Rocketry Reservoir:

a Stockpile of Resources for Rocketry Educators

By Tim Van Milligan
Illustrated By Dave Curtis

Introduction

In this document, you'll find a stockpile of resources that you can use in your rocketry unit at school. There are great things like overhead transparency images, handouts, award certificates, coloring pages, and quizzes that you can print out and give to your students. Pick and choose what works for you; the overhead transparencies will also work great in powerpoint presentations!

You'll find an extensive array of topics covered in this document, like how engines work, the five phases of a rocket's flight, and tracking model rockets. There is so much, that you'll probably only need to use a fraction of it. You are welcome to pick and choose which information will be most useful in your classroom. But it is my hope that some of the non-used pages will inspire you to dig a little bit deeper in rocketry to try some new things.

As great as this information is, you can go a lot further with rocketry than is presented here. In fact, I encourage it. To help you to explore the different topics, I have included teacher reference pages that include things like teaching tips, why the information is important, and references where you can find additional in-depth information on the topic. I'm sure you'll find these teacher pages extremely useful, and it is what sets our reference materials apart from anything that other rocketry suppliers have available. We are the rocketry experts at Apogee Components. So if you want to go even deeper in your knowledge, please feel free to give us a call or drop us an email. We'll be happy to point you in the right direction to find even more information.

If you find this information useful, I ask that you will consider placing an order for your rocketry supplies with Apogee Components. This is our preferred method of compensation for helping you out with your project. We're a small company with a great desire to help out teachers like you.

Please also tell your colleagues about how Apogee Components provide great resources for educators. Direct them to our web site for additional information (http://www.ApogeeRockets.com). We'll treat your friends right – that is my promise. And you'll end up looking like a hero to them for directing them to a source that can meet their rocketry needs in a timely manner.

Thank you for using our products. I do appreciate it.

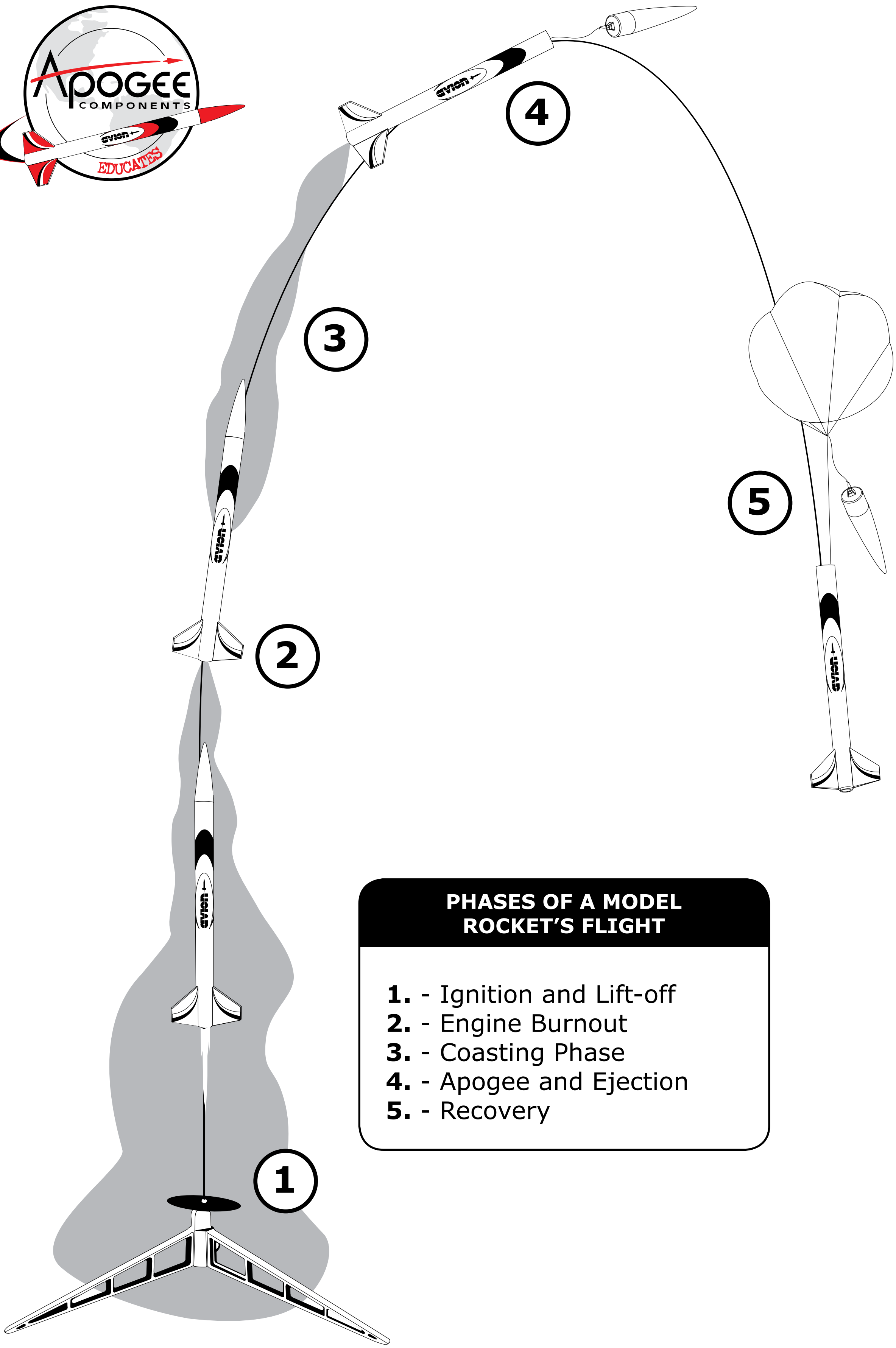
Timothy S. Van Milligan

Tim Van Milligan

Table of Contents

This is a list of the chapters in this packet.
Clicking on them will bring you to the start of each chapter.

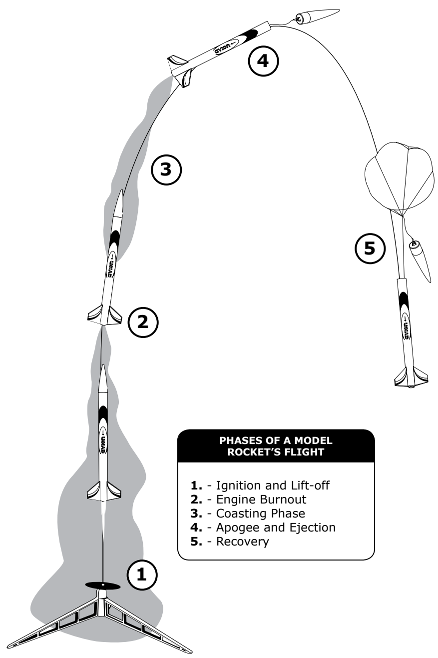
APOGEE COMPONENTS EDUCATES



PHASES OF A MODEL ROCKET'S FLIGHT

1. - Ignition and Lift-off
2. - Engine Burnout
3. - Coasting Phase
4. - Apogee and Ejection
5. - Recovery

Flight Profile of a Model Rocket



Flight Profile of a Model Rocket

Flight Profile of a Model Rocket:

Purpose: To prepare the students for the upcoming flight of a model rocket. You want them to know in advance what are the criteria for a successful flight. If any one phase is a failure, the whole flight is a failure. Because of safety concerns, there should not be any tolerance for a "partial success" in rocketry.

Additional Information:

http://www.ApogeeRockets.com/launch_events.asp : This web page goes over each of the five phases in greater detail telling you how to ensure that each one is a success. You'll also find additional references to dig even deeper.

Teaching Idea: Use the RockSim software to demonstrate the five phases of flight. The 2D Flight Profile feature will show all the phases in detail.

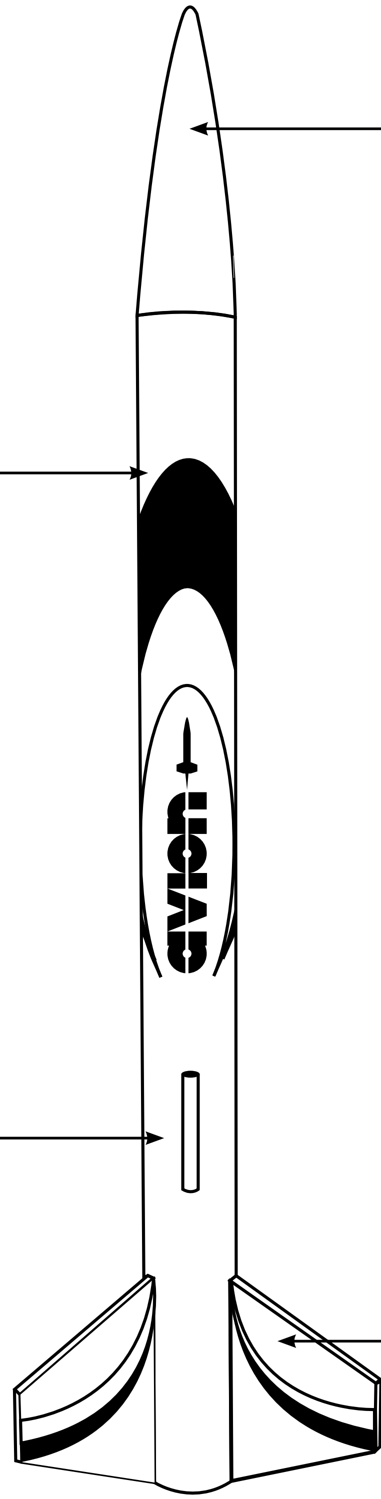
NOTES:

NOSE CONE

The purpose of the nose cone is to reduce aerodynamic drag on the model.

BODY TUBE

The body tube holds all of the internal parts of the rocket (like the parachute), and separates the nose from the fins of the rocket.



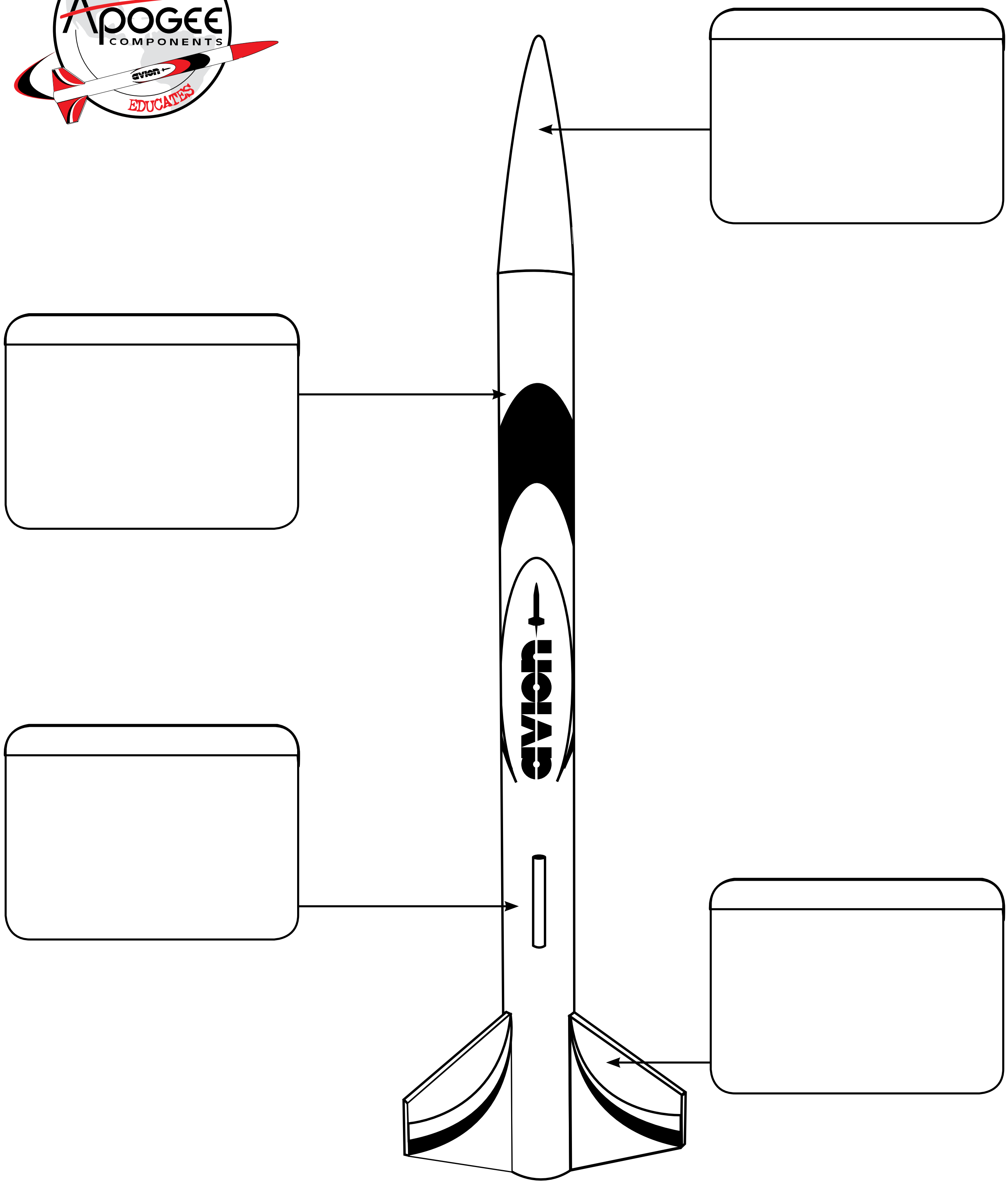
LAUNCH LUG

This part holds the rocket on the launch rod while the engine is pushing the rocket up to a safe lift-off speed. The minimum lift-off speed is approximately 30 miles per hour.

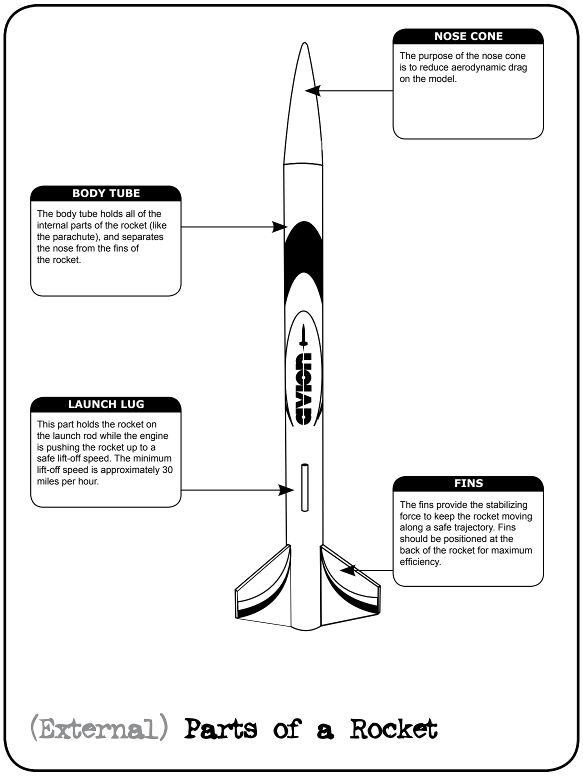
FINS

The fins provide the stabilizing force to keep the rocket moving along a safe trajectory. Fins should be positioned at the back of the rocket for maximum efficiency.

(External) Parts of a Rocket



(External) Parts of a Rocket



(External) Parts of a Rocket:

Purpose: To give students the proper terminology to use when talking about their model rockets. This illustration also tells why each external component is important.

Additional Information:

http://www.apogeerockets.com/education/rocket_parts.asp - This web page has even more information about the external components of a model rocket. It contains an interactive drawing of a model rocket that you can click on to display the information about each component that makes up a rocket. Inside those descriptions are links to web pages that will provide even more info and where to order those parts to build your own rocket designs.

Teaching Idea: We have included a page with blank bubbles that you can use as a handout. Have the students fill in the names and what each part is used for.

NOTES:

SHOCK CORD

The shock cord is used to attach the nose of the rocket to the body tube. This is desirable since it keeps the rocket all together instead of in many parts.

RECOVERY SYSTEM

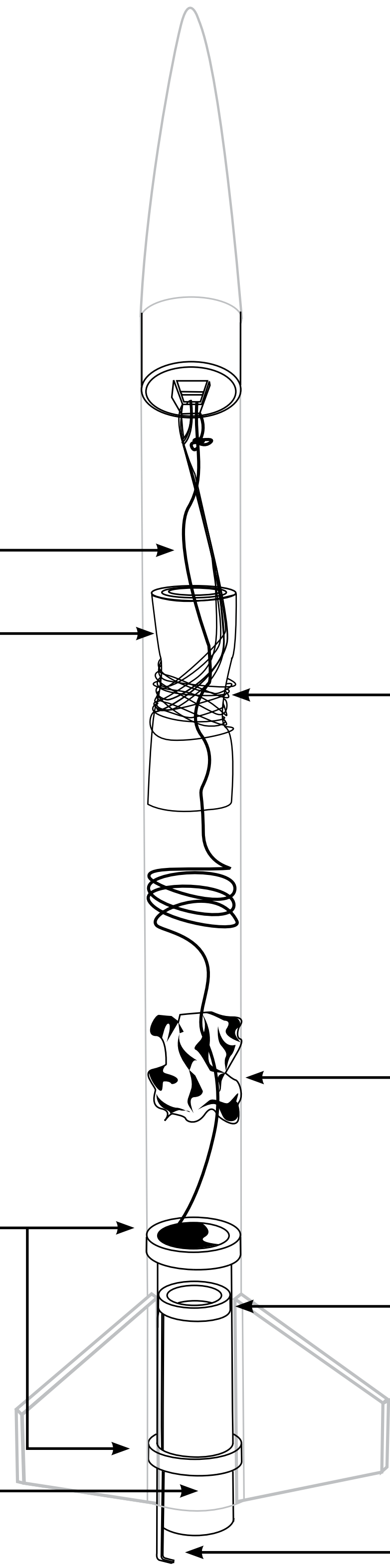
The recovery system is used to slow the rocket as it descends to the ground. The recovery system is pushed out of the tube by the ejection charge of the rocket engine.

CENTERING RINGS

The centering rings align the tubes inside the rocket and prevent parts from shifting around during flight.

MOTOR TUBE

The motor tube holds the engine inside the rocket.



PARACHUTE STRING

The parachute string, also called “suspension lines,” is used to connect the canopy to the rocket.

WADDING

Wadding is flame-proof paper that protects the parachute from the high heat of the ejection charge of the rocket engine.

ENGINE BLOCK

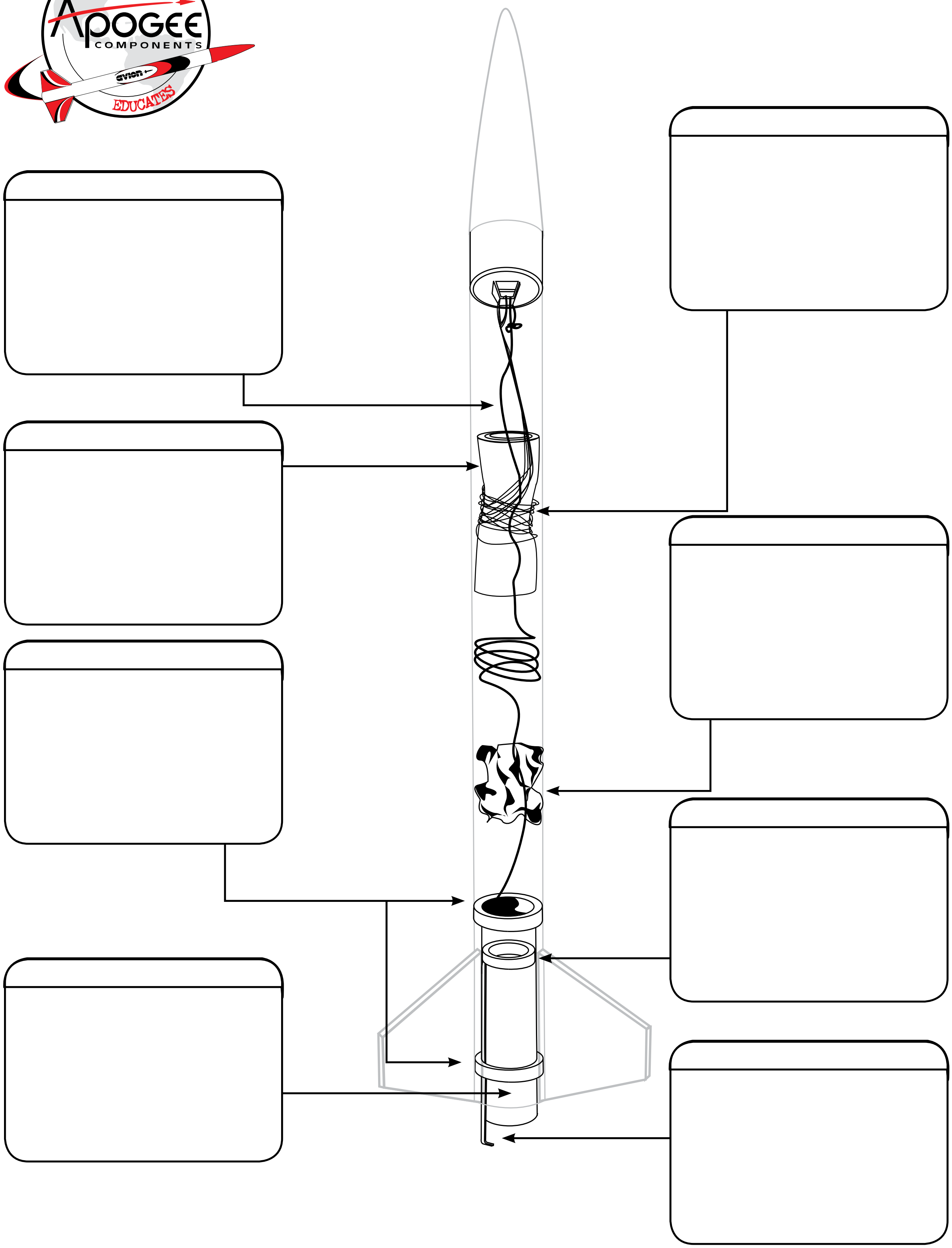
The engine block is glued into the motor tube ahead of the rocket motor. It prevents the motor from sliding up into the tube while the engine produces thrust.

ENGINE HOOK

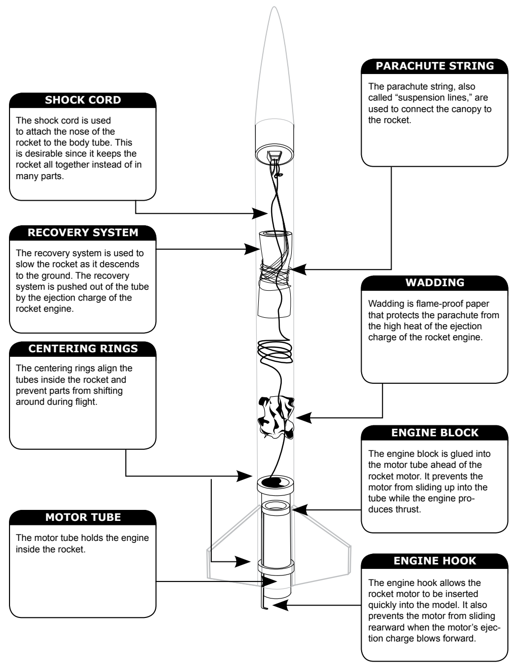
The engine hook allows the rocket motor to be inserted quickly into the model. It also prevents the motor from sliding rearward when the motor’s ejection charge blows forward.

(Internal) Parts of a Rocket

3355 Fillmore Ridge Heights Colorado Springs CO, 80907 (719) 535-9335 www.ApogeeRockets.com



(Internal) Parts of a Rocket



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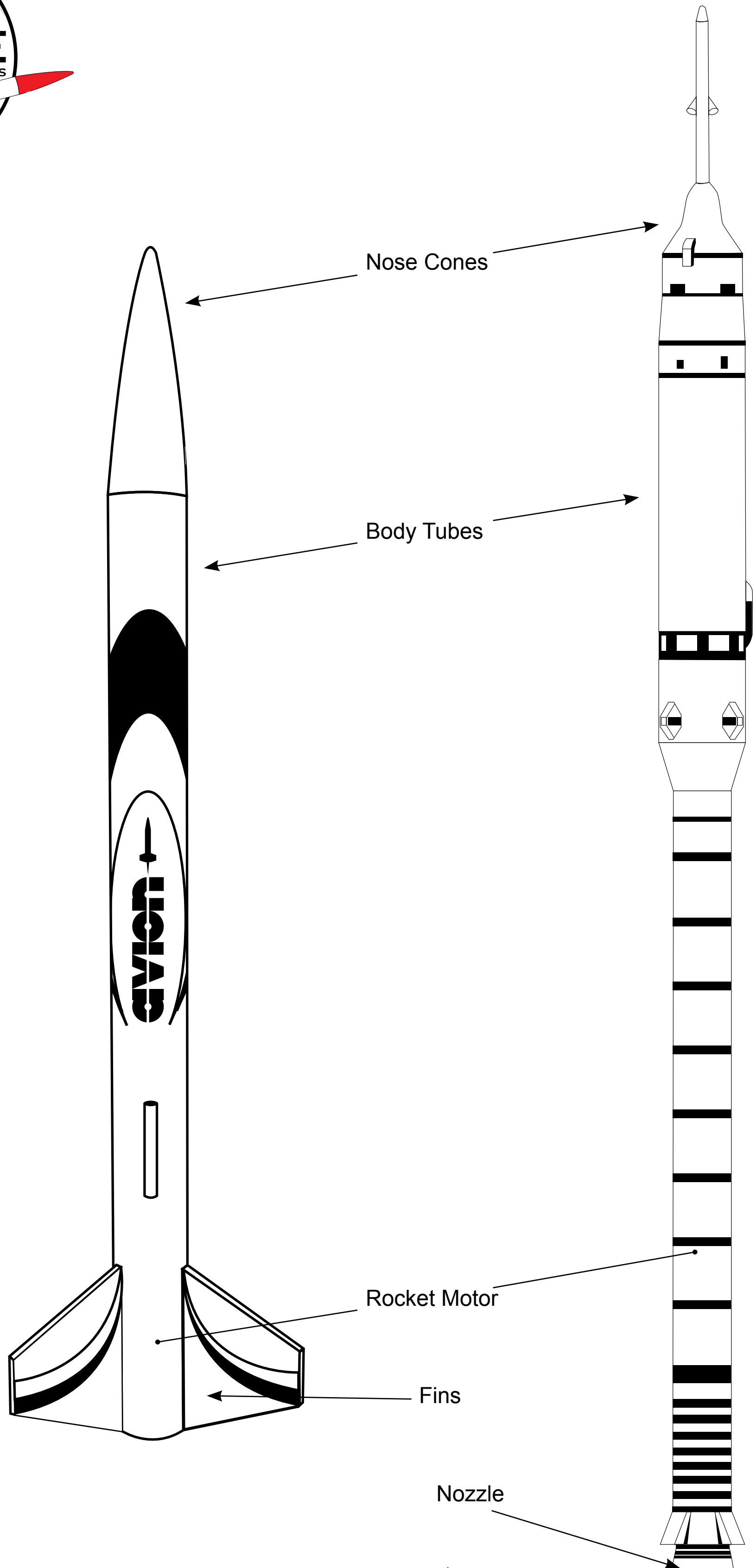

Compare Model Rockets to the Real Thing

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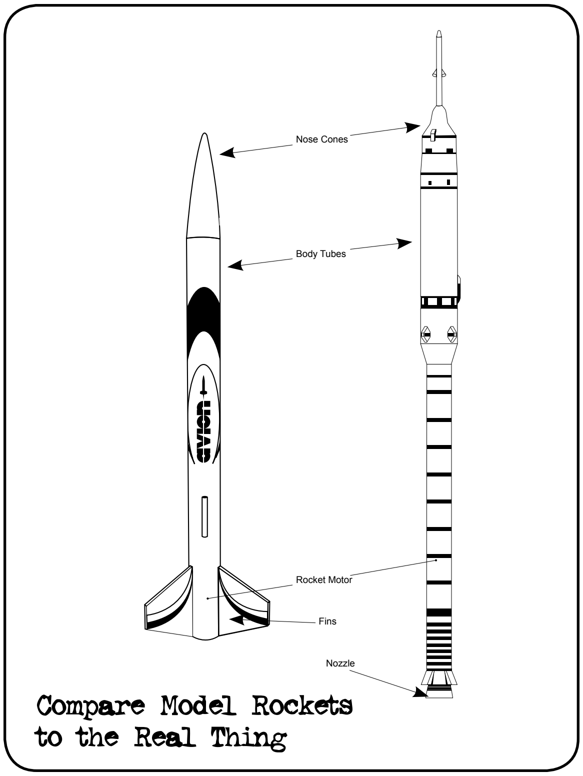


Compare Model Rockets to the Real Thing

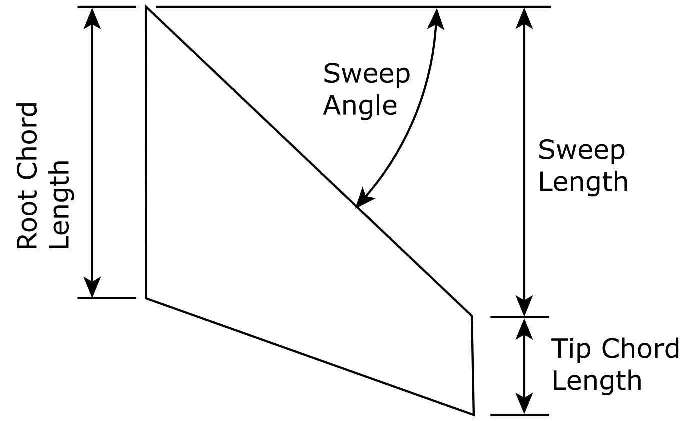
Purpose: To demonstrate that model rockets are REAL rockets. The only difference between a model rocket and a rocket like NASA's Aries rocket is the size and cost. They both function the same way!

