BOONE COUNTY 4H AEROSPACE PROJECT

"ROCKETRY 101"

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Purpose

This is a guidance document for 4H kids and parents to help them understand the Aerospace Project and how to build and launch rockets in an enjoyable and safe manner. Aerospace and model rocketry are an interesting field of study and hobby, so it would be impossible to capture all there is to know in this one handout. However, this should be enough to get you started, and ALWAYS feel free to call the Project Leaders if you have any questions.

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4H Project Requirements

General Requirements (all age groups)

1. Build, launch and recover a model rocket following the design criteria specific to the 4Her's age group.
    a. Take a photo of the rocket on the launch pad prior to launch and another photo of the rocket after the launch.
    b. The photos are to be taped on two edges and taped to the back of the record sheet.
    c. The rocket you launch DOES NOT have to be the same rocket you exhibit, but it DOES need to meet the exhibit requirements.
2. Exhibit one model rocket built by the 4H member following the design criteria specific to the 4Her's age group
    a. Rockets must have a display stand which is NOT a launch pad/rod, unless the rocket design is such that it will stand vertically on its own.
    b. The exhibit should be flight ready (include recovery wadding) except DO NOT include a live motor
    c. No rockets requiring a G motor or larger are permitted
    d. No "ready-to-fly" (RTF) models are permitted
    e. The schedule for turning in exhibits can be found in the fair catalog you will get from your township club leader
3. When the rocket is turned in, also turn in the following:
    a. Completed record sheet with leader and parent signatures
    b. The activity manual with three completed activities
    c. In place of the activity manual, the 4Her has the option to instead write a 200-250 word report on any aerospace topic
    d. If for some reason, you don't turn in an exhibit, you should still complete a record sheet and activity manual to get full credit for completing the project
    e. The record sheet and activity manual are obtained from your township club leader

Beginner (grades 3-5) Specific Requirements

Build, launch and exhibit a rocket that meets at least one of the following design criteria.
    a. streamer recovery
    b. tumble recovery
    c. uses a mini-motor (for example, ¼ A3-3T, ½ A3-2T, A3-4T)

A different rocket must be exhibited every year.
[Beginner activity manual : Stage 2 "Lift Off" (BU-6843)]

Intermediate (grades 6-8) Specific Requirements

Build, launch and exhibit a rocket that meets at least one of the following design criteria.

a. parachute recovery
b. powered by A, B or C motor
c. multi-stage rocket

A different rocket must be exhibited every year.
[Beginner activity manual : Stage 3 “Reaching New Heights” (BU-6844)]

Advanced (grades 9-12) Specific Requirements

Build, launch and exhibit a rocket that meets at least one of the following design criteria.

a. scale model of an actual rocket or missile (fictional scale models such as Star Wars or Star Trek spaceships do not qualify)
b. a special project model chosen by the Project Leader
c. powered by at least a D motor but no more greater than an E motor

A different rocket must be exhibited every year.
[Beginner activity manual : Stage 4 “Pilot in Command” (BU-6845)]

Exhibit Judging Guidelines

The most important part of the 4H experience above all else is the social and leadership skills that come from interacting with other 4Hers and volunteers during club activities, workshops, and fair events. One of the next most important things about 4H is the learning that takes place from completing projects. Completing projects teaches the 4Her responsibility in following through on something they said they were going to do. It also teaches other more technical skills that might in later life translate into decisions about a career path.

We exhibit projects at the fair because some competition can be fun, when taken in the right positive spirit. It is also a way for the 4Her to assess how well they have learned the technical skills being taught in a project. The most important thing about exhibiting a project is not whether the 4Her got a blue ribbon, but if they learned something in the process. If a 4Her got a lower ribbon, but they learned from their mistakes, that is still a great outcome. Sometimes the lessons we learn from initial shortcomings are the lessons that stick with us the best.

That being said, there are still occasional questions from 4Hers and parents about what exactly the judge will be looking for in order to award a certain ribbon. Here are the guidelines which judges in Boone County are given when making a decision about awarding ribbon grades.

Honor group : The exhibit is extremely well constructed and has a been very well painted and finished.

Blue: The exhibit has been painted and finished, and the 4Her has done a good job on the construction of the rocket (no question about being flight worthy).

Red: The exhibit is not painted and finished, or the rocket has been constructed in such a manner that it is questionable whether it is flight worthy. Some examples of not being flight worthy are: fins crooked or not spaced properly, very weak glue joints, improperly constructed recovery system, nose cone too tight, etc.

White: The exhibit is missing major functional components necessary for flight. For example: missing recovery system, missing motor tube, missing thrust ring, etc.

