-scale rockets that use clustering include

(Cont. on Page 10)

Letter Code	Total Impulse Range, Newton-Seconds
1/4A, 1/2A	0 – 1.25
A	1.26 – 2.50
B	2.51 – 5.00
C	5.01 – 10.00
D	10.01 – 20.00
E	20.01 – 40.00
F	40.01 – 80.00

Model rocket engines have a three-part letter-number-number code such as “B6-4.” The first part of the code (the letter) designates the total impulse as shown in the table above. The first number in the engine code is the average thrust of the engine in Newtons and the last number is the duration of the time delay in seconds.

Thus, the code B6-4 tells you the total impulse is 5.00 Newton-seconds; the average thrust is 6 Newtons (about a pound and a half); and the duration of the time delay is 4 seconds.

MODEL ROCKET BASICS

Model Rocket Engines

(Cont. From Page 9)

the Saturn V, which had five engine at lift off and the Falcon 9, with nine engines.

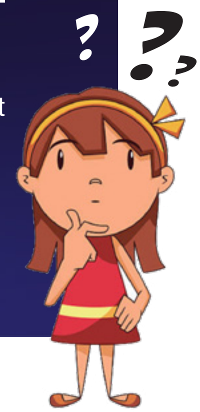
Reliable ignition is the most important part of successful clustering. All engines must ignite simultaneously; this requires a heavy-duty launch controller that can supply high current levels. The 2240 Pro Series II™ Launch Controller delivers enough current for a cluster engine ignition.

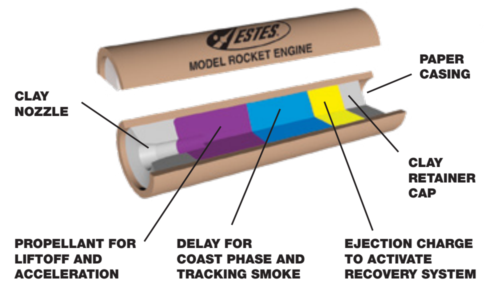
A custom designed controller using a 12 volt car battery for the power supply and heavy gauge wiring is also suitable. Just be sure the launch controller has a safety interlock in series with the launch switch and that the launch switch returns to the "off" position when released, per the NAR Model Rocket Safety Code (Pg. 24).

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

HOW DOES A MODEL ROCKET ENGINE WORK?

1. When the engine is ignited, it produces thrust and boosts the rocket into the sky.
2. After the propellant is used up, the delay is activated, producing tracking smoke and allowing the rocket to coast.
3. After delay, the ejection charge is activated, deploying the recovery system.





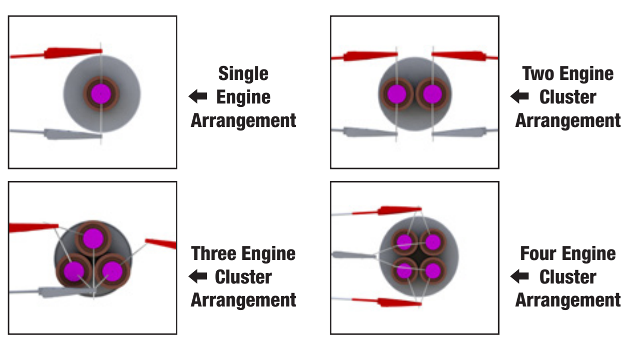
Did You Know?

ESTES MODEL ROCKET ENGINES

Famous for making model rocketry what it is today, the Estes engine started it all in 1958. Since then, Estes model rocket engines have been proven consistent and reliable in over 500,000,000 launches.

Engine Configuration for a Cluster Launch

Attach Micro Clips to Igniter Leads as Shown



Recovery Systems

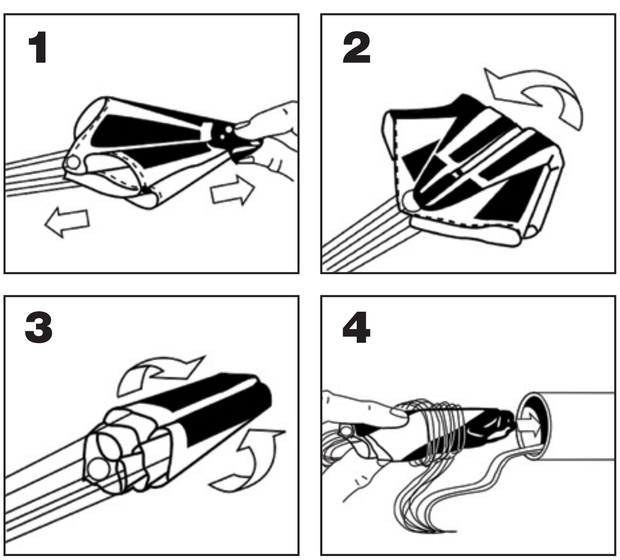
Model rockets must contain a recovery system that safely returns them to earth without damaging them or presenting a hazard to people on the ground. Small lightweight rockets may use a streamer that flutters, tumble, or featherweight recovery. Larger rockets like those built for The American Rocketry Contest use parachutes.