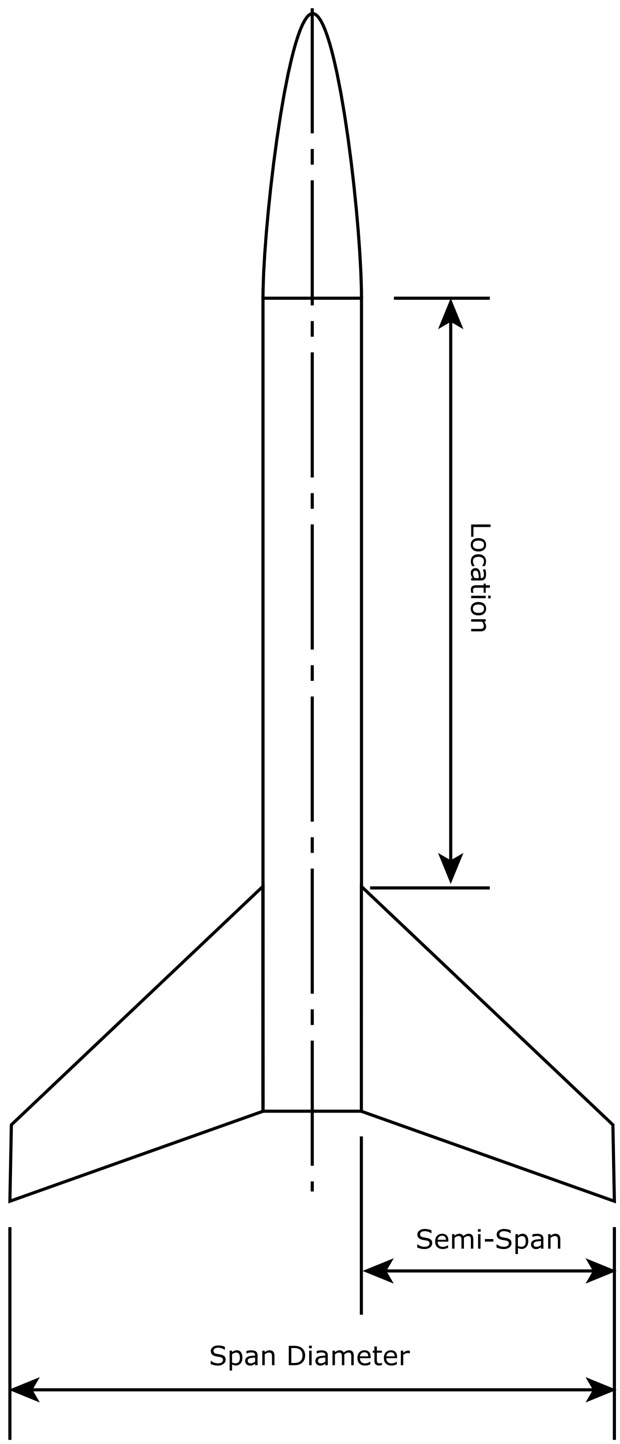
Additional Information:

http://www.ApogeeRockets.com/links/historyofspacecraft.html - This web page gives links to other web sites that have information about real rockets that have flown into space.

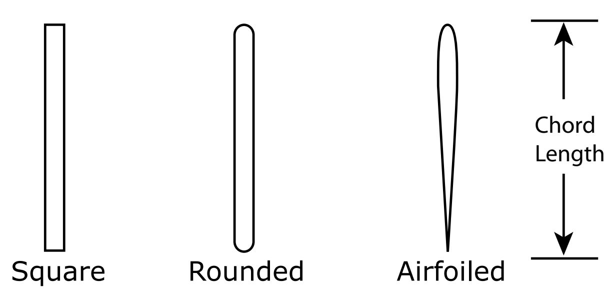
Teaching Idea: Ask the students why only a few of the big rockets have fins. The answer is that big rockets have steerable rocket nozzles. Like an outboard motorboat, the nozzle on many big rockets can be swiveled to point the thrust of the motor. This then changes the direction that the rocket takes. The special name given to the motor is called gimbaled rocket nozzles. http://exploration.grc.nasa.gov/education/rocket/gimbaled.html

NOTES:

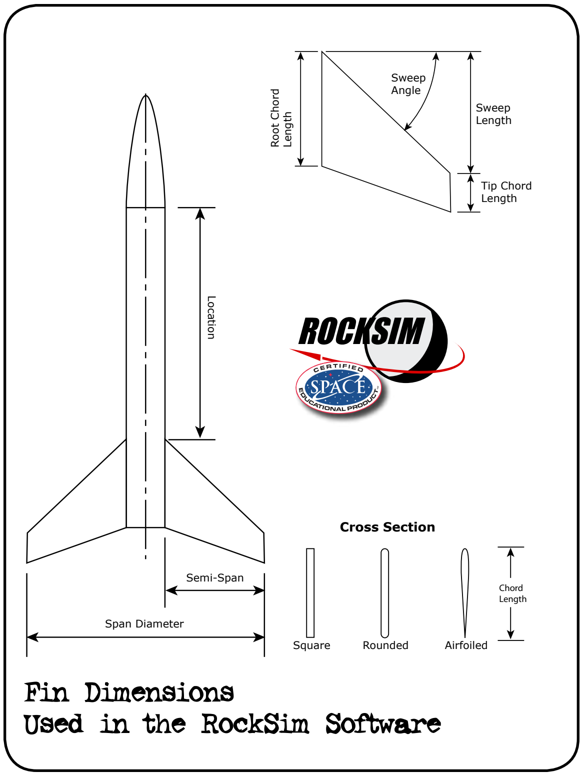




Cross Section



Fin Dimensions
Used in the RockSim Software



Fin Dimensions Used in the RockSim Software

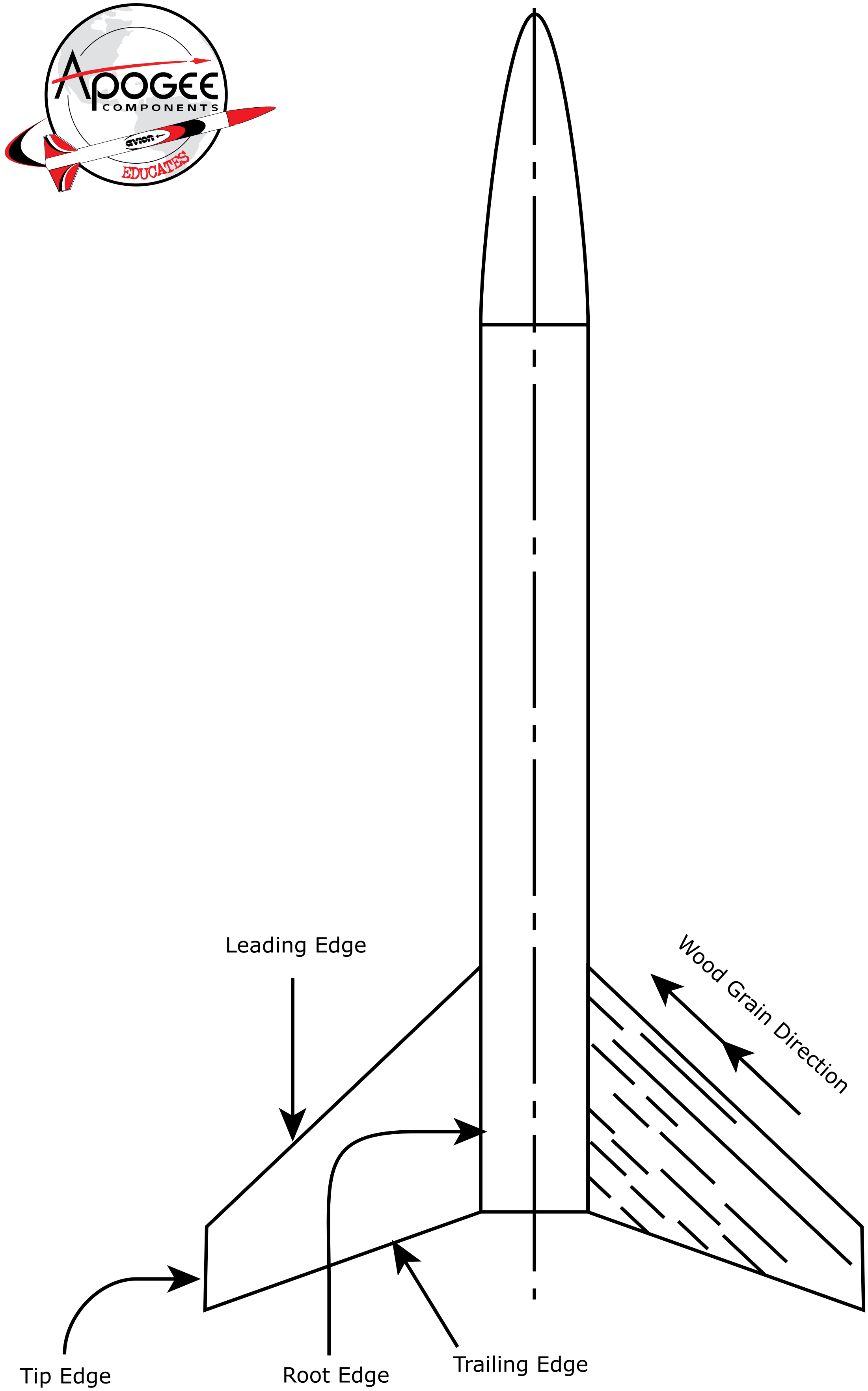
Purpose: To give students the proper terminology to use when talking about their model rockets. If the student is to design their own rocket, they will need to describe the different dimensions of the fins on their rocket, as well as what the different airfoil types are.

Additional Information:

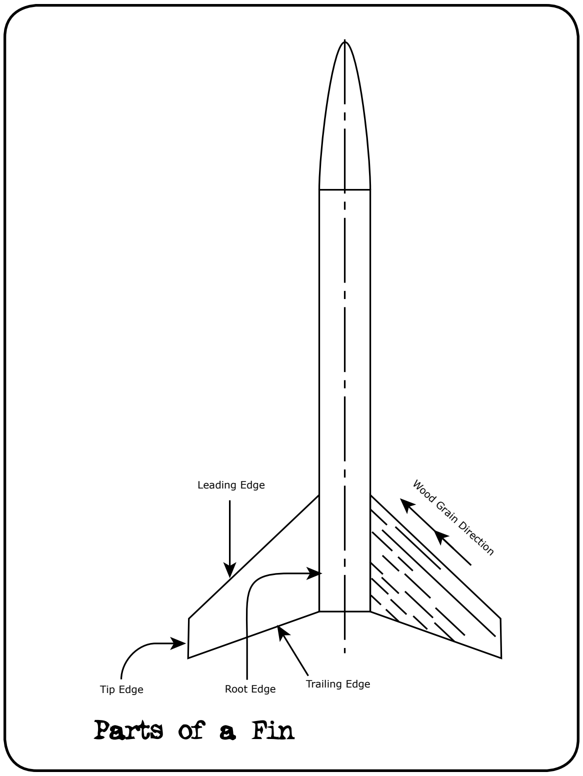
The RockSim software (http://www.ApogeeRockets.com/rocksim.asp) has a great interface that allows students to design fins very quickly. They will be able to see how changes in the fin shape affect the stability of their rocket designs.

Teaching Idea: Have the students experiment with different fin shapes in the RockSim software. This will give them some idea of which parameters are the most important at controlling the position of the CP on the rocket. The answer is that "location" and "semi-span" have the greatest influence.

NOTES:



Parts of a Fin



Parts of a Fin

Purpose: To give students the proper terminology to use when talking about their model rockets. The grain direction of the wood plays a huge influence over how strong the fin is. The grain should be as close to parallel to the leading edge of the fin as possible.

Additional Information:

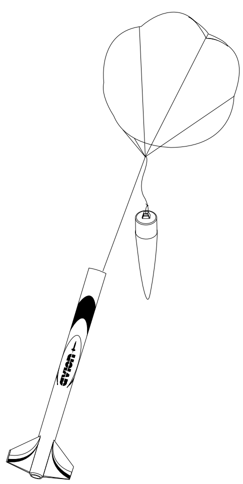
The book: *Model Rocket Design and Construction* gives a number of ways that the fins can be made stronger. http://www.ApogeeRockets.com/design_book.asp. Just as important is the technique used to attach fins to a rocket. You'll find video instructions of attaching fins on the CD-ROM Building Skill Level 1 Model Rocket Kits. http://www.ApogeeRockets.com/skill_level_1_video.asp

Teaching Tip: A fin that has its wood-grain running in the wrong direction (parallel to the tube) is very weak and is called a "pop fin." That is the sound it makes as snaps in two. Show the students a properly oriented fin versus a fin that has an incorrect grain direction. It makes a great visual to see how strong fins are if they are built properly.

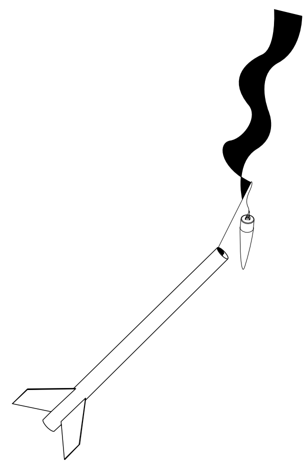
NOTES:

Types of Model Rocket Recovery

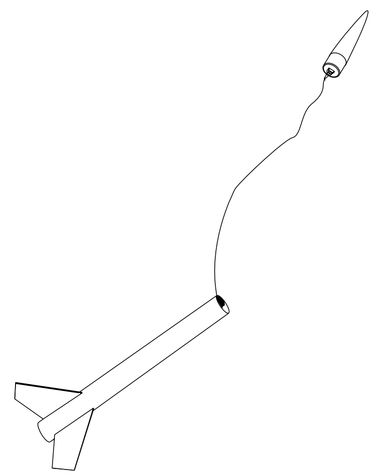
Parachute Recovery



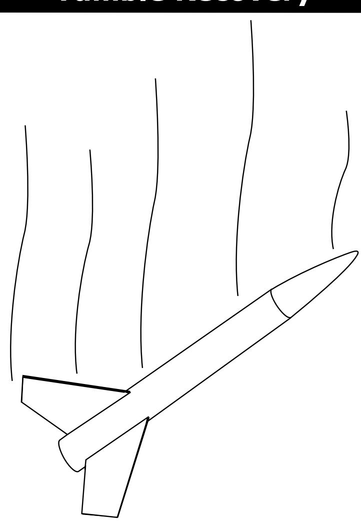
Steamer Recovery



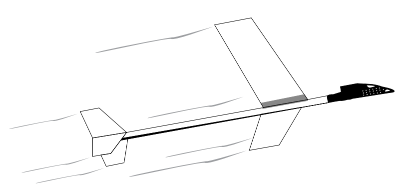
Nose-blow Recovery



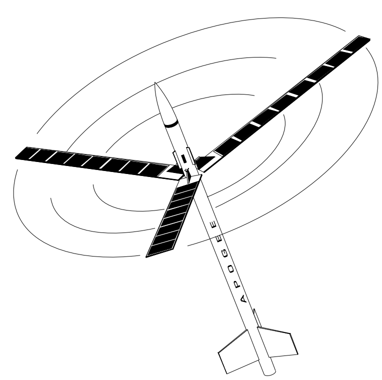
Tumble Recovery

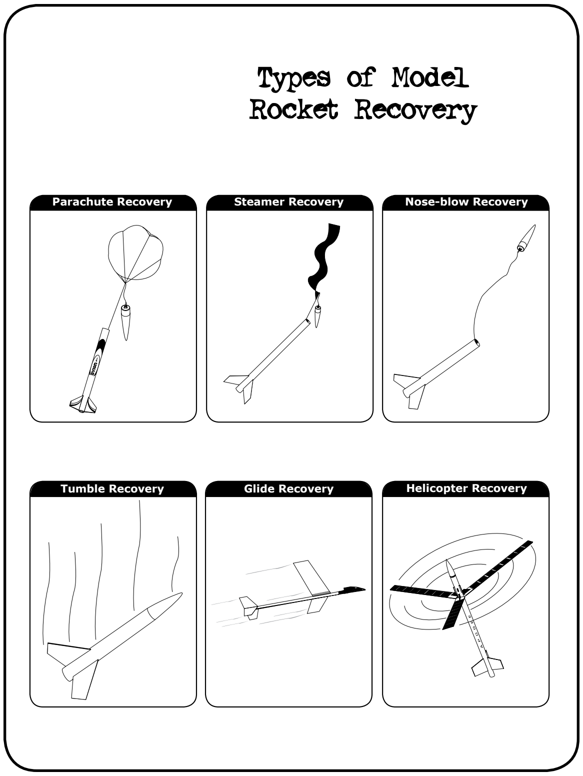


Glide Recovery



Helicopter Recovery





Types of Model Rocket Recovery

Purpose: To show the students the wide variety of recovery methods that can be employed to bring a rocket safely to the ground. A lot of students think rocketry is boring because most just seem to come down with a parachute. The variety of rocket recovery methods is what spices up rocketry.

Additional Information:

The book: Model Rocket Design and Construction describes each of the different recovery methods in much greater detail, as well as giving recommendations on the different sizes for each type of rocket. There are actually two additional recovery methods shown in the book that are not shown here! http://www.ApogeeRockets.com/design_book.asp.

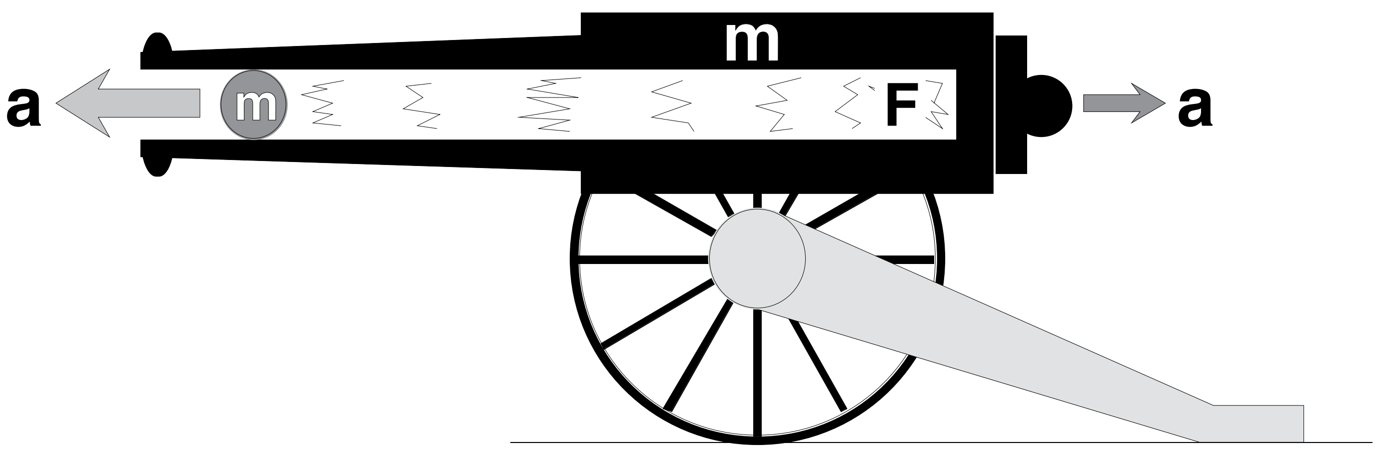
Teaching Tip 1: Use the RockSim software to pick the right size parachute for your rocket based on desired descent speed. Then experiment by using the software to find the best launch angle that will bring the rocket down as close to the pad as possible. http://www.ApogeeRockets.com/rocksim.asp

Teaching Tip 2: There are several ways to modify your parachutes to increase the variety of this one recovery method. How about a parachute that spins down? Find ideas on parachute modifications at: http://www.ApogeeRockets.com/Peak-of-Flight_index.asp#parachutes

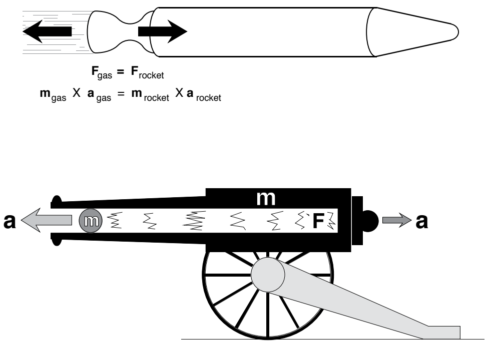
NOTES:

$$F_{gas} = F_{rocket}$$

$$m_{gas} \times a_{gas} = m_{rocket} \times a_{rocket}$$



How Engines Work



How Engines Work

How Engines Work

Purpose: To show how Newton's Third Law of Motion is used to explain how rocket engines work. For every action, there is an equal and opposite reaction.

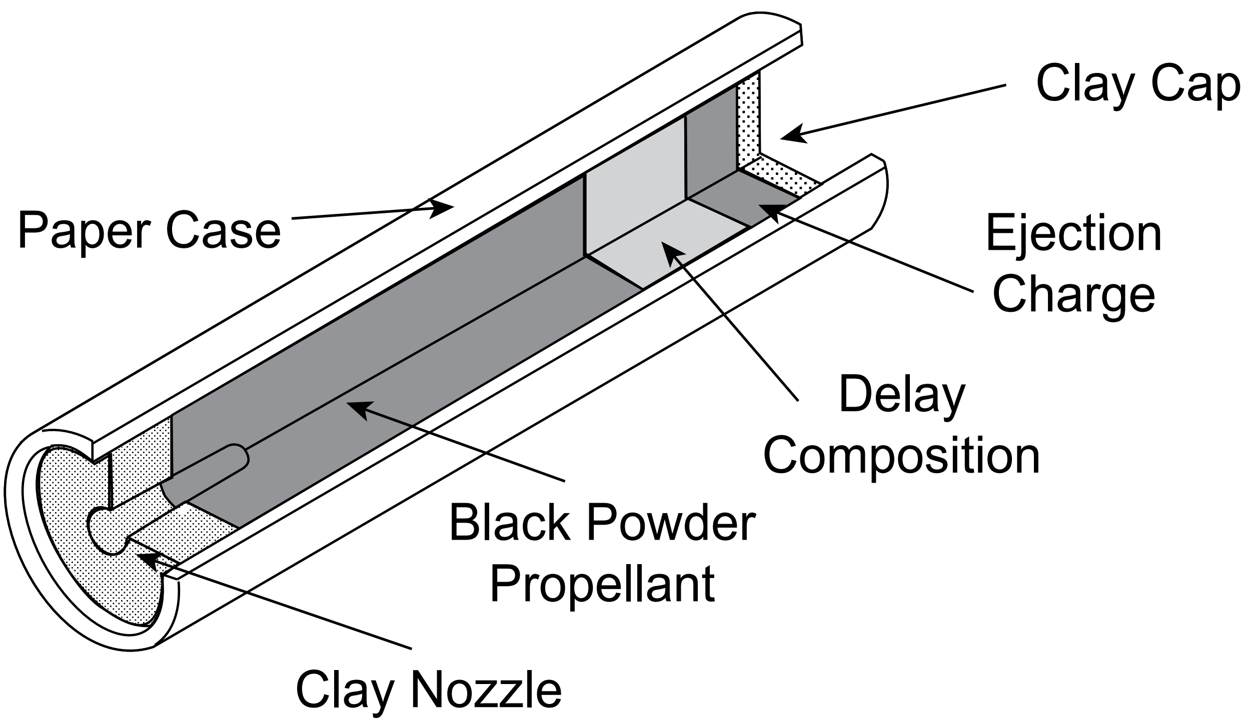
Additional Information:

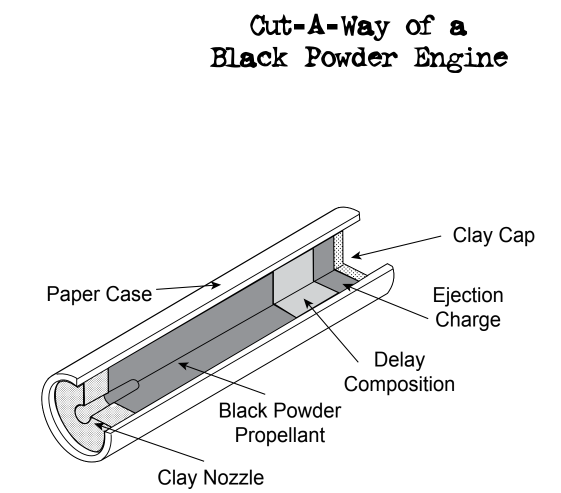
The book "*Model Rocket Propulsion*" explains in detail how rockets create thrust. http://www.ApogeeRockets.com/mod_rocket_propulsion_bk.asp. For a description of Newton's Three Laws of Motion, see: http://www.ApogeeRockets.com/education/downloads/Newsletter106.pdf

Teaching Tip: The video book *Teaching Science Through Model Rocketry* contains a number of visual demonstrations you can use to show Newton's Three Laws of Motion. http://www.ApogeeRockets.com/teaching_science.asp

NOTES:

Cut-A-Way of a Black Powder Engine





Cut-A-Way of a Black Powder Engine

Purpose: To show the components inside a black-power propellant rocket engine. It is dangerous to open up an engine, so this visual can be used to quiet the curiosity of the students.

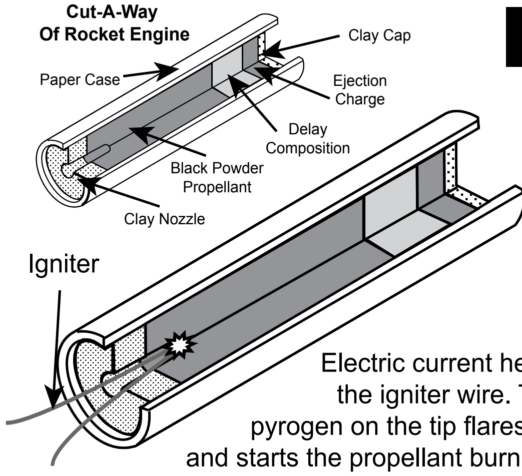
Additional Information:

http://www.ApogeeRockets.com/education/rocket_propulsion.asp This web page gives links to other sites that have great information on rocket propulsion.

NOTES:

Black Powder Motors

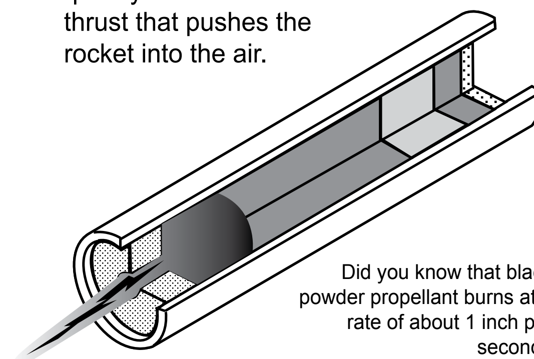
1



Electric current heats the igniter wire. The pyrogen on the tip flares up and starts the propellant burning.

2

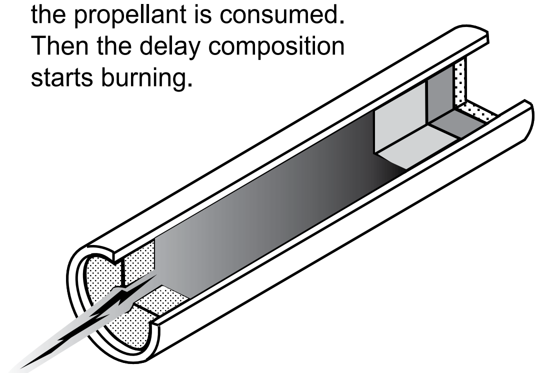
The black powder propellant quickly burns and creates the thrust that pushes the rocket into the air.



Did you know that black powder propellant burns at a rate of about 1 inch per second?

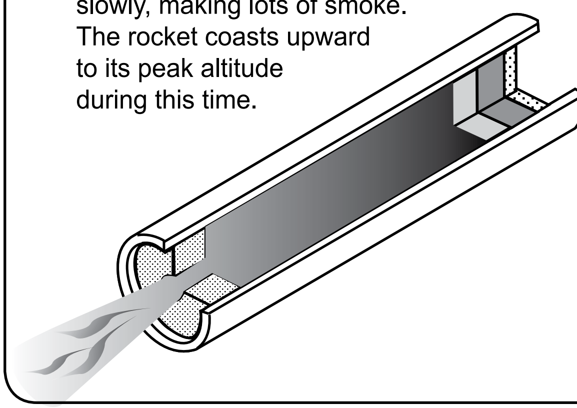
3

Thrust continues until all the propellant is consumed. Then the delay composition starts burning.



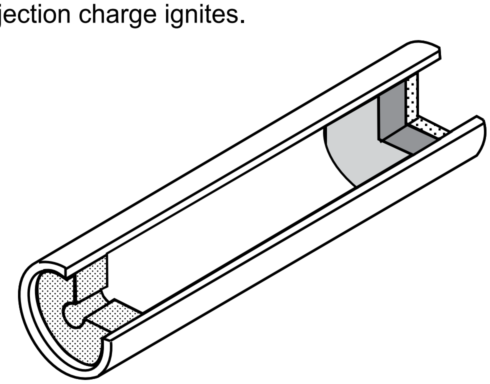
4

The delay composition burns slowly, making lots of smoke. The rocket coasts upward to its peak altitude during this time.