Other tips for exhibitors:

If there is something unusual or unique about your rocket design, you may want to include a note on a 3"X5" note card letting the judge know. An example might be to let the judge know what size motor it flies with, if it uses an unusual recovery system, or if it launches using a launch rail instead of a launch rod. If it is a scale model you might want to include info about the rocket or missile from which it is a scaled-down version.

You won't be rewarded by the judge for attempting to build a very complex model, unless it is done well. It is better sometimes to exhibit a model that you know you can do well than tackle something that you know you are not ready to do well yet. It is not always the most expensive kit at the fair which gets the best ribbon, but the most well done kit.

Report Topic Ideas

Instead of the three activities from the activity book, a 4Her may choose to write a 200-250 word report on any aerospace topic instead. This could be a report done for school. Here are a few ideas for report topics.

1. Write a report on any famous figure in aviation/aerospace history
2. Write a report on any famous civil aviation or military aircraft
3. Neil Armstrong, Gus Grissom, Amelia Earhart and the Wright brothers are all important figures in aerospace/aviation history with Indiana ties. What did these people do and what are their Hoosier ties?
4. There are many famous women or minority people who have played significant roles in aviation/aerospace history such as Amelia Earhart and the Tuskegee Airmen. What have their contributions been?
5. Watch the movie "October Sky". What did the Coalwood boys learn about rocket design and flight? What things did they do which would not be allowed by the NAR Safety Code?
6. Write a report on a famous space disaster such as the Apollo 13 mission, the space shuttle Columbia or Challenger, or the fire that killed Gus Grissom. What went wrong and how did NASA learn from their mistakes?

7. Interview someone you know who works in the aviation industry such as an airline pilot, someone who is in the US Air Force, an air traffic controller, an airplane mechanic, a helicopter pilot, or a crop duster.
8. Investigate what sort of college degree programs there are at Purdue University which are related to the aviation/aerospace industry.
9. Visit an aviation museum such as the air museum at Grissom Air Force Base, or at Dayton, Ohio. What did you see and learn?
10. Attend an NAR sponsored high-powered rocket launch. Talk to some of the hobbyists and ask questions. What did you see and learn?

Getting Started in Model Rocketry

Rocketry can progress from being a "toy" that provides fun for a few minutes, to a long-term hobby, to a professional career. You will choose which of these fits your interests. In 4-H, we discourage the "toy" thinking, because no learning takes place. We promote the "hobby" as an activity that 4-H members and parents can do together.

The minimum equipment you need to put a model rocket in the sky is: (1) a rocket; (2) a rocket motor; (3) a launch system. Rockets can be purchased a "ready to fly (RTF)" where no assembly is required or as kits which include parts and instructions for assembly. Kits have varying degrees of difficulty, so look for the "Skill Level" on the kit before purchasing it. Young people should spend a year (or two) building Skill Level 0 or 1 kits before moving up. Skill Level 3 kits require a good deal of patience and manual dexterity. Skill Level 4 and 5 kits are very demanding, and usually contain intricate details and paint patterns that require masking and multiple colors. Buying a Skill Level 3 kit for a first-year builder is a recipe for frustration. As your skills increase and your understanding of flight stability deepens, you can buy parts from vendors and build your own kits. This lets you express your creativity in design, and many older hobbyists find this very rewarding.

How Much Does This Hobby Cost?

Model rocketry has an "initiation" cost of approximately $30. This buys a Starter Set that includes a rocket, launch system, and a couple of motors. This is a simple way to get started in rocketry, especially if you don't have anyone around to help you. The launch system works fine for beginners, but as you learn more, you'll probably want to make your own system. But that comes later.

After you have the launch system, you can start purchasing kits and motors separately. Rocket kits will usually be in the $8-20 range, but can go as high as $40-80 for larger, more complex kits. Rocket motors are usually packaged in sets of 3 for $5-8, depending on the motor's total impulse ("C" motors are more expensive than "A" motors). This does not include the cost of building supplies like glue, paint and such.

If you plan to launch rockets on a regular basis, it is very helpful to create a "flight box". This is a fishing tackle box, sewing box, or some other small box that makes a convenient

place to store rocketry supplies that you need at the launch range. Some people also put their building supplies in the box. A well-equipped flight box can set you back $50-100 if you buy all new tools and supplies, but many people use tools they already have. See the section on "Making a Flight Box" for additional information and tool ideas.

Model Rocket Safety

Before we discuss risks, let's put rocketry risks in perspective. If you follow the safety code, your risk of being hurt in any way is less than 1 in a million. To date, there have been no deaths attributed to hobby rocketry since commercial motors became available (there were many deaths and dismemberments when kids were trying to make their own motors in 1950's prior to commercial motors being available). In context: a child is FAR more likely to be hurt playing a sport than by flying model rockets. It's really that safe.