Generally, plastic parachutes are not sturdy enough for heavier rockets so you will want to use a nylon parachute like the Pro Series II™ 24 in. – or 30 in. – parachute. If the flight duration with one of these parachutes is too long, try cutting a "spill hole" in the center of the fabric canopy to increase the descent rate.

RECOVERY WADDING is the term used to describe material that protects the parachute from hot ejection gases. Without recovery wadding, the ejection charge will scorch or melt the parachute. Estes' recovery wadding has been chemically treated to not burn. It will char but will not carry burning sparks back to the ground. Recovery wadding **MUST** be flame proof to prevent grass or brush fires. Regular tissue paper will continue to smolder after ejection and can cause fires. Estes' 3556 Pro Series II™ Recovery Wadding is highly recommended. ▪

To use the recovery wadding, tear the lengths of recovery wadding into individual squares. Crumple the individual squares loosely and insert them into the body tube.

Fill the loosely packed wadding for a depth of at least twice the body diameter. The wadding should fit against the side of the tube all the way round to give a good seal.



1. **To pack the parachute, hold it between two fingers at its center.**
2. **Pass the other hand down it to form a "spike" shape.**
3. **Fold this spike into several sections and loosely wrap the shroud lines around the parachute several times.**
4. **Push the folded parachute down into the tube on top of any remaining shroud lines and shock cord, then slide the nose cone into place. When packed, the parachute should slide smoothly in and out of the body tube.**

MODEL ROCKET BASICS

Launch Pads & Controllers

Just like professional rockets, model rockets are launched electronically from a safe distance. You will need both a launch pad and launch controller. The launch pad includes a launch rod or rail to guide the rocket until it is moving fast enough for the fins to stabilize it. The launch controller provides the electrical current for the starter.

The starter comprises a piece of resistant wire with an insulated coating. When electrical current (usually 6 – 12 volts) passes through the starter, the wire begins to glow and give off heat which ignites the engine.

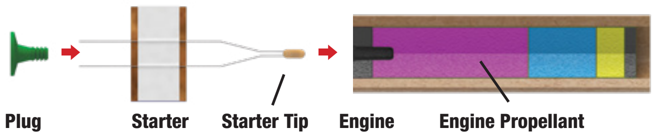
For TARC flights, you will need a launch controller with at least 30 feet of cable. Small rockets (D-power or below) may be launched with a controller like the 2220 Electron Beam® Launch Controller, which has 15 feet of cable. The NAR Safety Code recommends 30 feet of cable for anything with a larger sized engine. If you are planning to fly a variety of model rocket types and power levels, consider the 2240 Pro Series II™ Launch Controller because it will meet all your launch needs.

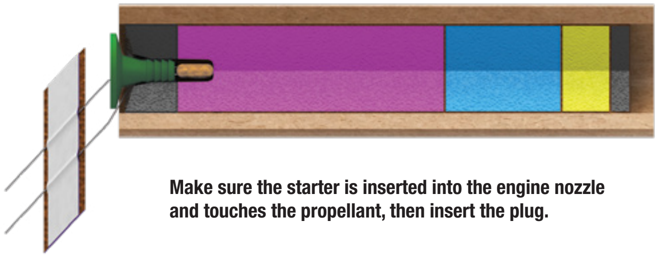
You also have a choice of launch pads. The 2215 Porta-Pad® II Launch Pad will meet your basic needs for rockets powered by 13 mm, 18 mm and 24 mm engines that use either a 1/8-inch or 3/16-inch diameter launch rod. This launch pad isn't suitable for larger rockets, like the ones you will be launching for The American Rocketry Contest; challenge rockets require a 1/4-inch diameter rod or rail launcher for qualifying flights.

Estes offers the 2310 Lifetime Launch System, which includes the heavy-duty Lifetime Launch Pad and 2240 Pro Series II™ Launch Controller. The Lifetime Launch Pad can accommodate 1/8-inch, 3/16-inch, or 1/4-inch launch rods.

You may use a 1/4-inch diameter launch rod for qualifying flights but if your team advances to the national fly-offs, they will need to use a 1-inch launch rail. For convenience, we suggest developing and testing your rocket concept to the desired objective with a 1/4-inch launch rod device, but then complete your "finals" model with rail buttons attached to meet the launch specifications set by The American Rocketry Callenge. ■

Preparing Your Rocket for Launch





Make sure the starter is inserted into the engine nozzle and touches the propellant, then insert the plug.