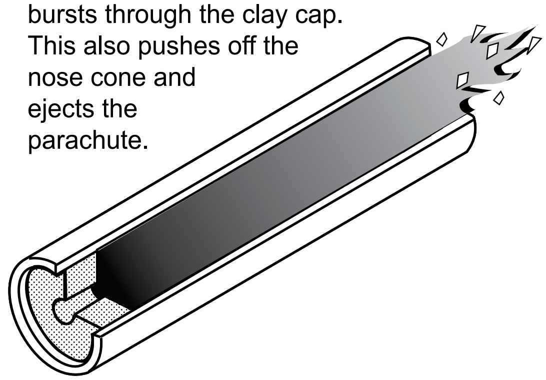
5

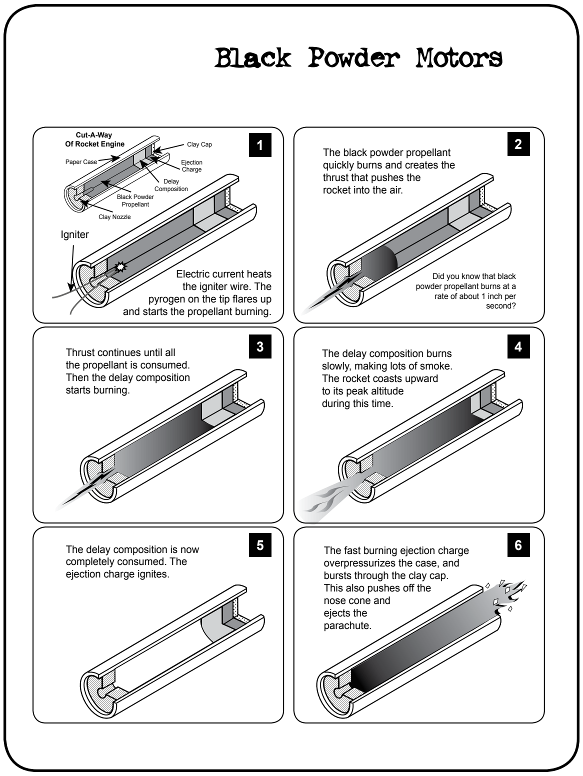
The delay composition is now completely consumed. The ejection charge ignites.



6

The fast burning ejection charge overpressurizes the case, and bursts through the clay cap. This also pushes off the nose cone and ejects the parachute.





Black Powder Motors

Purpose: To show how a black powder propellant rocket engine works.

Additional Information:

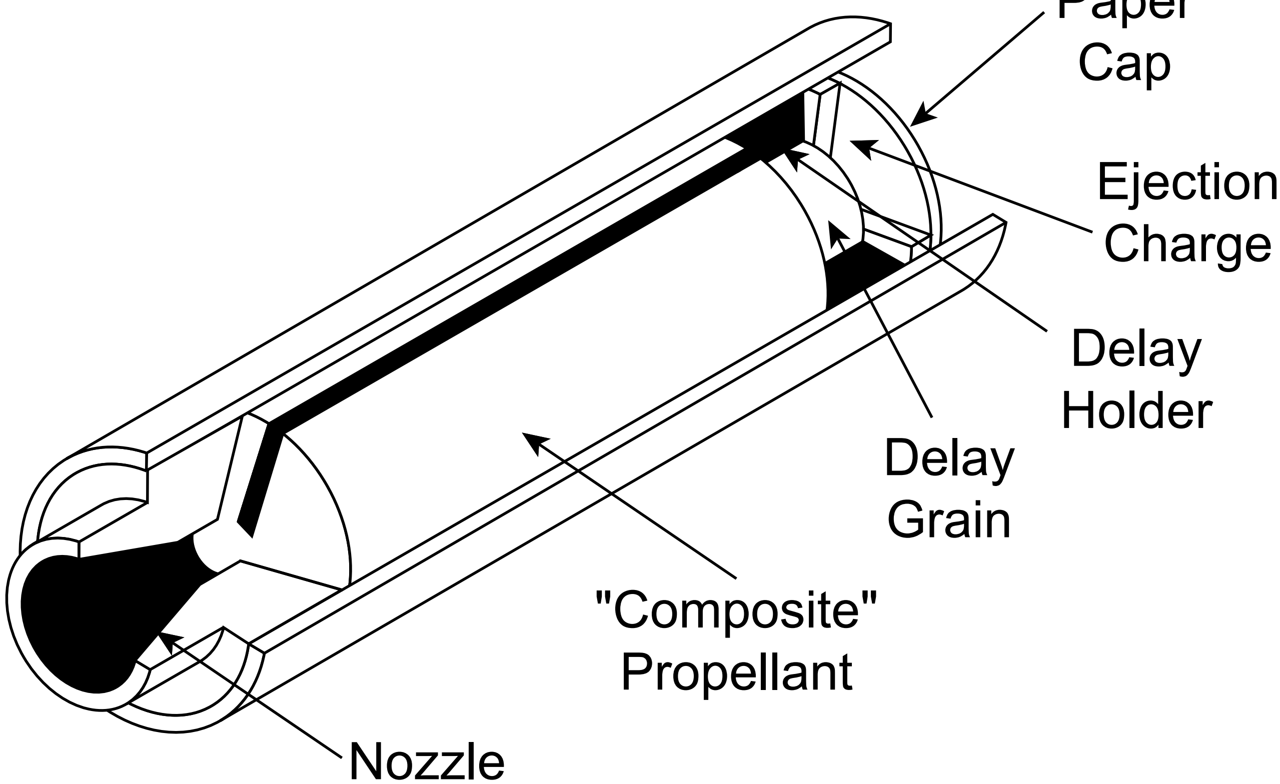
http://www.ApogeeRockets.com/education/how_engines_work.asp. This web page has a great interactive animation of how rocket engines work. Students may get a better grasp of what goes on inside a rocket engine as it burns by watching the animation.

http://www.ApogeeRockets.com/education/downloads/Newsletter98.pdf This newsletter contains part 1 of a detailed article that explains how "booster stage" engines work.

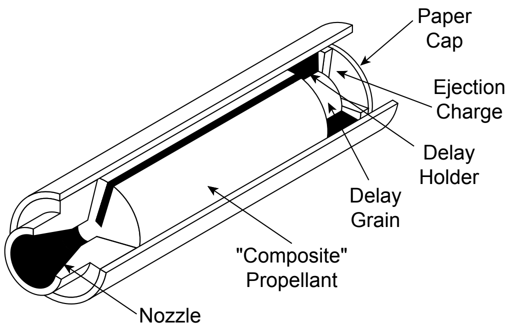
http://www.ApogeeRockets.com/education/downloads/Newsletter99.pdf This newsletter contains part 2 of a detailed article that explains how "booster stage" engines work.

NOTES:

Cut-A-Way of a Composite Engine



Cut-A-Way of a Composite Engine



Cut-A-Way of a Composite Engine

Purpose: To show the components inside a composite propellant rocket engine. It is dangerous to open up an engine, so this visual can be used to quiet the curiosity of the students.

Additional Information:

http://www.ApogeeRockets.com/education/rocket_propulsion.asp This web page gives links to other sites that have great information on rocket propulsion.

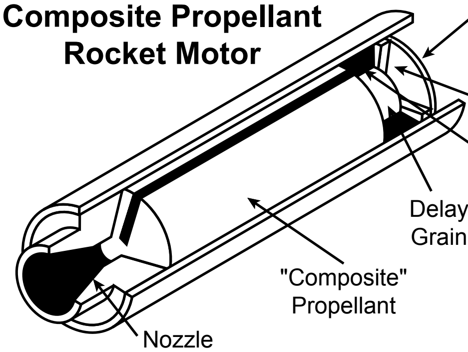
http://www.ApogeeRockets.com/aerotech_motors.asp This web page gives a better description of what composite propellant actually is, and how it compares to black-powder propellant for rocket engines. You'll also get some information on when it is wise to choose composite propellant rocket engines.

NOTES:

Composite Propellant Motor

1

Parts of a Composite Propellant Rocket Motor



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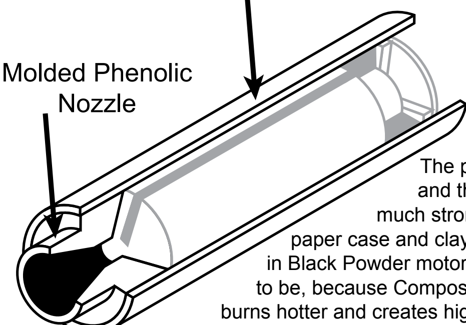
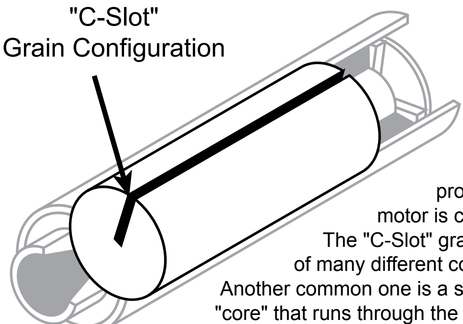


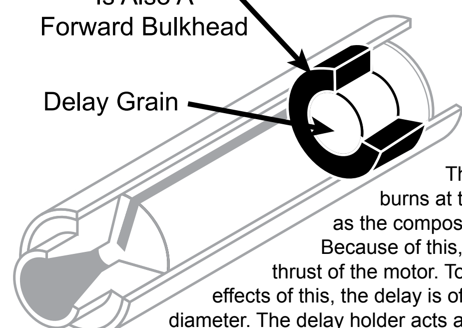
The phenolic case and the nozzle are much stronger than the paper case and clay nozzle used in Black Powder motors. They need to be, because Composite propellant burns hotter and creates higher pressure inside the motor.

3



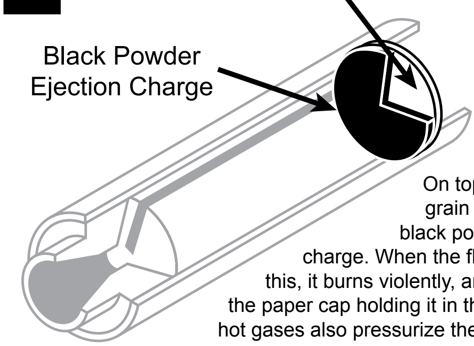
The slug of propellant in the motor is called a *grain*. The "C-Slot" grain is just one of many different configurations. Another common one is a single hole or "core" that runs through the middle of the propellant slug.

4



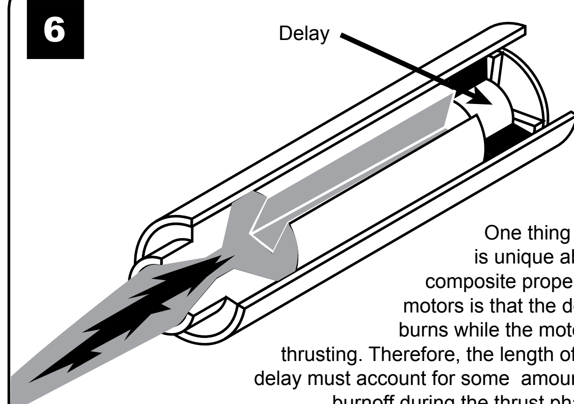
The delay grain burns at the same time as the composite propellant. Because of this, it adds to the thrust of the motor. To minimize the effects of this, the delay is often smaller in diameter. The delay holder acts as a bulkhead, holding the pressure inside in the motor.

5

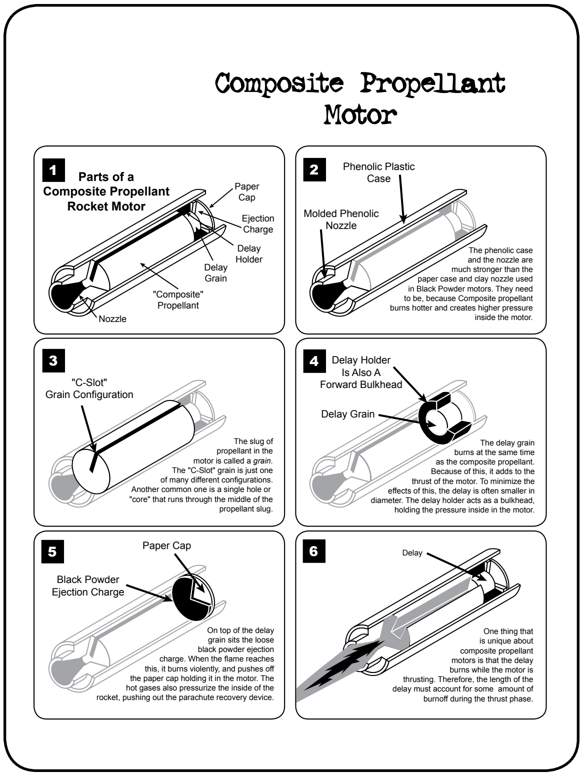


On top of the delay grain sits the loose black powder ejection charge. When the flame reaches this, it burns violently, and pushes off the paper cap holding it in the motor. The hot gases also pressurize the inside of the rocket, pushing out the parachute recovery device.

6



One thing that is unique about composite propellant motors is that the delay burns while the motor is thrusting. Therefore, the length of the delay must account for some amount of burnoff during the thrust phase.



Composite Propellant Motor

Purpose: To show how a composite propellant rocket engine works.

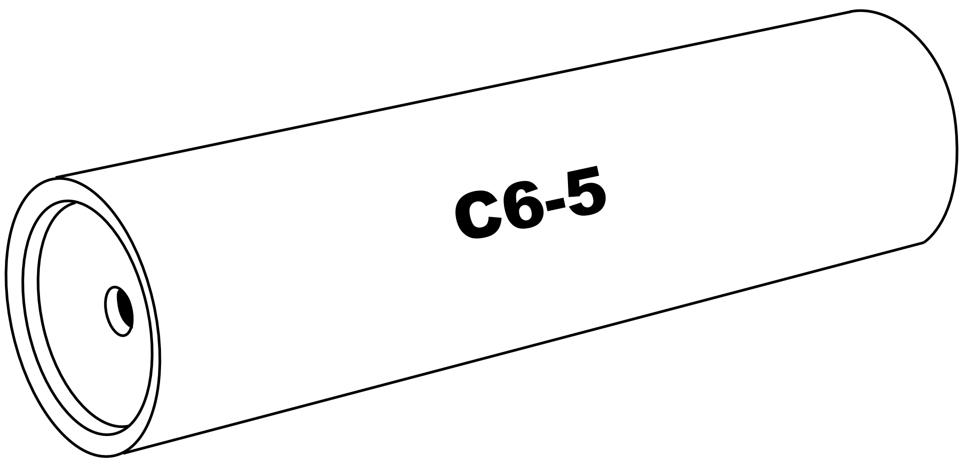
Additional Information:

http://www.ApogeeRockets.com/education/how_composites_work.asp. This web page has a great interactive animation of how rocket engines work. Students may get a better grasp of what goes on inside a rocket engine as it burns by watching the animation.

Teaching Tip: Point out to your students that a composite motor burns from the middle out to the sides. Compare this to how a black-powder motor burns from the back end toward the front. This makes composite propellant motors burn quicker, and hence they typically have a lot more thrust than a black-powder rocket motor.

NOTES:

Rocket Engine Classification

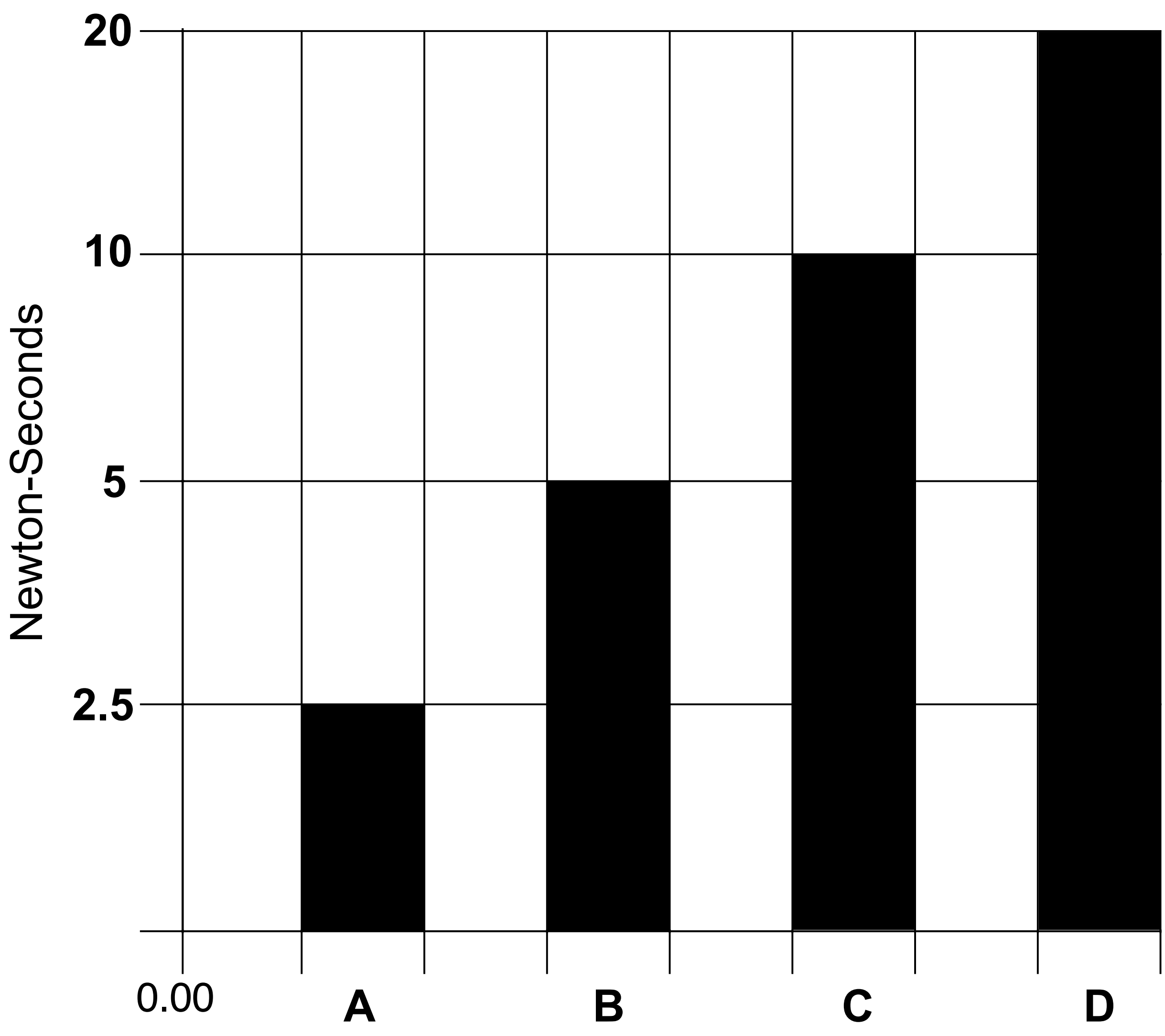


What does the "C6-5" mean?

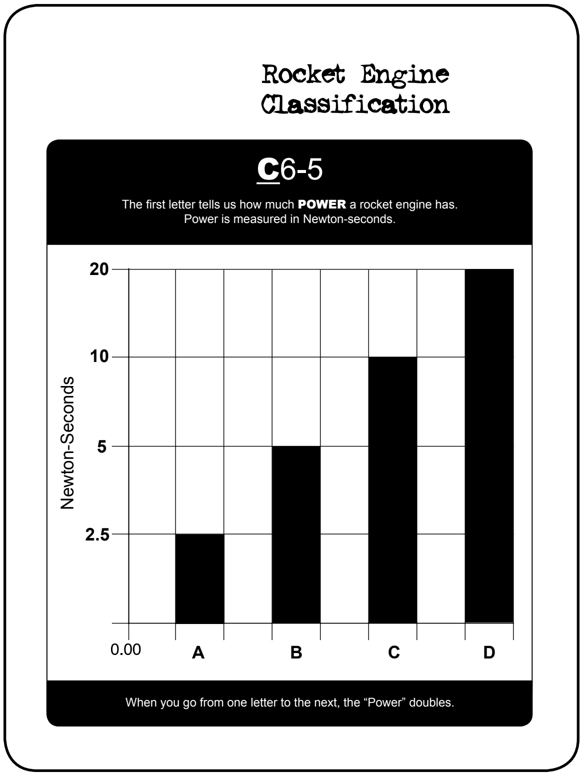
Rocket Engine Classification

<u>C</u>6-5

The first letter tells us how much **POWER** a rocket engine has.
Power is measured in Newton-seconds.



When you go from one letter to the next, the “Power” doubles.



Rocket Engine Classification

Purpose: To teach students the nomenclature used to classify model rocket engines. The power level of the motor doubles when jumping up to the next letter.

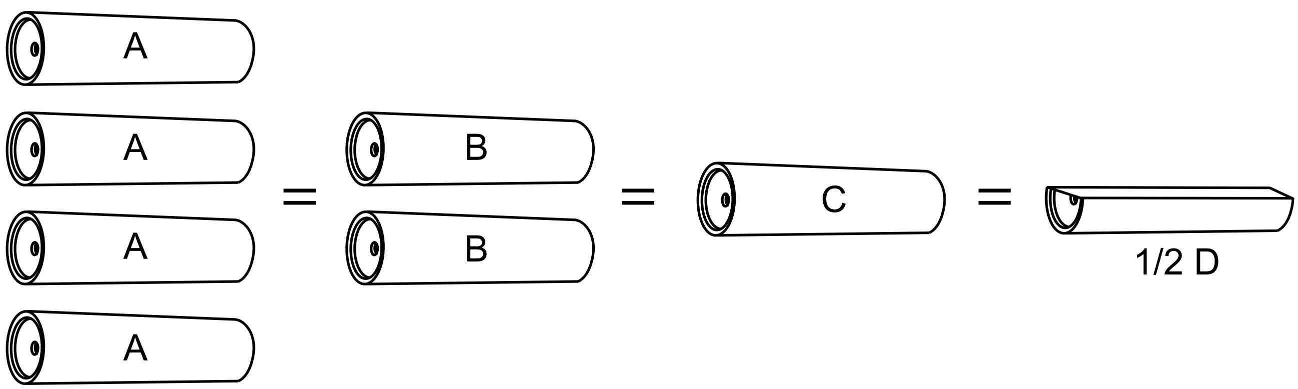
Additional Information:

http://www.ApogeeRockets.com/education/downloads/Newsletter106.pdf This newsletter contains a detailed article that explains the engine code classification system.

http://www.ApogeeRockets.com/Teacher_DVD.asp This DVD contains a live presentation on how to teach model rocketry. It goes over the engine code classification system in great detail.

NOTES:

Rocket Engine Classification

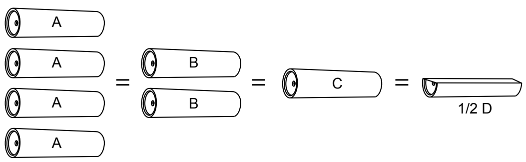


CODE	POWER (Newton-Seconds)
1/4A	0 - .625
1/2A	.626 - 1.25
A	1.26 - 2.50
B	2.51 - 5.00
C	5.01 - 10.00
D	10.01 - 20.00
E	20.01 - 40.00
F	40.01 - 80.00
G	80.01 - 160.00
H	161.01 - 320.00
I	320.01 - 640.00

Rocket Engine Classification

Purpose: To reinforce the concept that the power doubles from one letter to the next. Therefore to make a rocket that uses equivalent power, you need twice the number of smaller motors.

Rocket Engine Classification



CODE	POWER (Newton-Seconds)
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D	10.01 - 20.00
E	20.01 - 40.00
F	40.01 - 80.00
G	80.01 - 160.00
H	161.01 - 320.00
I	320.01 - 640.00

Teaching Tip: Motors come in a variety of sizes, even though they have the same power. Display an “A” size motor (the Estes mini engine) versus a regular size (18mm diameter) “A” motor. They both have the same power, even though one is physically larger than the other. You can do the same with a composite propellant “D” motor (such as the Apogee Components D10) and compare it to a Estes “C6” motor. Even though they are the same size, the D motor has TWICE the power, so it will go approximately twice as high in the same rocket.

NOTES:

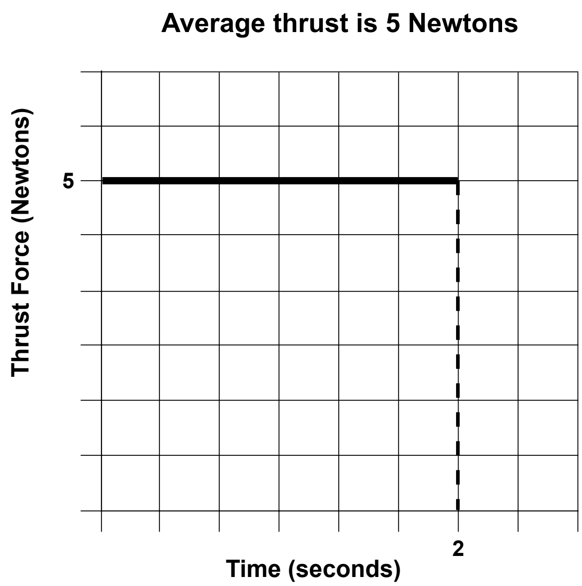
Test Your Knowledge

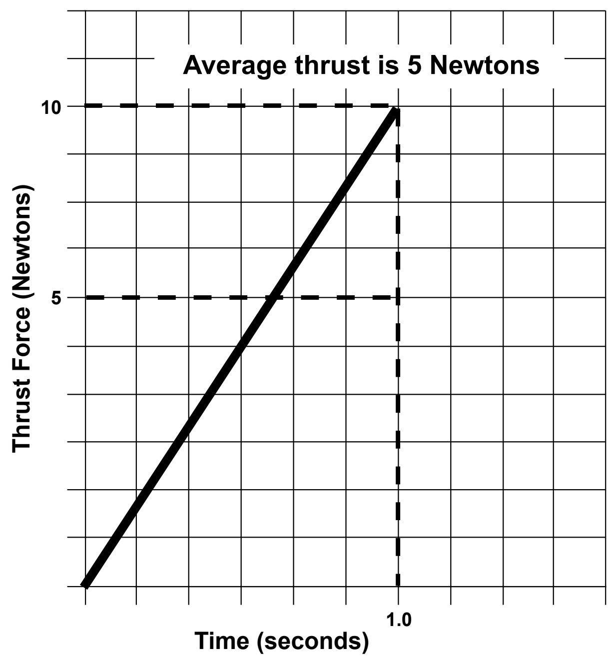
How many “A” engines would it take to have the equivalent to a full-size “E” engine?

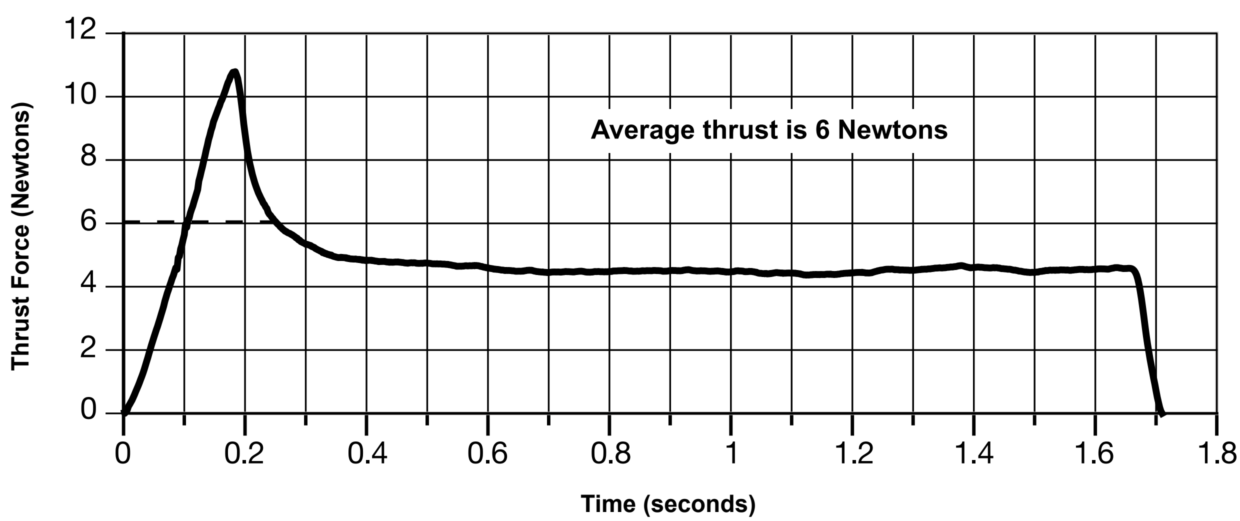
Rocket Engine Classification

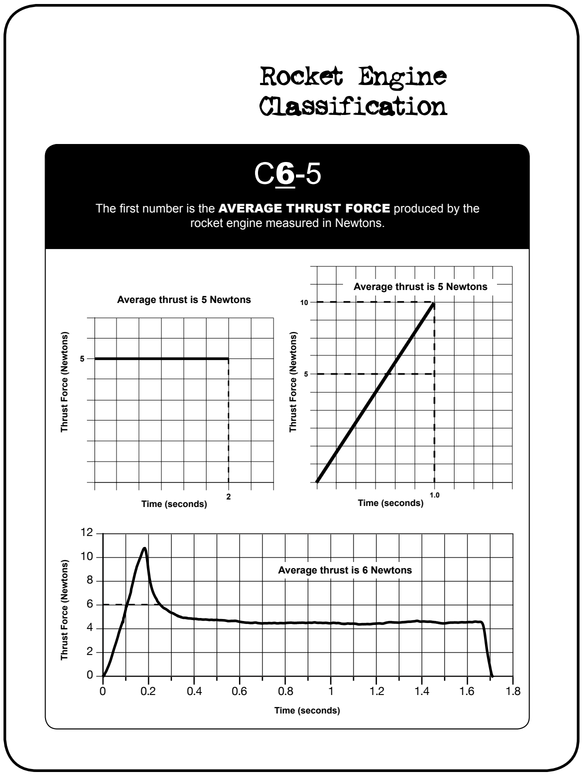
C6-5

The first number is the **AVERAGE THRUST FORCE** produced by the rocket engine measured in Newtons.