Rocketry is safe because the national rocketry organizations all emphasize safety. Model rocketry has been around for a long time now, and the experiences of many model rocketeers over the years has led to development of tried-and-true safety practices. The National Association of Rocketry (NAR) publishes a Model Rocketry Safety Code (which we follow in 4-H). 4H member and parent alike should read (and re-read) the code before launching any rocket. With practice, the code will become second nature to you.

The greatest risk when handling model rockets is igniting a motor while your hands are on it (or near it). To reduce this risk, we use an igniter that is electrically activated, so everyone can be a safe distance from the rocket. We don't connect the electrical system to the igniter until the rocket is on the launch pad. To prevent someone from igniting the motor while connecting the electrical system to the igniter, we have a removable safety key—once removed, nobody can ignite anything. At 4-H launches, we have a person entirely dedicated to range safety, watching to see that nobody creates an unsafe condition. Igniting a rocket motor while near it could create severe buns on the hands and wrists.

Another risk with rockets is having the rocket hit a person while either in flight, or while descending under parachute. Hitting a person is not easy to do and requires two things to happen at once: (1) rocket becomes unstable in flight due to bad design, loss of fins or motor failure, and (2) people on the ground did not move because they were seated or not watching the flight. Remember, to avoid being hit, you only have to move 1 step to the side and you're safe. The Safety Code requires rockets to be made of lightweight materials like cardboard and wood. When lightweight rockets hit anything, they simply disintegrate rather than damaging the object they strike. Mark Newton says, "I've seen one flight where a person was hit, when a rocket lost a fin while under thrust. The rocket struck the person standing 50 feet away and the person was not injured."

Rockets descending under parachute can hit a person or vehicle, but they should cause little damage if they are lightweight rockets and have a properly sized parachute. The most likely damage, if any damage at all, is a scratched paint spot on a vehicle.

Remember when a rocket is descending that it is always best to let it hit the ground rather than try to catch it in mid-air.

The chance of personal injury from model rockets is remote, but the risk rises as the rockets get larger, heavier, and faster. Rockets weighing more than one pound and using motors larger than E have greater risks, and require more distance from the launcher and people watching the launch so they can move if necessary. The range safety officer (RSO) will determine when rocket flights deserve an extra measure of safety and will inform viewers prior to the flight.

In summary, there are some risks in rocketry but when the Safety Code is practiced, the risks are small and the chance of injury is remote. Rocketry is a safer hobby than any organized sport.

National Association of Rocketry (NAR)
Model Rocketry Safety Code

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

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.

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.

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.

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.

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.

National Association of Rocketry (NAR)
Model Rocketry Safety Code, continued

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. If my model rocket weighs more than one pound (453 grams) at liftoff or has more than four ounces (113 grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

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.

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. 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.

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.

Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.

LAUNCH SITE DIMENSIONS

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

Where to Buy Rockets

Rocket kits can sometimes be purchased locally at places like Hobby Lobby and Michael's. These stores are accessible and offer competitive prices, but have a relatively small selection of rockets (usually just Estes rocket kits).

Other local hobby shops may have a wider selection of kits and supplies. One of our local favorites is a northeast-side Indianapolis hobby shop called HobbyTown USA. Its address is 8326 Castleton Corner Drive (phone 317-845-4106). It is located just northeast of Castleton Mall, next to Half-Price Books.

Another way to obtain unique kits, still often at a competitive price is through the internet. There are many small "mom & pop" type small businesses out there that are run by folks that are active model rocket enthusiasts. Many of their kits are unique products which they have created. The following table lists some of these internet-based vendors that you are encouraged to check out.

DEALERS	COMMENTS
Aerospace Specialty Products P.O. Box 1408 Gibsonton, FL 33534 Ph 813-741–0032 www.asp-rocketry.com	Sells scale model kits you can't find anywhere else. Also books, competition kits, T-shirts/hats, glues, and other stuff. Has a good selection of parts (tubes, nosecones, etc) at reasonable prices—cheaper than Estes stuff, for sure.
Apogee Components 3355 Fillmore Ridge Heights Colorado Springs, CO, 80907 Ph 719-535-9335 www.apogeerockets.com	Carries a large selection of education materials. Has a nice set of quick-time videos on a CD/ROM that teach skills for Level 1 modelers, and several books as well. Has several unique kits, such as helicopter recovery, gliders, and some fantastic scale models. Sells the best rocket design/ simulation software around—Rocksim. The owner, Tim Van Milligan, is also a long time NAR competitor, and publishes a FREE e-newsletter on rocketry. Will also answer your rocketry questions.
Balsa Machining Services 11995 Hillcrest Dr. Lemont, IL 60439 630-257-5420 www.BalsaMachining.com	Makes balsa (or basswood) nosecones in sizes up to 4". The owner has a laser cutter, and makes centering rings and fins as well. He can make custom fins, rings, and nosecones. He also sells body tubes. This is a great place to get parts if you want to design your own rockets. SELLS KITS TOO!