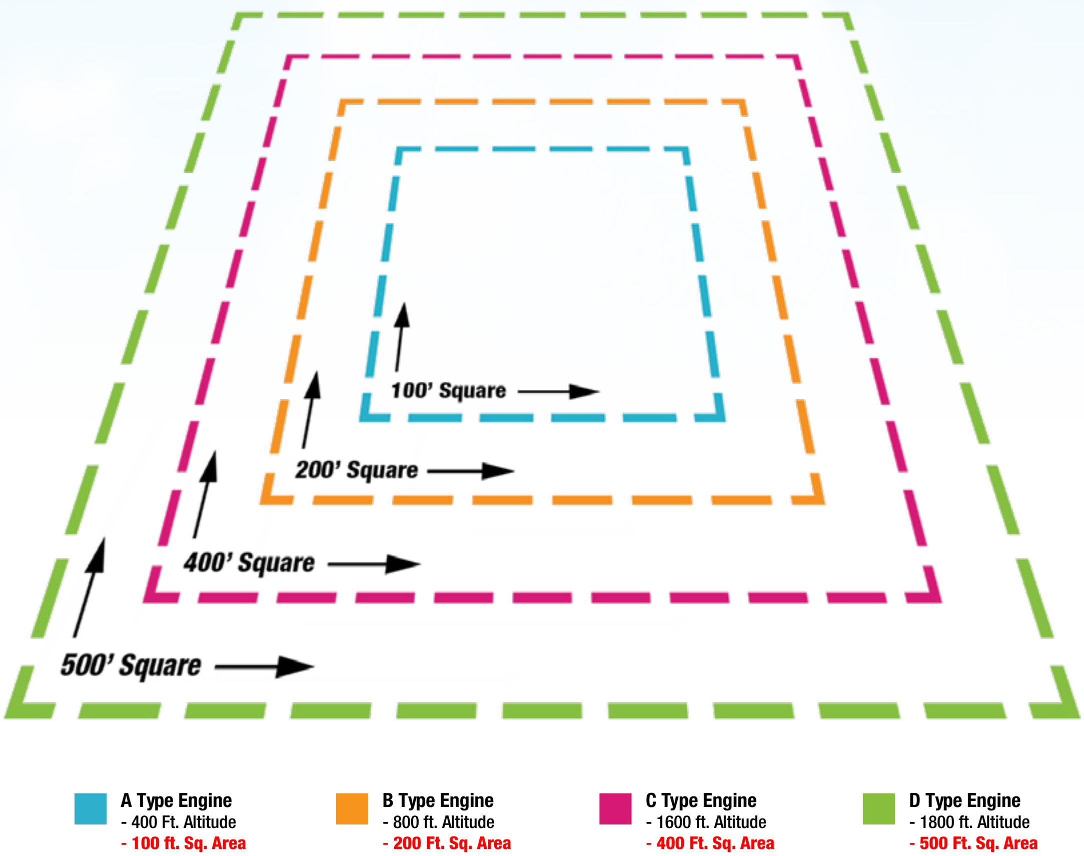
Launch Site Requirements

Choose a large field away from power lines, buildings, tall trees and low flying aircraft. Make sure the launch area is free of obstructions, dry weeds, brown grass or other highly flammable materials.

While a school athletic field is adequate for smaller size rockets, as total impulse and altitude increase so does the need for a larger flying area.

Per the NAR Safety Code, model rockets with a total impulse over 20.01 Newton-seconds (E-power or above) should be launched in a field at least 1,000 feet on a side.

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



DESIGN & CONSTRUCTION

First Kits

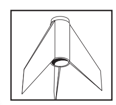
To maximize your student's chance of success, their challenge entry should not be the first rocket they build. A more gradual approach where they learn the fundamentals of model rocketry is highly recommended. For a first rocket, the Generic E2X®, Alpha® or Alpha III® all make excellent choices for a first build. These models are available as single rockets or in packs of 12.

Your students may be eager to put the largest possible engine in their rocket "to see how high it will go," but sometimes it's best to stick with lower power engines for a first flight. An Alpha III® with a C6-5 will easily top 1,000 feet. If you are launching from a school athletic field, there's a strong likelihood the rocket will be lost. An A8-3 is a better choice for a first flight because the rocket will still climb several hundred feet into the air and it can be recovered.

Once your students have built their first rockets, have them progress to a larger rocket. The 1948 Big Bertha® is a great choice for a second rocket. This will "push the envelope" of their experience, letting them move up to B- and C-engine power rockets. The 0651 Der Red Max™ is also a good choice. Progressing to one of these models will let your students gain experience with larger diameter rockets, constructing fins from balsa and more powerful engines. ■

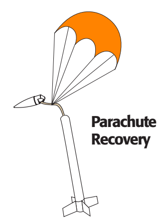
ALPHA III
BULK PACKS

Parachute Recovery

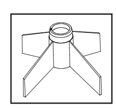


One-piece molded fin unit.