Rocket Engine Classification

Purpose: To show graphically what is meant by average thrust. When a rocket engine burns, it produces a thrust force. Graphing that thrust versus time gives us a chart called a thrust curve. The average thrust level gives us a general indication of whether a motor makes a lot of thrust or just a little bit.

The top two graphs show simple curves (straight lines) where it is easy to determine the average thrust. The bottom chart is the thrust curve of an Estes C6-5 motor. It is more complex to determine the average thrust.

Additional Information:

http://www.ApogeeRockets.com/education/downloads/Newsletter106.pdf This newsletter contains a detailed article that explains the engine code classification system.

http://www.ApogeeRockets.com/Teacher_DVD.asp This DVD contains a live presentation on how to teach model rocketry. It goes over in great detail the engine code classification system.

Teaching Tip 1: Compare the thrust curves of the Estes A3 versus the Estes A10 motor. Both are the same physical size and have the same total power (A-motor). But one is high thrust (burns quickly), and the other is low thrust (longer duration of thrust). The thrust curves can be found in the RockSim software (use the EngEdit program that comes bundled with RockSim to open up the Estes engine data file).

Teaching Tip 2: Have the students create their own thrust curve profile using the EngEdit software (which comes bundled with RockSim). Take the Estes C6 motor, and change it into a C4 engine. Remember that the total Impulse must remain under 10 N-seconds. Then have them change it into a C10 motor.

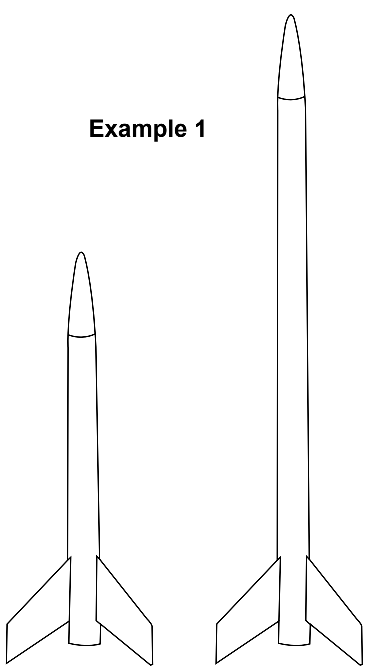
NOTES:

Rocket Engine Classification

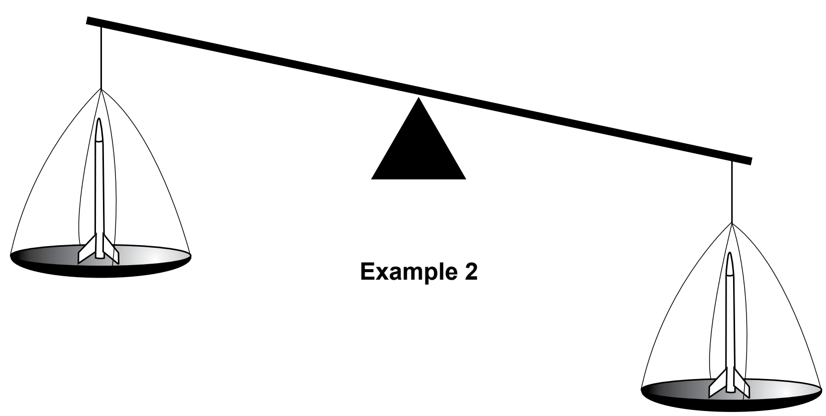
(Average Thrust Level)

Test Your Knowledge

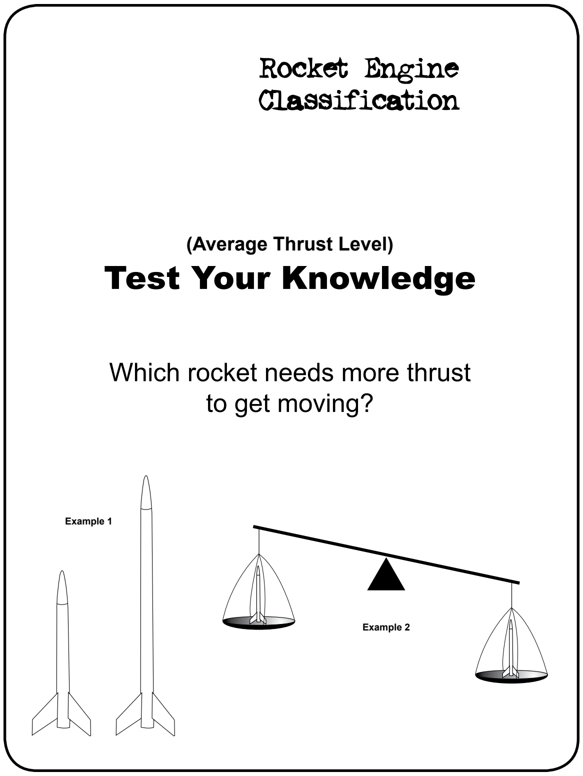
Which rocket needs more thrust
to get moving?



Example 1



Example 2



Rocket Engine Classification

Purpose: To reinforce the concept of Average Thrust Level by putting it into a perspective the students may understand. Before displaying this illustration, ask them to think of situations when a rocket may need more thrust? A bigger rocket (which has higher drag), or one of the same size but that is heavier, is going to need more thrust to get it moving.

Additional Information:

http://www.apogeerockets.com/Teacher_DVD.asp This DVD contains a live presentation on how to teach model rocketry. It gives a great synopsis of Average Thrust level and gives you ideas on how to explain it to students.

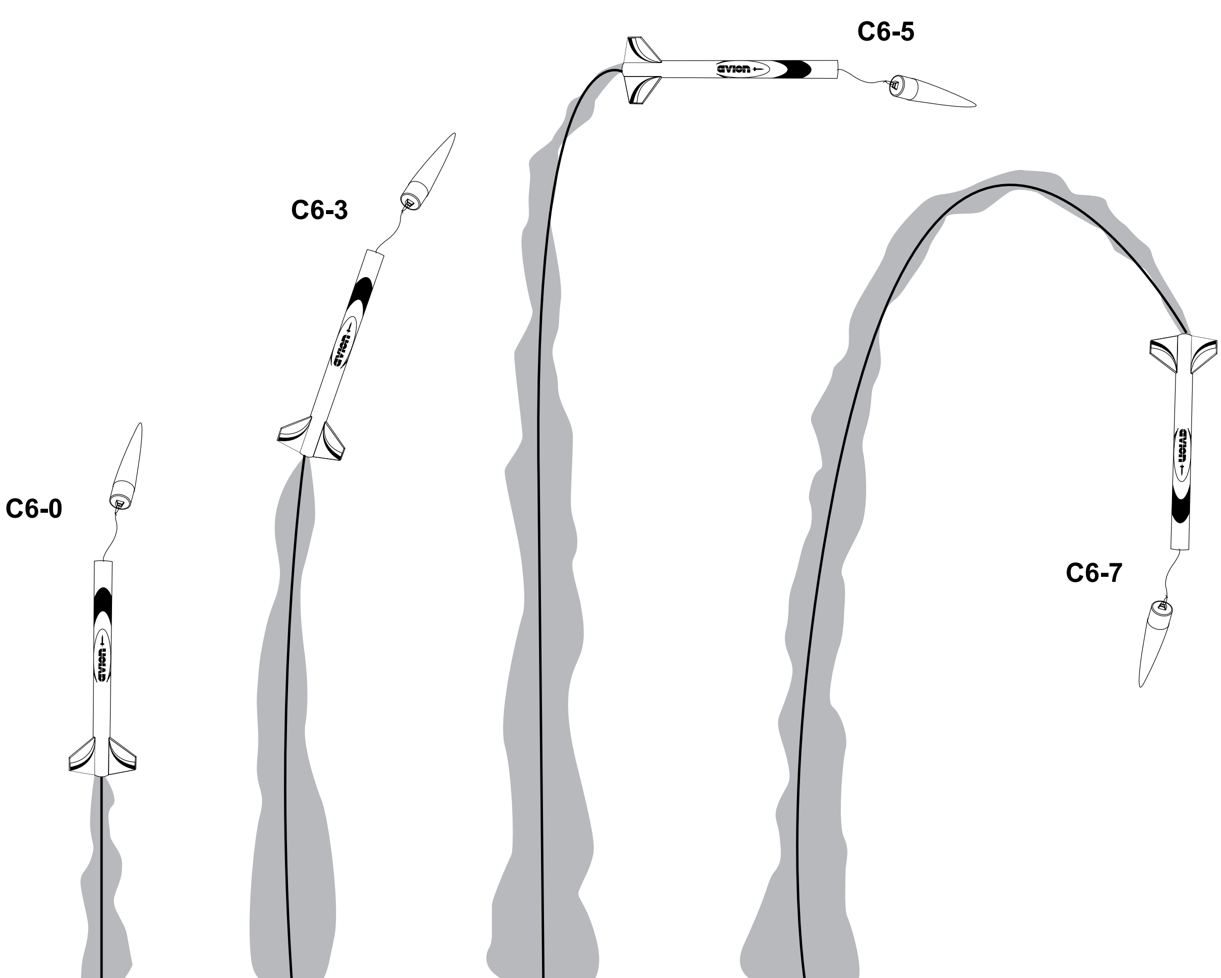
Teaching Tip: The RockSim software is a wonderful tool to use for experiments with rocket engines. In the case of average thrust, you can take a simple rocket and simulate a low thrust motor versus a high thrust motor. Have the students compare maximum speed and altitude. Which goes higher, which goes faster? Add wind to the simulation and again compare the results.

NOTES:

Rocket Engine Classification

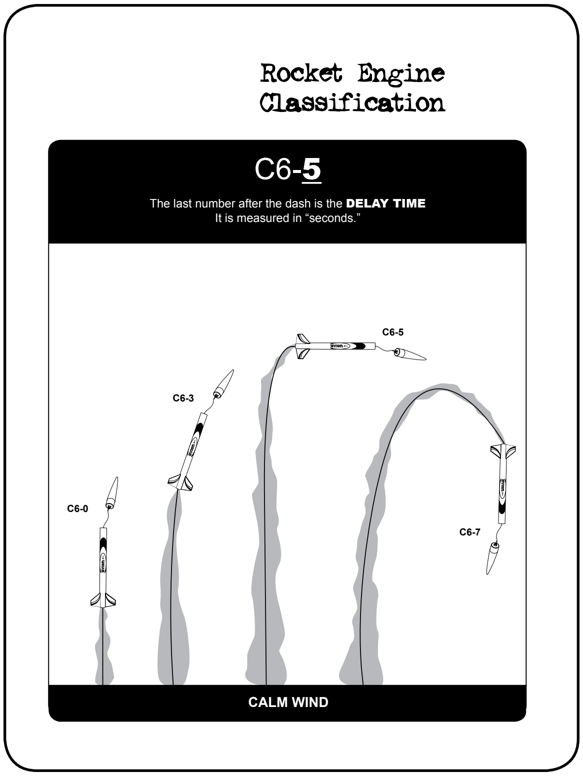
C6-**5**

The last number after the dash is the **DELAY TIME**
It is measured in “seconds.”



CALM WIND

3355 Fillmore Ridge Heights Colorado Springs CO, 80907 (719) 535-9335 www.ApogeeRockets.com



Rocket Engine Classification

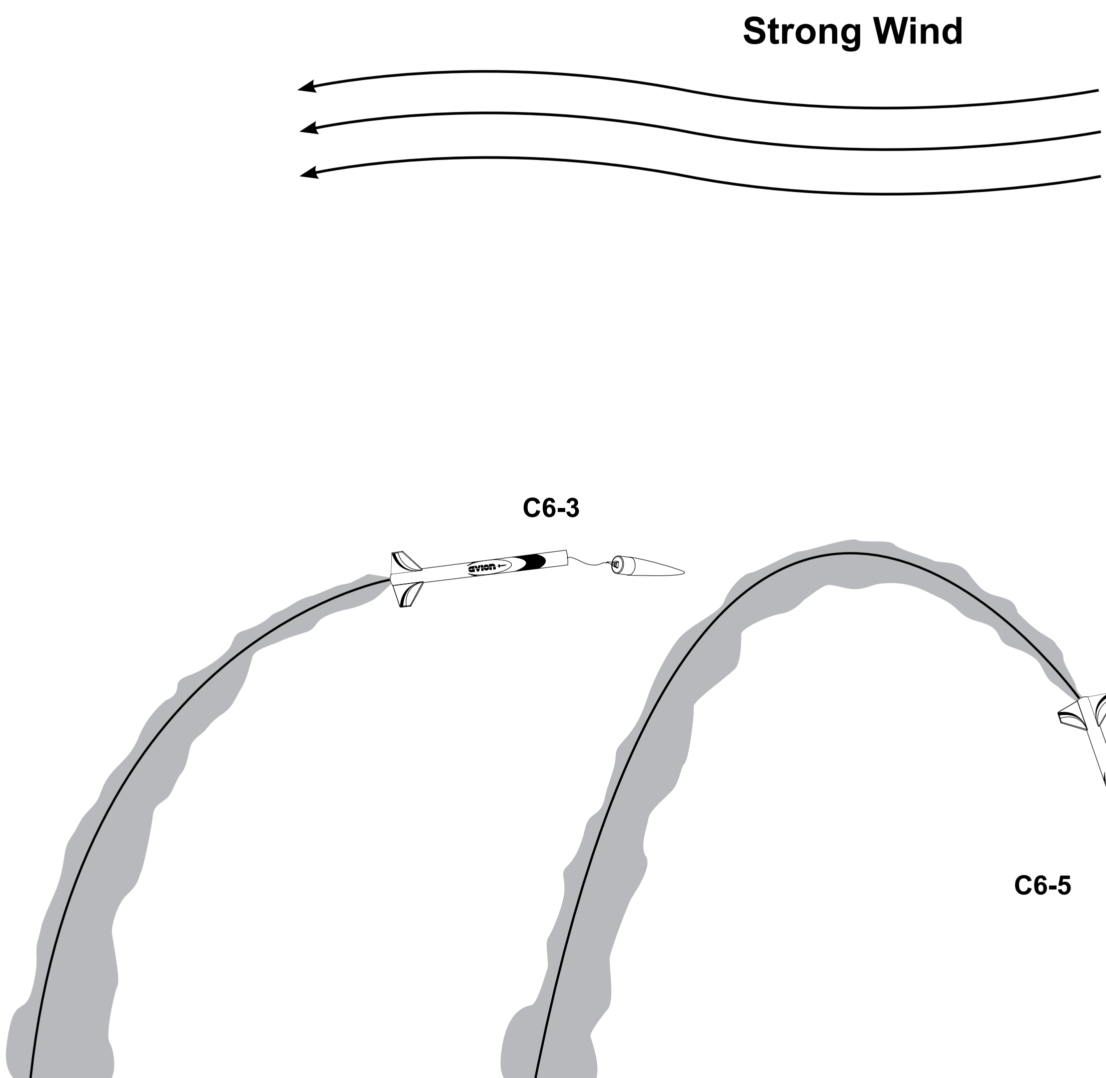
Purpose: To illustrate the concept that the selection of an incorrect delay time for the flight affects how high the rocket may travel and when during the flight the parachute is deployed.

Teaching Tip: The 2D Flight Profile feature of RockSim can be used to visually illustrate the concept of delay selection. Pick a rocket and change the delay value for the engine. Look at the 2D Flight Profile and see where the ejection occurs in the flight. From the Summary table on the main screen, look at the velocity at deployment. If the rocket is traveling too fast at deployment, the parachute can be stripped off the rocket. Typically you want to keep the speed under 30mph to keep the parachute intact.

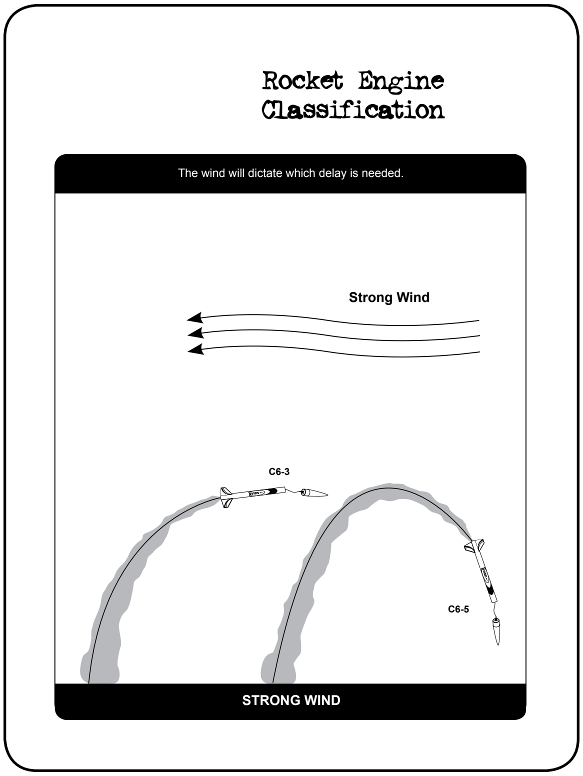
NOTES:

Rocket Engine Classification

The wind will dictate which delay is needed.



STRONG WIND



Rocket Engine Classification

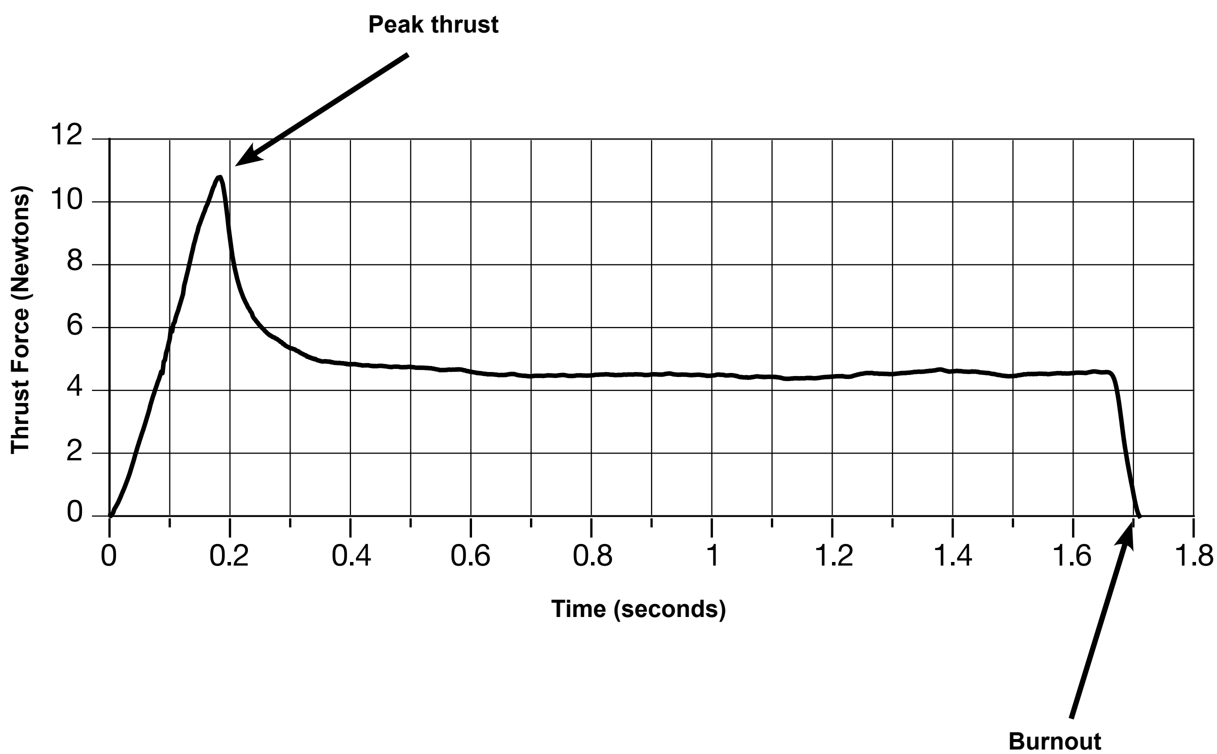
Purpose: To illustrate the concept that delay selection actually depends on the wind conditions at launch time. What is a good delay for calm winds may not be a good engine delay for when the winds are blowing strong.

Teaching Tip: The 2D Flight Profile feature of RockSim can be used to visually illustrate the concept of delay selection and how wind will affect the best delay choice. Pick a rocket and launch it straight up with zero wind. Find the best delay that gives the highest altitude. Now add wind to the simulation (a very strong wind). Rerun the simulation and see if the old delay still ejects at the highest point in the flight. Now find the best delay for the weather conditions.

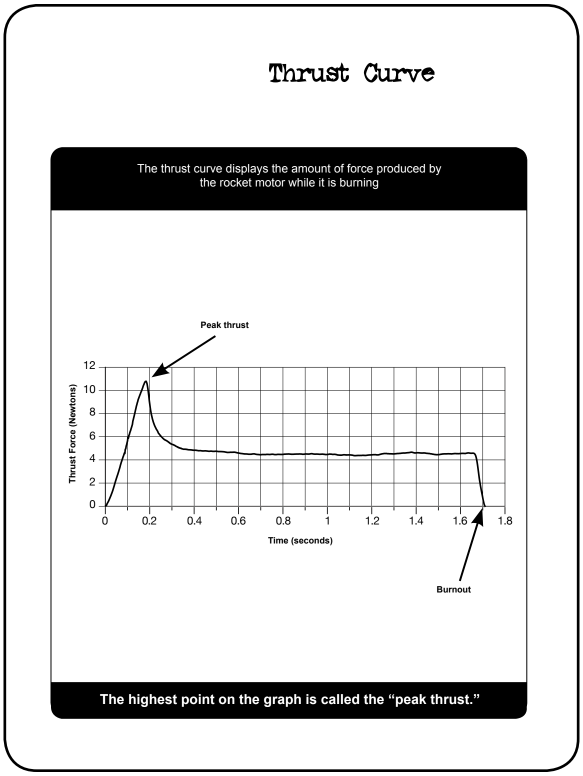
NOTES:

Thrust Curve

The thrust curve displays the amount of force produced by the rocket motor while it is burning



The highest point on the graph is called the "peak thrust."



Thrust Curve

Purpose: To show some of the key points on a thrust curve.

Background: When a rocket engine burns, it produces a thrust force. Graphing that thrust versus time gives us a chart called a thrust curve. The peak thrust point is the highest level of thrust that the rocket engine creates. The Burnout point is when the motor stops producing a measurable thrust force.

Additional Information:

http://www.ApogeeRockets.com/education/downloads/Newsletter106.pdf This newsletter contains a detailed article that explains the engine code classification system.

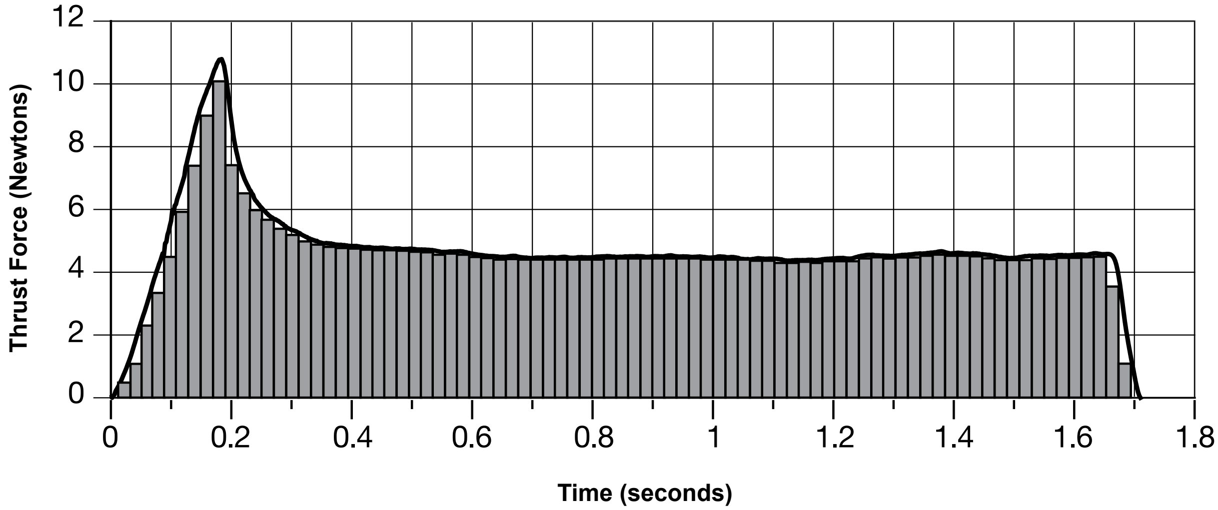
http://www.ApogeeRockets.com/Teacher_DVD.asp This DVD contains a live presentation on how to teach model rocketry. It goes over the engine code classification system in great detail.

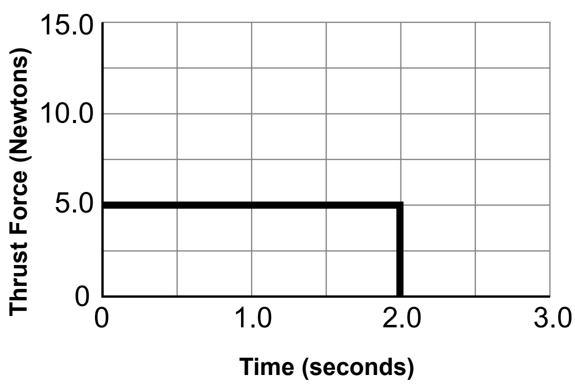
Teaching Tip: Compare the thrust curves of the Estes C6 versus the Apogee Components C10 motor. From their thrust curves, find the peak thrust and burnout times of each. The thrust curves can be found in the RockSim software (use the EngEdit program that comes bundled with RockSim to open up the engine data files).

NOTES:

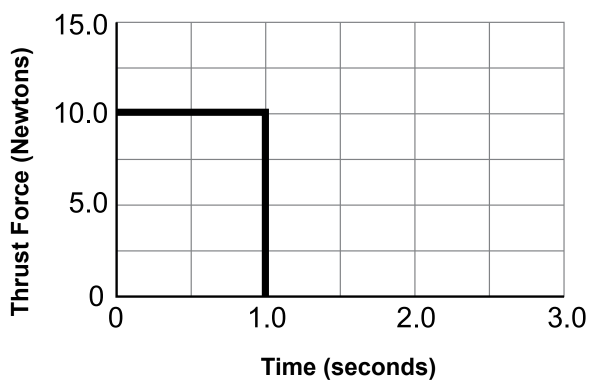
Total Impulse

Total Impulse is the power of the motor.
It is determined by finding the area under the thrust curve.



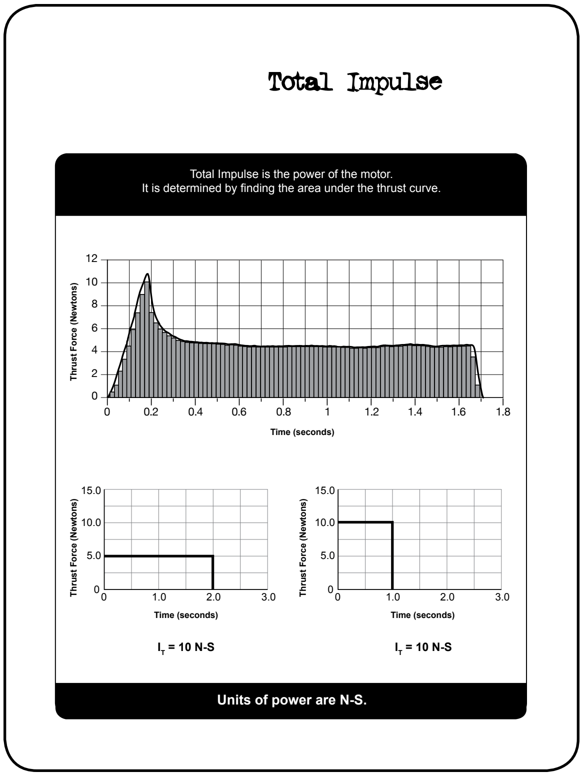


I_T = 10 N-S



I_T = 10 N-S

Units of power are N-S.



Total Impulse

Purpose: To show that a rocket engine's power (called Total Impulse) is found by determining the area underneath the thrust curve.

Background: Simple thrust curves, that are rectangular or triangular in shape are easy to find the area of. But rocket engines don't usually burn so uniformly. The shape can be quite complex. To find the total area, one must break up the area into multiple rectangles, and then add up the combined areas of these smaller rectangles, or use basic calculus.