DEALERS, CONT'D.	COMMENTS
FlisKits, Inc. 6 Jennifer Drive Merrimack, NH 03054 (603) 494-1145 www.fliskits.com	Jim Flis carries a wide assortment of model rocket kits, including the famous Deuces' Wild cluster rocket. Great customer service, fair prices, and good quality of materials. Even has some free stuff to download. Very unique model designs.
Pemberton Technologies 2330 HWY 321 N Ward, AR 72176 (501) 843-5009 www.pembertontechnologies.com	A relative newcomer. This company has some kits which are unique in design, and would be good for the intermediate or advanced member. The 4Her will will want to select one of the Low power kits. BETTER FOR ADVANCED LEVEL
Pratt Hobbies 2513 Iron Forge Rd Herndon, VA 20171 Ph 571-221-5820 www.pratthobbies.com	Maker of the Super Six kit which we have used for beginner's workshops. Doug Pratt sells a number of kits, as well as unique items like Kevlar line, Nomex protectors, electronics, and his famous, "Rocket Scientist" T-shirts. Great customer service and quality.
True Modeler's Rocket Kits P.O. Box 186 Harbeson, DE 19951 www.truemodeler.com	Mark Henning has several scale model kits for sale, like the NASA Scout, Nike-Smoke, Juno 1 (beautiful kit!). His kits are a little more expensive, but he uses good quality materials—will not disappoint you.

Making a Flight Box

This paper provides some items you may want to purchase when you are ready to create your box. As your building skills improve, you will reach a place where you'll want to create a "flight box" to keep spare parts, motors, and building tools in a convenient location. The things in your flight box are the things you need to launch and repair rockets on the launch range. Flight boxes range from a shoebox, to a carpenter's box, to a multi-drawer tool box. Fishing tackle boxes or sewing boxes make good flight boxes, too, because they have lots of slots to store small items. The amount of tools you want depends a lot on the type – and size – of the rockets you build.

Recommended Flight Box Items

Baby Powder	Buy talcum powder, not corn starch powder. Put talc powder on plastic parachutes before launch to make them open easily. A small bottle is about $1, and will last a couple of years in normal use.
Bag of Wadding	Get some blown cellulose insulation and put it in a small Zip-lock bag. A "cube" of blown insulation can be purchased at a lumber center, and will last for years. Or get a handful from your attic.
Extra Shock Cord	You may need an extra cord if your rocket separates in flight. You can buy stretch nylon at Wal-Mart in the craft section. It costs about $1 for 12 feet of cord.
Snap Swivels	Carry a package of snap swivels. Use them on the end of your parachute to make it removable. Buy snap swivels in the fishing section of Wal-Mart for less than $1 a pack.
Cellophane Tape	A multi-purpose tool, friction fits motors in lightweight rockets, repairs tears in plastic parachutes, etc. The glossy tape is usually better for rocketry purposes.
Masking Tape	Again, a multi-purpose tool for friction-fitting nose cones, rocket engines, etc. You might even want to buy different widths, like ½ inch and 1 inch to carry in your box.
Hobby Knife (X-Acto Knife)	Cut tape, remove damaged areas, etc. Never go to the flight range without a hobby knife!
Extra Igniters	You never know when an igniter will fail. Estes sells extra igniters for $4 a package.
Yellow Glue	Keep a small bottle of yellow glue to re-attach paper or balsa fins. However, on the flight range, cyanoacrylate glue (below) is faster and just as strong.
Cyanoacrylate (CA) Glue	Also called "super glue". Great for field repairs of damaged rockets. It bonds almost instantly and is as strong as yellow glue. CA can be purchased in thick or thin formulas. Thin is best for most rocketry applications. A small bottle is sufficient for any flight box. (Wal-Mart sells a small bottle for about $3).
Pen and Pencil(s)	A necessary tool we often overlook.
Ruler	A good steel ruler (available at office supply stores) is useful for marking straight lines and making a straight edge when cutting a line with a hobby knife.
Pliers	Nothing else is as nice for pulling out hard-to-grasp friction fit motors than a good pair of pliers. Don't cheat yourself—go buy a good pair. They will cost $7-12, but they have better teeth to get a good grip on motors, etc.
Screwdriver (long)	You won't use it as a screwdriver nearly as much as you will use it to push things in (or out) of rocket body tubes. You could substitute a long dowel rod.
Clothespins or Alligator Clips	Clip them on the launch rod to hold up a rocket so it doesn't slide to the bottom of the launcher. They also work as clamps when holding parts together.
Silicone spray and a small scouring pad	Spray a little silicone on your launch rod, then scrub the rod with the scouring pad. Wipe it with a piece of tissue or a rag, and you have a smooth launch rod. Put silicone on rods before storage—prevents rust.
Sandpaper	A few small pieces of 150, 220 & 400 grit paper are handy to sand broken areas before repair, sanding off rusty/dirty launch rods, & making tight things fit together.
Chalk line powder or Tempera paint flakes	A squirt of chalk line powder or tempera paint flakes inside the rocket just before inserting the nose cone provides a visible "puff" when the nose is ejected from the rocket. This greatly aids tracking and recovery. Use dark red, black, or fluorescent orange colors—they are more visible. Wipe the rocket after each flight with soap/water to remove the dust, or it may become permanent. A neat trick is to put the puff of chalk inside a square of flameproof wadding and fold over the corners. This keeps the chalk from going everywhere until it is out of the rocket.
Extra parachutes	If possible, buy an extra 12, 18, and 24 inch parachute at a hobby shop. Make each parachute, fold, and place it in a small zip-lock baggie inside your box. This will permit you to change parachutes if wind conditions change.