GENERIC E2X
BULK PACKS



Parachute Recovery



One-piece molded fin unit.

Designing Stable Rockets

The most important part of any model rocketry activity is safety. The key to this, the rocket must make a stable, predictable flight. For stability, the center of gravity of the rocket needs to be forward of its center of pressure. By stable we mean that it will tend to keep its nose pointed in the same direction throughout its upward flight. Good aerodynamic stability will keep the rocket on a true flight path even though some force (such as an off-center engine) tries to turn the model off course.

If a model is not stable, it will constantly turn its nose away from the intended flight path. As a result it will try to go all over the sky, but end up going "nowhere." An unstable rocket will usually tumble to earth after the engine burns out, damaging the model. When a free-flying object rotates, it always rotates around its balance point. The proper term for the balance point is the center of gravity, abbreviated as CG. Thus the balance point (CG) is the pivot for all forces trying to turn the rocket.

The center of pressure, or CP, can be thought of as the aerodynamic balance point. The CP is where all the aerodynamic forces acting on a rocket are centered. If a rocket starts to rotate in flight, it will rotate around its CG. So long as the CP is behind the CG, aerodynamic forces will cause it to rotate back to a straight flight. For stability, the CP should be at least one body diameter behind the CG at launch. A great way to practice designing stable rockets is with our 2207 Rocket Stability Kit! The kit comes with everything you need to create, design, and test a rocket - no launch required! Check out the accompanying lesson plan as an activity with your team. ■

Click the link below for more resources on rocket stability

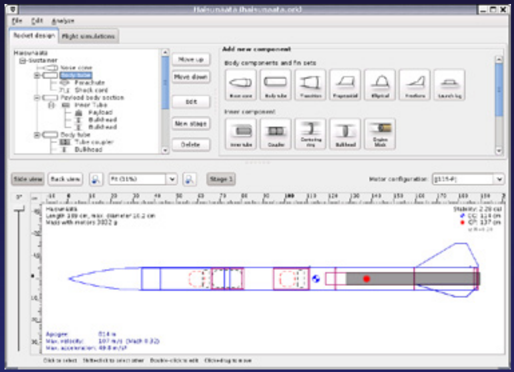
- *Rocket Stability Slide Presentation*
- *How To: Fly With Stability*

Simulation & Prediction

Using a design and performance software program like Open Rocket is very important to a successful TARC program. Open Rocket is easily learned and mastered.

During the design phase, this program is a particularly useful tool. It automatically calculates the center of pressure and center of gravity locations. Thus, you can easily (and safely) eliminate unstable designs before going to the time and expense of building an unsuitable rocket.

The software allows you to select different engines to model the performance of the rocket. This enables you to narrow down the possible engine choices to find the one that is most appropriate.



Download a FREE version of Open Rocket at:
www.openrocket.info

Design & Build a Rocket

The American Rocketry Challenge requires students to design their own rocket that meets the challenge requirements. In other words, commercial kits are not allowed. To gain experience, your students should design and construct a model rocket in the A – C power range before progressing to their final design. The 1980 Designer's Special™ is a great way to gain this experience.

Challenge your imagination!

Designer's Special

The Designer's Special™ contains an assortment of body tubes, nose cones, engine mounts, and other supplies to build at least eight rockets.

Have your students design a rocket using Open Rocket to calculate its center of pressure and center of gravity,and predict its performance. They can build and fly their rocket to see how close their prediction matched actual performance.

DESIGN & CONSTRUCTION

Payloads

The American Rocketry Challenge is a payload-carrying event. Depending upon the challenge, rockets need to carry one or more Grade A raw eggs and an electronic altimeter to record the altitude. Be sure to familiarize yourself with the contest altitude scoring rules and approved altimeters.

During the skill-building phase, the 2246 Estes® Altimeter is a good choice for students. It will automatically record the maximum altitude achieved on the last ten flights. It is rugged and easy to use.

Eggs are fragile, which is the purpose of flying them in model rockets. Being able to launch and recover a raw egg without damage requires skill and knowledge. An egg must be securely contained in the rocket's payload section or nose so that it doesn't bounce around during the flight. It should be cushioned, but not too tightly. The egg should be fully supported at both the bottom and top ends. Foam, paper towels, tissue paper or cotton may all be used as cushioning material. The important thing is to make sure the egg is evenly supported with no pressure points that may cause stress concentrations and damage the shell.

As a practical matter, it's probably a good idea to place the egg in a plastic bag or plastic food wrap just in case the shell breaks so you don't end up with a gooey mess in your rocket.