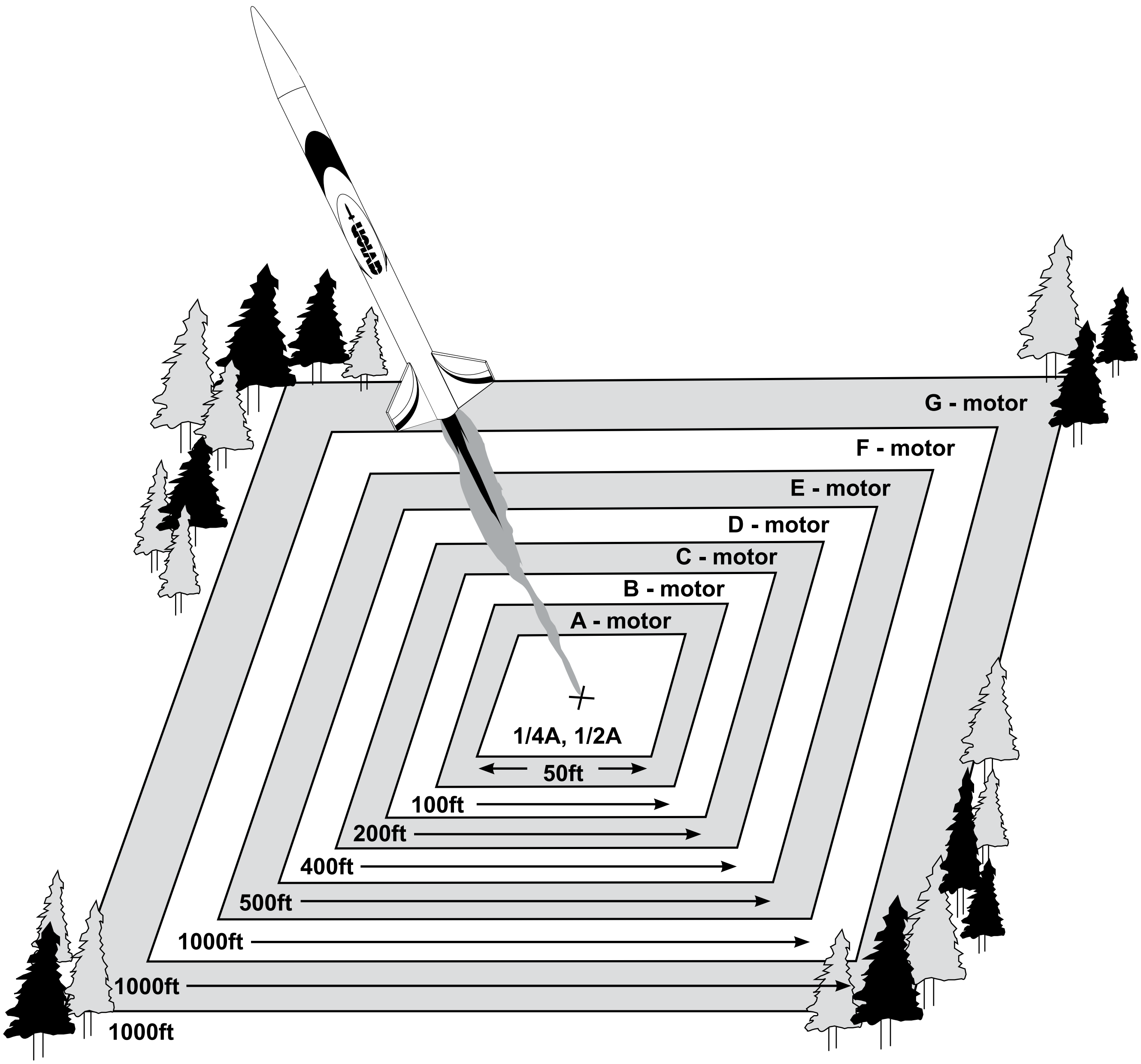
Additional Information:

http://www.ApogeeRockets.com/Teacher_DVD.asp This DVD contains a live presentation on how to teach about rocket engines. It explains the concept of Total Impulse in a way that students will easily understand.

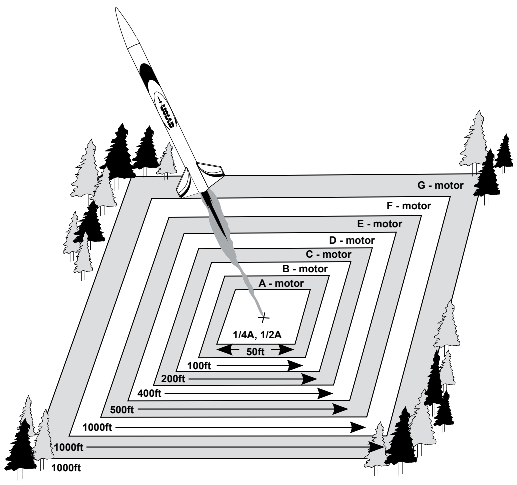
Teaching Tip: Have the students create their own thrust curve profile using the EngEdit software (which comes bundled with RockSim). Take the Estes B6 motor, and change it into a C6 engine. Remember, for a "C" engine, the total Impulse must remain under 10 N-seconds. Have them make a thrust curve so there are no horizontal lines on it.

NOTES:

Minimum Field Size



Minimum Field Size



Minimum Field Size

Purpose: To show students that the size field they'll need when launching rockets is going to depend on how high they expect their rocket to fly.

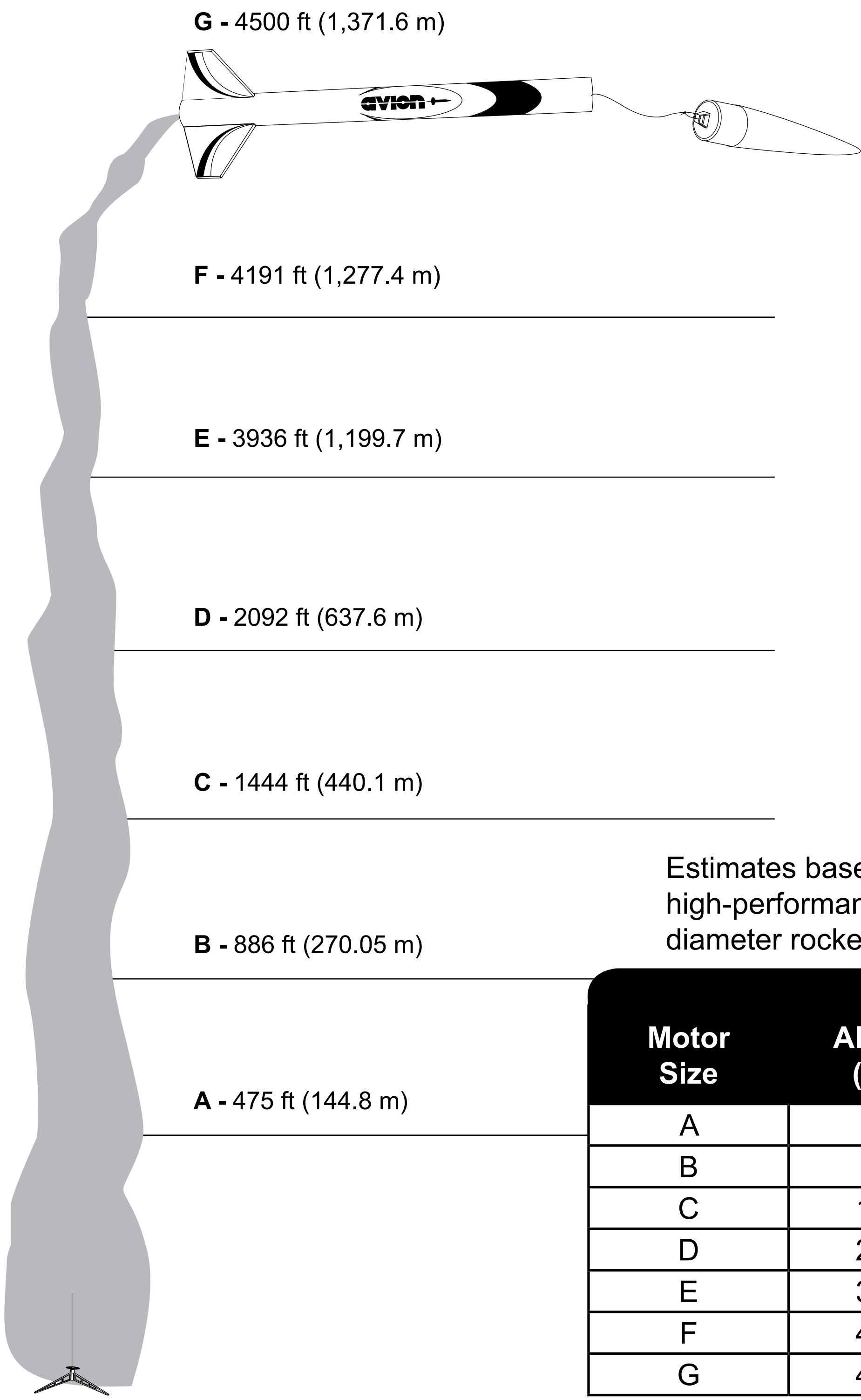
Additional Information:

The field sizes listed here are based on the National Association of Rocketry's Safety code.
http://www.nar.org/NARmrsc.html#sitedimensions

Teaching Tip: The 2D Flight Profile feature of RockSim can be used to visually illustrate the concept of how far downrange a rocket will drift when launch conditions are windy. It can also be used to help determine the launch angle that can be used to minimize the amount of drift. Ask the students which variables might make simulations inaccurate? Answers should include things like wind speed and direction variation, inaccurate measurement of launch angle and direction, poorly aligned fins on the rocket, variation in predicted drag because of poorly constructed rocket, variability of engine performance, and maybe erosion of the engine nozzle causing a canting of the thrust force. Because of all these variables, the "minimum" size launch field is for safety considerations and should not be reduced even if the software predicts that the rocket is going to land close to the pad.

NOTES:

Approximate Altitude

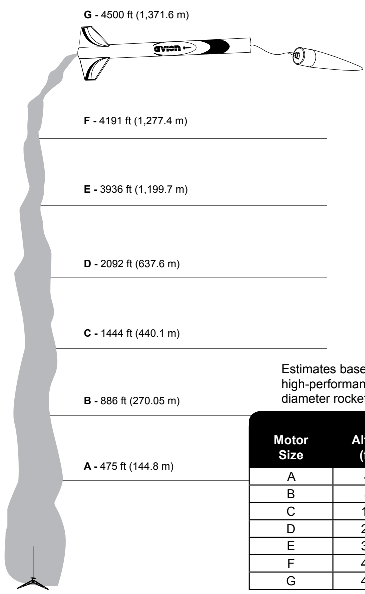


Estimates based on ultra high-performance minimum diameter rockets

Motor Size	Altitude (feet)	Altitude (meters)
A	475	144.8
B	886	270.05
C	1444	440.1
D	2092	637.6
E	3936	1,199.7
F	4191	1,277.4
G	4500	1,371.6

Typical rocket kits will be much lower than these values.
Use this chart as a maximum value your rocket might achieve.

Approximate Altitude



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F	4191	1,277.4
G	4500	1,371.6

Typical rocket kits will be much lower than these values.
Use this chart as a maximum value your rocket might achieve.

Approximate Altitude

Purpose: To give students a rough idea of how high a given rocket engine could loft their model rocket.

Background: Notice in the chart that altitude does not always double when a more powerful rocket engine is used. The reason is that the next size engine may by physically larger in diameter. This requires a bigger diameter rocket, which has more frontal area and higher drag, as well as being heavier. Because of this, the efficiency of the rocket is reduced and it won’t travel as high.

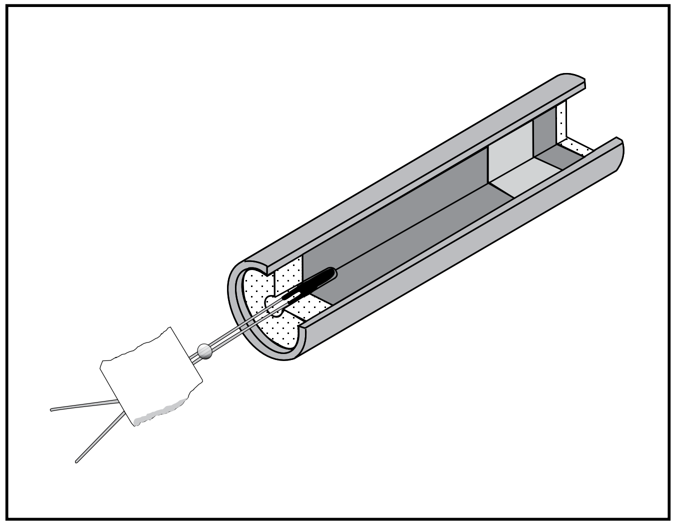
Teaching Tip: Let the students try to design ultra-high performance model rockets using the RockSim software. Give them some constraints, such as the maximum size rocket engine to use for the simulations and that they must used a fixed drag coefficient of .75. Also add some wind to the simulations to make sure that an unstable rocket will go crazy.

NOTES:

Inserting an Igniter

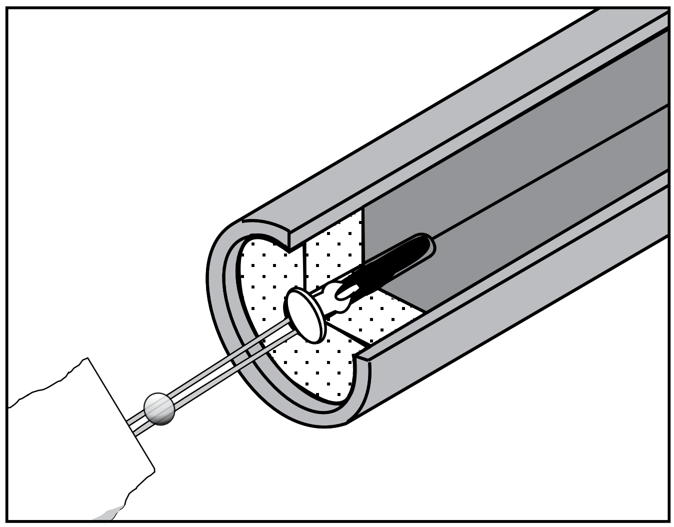
Step 1

Insert the igniter into the engine as far as it will go.



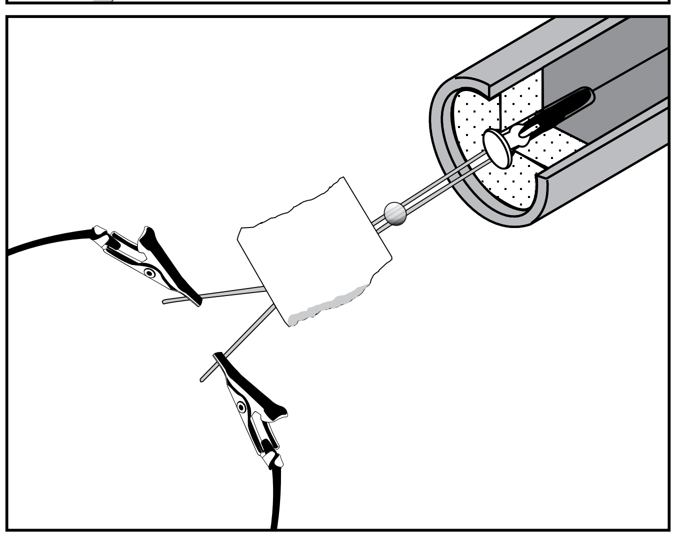
Step 2

Put the igniter plug into the same hole as the igniter went in. PRESS HARD!

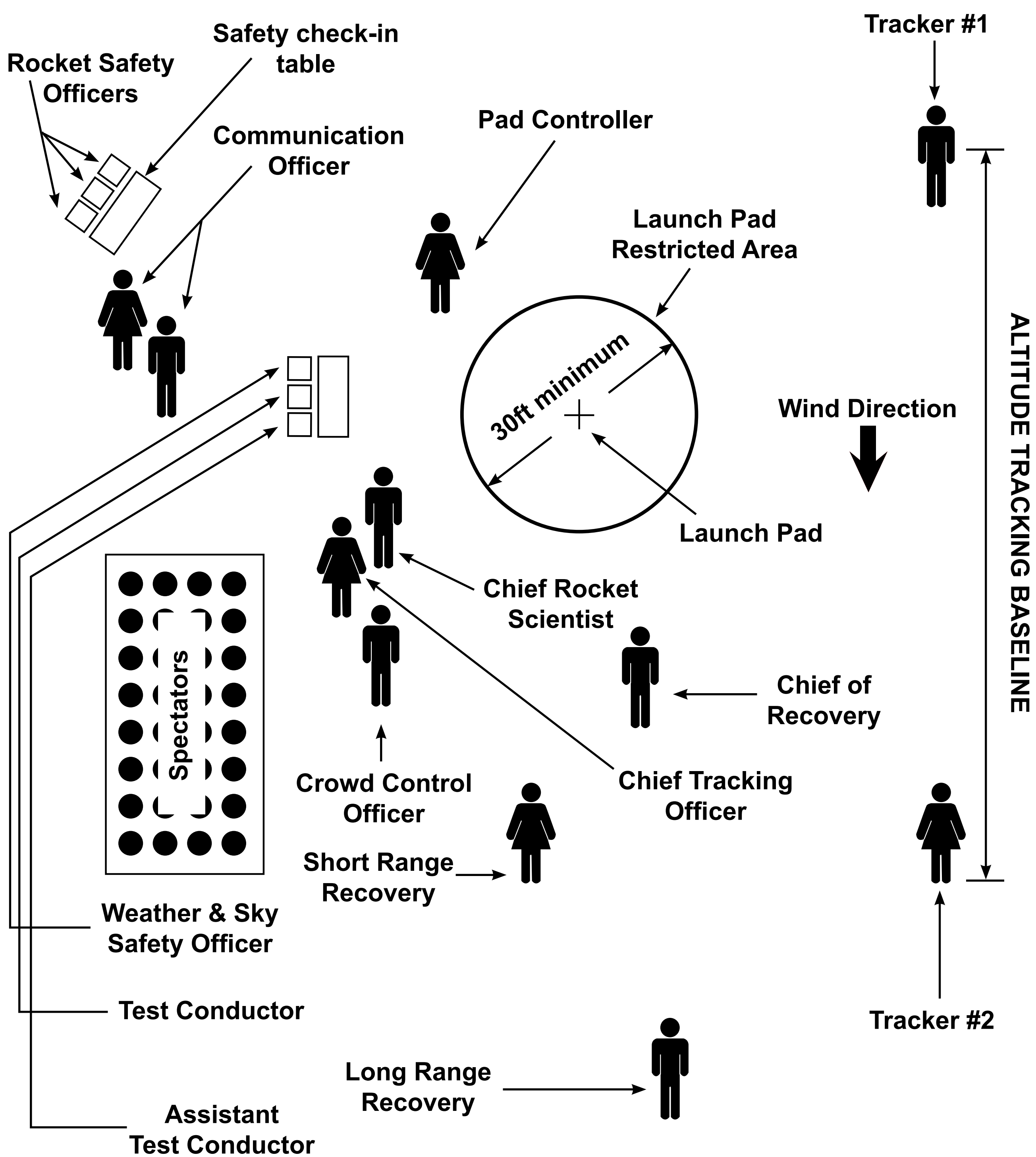


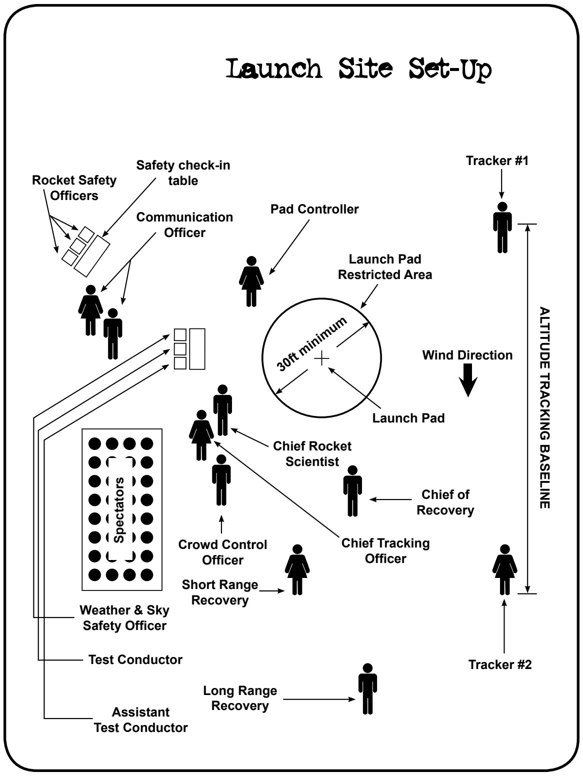
Step 3

Connect the launch controller clips to the igniter wires. Make sure they do not touch each other.



Launch Site Set-Up





Launch Site Set-Up

Purpose: To give the students an idea of where they will be stationed on launch day.

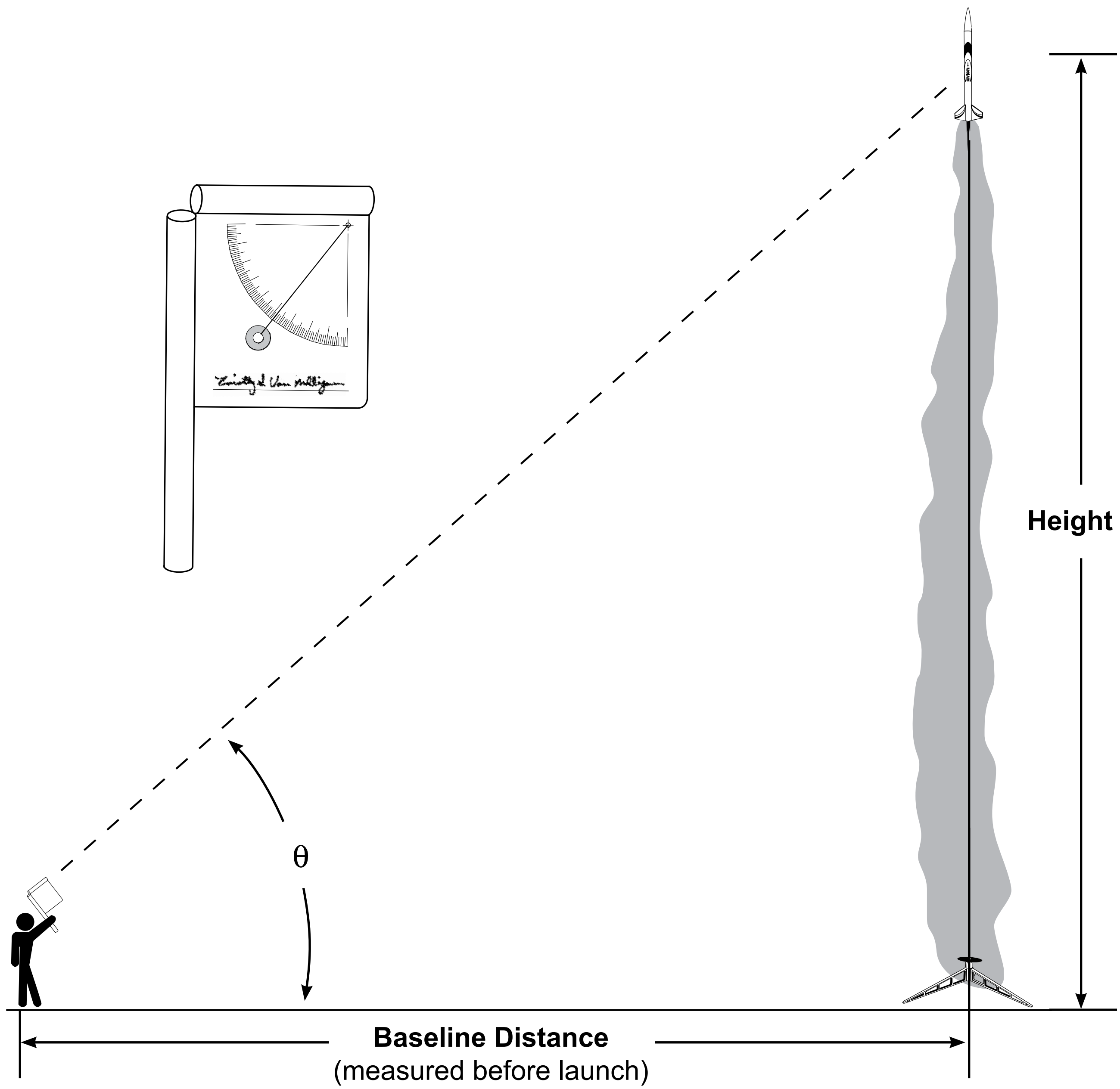
Additional Information:

This image comes from the book "*Conducting a Safe & Scientific Launch In Large Group Settings*." http://www.apogeerockets.com/safe_launch_bk.asp The book goes into great detail what each student's assignment is during the launch day activities.

Teaching Tip: Use this drawing to help you set up your rocket range. A great way to enhance it is to overlay the range on a aerial photograph of the actual launch site. This can be found using the FREE Google Earth software (http://www.earth.google.com).

NOTES:

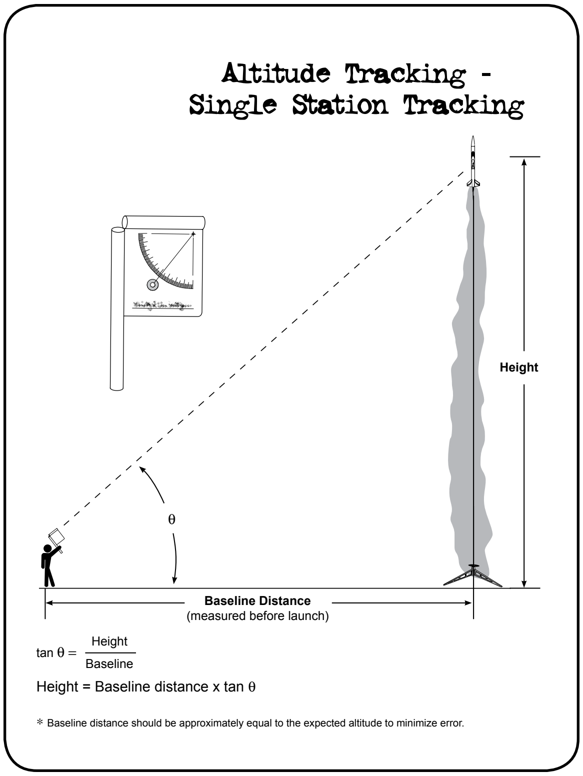
Altitude Tracking - Single Station Tracking



$$\tan \theta = \frac{\text{Height}}{\text{Baseline}}$$

Height = Baseline distance x $\tan \theta$

* Baseline distance should be approximately equal to the expected altitude to minimize error.



Altitude Tracking – Single Station Tracking

Purpose: To show the geometry of tracking a model rocket using the simple elevation angle tracker.

Additional Information:

http://www.ApogeeRockets.com/education/downloads/Newsletter92.pdf This newsletter contains a detailed article that explains how to track a model rocket using single-station tracking.

http://www.ApogeeRockets.com/altitude_tracker.asp - This simple tool will help you measure the angle of launch for your rocket. If you use a 100m baseline, you can use it without doing any math!

NOTES:

Altitude Tracking - Single Station Tracking

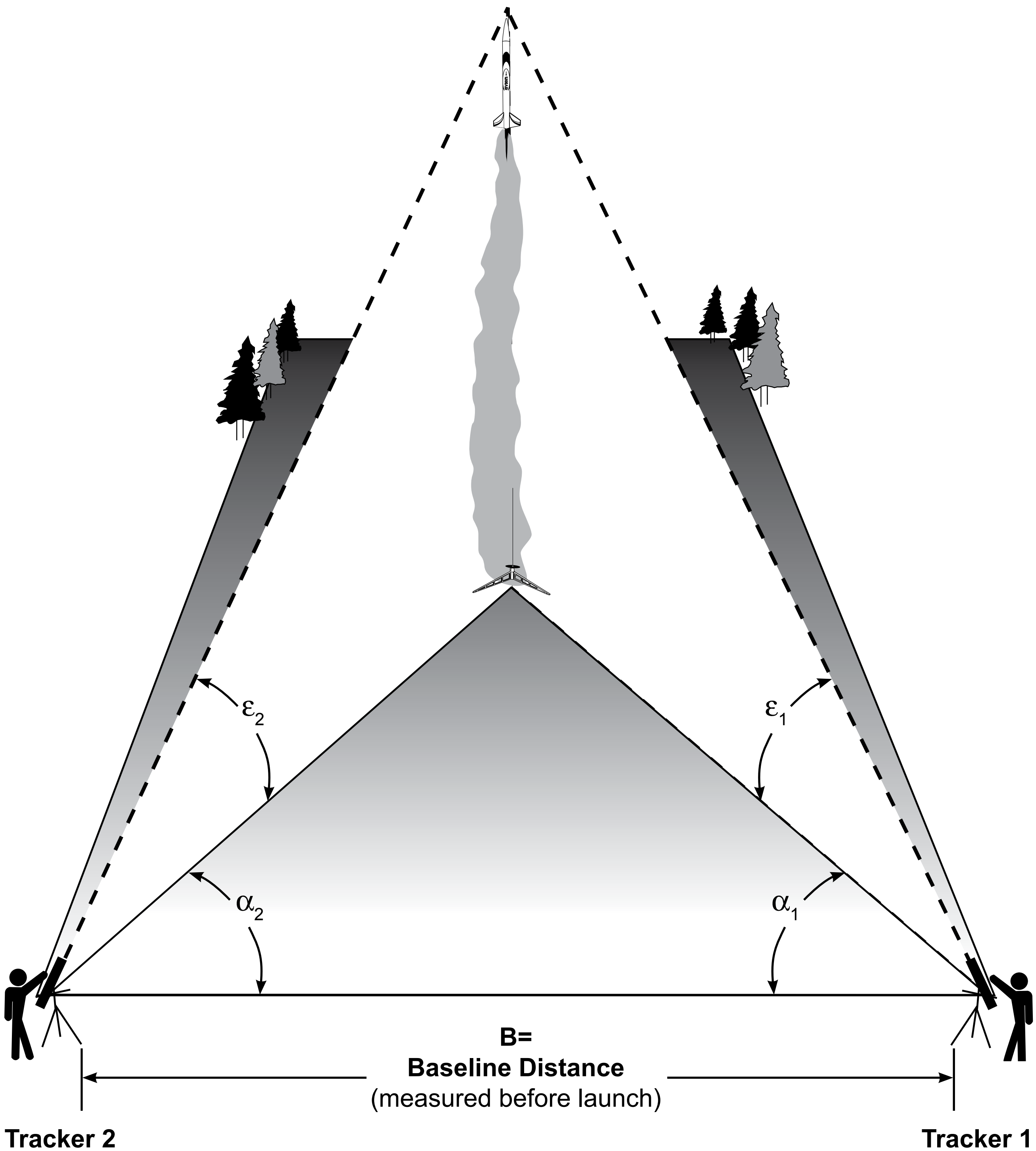
Advantages:

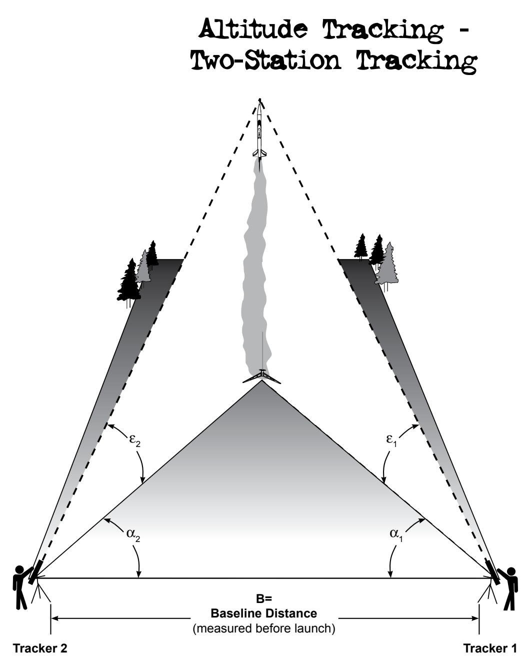
1. Simple equations
2. Inexpensive equipment
3. Does not require the rocket to return after flight
4. Requires only two people, one to launch the rocket and one to take measurements

Disadvantages:

1. Not very accurate, because the rocket may arc over and then baseline distance has changed

Altitude Tracking - Two-Station Tracking





Altitude Tracking – Two-Station Tracking

Purpose: To show the geometry of tracking a model rocket using two trackers that are each taking elevation and azimuth angle readings from a theodolite.