Additional Information Sources

If you were only permitted to have one book for rocketry, the book would be the Handbook of Model Rocketry by G. Harry Stine. It can be purchased online at Amazon.com, and probably by special order if you ask at a Barnes & Noble or Borders store. It is pricey at $25 for a paperback, but a wealth of information and easy reading too. You might be able to get a used earlier edition copy at Amazon for a bit cheaper. The older editions are almost as good as the newest and still worth owning. Everybody in rocketry should own this book!

For additional information, get books from Apogee Components (*www.apogeerockets.com*). Tim Van Milligan's book, Model Rocket Design and Construction is very similar to the Handbook of Model Rocketry (and priced similar). The Apogee website has lots of good educational information and there is a free newsletter you can receive by registering online. Tim Van Milligan is also good at answering questions, and he likes to help young people in rocketry.

NASA's Jet Propulsion Laboratory web site (*www2.jpl.nasa.gov*) has a wealth of information about space travel and astronomy. Their manual, *Basics of Space Flight,* is a great introduction to space, and some of the details involved in interplanetary missions (*www2.jpl.nasa.gov/basics*). The manual can be read online or can be downloaded as a pdf file. Beware the pdf file is about 6 Mb though.

To exchange information and ask questions, the Rocketry Forum (*www.rocketryforum.com*) is a recommended site. Teenagers and adults both post information here. You can browse as a guest, but you need to register with the webmaster to add entries (it's free and fast). Several different forums are here, and the participants are nice (not true for all forums). Another online source of rocketry information is INFOcentral (*www.info-central.org*), a part of Rocketry Online (*www.rocketryonline.com*). INFOcentral has good information on numerous rocketry topics, including construction, design, and regulations. It also has information about larger (high powered) rockets that you can fly after you've turned 18 years of age.

Then of course, there is the National Association of Rocketry (NAR) website, *www.nar.org*.

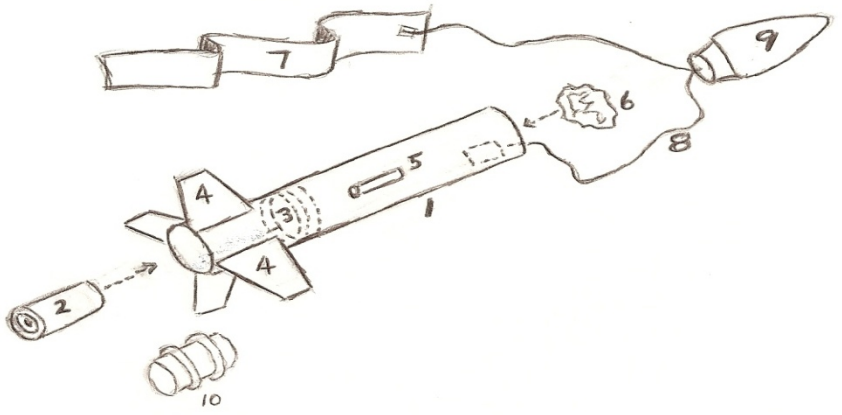
Local (Non-4H) Rocket Clubs

There are a few local rocket clubs organized and operated by adult hobbyists. As the saying goes, "the bigger the boys, the more expensive the toys" and if you attend one of these clubs' launches, you can be treated to seeing some rather large, high altitude, high-powered rockets being launched. The nearest Indiana NAR chapter is the Rocketeers of Central Indiana (ROCI). Their website is *www.indyrockets.org* and if you look at their calendar page, you can see when they are having launch events. ROCI hosts launches at the AMA Aeromodeling Center near Muncie about once a month during warmer weather months. Kids under 18 are allowed to launch at these events for free.