Estes Industries produces an egg lofting kit that can provide experience for your students on handling, launching and recovering fragile payloads. The 1718 Green Eggs™ Bulk Pack, which comes with 12 kits, is a great choice for contest teams wishing to gain experience. Look for the Green Eggs™ bulk pack online or at your local hobby stores. ▪

DESIGN & CONSTRUCTION

Higher Power 29 mm Motors (Engines)

As your students' skills and confidence progresses, have them advance to D, E, and F-power rockets. The 9720 Doorknob Pro Series II™ kit is a great choice for an E-powered rocket. For TARC, however, even better choices might be the 7293 Olympus™ or the 9719 Pro Series II™ Super Big Bertha®.

The Olympus™ is built from the BT-65 body tube, which is large enough to accommodate an egg and an altimeter. It is also powered by either a D or E engine. The Olympus™ will let your students refine all the skills necessary for The American Rocketry Challenge – egg launching, inclusion of an altimeter, and an E-powered engine. The Pro Series II™ Super Big Bertha®, features a BT80 diameter body tube and is powered by either a E16-4 or F15-6 engine.

The Olympus™ kit is another new addition to the Estes collection, and is available exclusively at Hobby Lobby retail stores. The Pro Series II™ Super Big Bertha® is currently available online or at your local hobby store.

For higher-power models, the white glue that you likely used for the first rockets won't be suitable. Instead, you will need to use wood glue or epoxy. Simply gluing the fins to be body tube like you did with lower power rockets is no longer adequate.

You may have noticed that rockets like the Green Eggs™, Doorknob Pro Series II™, Olympus™ and the Super Big Bertha® all use through the wall fin construction. The fins have a tab on them that extends through a slit cut in the body tube and are attached to the engine mount tube. Through the wall construction maximizes the strength of the fin attachment. ■

Competition Rocket

Congratulations! If you followed our Tactical Plan to The American Rocketry Challenge (p. 20-22), your students will have mastered the basics of model rocketry in a few short months. They'd have built and flown models using A – E powered engines; learned how to design a stable rocket; learned how to predict the performance of a model rocket; and successfully launched and recovered an egg and altimeter.

Now it's time to design a contest rocket and predict its performance. Be mindful of the design parameters for The American Rocketry Challenge such as maximum weight, overall length and any other published criteria. 3-Dimensional printing of parts is allowed as long as the students do the programming and run the printer.

Build the prototype and test it to verify performance. If needed, make any design refinements to your rocket at this time. Be sure to document the changes so you can incorporate them into the competition rockets.

Once you have a prototype that delivers the desired performance, build your competition models. You should have at least three rockets: the primary, a backup, and a spare. Bring all three to any test flying sessions. That way, if anything happens to the primary rocket, you can continue flying that day. ■

RESOURCES

Estes Industries has a variety of products to help you and your students in your TARC pursuit. The web page for educators is www.estesrockets.com/edu/.

Estes sells the latest edition of The Handbook of Model Rocketry by G. Harry Stine and Bill Stine. In its seventh edition, this is the standard reference for model rocketry. You may find this at www.estesrockets.com/product/03-handbook-of-model-rocketry-seventh-edition/.

APPENDIX

TARC: 3-MONTH TACTICAL PLAN

PREPARING FOR THE AMERICAN ROCKETRY CHALLENGE

Ready to take your team to The American Rocketry Challenge? If you're reading this, chances are you're thinking about it or have already registered to take part in this years challenge.

Throughout your contest journey, students, competitors and team leaders will need to think through the various engineering challenges associated with how to design, build, launch and recover a model rocket that meets the objectives of the competition. As you may already know, or can imagine, this is not an easy feat.

This 3-month guide will walk you through the process on how to teach your team the basic principles and working knowledge of model rocketry so they can successfully compete in this year's challenge.

MONTH 1: Understanding Basic Model Rocketry

For those with only a little understanding of aerospace sciences, we suggest beginning the challenge journey by developing some basic model rocket assembly, launching and recovery skills. This will provide a solid foundation on which to begin the larger task of designing and developing a custom-made competition rocket.

Week 1: The first step is to practice basic model rocket building and launching skills. The rockets suggested below can easily be assembled in a short amount of time. When launched with various powered rocket motors (engines), the team will start developing a basic understanding of rocketry. Develop a schedule that will allow for incremental rocket research and development throughout the qualifying season – September through April.

- [ ] **Build and launch your first rocket.**
- [ ] **Use low impulse A and B model rocket engines.**
- [ ] **Start developing data recording skills by having students track peak altitude using an altimeter and a stopwatch to measure the duration of flights.**

Suggested Rockets: 2008 Generic E2X®*, 1256 Alpha III®*, 1225 Alpha®*
Suggested Altimeters: 2246 Estes Altimeter, 2232 Altitrak
** Also available in bulk packs*

Week 2: Competition rockets will have to be large enough to carry a payload. This week, your team should practice building and launching larger rockets to help them better understand what they will need to do to meet competition goals.