Additional Information:

http://www.ApogeeRockets.com/education/downloads/Newsletter93.pdf This newsletter contains a detailed article that explains how to track a model rocket using two people, each taking just Elevation angles.

NOTES:

Altitude Tracking - Two-Station Tracking

$$\mathbf{h_1} = \text{height measured by tracker 1} = B\,\frac{\sin\alpha_2 \tan\varepsilon_1}{\sin(\alpha_1+\alpha_2)}$$

$$\mathbf{h_2} = \text{height measured by tracker 2} = B\,\frac{\sin\alpha_1 \tan\varepsilon_2}{\sin(\alpha_1+\alpha_2)}$$

$$\textbf{Alt} = \frac{h_1 + h_2}{2}$$

$$\textbf{Closure error \%}\,{}^{*} = \left|\frac{h_1 - h_2}{2\,\text{Alt.}}\right|$$

* Closure error must be ≤ 0.1 for altitude to be considered reliable.

Altitude Tracking - Two-Station Tracking

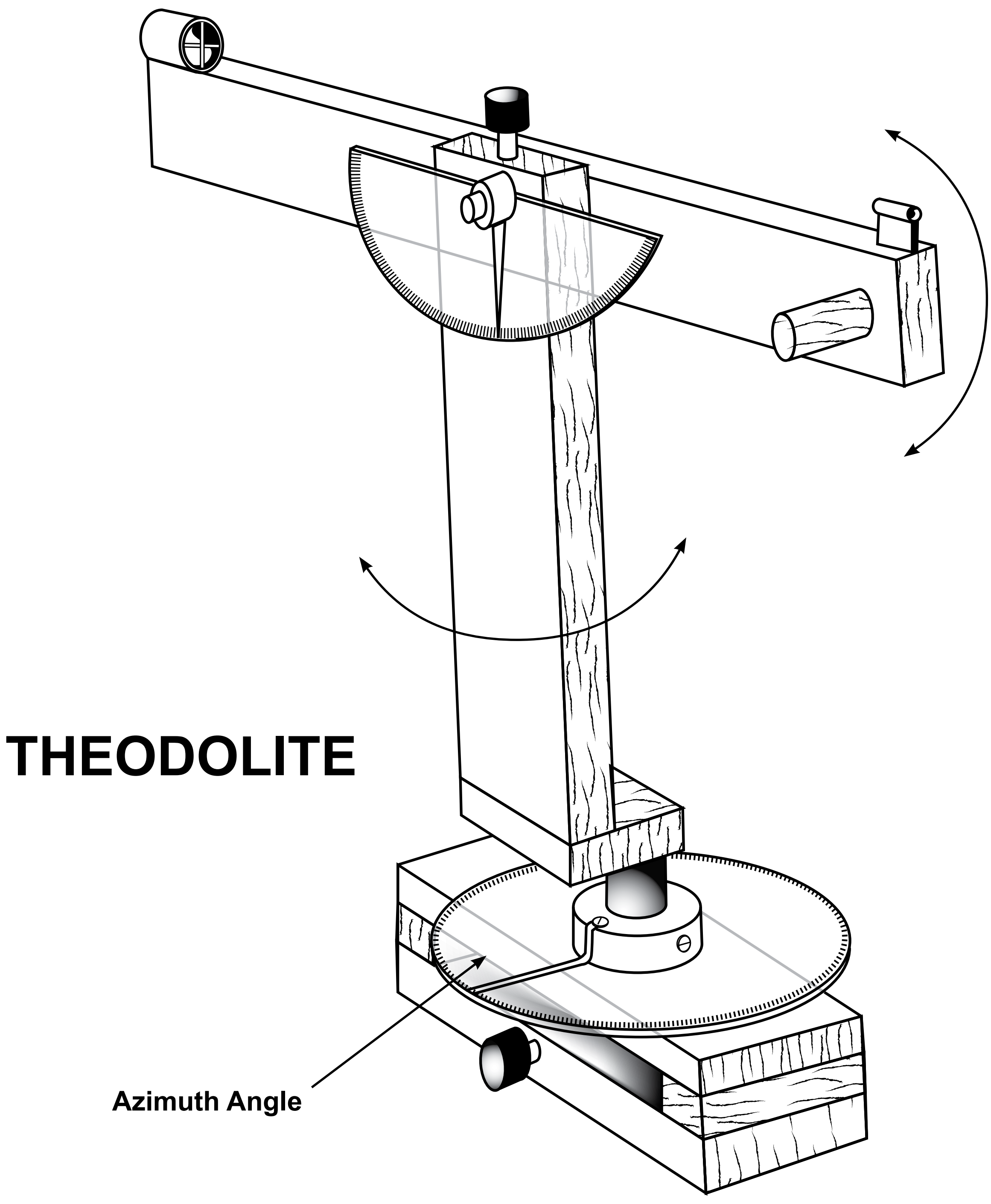
Advantages:

1. Accurate
2. Rocket does not have to fly perfectly vertical
3. Rocket does not have to be recovered

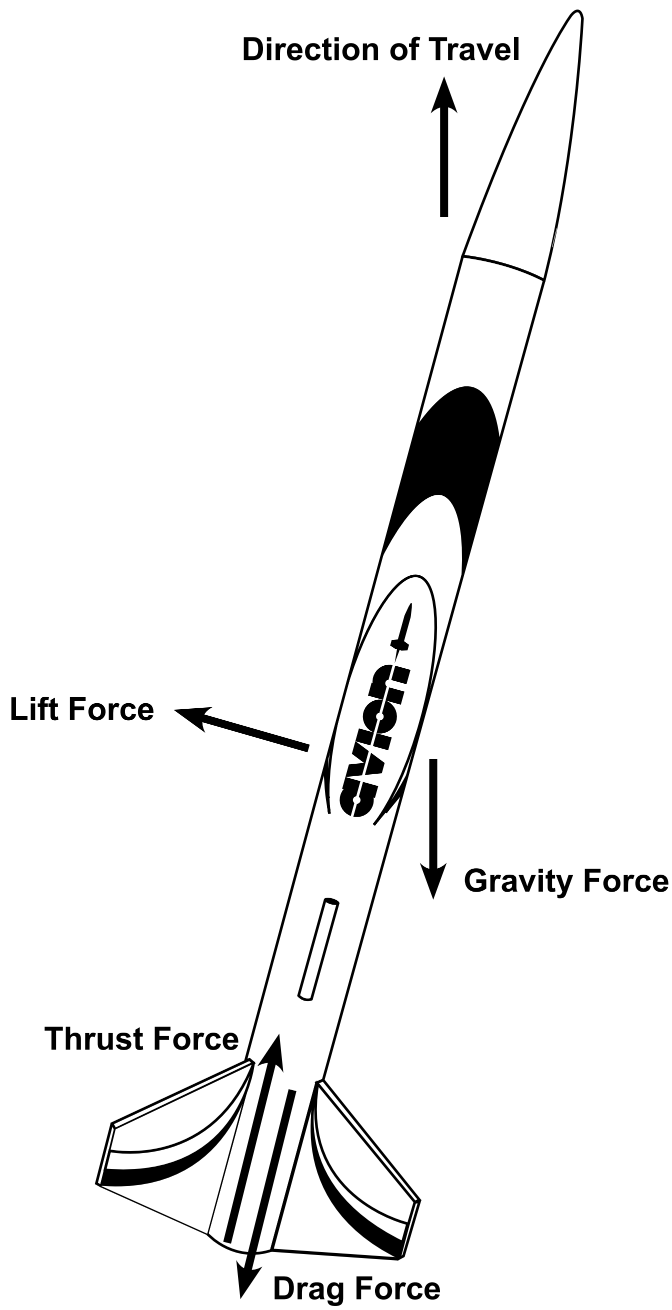
Disadvantages:

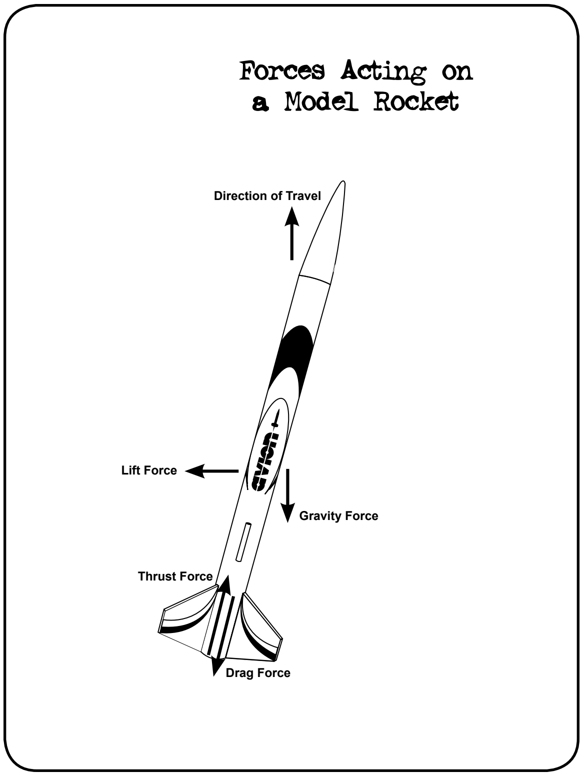
1. Requires tracking theodolites
2. Minimum of three people: one to launch and two to track
3. Equations are a little bit harder to complete and take more time

Altitude Tracking - Two-Station Tracking



Forces Acting on a Model Rocket





Forces Acting On a Model Rocket

Purpose: To define the forces acting on a rocket. The combination of these forces determines how a rocket behaves when launched.

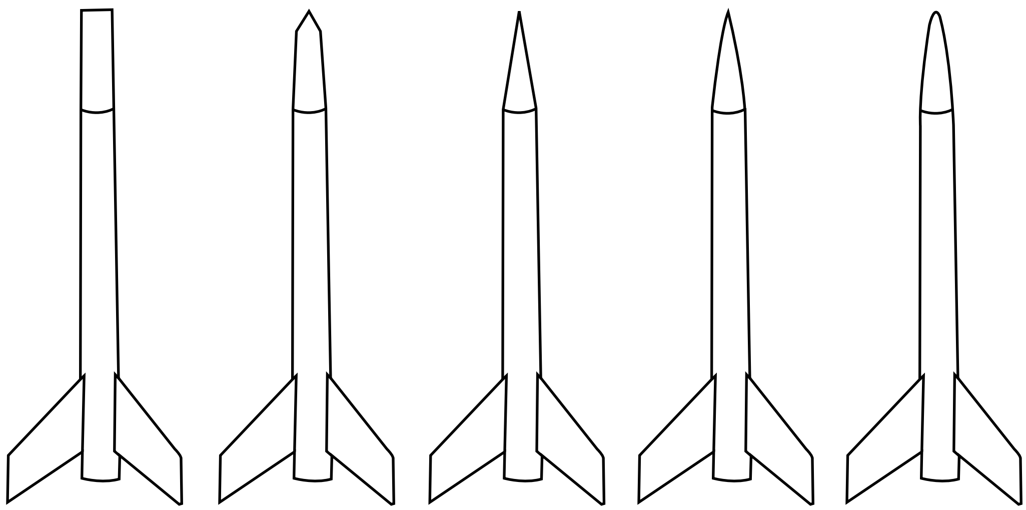
Additional Information:

http://exploration.grc.nasa.gov/education/rocket/rktfor.html This NASA web site gives a brief explanation of the forces acting on a rocket.

NOTES:

Drag on a Model Rocket

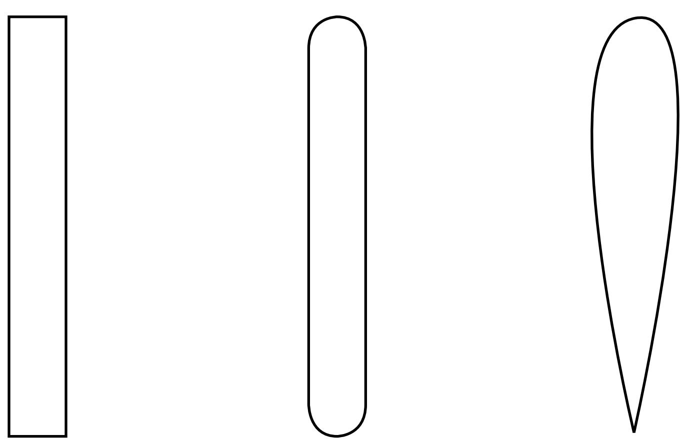
1. Form Drag - related to the shape of the model rocket



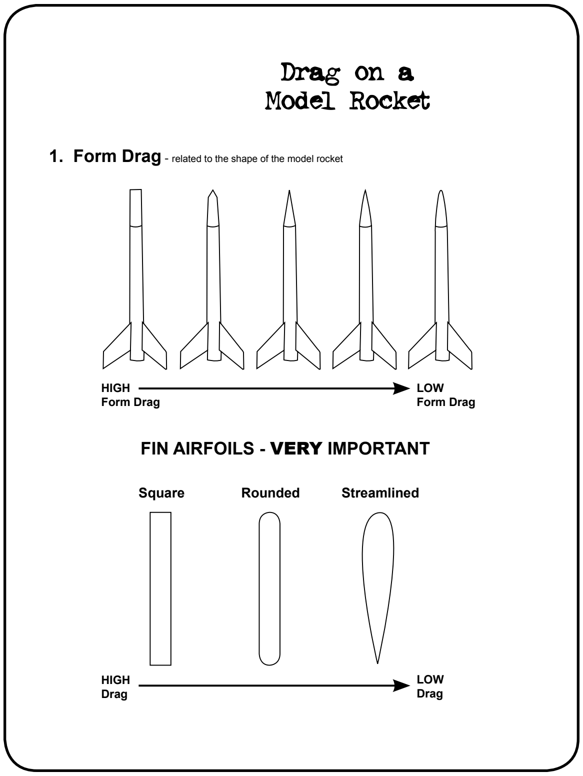
HIGH Form Drag → **LOW Form Drag**

FIN AIRFOILS - **VERY** IMPORTANT

Square **Rounded** **Streamlined**



HIGH Drag → **LOW Drag**



Drag on a Model Rocket

Purpose: To illustrate the first component of drag on a rocket: Form Drag.

Additional Information:

The book *Model Rocket Design and Construction* has a great chapter on drag reduction and aerodynamics! http://www.ApogeeRockets.com/design_book.asp.

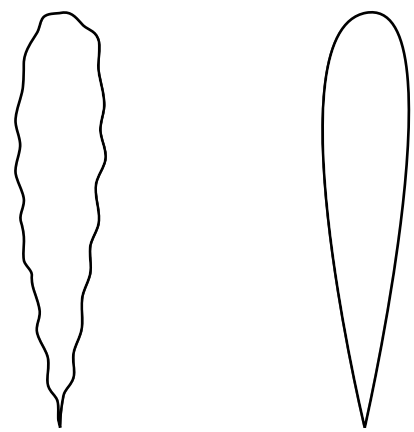
What fin shape is best for your rocket? This is probably the worst experiment you can do with model rockets, because it doesn't yield good data. Find out what is the best fin shape at: http://www.ApogeeRockets.com/technical_publication_16.asp

Teaching Idea: Increasing the number of fins on a rocket is a good way to see the effects of form drag. This can be simulated in the RockSim software (http://www.ApogeeRockets.com/rocksim.asp). Just create a design in the software and vary the number of fins and see how the altitude and speed changes.

NOTES:

Drag on a Model Rocket

2. Skin Friction Drag

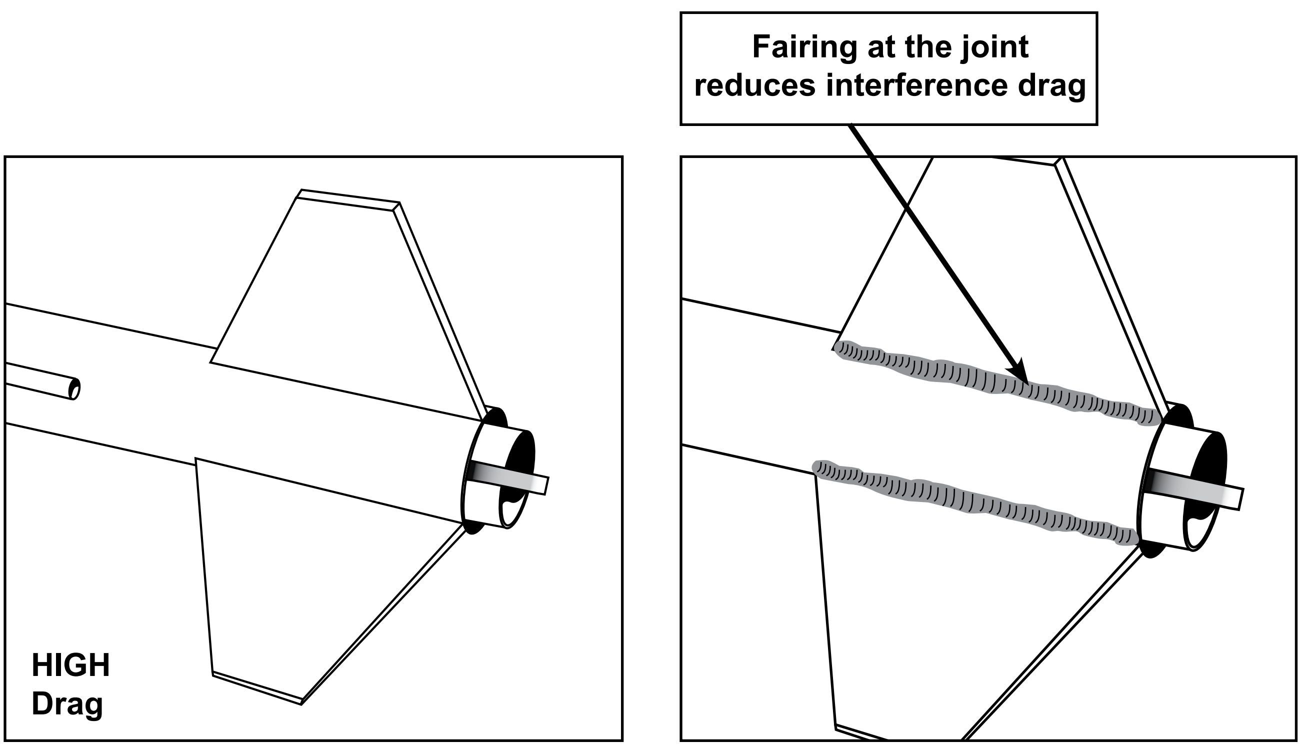


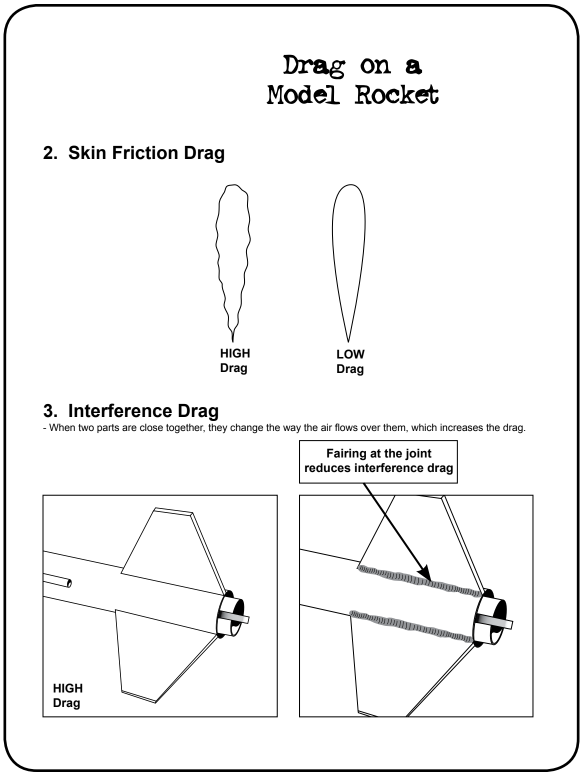
HIGH
Drag

LOW
Drag

3. Interference Drag

- When two parts are close together, they change the way the air flows over them, which increases the drag.





Drag on a Model Rocket

Purpose: To illustrate the next two components of drag on a rocket: Skin Friction and Interference Drag. The surface texture of the rocket, how smooth it is, determines the amount of skin friction drag the rocket will have. Smoothing airflow in tight corners will help reduce interference drag.

Additional Information:

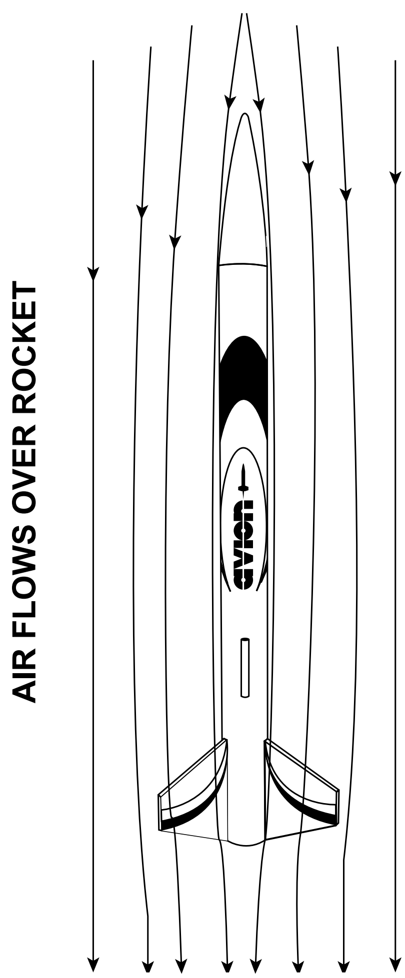
The book *Model Rocket Design and Construction* has a great chapter on drag reduction and aerodynamics!
http://www.ApogeeRockets.com/design_book.asp

How do you get the smoothest surface on your rocket and the best fin fillets? The secret is the techniques you use to apply the filler and the paint on your rocket. You can only learn these drag reducing techniques by watching an expert do it. Reading about techniques is difficult; no child learned to tie their shoelaces without watching it done by someone else. It is the same with getting a great surface finish on your rocket. You have to watch the techniques to learn them.
http://www.ApogeeRockets.com/Building_1_2_videos.asp

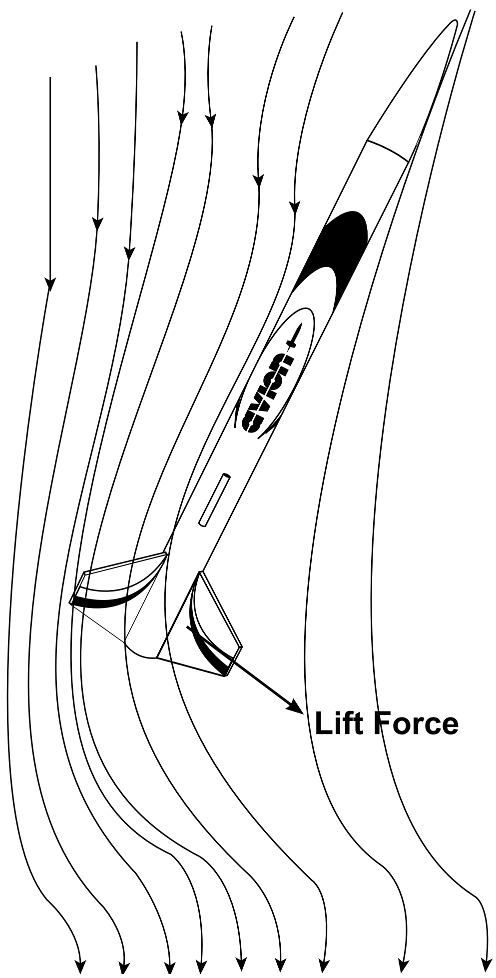
NOTES:

Drag on a Model Rocket

4. Induced Drag - Extra drag that results because the fins produce a lift force



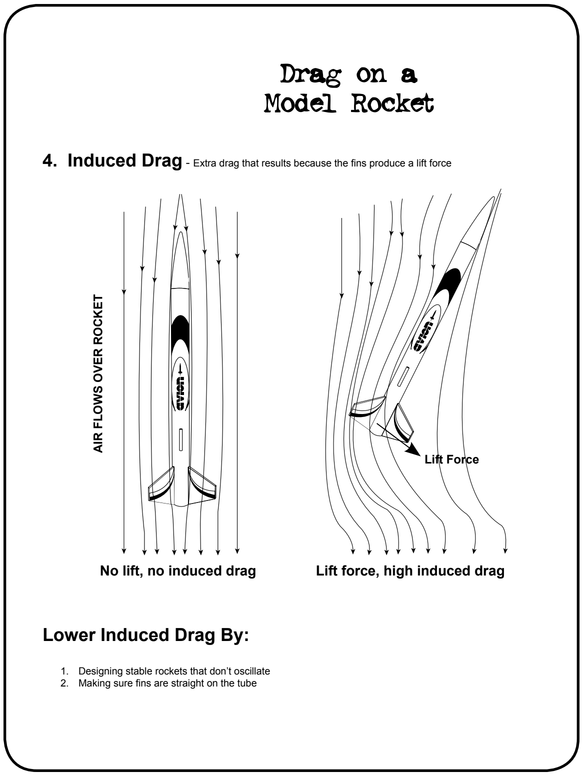
No lift, no induced drag



Lift force, high induced drag

Lower Induced Drag By:

1. Designing stable rockets that don't oscillate
2. Making sure fins are straight on the tube



Drag on a Model Rocket

Purpose: To illustrate the fourth component of drag: Induced Drag. This drag only occurs when the fins create lift, so it can be reduced by making sure the rocket flies as straight (zero angle-of-attack) as possible.

Additional Information:

http://www.grc.nasa.gov/WWW/K-12/airplane/induced.html This web page from NASA describes how induced drag is created.