Parts of a Rocket

The drawing below shows the parts which must all be assembled properly for your rocket to have a good flight

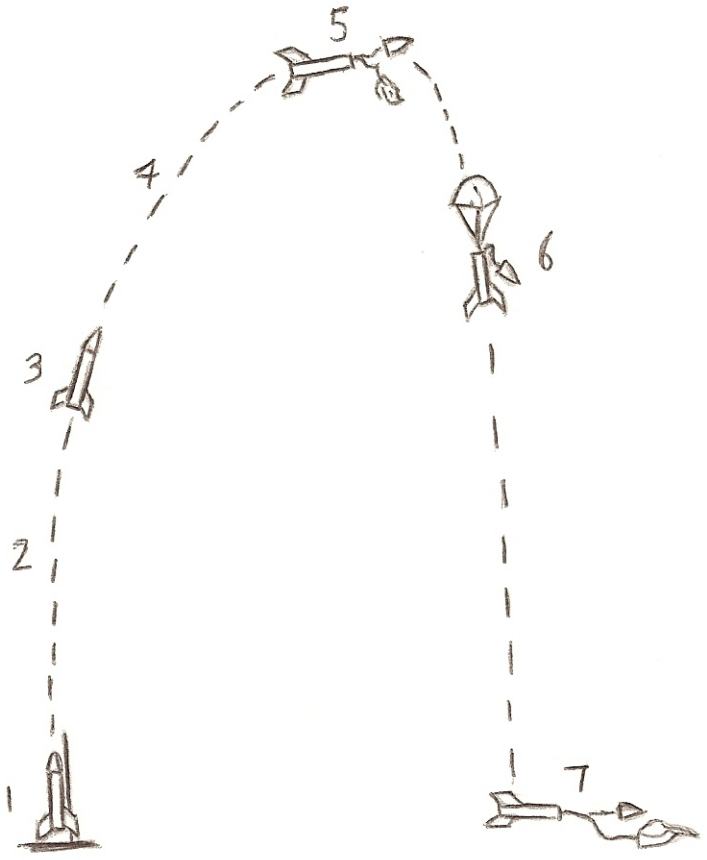
1. **Body tube** – This is the main body or "fuselage" of your rocket. All other components are attached to it.
2. **Motor** – This is what powers your rocket in flight after it ignites
3. **Motor Mount (or Thrust Ring)** – This is what keeps the motor stationary during flight. Without this, the motor would shoot up through the body tube without the rocket ever leaving the launch pad
4. **Fins** – The fins are the balsa wood or plastic blades attached to the aft part of the body tube which allow your rocket to fly in a nearly straight trajectory
5. **Launch Lug** – This is the small lightweight plastic tube attached to the outside of the body tube to guide the rocket up the launch rod
6. **Ejection Wadding** – This is the loose flame proof material stuffed in the body tube between the motor and the recovery system. It is installed in the tube loosely enough that it is ejected along with the recovery system when the ejection charge blows from the top end of the motor. Without the wadding, the hot gas from the ejection charge could melt or burn the plastic streamer or chute, and the shock cord.
7. **Recovery System** – This is the parachute or streamer which is attached to the shock cord. When it is ejected, it unfolds and causes enough drag so that the rocket drifts slowly and safely to the ground.
8. **Shock Cord** – This is the elastic cord which attaches the recovery system and nose cone to the body tube so that all the pieces come down together.
9. **Nose Cone** – This is the bullet-shaped tip of the rocket which must be removable so that the recovery system can deploy when the ejection charge blows
10. **Motor Tube** – If the motor has a smaller diameter than the body tube, then the motor tube is glued in the aft end of the body tube to hold the motor. The motor tube will have a couple of **centering rings** which hold it in place inside the body tube. If the motor diameter is just a little smaller than the body tube diameter, it may be held snug in place by "friction fit" without using a motor tube.