- [ ] **Build and launch larger rockets.**
- [ ] **Use low impulse C model rocket engines.**
- [ ] **Continue to record peak altitude and duration of flights.**

Suggested Rockets: 1948 Big Bertha®, 0657 Der Red Max™

Week 3 & 4: Now that your team is familiar with model rocketry basics, it's time to put what they've learned to the test. Acquire a rocket design/performance software such as Open Rocket. This is a robust simulator, however, a beginner rocketeer should get the hang of designing a simple rocket in a short amount of time.

- [ ] **Start working with your team on designing and simulating a basic, stable rocket.**
- [ ] **Construct and test your team's rocket concept using the simulator.**
- [ ] **Compare the simulation rocket with the test results from the previous rocket building and launching experiments. Discuss similarities, differences and if the overall objective was met.**

Suggested Rockets: Simulations in Open Rocket

MONTH 2: Design and Build Your Own Custom Model Rocket

The next phase of the program will focus on developing your own rocket designs and testing the results. Using knowledge gained from building rockets during the first month, coupled with the new computer simulation software, students can begin to create a systematic comparison between predictions and actual results.

Weeks 5-6: Use Open Rocket simulation software to design your own custom, low impulse model rocket.

- ☐ **Design and build a simple, custom model rocket.**
- ☐ **Build your custom rocket from manufactured rocket parts or print your own parts using a 3D printer.**
  (Commercial kits are not allowed at The American Rocketry Contest, however, for your official competition rocket you can use parts from several kits or any part you want from one kit, as long as you don't use one complete kit with minimal modifications. Having parts made on a 3-dimensional printer is permissible as long as the students write the program and run the printer. To learn the basics of 3D printing rocketry parts, check out 1706 Orbis™ 3D.)
- ☐ **Flight test and record your findings using A-C powered engines.**
- ☐ **Evaluate predictions versus real world rocket flight.**

Suggested Rockets: Design and build your own rocket. The Estes 1980 Designer Special contains over 100 useful parts, which can be used to create up to eight individual rockets.

Weeks 7-8: During the final fly-off, a team will be disqualified if their payload (raw egg) is damaged during flight or recovery. Gaining experience with the various aspects of lifting and recovering a fragile payload (raw egg) is key to winning this competition.

- ☐ **Prepare a payload rocket that can hold an egg and altimeter.**
- ☐ **Practice launching and successfully recovering the rocket with the payload intact.**

Suggested Rocket: 1718 Green Eggs™ (Bulk Pack Only)

MONTH 3: Design, Build and Launch Your Competition Prototype Rocket

The final phase of this program is to begin to design, build, launch and recover model rockets that meet actual competition requirements. Practice rocket kits will be larger in size and use higher powered motors (engines). Students will start to test and measure objectives equivalent to what will be needed for their TARC competition rocket.

Weeks 9-10: Students and participants should start to build and launch rockets that have similar design and performance elements required by The American Rocketry Challenge rules and regulations.

- ☐ **Build** – *According to the performance objectives of the event.*
- ☐ **Launch** – *According to the performance objectives of the event.*
- ☐ **Recover Rockets** – *According to the performance objectives of the event.*
- ☐ **Weight** – *According to the performance objectives of the event.*
- ☐ **Length** – *According to the performance objectives of the event.*
- ☐ **Altitude** – *According to the performance objectives of the event.*
- ☐ **Payload and duration of flight** – *According to the performance objectives of the event.*
- ☐ **Familiarize your team with higher-powered, D, E, and F motors (engines).**
- ☐ **Start the process of converting to a rail launch system by adding rail buttons to your rockets.**
  (During your local practice and qualification flights you may use either a rail or a ¼-inch diameter, 6-foot launch rod. However, at the national Finals you will be required to use only a rail, rods will not be permitted.)
- ☐ **Record launch results and compare against design simulation.**
- ☐ **Evaluate the results and use as the basis for your final TARC competition rockets.**

Suggested Rockets: 7293 Olympus™, 9720 Doorknob Pro Series II™, 9719 Super Big Bertha®

MONTH 3: Design, Build and Launch Your Competition Prototype Rocket (Cont.)

Weeks 11-12: It's the final stretch to The American Rocketry Challenge. If you followed through with this plan you and your team should be ready to create a TARC prototype rocket! You should have plenty of data from previous tests which measured how your rockets performed against TARC objectives. Now it's time to finalize your team's design and build a prototype. Launch your prototypes in different weather conditions and times of day. If needed, make adjustments and then test it again.