It is also very important that the fins on a rocket are perfectly aligned with the body tube of the rocket. This is done during the construction of the model. To see how this is accomplished, check out the videos in "Building Skill Level 2 Model Rocket Kits" at: http://www.ApogeeRockets.com/skill_level_2_book.asp

NOTES:

Drag on a Model Rocket

Drag Force Equations

D = 1/2 $\rho\ V_2\ A\ C_d$

Where:

ρ = density of air

V = Velocity of the rocket

A = Reference Area - usually the maximum diameter of the rocket

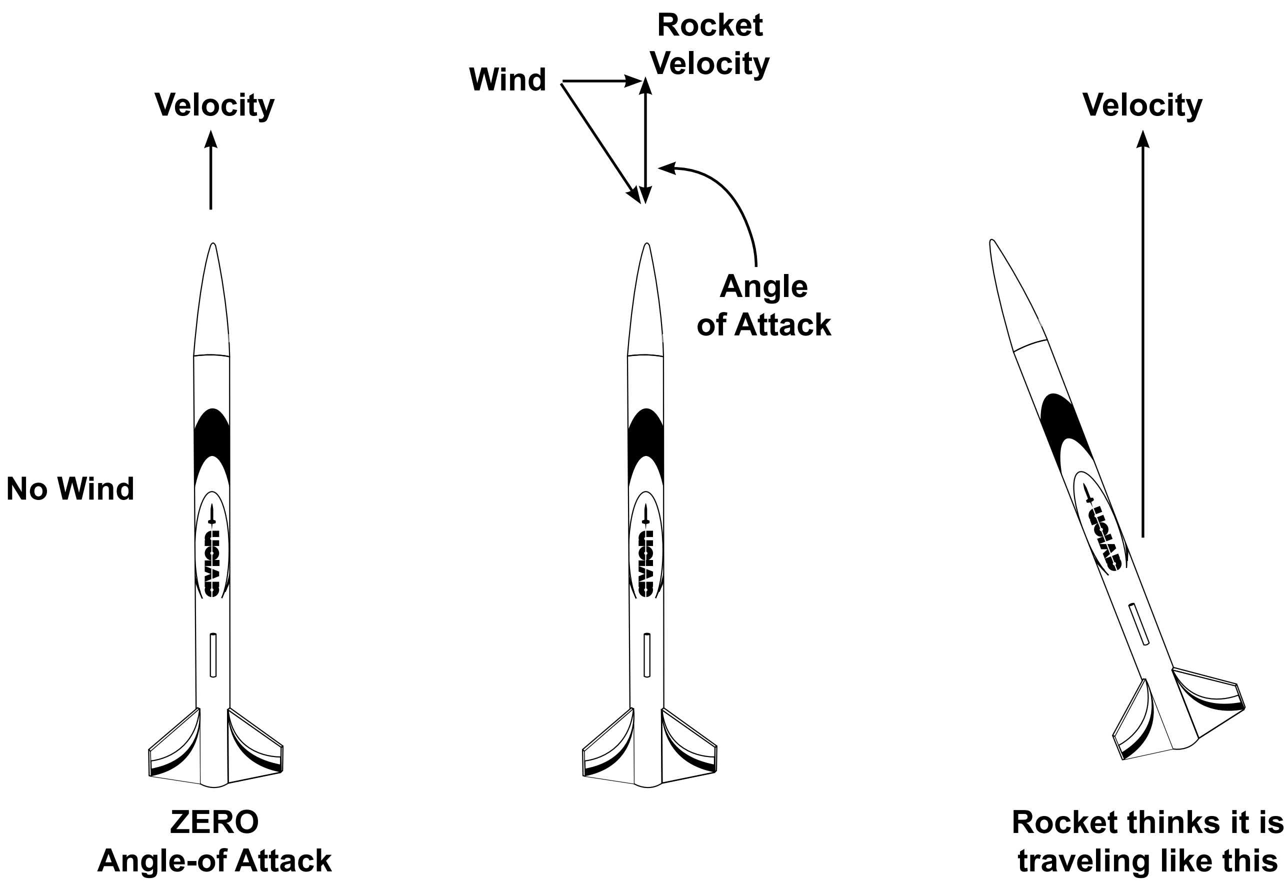
$$A = \frac{\pi}{4} D^2$$

Where D = diameter of the rocket

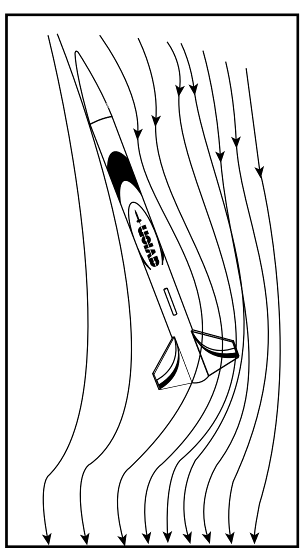
Cd = Drag Coefficient - unit less number that takes into account the four types of drag that act on the rocket

The value of Cd is usually between 0.4 and 1.7

Angle - of - Attack

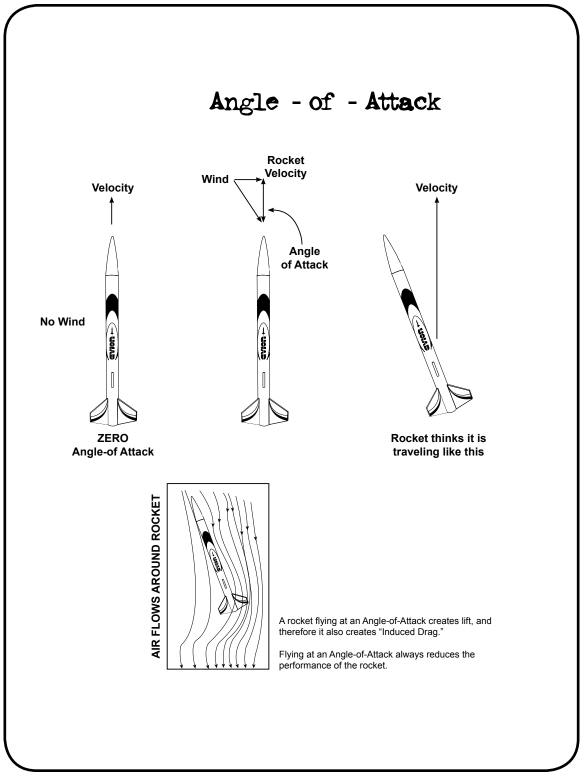


AIR FLOWS AROUND ROCKET



A rocket flying at an Angle-of-Attack creates lift, and therefore it also creates “Induced Drag.”

Flying at an Angle-of-Attack always reduces the performance of the rocket.



Angle-of-Attack

Purpose: To illustrate the concept of the rocket flying in one direction, but with its nose pointed in a different direction. It can be described to the students as “crab-walking.”

Additional Information:

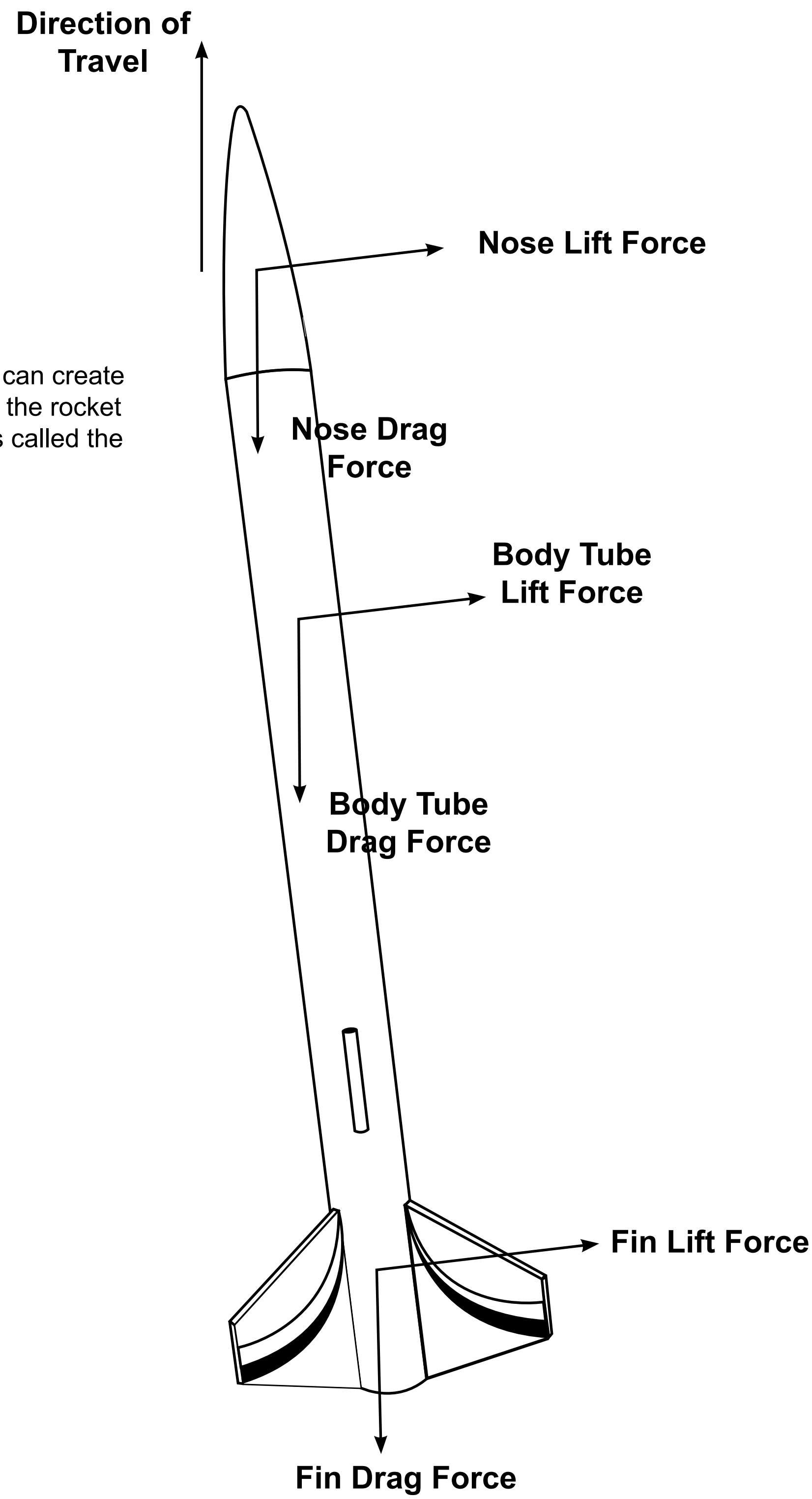
The airfoils on a rocket are symmetrical, and produce NO lift when flying at a zero degree angle-of-attack. When the rocket hits a disturbance, such as a gust of wind, the fins are now at an angle of attack, and start producing lift and induced drag. The lift force cause the rocket to rotate about the CG to zero out the angle-of-attack so it continues to fly straight. But the drag always slows the rocket down, and reduces the altitude it is capable of achieving.

There is a nice little JAVA simulator at: http://wright.nasa.gov/airplane/incline.html. It allows students to change the angle-of-attack of a wing and see how the lift of the wing increases. Airplane wings are not usually symmetrical so they do produce a lift force at zero degrees angle-of-attack.

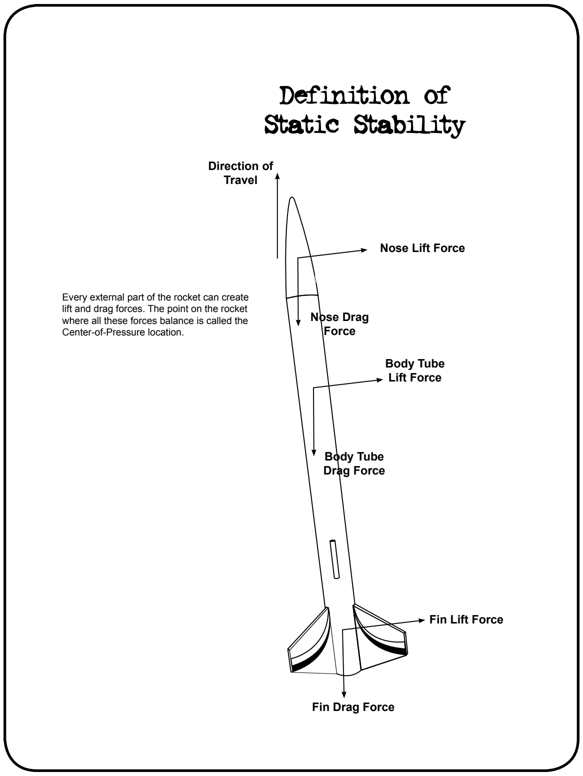
Teaching Tip: In the RockSim software, have students run a simulation of their favorite rocket. Add some wind to the simulation. When the rocket enters the cross-wind, its angle-of-attack changes. Using the plot feature of RockSim, graph out “wind angle of attack” versus time. See how long it takes the rocket to zero out its angle-of-attack.

NOTES:

Definition of Static Stability



Every external part of the rocket can create lift and drag forces. The point on the rocket where all these forces balance is called the Center-of-Pressure location.



Definition of Static Stability

Purpose: To show that each component (not just the fins) creates both lift and drag when flying at an angle-of-attack. The fins produce the most forces, but the other parts contribute as well.

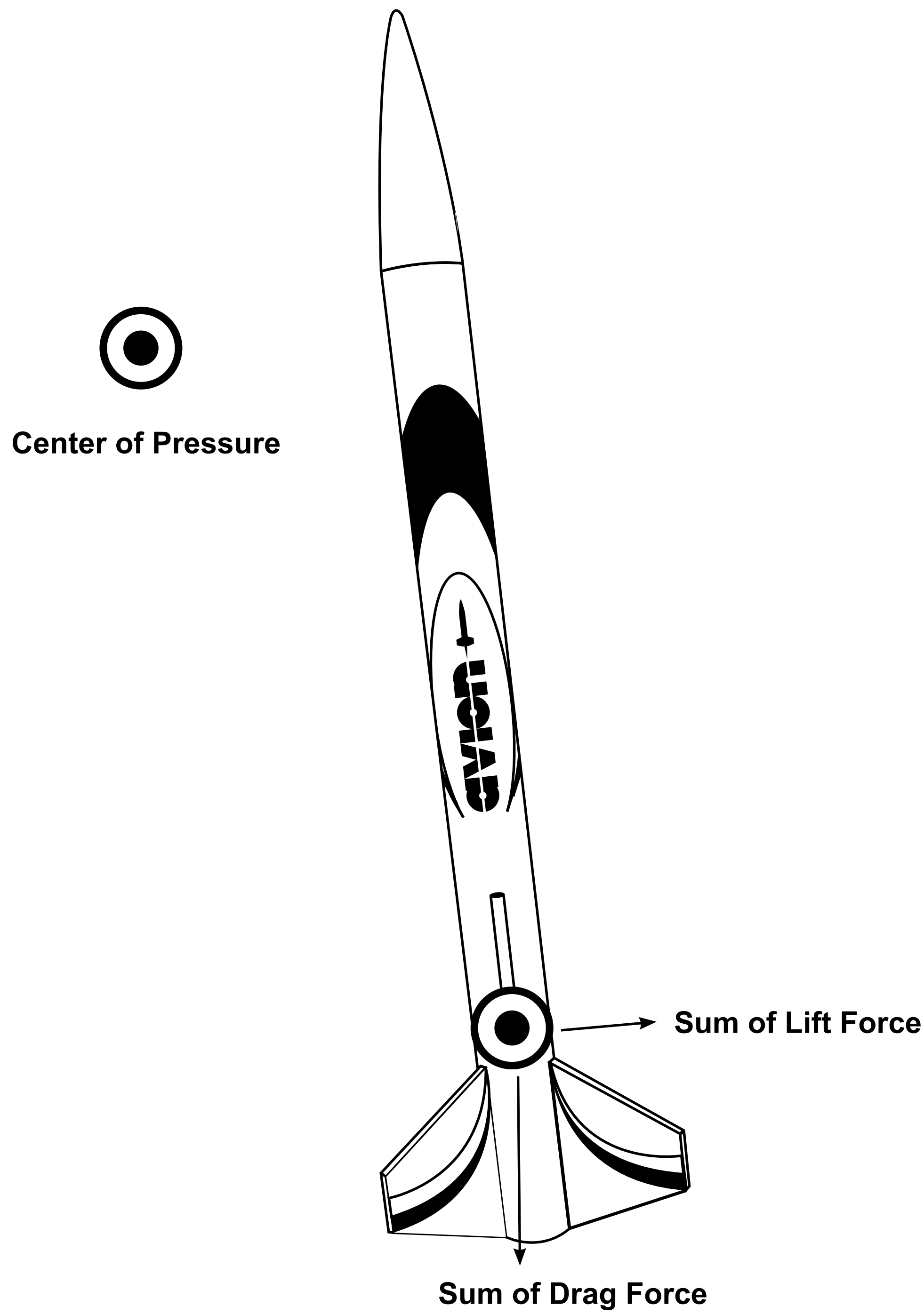
Additional Information:

The NASA web site shows a distribution of air-pressure over the surface of a rocket. The summation of all that pressure can be summarized as a single force acting at a specific point on the rocket. This point is called the Center-of-Pressure.
http://exploration.grc.nasa.gov/education/rocket/cp.html

Teaching Tip: In the RockSim software, take a rocket design and edit the fins. Move the location of the fins with the slider bar and have the students watch the CP location also shift.

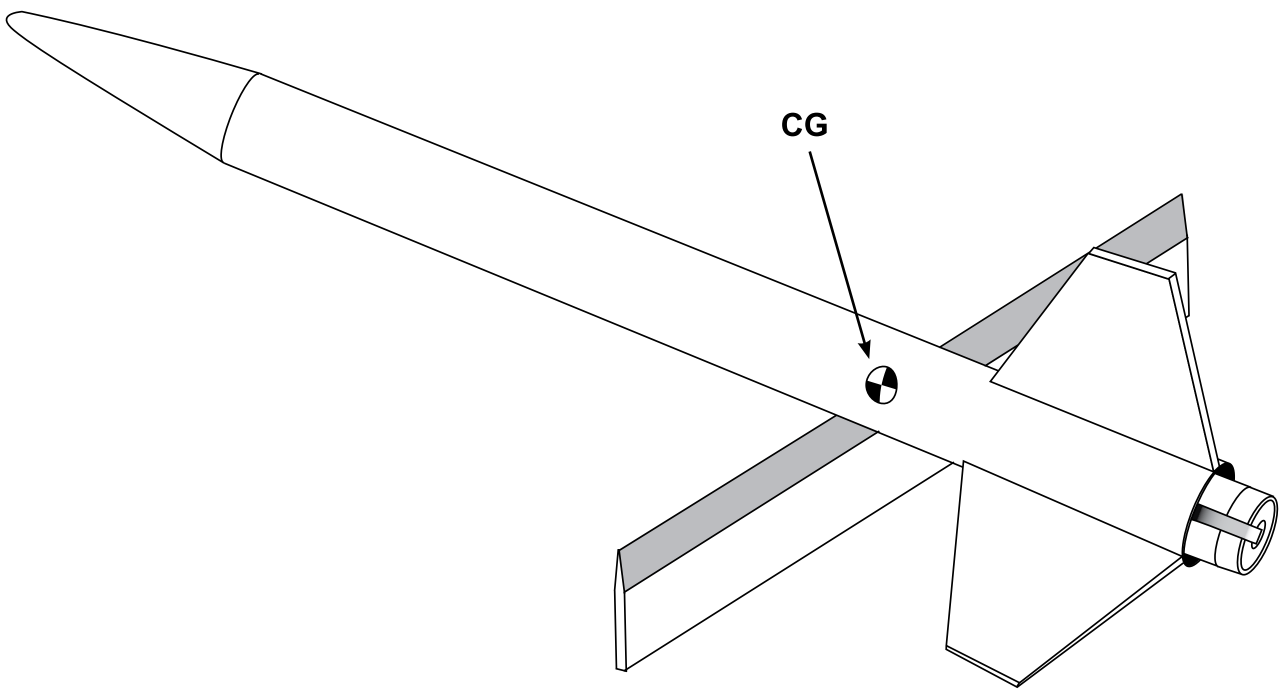
NOTES:

Definition of Static Stability

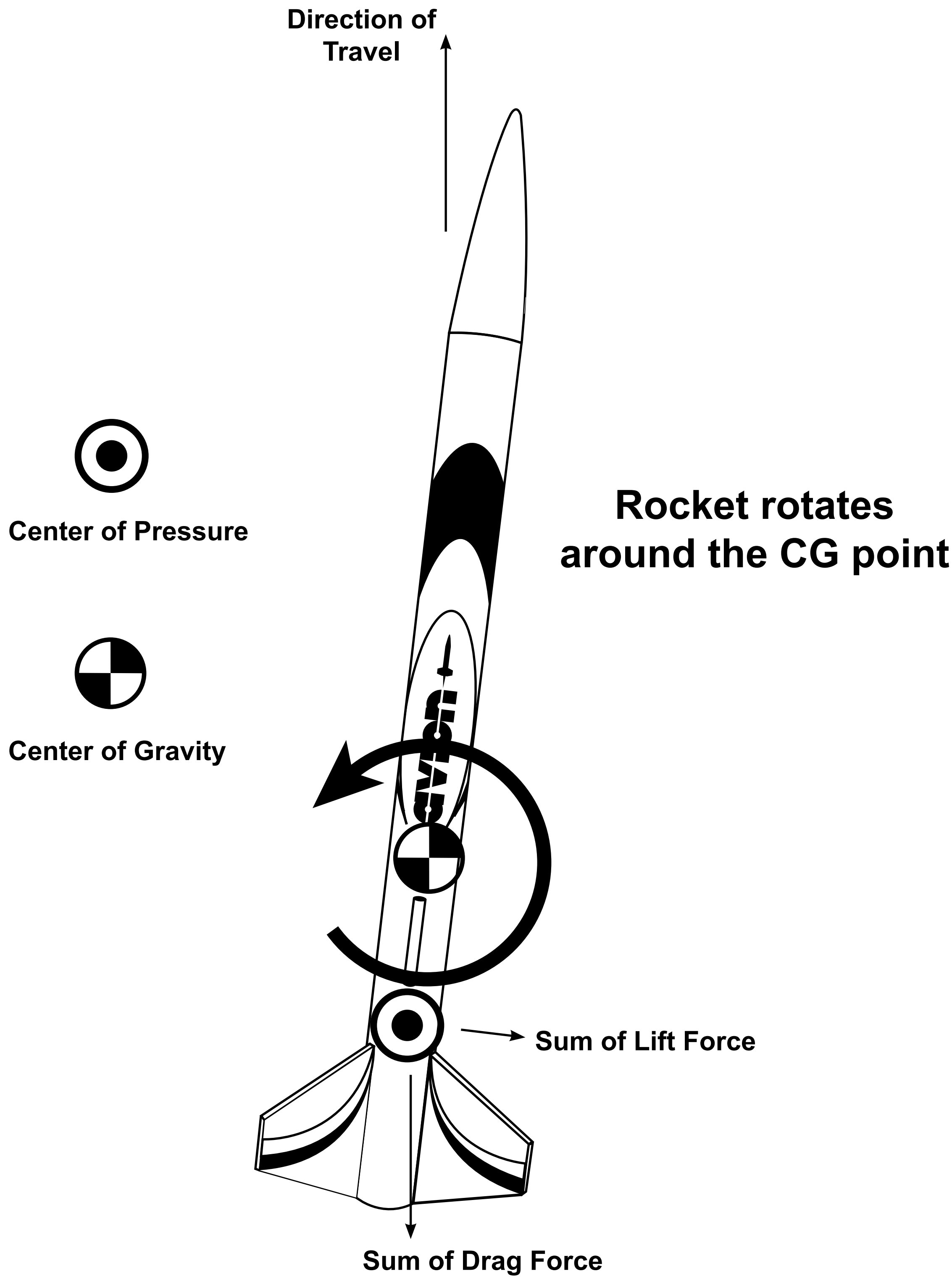


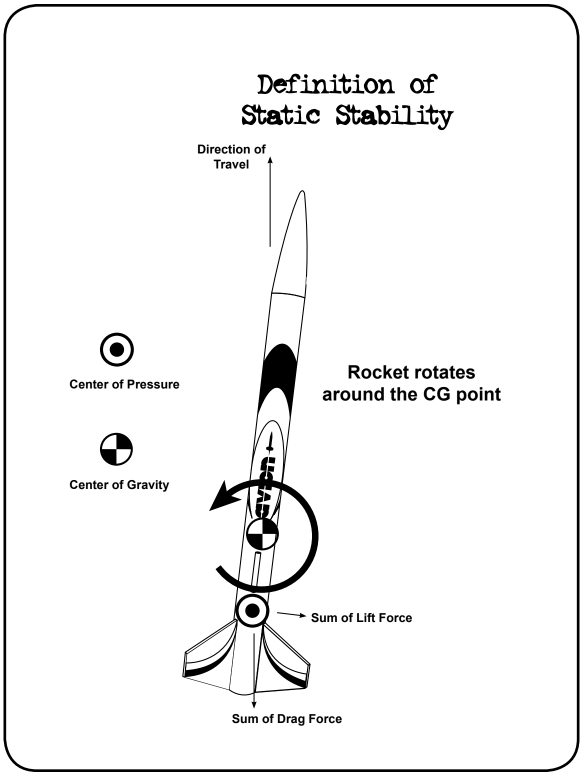
Definition of Static Stability

The CG point is where the rocket balances



Definition of Static Stability





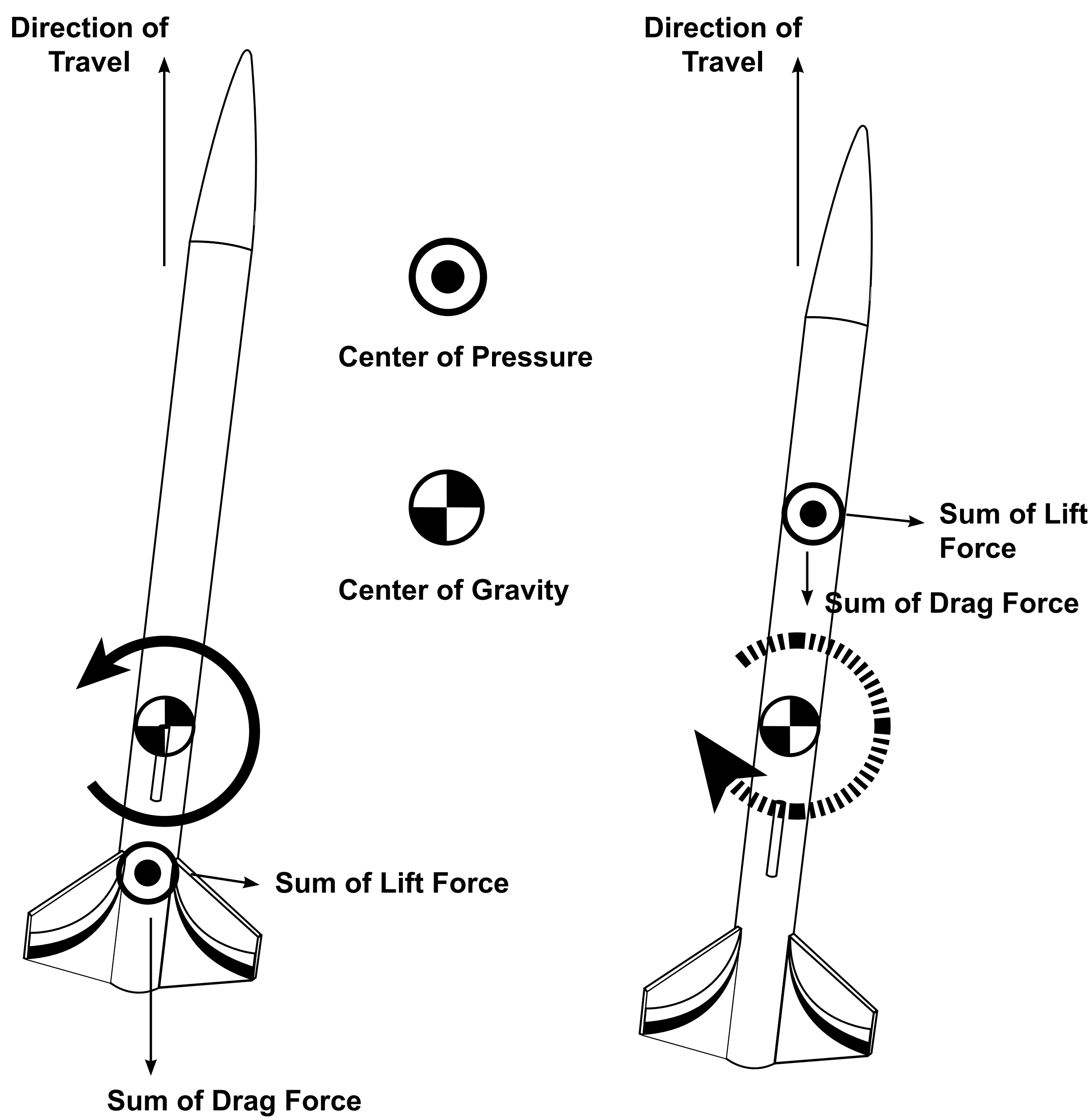
Definition of Static Stability

Purpose: To show the students that any object will rotate around its own CG point. A torque is produced by the aerodynamic forces acting at the CP point. This is what causes the rotation around the CG point.

Teaching Idea: Take a large sheet of cardboard. Cut it into an irregular shape so that the location of CG point would be difficult to guess. Hold the cardboard from a corner point and let it swing loosely between your fingers. Now draw a line straight down from that point on the cardboard. Do this again from a different corner of the cardboard sheet. Where the two lines intersect is the CG location of the shape. Draw a large dot at that point. Show the students by tossing the shape into the air that the dot remains fixed while everything else spins around it. This demonstrates that all objects will always rotate around their own CG point. Experiment with different shapes, such as a hollow ring; this can show that the CG point might not even be on the object itself!

NOTES:

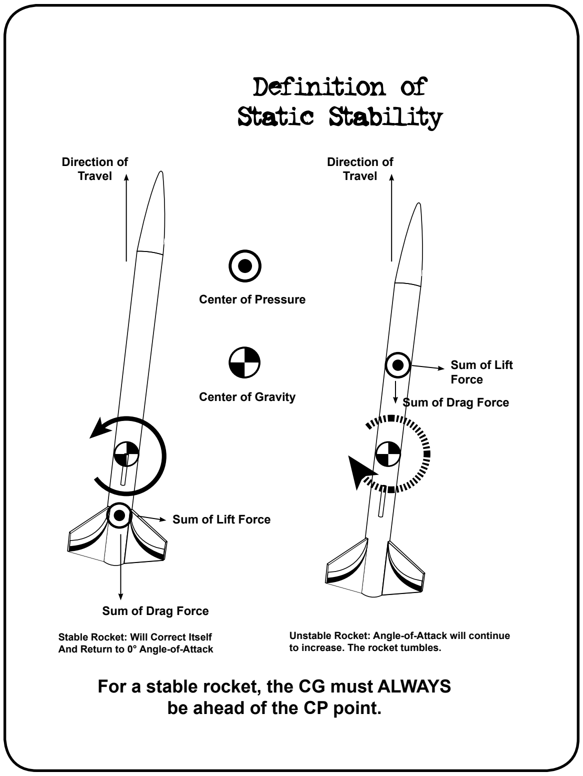
Definition of Static Stability



Stable Rocket: Will Correct Itself And Return to 0° Angle-of-Attack

Unstable Rocket: Angle-of-Attack will continue to increase. The rocket tumbles.

For a stable rocket, the CG must ALWAYS be ahead of the CP point.



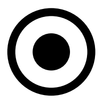
Definition of Static Stability

Purpose: To illustrate the definition of stability. If the CP is forward of the CG, the angle-of-attack will increase when a force pulls on the CP point.