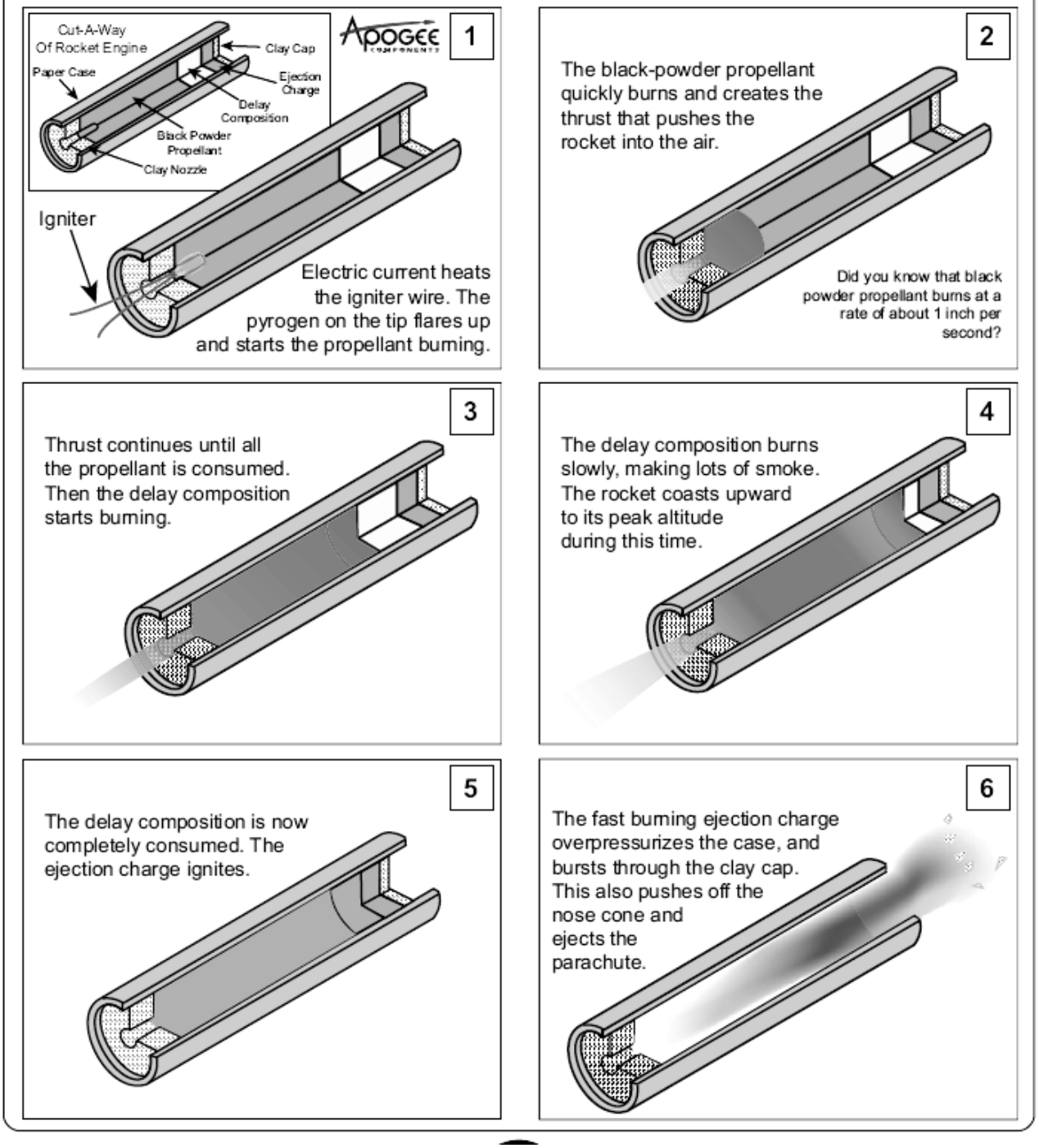
Phases of Flight

The diagram below illustrates the phases of flight for a successful rocket launch.

1. Launch – The rocket motor is ignited to begin to lift the rocket from the launch pad.
2. Powered Flight – The rocket is propelled upwards by the thrust of the burning rocket motor.
3. Burnout – This is the point when the motor fuel is all used up so the motor stops burning.
4. Coasting Flight – After burnout, the rocket continues traveling upwards, due to the velocity that was imparted on the rocket by the motor during powered flight. However since the motor is no longer burning, the negative acceleration due to the Earth's gravity is now beginning to slow down the rate of climb of the rocket.
5. Peak Altitude – The negative acceleration due to gravity has finally caused the rocket to stop moving upwards. At this instant in time, its velocity is zero. Hopefully the recovery system deploys very close to the peak altitude.
6. Descent – The parachute or streamer should be deployed. The extra drag caused by the recovery system causes the rocket to drift slowly to the ground. If the recovery system does not deploy properly, the rocket could reach the same speed coming down as it attained on its way up.
7. Landing – It is best to just let the rocket land on the ground. You can hurt yourself or damage the rocket too easily if you try to catch it in the air.



How Black Powder Rocket Motors Work



Rocket Motors – What Do the Numbers & Letters Mean?

One of the first things that people notice when looking at a rocket motor is the large strangely printed numbers and letters on the side : A8-3, B6-4, C6-3, or something similar. Why are these numbers here? Do they matter to me?