- [ ] **When your team is satisfied with the final design, build THREE competition rockets.**
- [ ] **Conduct qualifying launches with your mentor and a NAR member.**
- [ ] **Submit qualifying launches to the contest by appropriate deadline.**
- [ ] **Complete your Engineering Manual if your team plans on submitting it for a chance to win an additional prize.**
- [ ] **Take the time to make your mark on The American Rocketry Challenge! Don't forget to paint and decorate your team's final competition rocket. The contest finals can be costly to attend. Teams are permitted to sell decal spots on final competition rockets to help raise money to cover the cost of the competition. Team sponsors may get national coverage if your team qualifies for the Finals or better yet, wins the competition!**

Suggested Rockets: Your team's TARC prototype.

APPENDIX - Additional Resources From Estes®

Estes® Industries Rocket Building Classifications

BEGINNER	A basic entry point for beginning model rocketeers. Can be either almost ready to fly or very easy to assemble with molded and pre-colored parts.
INTERMEDIATE	The next level up from Beginner. Requires some model building and finishing experience. However, rockets in this category can be high performance launch vehicles.
ADVANCED	Rocket kits in this category require more extensive modeling experience to include larger engine sizes, advanced recovery systems, scale and staged rockets.
EXPERT	This category is intended for model rocketeers that have advanced building, finishing and model rocket launching skills though not necessarily just limited to complex scale model rockets.
MASTER	As the name suggests, a master of building and launching techniques of any size model rocket. A dedicated model rocketeer that can tackle any sophisticated model rocket project to an exceptional degree.
PRO-SERIES	Rockets in this category are intended for those rocketeers that have advanced through our lower impulse rockets and are interested in building larger rockets using more powerful 29 mm model rocket engines.

BEGINNER KITS:

2008 Generic E2X®
1256 Alpha III®
2207 Rocket Stability Kitt

BEGINNER - BULK PACKS

1764 Generic E2X® Bulk Pack (12 PK)
1751 Alpha III® Bulk Pack (12 PK)
1706 Orbis 3D Bulk Pack

INTERMEDIATE KITS:

1225 Alpha®
1948 Big Bertha®
0657 Der Red Max™

INTERMEDIATE - BULK PACKS

1756 Alpha® Bulk Pack (12 PK)
1718 Green Eggs™ Bulk Pack (12 PK)

ADVANCED KITS:

7293 Olympus™

EXPERT KIT:

9720 Doorknob Pro Series II™

PRO-SERIES KIT:

9719 Super Big Bertha®

LAUNCH SUPPLIES:

2310 Lifetime Launch System
2222 Porta-Pad® II Launch Pad & Electron Beam® Launch Controller
2215 Porta-Pad® II Launch Pad
2220 Electron Beam® Launch Controller
2240 Pro Series II™ Launch Controller
3556 Pro Series II™ Recovery Wadding
2246 Estes® Altimeter
2232 Altitrack™

*(**NOTE:** Estes® Altimeter does not meet the criteria set by the contest for altitude monitoring. It should only be used in introductory launches as a resource.)*

ROCKET PARTS:

1980 Designer's Special™
2261 Pro Series II™ 24 inch Nylon Parachute
2273 Pro Series II™ 30 inch Nylon Parachute

*(**NOTE:** Estes kit rockets (including Master Kits) do not meet the criteria set for The American Rocketry Challenge and are only suggested to offer introductory rocketry and building experiences.)*

APPENDIX - Additional Resources From Estes®

Estes® Engine Specifications & Performance Chart

- Delays have a tolerance of plus or minus 10% or one second, whichever is greater.
- All Estes engines come complete with starters and starter plugs. The Estes starter plug makes engine ignition extremely reliable