The simple answer is: yes, they do matter. To have a successful rocket flight, you must pick a rocket motor that is matched to the rocket you will be flying. So, you need to learn to read the numbers and letters (the "motor code") and decipher their meaning. Fortunately, these numbers are easy to understand (by design).

A8-3 B6-4 C6-7 D12-0

All the motors above are different, but they all use the same numbering system. In all of them, the letter tells the total impulse range (total thrust) of the motor. *In general, as you move up the alphabet, each letter has roughly twice the total impulse of the letter below*. In other words, a "B" has twice the total impulse of an "A"; conversely, the "B" has only half the total impulse of a "C" motor. Since each letter doubles, a "D" motor has 4 times the total impulse of a "B" motor and eight times the total impulse of an "A" motor. Now, we need to clarify that "twice the total impulse" does not equal "twice as high in the sky". More impulse will usually make the rocket travel faster, but faster rockets have more drag as they move faster through the air. Practical experience says that "twice the impulse" equates to about 1.5 to 1.7 times more altitude. A typical rocket that reaches 250 feet with an "A" motor will achieve about 400 feet with a "B" motor and 600 feet with a "C" motor. But the bottom line is:

letters higher in the alphabet = more total impulse = more altitude = more cost

Total impulse is measured in Newton-seconds (N-s) of thrust. An "A" motor gives up to 2.5 N-s; a "B" motor up to 5 N-s, and so on—each letter doubling the one below. You get the Newton-seconds of impulse when you multiply the average thrust (in Newtons) by the fuel burn time (in seconds). Average thrust (Newtons) x fuel burn time (sec) = Total impulse (N-s).

The first number in the motor code (before the dash) provides the average thrust of the motor (in Newtons). The average thrust number can tell you how quickly the motor delivers its total impulse. For example:

E9-7 E15-7 E30-7

All of these motors have the same total impulse. They are all "E" motors, which is to say they could all have up to 40 N-s of total impulse. However, because the average thrust number is different for each of them, they will each burn fuel for a different amount of time. Also, the motor which burns longest of the three shown above will deliver the least amount of thrust.

For example, if the E9-7 motor has 40 N-s of total impulse, and its average thrust is 9 Newtons (the first number in the motor code), then the approximate amount of time the rocket motor will burn fuel is 4.4 seconds.

9 Newtons X 4.4 seconds = 40 N-s

If you had the E30-7 motor instead, it would still deliver 40 N-s of total impulse because it is still an "E" motor. However, it would have 15 Newtons of average thrust, because the first number in the motor code is 15. The approximate burn time of this motor would be shorter (2.7 seconds).

15 Newtons X 2.7 seconds = 40 N-s

That is to say, the E30 gives a "quick kick" and the E9 is a "slow and long" burning motor. You need a "quick kick" motor when launching heavy, large rockets. "Slow and long" motors will not get a heavy rocket moving fast enough so that the fins can guide the rocket when it reaches the end of the launch rod. "Slow and long" motors are good choices when launching smaller, lightweight rockets. With these rockets, "quick kick" motors accelerate them very fast. Higher speeds increase the amount of air drag on the rocket, and increase the chance you will strip a fin off the rocket while in flight (a "shred").

The last number in the motor code (after the dash) tells you how long in seconds after the motor fuel (or *propellant*) is through burning that the ejection charge will blow. The ejection charge is a tiny explosive charge that is blown forward through the body tube to pop off the nose cone and eject the recovery system (streamer or parachute). There should be a delay between when the propellant stops burning and when the ejection charge blows. If the ejection charge blew right after the propellant was done burning, the rocket would still be coasting upward at a fast enough rate that the streamer or chute would be torn away from the rocket as it is ejected. The time delay helps ensure the rocket is done coasting upward very fast and gravity is about to start causing the rocket to fall earthward. If the streamer or chute is ejected at this point, it will not be torn away from the rocket, but will instead deploy properly.

What causes the time delay is the *delay composition*, which is a material that continues to burn after all the propellant is used up. Unlike the propellant, when the delay composition burns, it does not create any thrust. However, it may produce a nice smoke trail to help you find your rocket in the sky.

If the rocket motor has a zero after the dash, this rocket motor is meant for use in the lower stage of a multi-stage rocket. The zero means that there will be no delay from the end of the burn until the ejection charge blows. This is needed in a multi-stage rocket because you want the lower stage to detach as soon as the lower stage motor is done burning, in order to maintain the best upward momentum possible. You should not use a rocket motor with a zero after the dash for your single stage rocket, or else the streamer or chute could rip away from the rocket due to premature ejection. Then the rocket won't have a very safe or gentle descent to the ground.