Prod. No.	Engine Type	Total Impulse	Time Delay	Est. Max. Lift Wt.		Max Thrust		Thrust Duration	Initial Weight		Propellant Weight		Quantity per Pack
		N-sec	Sec	oz	g	Newtons	lbs	Sec	oz	g	oz	g	
SINGLE STAGE ENGINES													
1502	1/4A3-3T	0.625	3	1.0	28	4.90	1.1	0.25	0.21	5.9	0.05	1.3	4
1503	1/2A3-2T	1.25	2	2.0	57	8.30	1.9	0.30	0.23	6.4	0.07	1.9	4
1507	A3-4T	2.50	4	2.0	57	6.80	1.5	0.60	0.28	8.0	0.12	3.3	4
1511	A10-3T	2.50	3	3.0	85	13.00	2.9	0.80	0.29	8.1	0.12	3.5	4
1593	1/2A6-2	1.25	2	2.0	57	8.90	2.0	0.30	0.48	13.6	0.10	2.7	3
1598	A8-3	2.50	3	3.0	85	10.70	2.4	0.50	0.55	15.5	0.14	4.1	3
1601	B4-2	5.00	2	4.0	113	13.20	3.0	1.10	0.66	18.6	0.27	7.6	3
1602	B4-4	5.00	4	3.5	99	13.20	3.0	1.10	0.68	19.2	0.27	7.6	3
1605	B6-2	5.00	2	4.5	127	12.10	2.7	0.80	0.61	17.3	0.23	6.5	3
1606	B6-4	5.00	4	4.0	113	12.10	2.7	0.80	0.63	17.8	0.23	6.5	3
1613	C6-3	10.00	3	4.0	113	15.30	3.4	1.60	0.83	23.4	0.43	12.2	3
1614	C6-5	10.00	5	4.0	113	15.30	3.4	1.60	0.85	24.0	0.43	12.2	3
1522	C11-3	10.00	3	6.0	170	22.10	4.9	0.80	1.13	32.1	0.44	12.4	2
1523	C11-5	10.00	5	5.0	142	22.10	4.9	0.80	1.18	33.4	0.44	12.4	2
1566	D12-3	20.00	3	14.0	396	32.90	7.4	1.60	1.57	44.5	0.85	24.2	2
1567	D12-5	20.00	5	10.0	283	32.90	7.4	1.60	1.61	45.7	0.85	24.2	2
1692	E12-4	30.00	4	17.0	482	30.60	6.9	2.70	2.16	61.2	1.3	36.9	3
1693	E12-6	29.50	6	14.0	397	29.60	6.7	2.70	2.23	63.2	1.3	36.9	3
1651	F15-4	49.61	4	21.0	595	25.26	5.7	3.45	3.59	101.5	2.12	60	2
1652	F15-6	49.61	6	17.0	482	25.26	5.7	3.45	3.66	103.7	2.12	60	2
1696	E16-4	33.68	4	20.0	566	26.44	5.9	2.09	2.86	81.0	1.41	40	2
1697	E16-6	33.68	6	16.0	453	26.44	5.9	2.09	2.92	82.7	1.41	40	2
UPPER STAGE ENGINES													
1504	1/2A3-4T	1.25	4	1.0	28	8.30	1.9	0.30	0.23	6.6	0.07	1.9	4
1599	A8-5	2.50	5	2.0	57	13.30	3.0	0.50	0.55	15.7	0.14	4.1	3
1607	B6-6	5.00	6	2.5	71	12.10	2.7	0.80	0.64	18.2	0.23	6.5	3
1615	C6-7	10.00	7	2.5	71	15.30	3.4	1.60	0.85	24.3	0.43	12.2	3
1524	C11-7	10.00	7	4.0	113	22.10	4.9	0.80	1.19	33.8	0.44	12.4	2
1568	D12-7	20.00	7	8.0	226	32.90	7.4	1.60	1.62	46.0	0.85	24.2	2
1694	E12-8	29.80	8	12.0	340	31.80	7.1	2.70	2.24	63.5	1.3	36.9	3
1653	F15-8	49.61	8	15.0	425	25.26	5.7	3.45	3.69	104.4	2.12	60	2
1698	E16-8	33.68	8	14.0	396	26.44	5.9	2.09	2.99	84.7	1.41	40	2
BOOSTER STAGE ENGINES													
1510	A10-0T	2.50	NONE	4.0	113	13.00	2.9	0.80	0.24	6.8	0.12	3.5	4
1600	A8-0	2.50	NONE	3.0	85	13.30	3.0	0.30	0.47	13.5	0.14	4.1	3
1608	B6-0	5.00	NONE	4.0	113	12.10	2.7	0.80	0.55	15.7	0.23	6.5	3
1616	C6-0	10.00	NONE	4.0	113	15.30	3.4	1.60	0.76	21.4	0.43	12.2	3
1521	C11-0	10.00	NONE	6.0	170	22.10	4.9	0.80	1.03	29.2	0.44	12.4	2
1565	D12-0	20.00	NONE	14.0	396	32.90	7.4	1.60	1.43	40.4	0.84	23.8	2
1691	E12-0	28.80	NONE	16.0	454	31.30	7.0	2.60	2.05	58.1	1.3	36.9	3
1650	F15-0	49.61	NONE	19.0	539	25.26	5.7	3.45	3.32	94.0	2.12	60	2
1695	E16-0	33.68	NONE	18.0	509	26.44	5.9	2.09	2.58	73.2	1.41	40	2
PLUGGED ENGINES - FOR USE WITH ROCKET-POWERED RACERS & R/C ROCKET GLIDERS													
1505	A10-PT	2.50	NONE	3.0	85	13.00	2.9	0.80	0.26	6.83	0.13	3.5	4

The data listed above is from randomly chosen production samples. NOTE: The "T" designates a mini-engine.

⚠ WARNING:
This product can expose you to silica, which is known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

This warning is on all Estes engine packaging.

APPENDIX

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 accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour 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