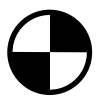
Teaching Tip: Take an old rocket that you won't fly again. Find it's CG point by balancing it on your finger. Poke a stiff wire through the rocket at that point. Show the students that the rocket rotates around this point. Now push on different portions of the rocket to simulate different CP points. Make sure the students know that when the CP is ahead of the CG location, that the rocket will become unstable (the angle-of-attack increases).

NOTES:

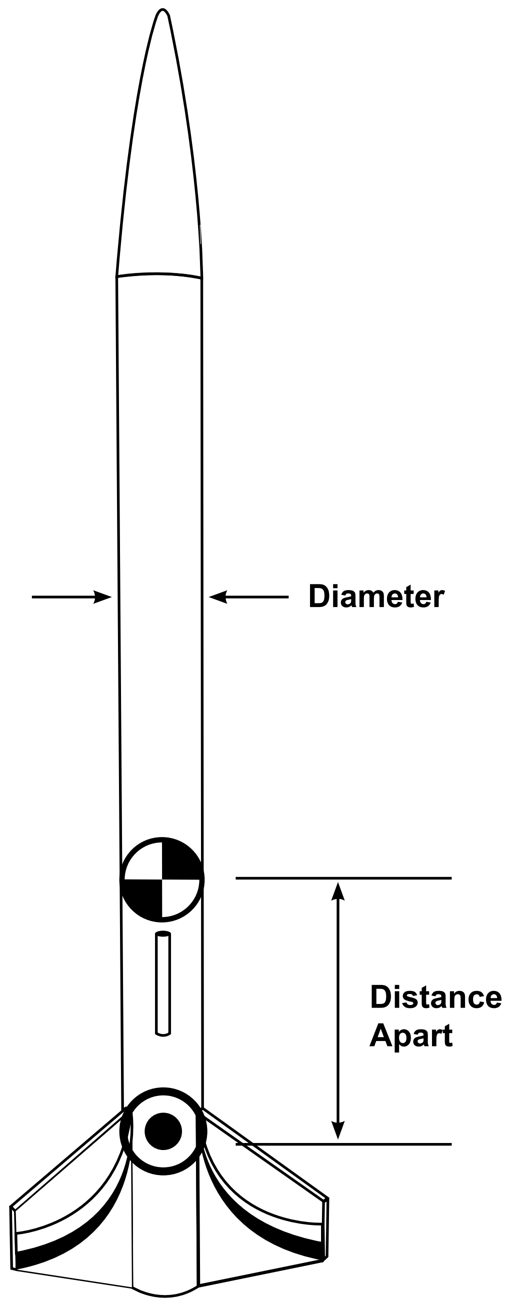
Definition of Static Stability



Center of Pressure

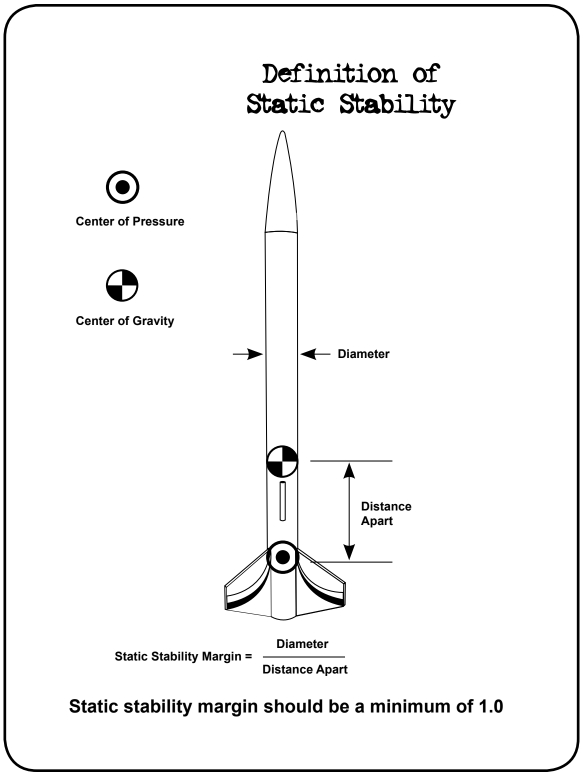


Center of Gravity



$$\text{Static Stability Margin} = \frac{\text{Diameter}}{\text{Distance Apart}}$$

Static stability margin should be a minimum of 1.0



Definition of Static Stability

Purpose: To illustrate a minimum safety requirement for model rockets.

Additional Information:

The CP of the rocket is difficult to compute because there are so many variables that affect its location. The most accurate way to find it is to actually put the model in a wind tunnel and see where it balances aerodynamically. Because of the uncertainty of its exact location on the rocket, we need to hedge a little bit, just to be certain that it is behind the CG. This hedging is done by requiring that the "best estimate" location of the CP is at least one body-tube-diameter behind the CG. This is called the safety margin. We need it just in case we have calculated the CP in the wrong location.

Teaching Tip: The RockSim software can use three different mathematical methods to estimate where the CP point is on a rocket. Show this to the students. Ask them which one is most conservative (the cardboard cutout method). Because it puts the CP furthest forward, extra weight would have to be added to the nose to move the CG further forward in order to maintain a static margin of 1.0. Then ask them if adding weight will make the rocket perform better or worse? The point you want to make is that getting an accurate location of the CP will help them to increase the performance of their rocket. The RockSim method is the most accurate of the three mathematical methods for determining the CP location.

NOTES:

Designing a Rocket

1. Define the objective of the flight.
   Example: Fly High or Fly Fast

2. List the variables that might prevent your rocket from meeting its objective.
   Example: wind, rocket engine used

3. Sketch out the rocket design on a piece of paper.

4. What factors might prevent you from building your rocket?
   Example: can't get a specific nose cone or motors are unavailable locally

5. Revise the rocket sketch as necessary. Label the size and part number of key components.

6. Input the design into the RockSim software. Check the Static Stability. Refine the design if necessary.

7. Run flight simulations using RockSim. Review the data: Is the mission objective being reached? If "no," return to step 6 after refining the design.

8. Review the design. Consider whether or not the design is buildable. Review the book "*Model Rocket Design and Construction*" for guidance on building your rocket.

9. Gather the individual parts that are needed to build the design.

10. Build the design. Review the video book "*Building Skill Level 1 Model Rocket Kits*" for construction techniques that gives the highest quality rocket.

11. Prior to launch, review the RockSim simulation. Make sure your rocket can achieve the mission objectives when considering the actual launch-day weather conditions.

12. After the flight: Review any observations and data collected during the flight. Was the objective achieved? What modifications might be needed on future flights?

Designing a Rocket

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   Example: Fly High or Fly Fast
2. List the variables that might prevent your rocket from meeting its objective.
   Example: wind, rocket engine used
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Designing a Rocket

Purpose: To show the steps a designer will go through to create a new model rocket.

Additional Information:

The book *Model Rocket Design and Construction* contains a lot of ideas for rocket designers, from how to get an idea for a cool design, to how to actually build it so that it survives dozens of flights. There is even a section on flight testing rockets. For ordering information, see: http://www.ApogeeRockets.com/design_book.asp

Teaching Tips: Here are some objectives that you can use when designing rockets:

1. Carry a raw hen's egg, and recover it unharmed (not cracked)
2. Parachute spot landing (the model that lands closest to the pad wins)
3. Parachute precision duration – the rocket that stays in the air closest to 60 seconds wins.
   Other contest events are described in the National Association of Rocketry's "Pink Book." This can be found online at: http://www.nar.org/pinkbook/index.html

NOTES:

Model Rocket Safety Code

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

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

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

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

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

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

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

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.

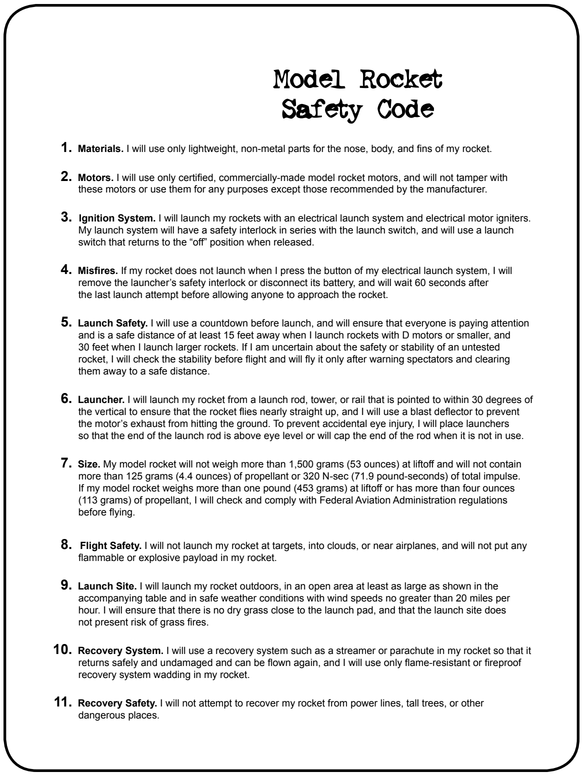
9. **Launch Site.** I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad, and that the launch site does 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.

Model Rocket Safety Code

Purpose: To provide guidelines to the students on how to keep rocketry safe.



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

Additional Information:

The National Association of Rocketry's web site contains additional information on the safety aspects of rocketry. You may need these to get permission from your school's administrator for flying model rockets. This can be found at: http://www.nar.org/safety.html

Teaching Tip: Give the students the NAR Rocketry Safety Code Quiz to make sure that they know and understand the safety guidelines pertaining to model rocketry.

NOTES:

Model Rocket Safety Code

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

NAR Rocketry Safety Code Quiz

What is the NAR safety code?

A. Rules intended to prevent accidents when building model rockets.
B. A set of common-sense guidelines to prevent injury and accidents when launching model rockets.
C. More government regulations that take away our freedom to have fun and only end up making rocketry more expensive for everyone.

What is the purpose of the launch lugs?

A. To give the rocket a cool look, just like the rockets NASA flies.
B. To slip over the launch rod, which guides the rocket until it reaches a stabilizing flight speed?
C. They help stabilize rocket a high speeds as described in the "Von Karman theory of aerodynamic stability."
D. The NAR Safety Code does not mention launch lugs.
E. Both B and D.

What is the maximum launch angle permissible in the NAR Safety Code?

A. 30° from vertical
B. 45° from vertical
C. 60° from vertical
D. The launch angle that results in the "closest-to-the-launch-pad-recovery" so you don't have to walk to far to retrieve the rocket. It is determined by using the RockSim software.

Are "shoulder mounted" launch tubes (like a bazooka or stinger missile launcher) permissible in the NAR safety code?

A. Yes
B. No

For "C" size rocket motors, what is the closest you can be to the launch pad when launching the rocket?

A. Rockets always go "UP" not sideways. So as long as you aren't standing over the pad, you're not in violation of the safety code.
B. 10 feet.
C. 15 feet.

What is the purpose of the blast deflector?

A. To keep the launch pad from tipping over on windy days.
B. To provide something solid for the rocket to push against so it can rise up into the air.
C. To keep the engine's flame from hitting the ground, where it might start a grass fire.

When is it permissible to use a match and a fuse to ignite a rocket engine?

A. Only when your launch controller's batteries are dead, and you have no other way to set off the engine.
B. After a heavy rain shower has really soaked the grass on the launch field and the possibility of a grass fire is remote.
C. It is never permissible.

NAR Rocketry Safety Code Quiz

Why shouldn't you use metal for nose cones, body tubes and fins?

A. Air flowing over metal creates a static-electric charge; making the rocket more susceptible of getting struck by lightning.
B. The glare of the sun reflecting off metal would blind spectators during the launch.
C. Because metal shows up on radar, and it would spook airline pilots into thinking someone is trying to shoot them down.
D. Because metal makes the rocket heavier and increases the potential of piercing objects it might strike should the launch take an unplanned course.

Why shouldn't you launch rockets into clouds?

A. You could trigger cloud-to-ground lightning
B. You lose site of the rocket, and then you don't know where it came down.
C. You can't see aircraft flying above or in the clouds, and you could pose a hazard to those within the aircraft.
D. All of the above.

Is gluing the nose cone onto the rocket permissible in the NAR safety code?

A. Yes
B. No
C. Trick Question: The NAR Safety Code does not say. As long as the rocket returns safely via a recovery device to the ground and is intended to fly again, it is permissible. So it depends on the rocket design.

Why does the NAR Safety Code say not to retrieve rockets from power lines?

A. You could get electrocuted.
B. You could fall down and get hurt.
C. Trick Question: The safety code does not give a reason.
D. All of the above

Are home-made engines are permissible in the NAR Safety Code?

A. Yes
B. No
C. The Safety Code does not say.

Are fire-crackers stuffed into a model rocket permissible in the NAR Safety Code?

A. Yes
B. No
C. The Safety Code does not mention fire-crackers.

NAR Rocketry
Safety Code Quiz

Extra Credit

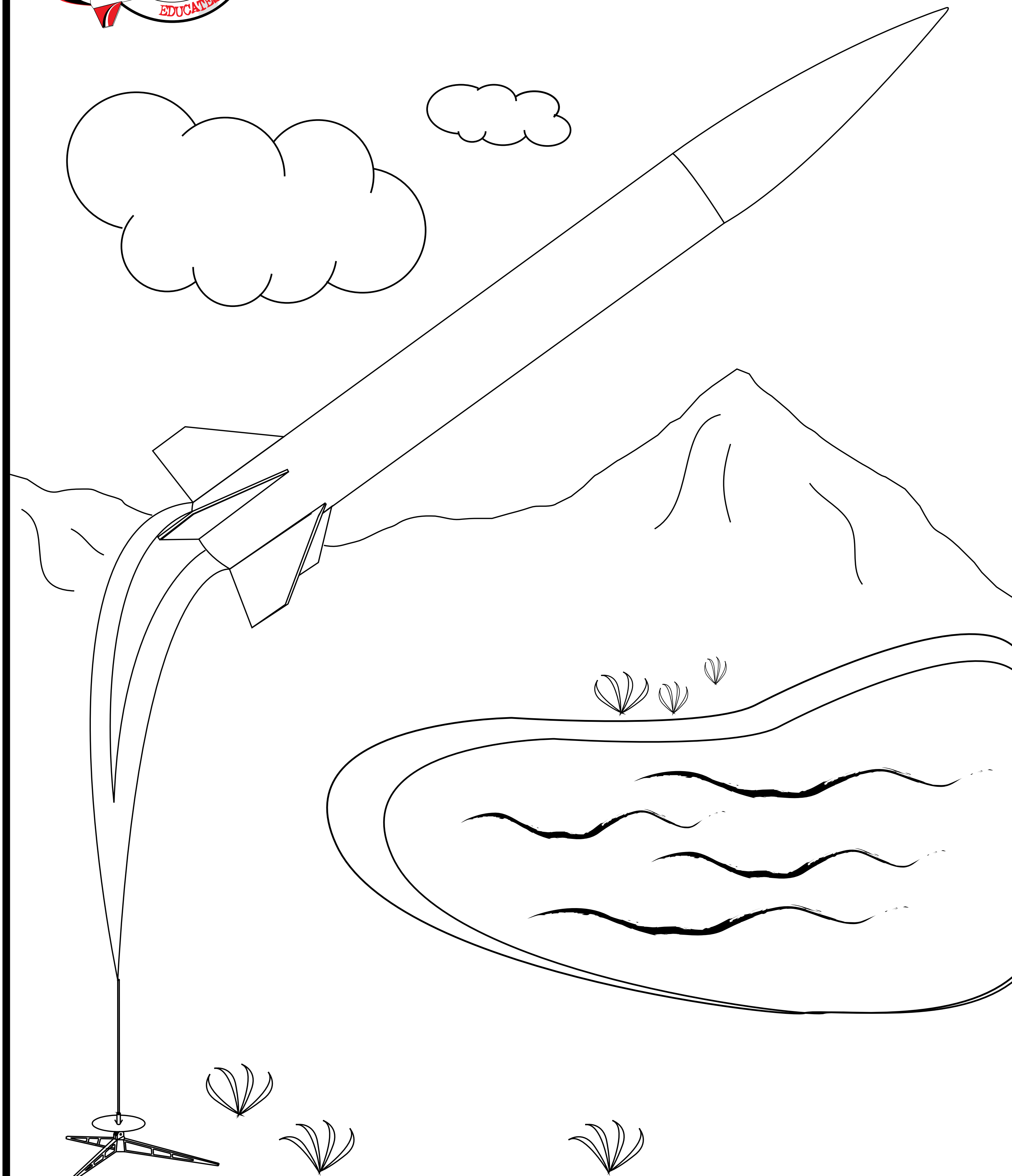
What is the minimum length for the launch rod?

A. 36 inches
B. 48 inches
C. The NAR safety code does not say.
D. Long enough for the rocket to reach a speed sufficient for the fins to provide aerodynamic stability before the model leaves the launch rod. Typically this is around 35 to 40 miles per hour.
E. Both C and D

Why should you always follow the NAR Safety Code?

A. It minimizes the chances of accidents occurring, keeping you safer.
B. By following the safety code, we demonstrate to government officials that we aren't terrorists, or out-of-control lunatics. They don't need to outlaw rocketry because it is done in a respectful and sane manner.
C. It helps keep insurance rates down for both consumers and manufacturers. This in turn keeps the costs of motors down.
D. All of the above.

Coloring Page



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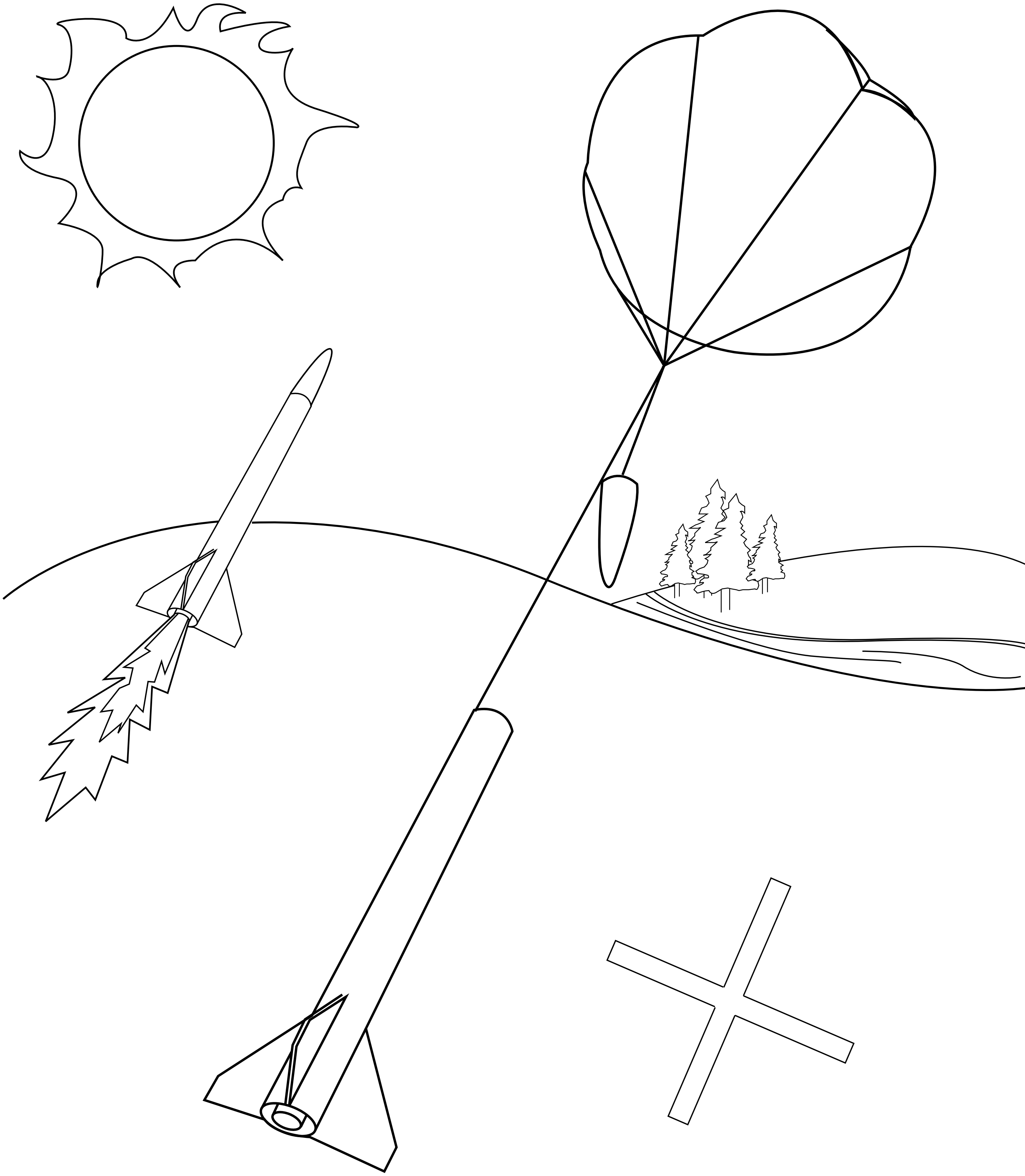

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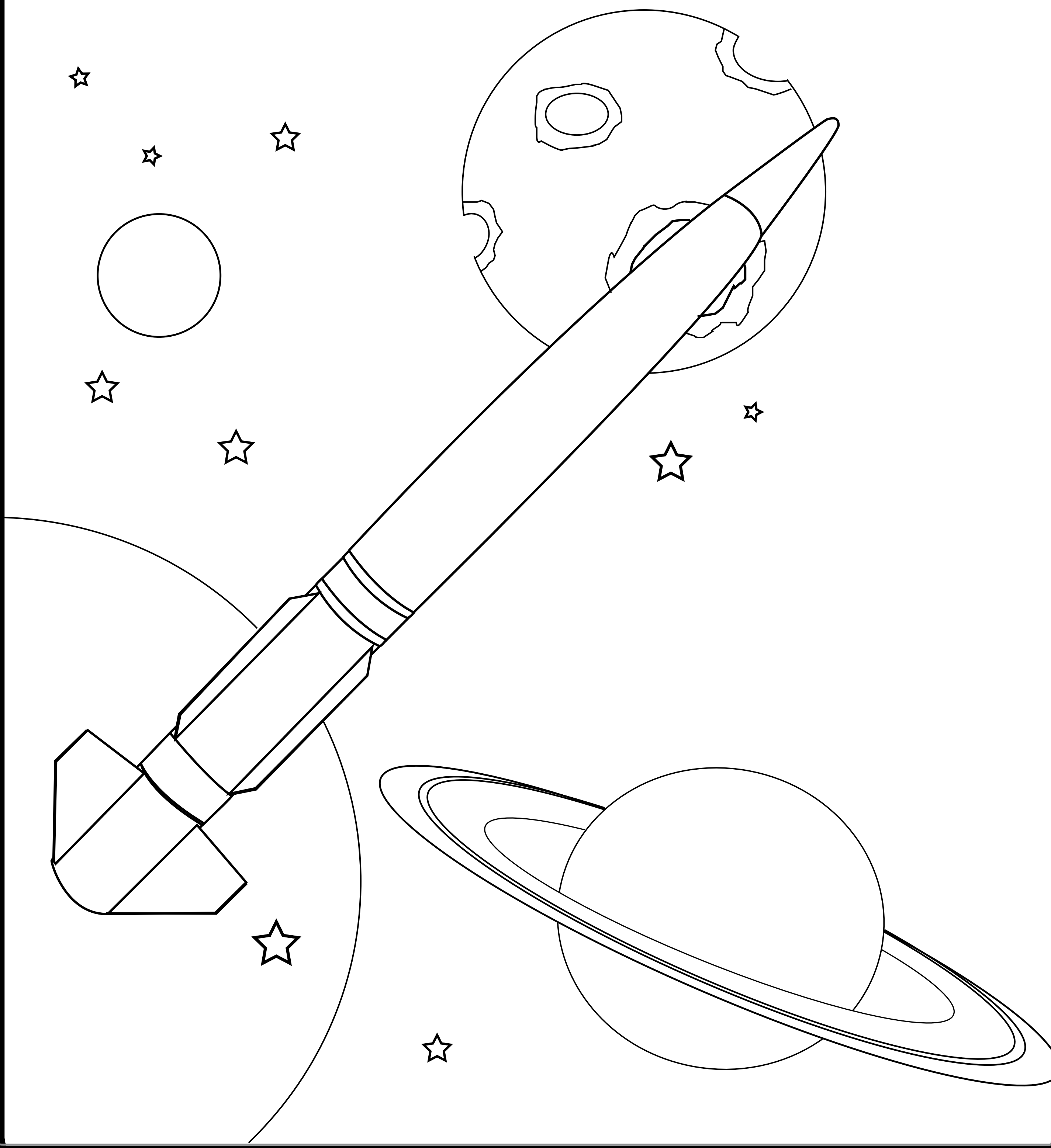


Apogee Countdown Checklist

Name ______________________________

Rocket Name ______________________________

Rocket Safety Check

- ☐ All Glue and Paint On Model Completely Dry.
- ☐ Motor Mount Secured, With No Loose Parts.
- ☐ Motor Block Securely Attached In Motor Tube.
- ☐ Examine Shock Cord, It May Have Black Soot On It, But No Dry Rot, No Frayed Or Burnt Fibers.
- ☐ Tug Firmly On Both Ends Of Shock Cord. It Should Not Move.
- ☐ Examine Recovery Device, Shroud Lines Should Be Firmly Attached, Of Equal Length And Not Tangled.
- ☐ Parachute Or Streamer Should Be Strong With No Tears or Rips.
- ☐ Recovery Device Must Be Firmly Attached To Nose Cone Or Rest Of Model.
- ☐ Check Screw Eye Or Plastic Loop On Nose Cone. It Should Not Come Loose If Tugged On.
- ☐ Place Nose Cone On Model. Shock Cord Mount Should Not Interfere With Nose Cone Shoulder.
- ☐ Nose Cone Fit Snug (Not Too Loose Or Too Tight).
- ☐ Fins Aligned Properly.
- ☐ Fin Wood Not Split.
- ☐ Try To Wiggle Fins To Make Sure Fillets Do Not Have Any Cracks And Fins Are Securely Attached.
- ☐ Launch Lugs Securely Attached to Rocket.
- ☐ Launch Lugs Aligned So They Won't Bind On Launch Rod.
- ☐ Tube Not Kinked

Preparation Phase

- ☐ Wadding Installed.
- ☐ Recovery System Folded Loosely.
- ☐ Recovery System Installed Into Rocket.
- ☐ Correct Motor For Rocket Selected.
- ☐ Motor Installed And Secured In Model.
- ☐ Igniter Touching Propellant.
- ☐ Igniter Holder Installed Correctly.

Pre-Launch Phase

- ☐ Check Straightness Of Launch Rod. Should Not Be Bent.
- ☐ Make Sure Launch Rod is Secured to Pad and Won't Come Out.
- ☐ Clean Launch Rod to Remove Any Dirt That Could Cause Rocket To Stick Or Hang Up
- ☐ Check Sturdiness of Launch Pad, Should Not Tip Over Easily.
- ☐ Check Strength of Controller Batteries
- ☐ Place Rocket On Pad.
- ☐ Angle Rod To Suit Wind Conditions, But Less Than 30° From Vertical.
- ☐ Remove Key From Launch Controller.
- ☐ Clean Igniter Clips.
- ☐ Check Insulation On Clip Wires, Should Not Be Able To Short Circuit Together.
- ☐ Secure Controller Wire To Launch Pad Or Other Sturdy Object.
- ☐ Hook Clips To Igniter Leads.
- ☐ Keep Clips from Touching Each Other or Metal Blast Deflector.
- ☐ Place Safety Cap On Top Of Rod Until Ready To Launch.

Count Down and Launch Checklist

- ☐ All Persons Back From Launch Pad At Least 15 Feet (5 meters).
- ☐ Sky Is Clear Of Low Flying Aircraft.
- ☐ Check Wind Speed (In Safe Range For The Rocket).
- ☐ Inform Spectators Of Intention To Launch Rocket.
- ☐ Inform Spectators Of Any Safety Precautions For This Particular Rocket.
- ☐ Remove Cap From Launch Rod.
- ☐ Insert Safety Key In Controller.
- ☐ Check For Continuity (Light or Buzzer Should Come On).
- ☐ Give A Loud Countdown, 5 . . . 4 . . . 3 . . . 2 . . . 1 . . . Launch!
- ☐ Remove Key From Controller.
- ☐ Place Safety Cap On Launch Rod.

Rocket Name ______________________

Owner's Name ______________________

Address ______________________

City ______________________

State ______________ Zip __________

Apogee COMPONENTS

ROCKET DATA SHEET

Model Description

Type of Rocket (select all that apply)

- ☐ Sport
- ☐ Multi-stage
- ☐ Cluster of Motors
- ☐ Competition
- ☐ Scale Model
- ☐ Fantasy Type
- ☐ Payload Carrier
- ☐ High Power Rocket
- ☐ Radio Controlled

Length __________

Diameter __________

Number of Fins __________

Empty Mass __________

Est. Drag Coef. __________

Color __________

Nose Shape __________

CP Location __________

CG Location __________

Date of Design __________

Date of Const. __________

No. of Stages __________

No. of Motors __________

Fin Shape __________

Fin Area (single fin) __________

Fin Airfoil Shape

- ☐ Square Edges
- ☐ Rounded Edges
- ☐ Chambered Airfoil
- ☐ Symmetrical Airfoil

Recommended Motors __________

- ☐ Scratch Built
- ☐ Kit: (Manufacturer) __________

Type of Recovery System

Primary Recovery System

- ☐ Tumble Recovery
- ☐ Streamer
- ☐ Parachute
- ☐ Glider
- ☐ Helicopter
- ☐ Drag Brakes
- ☐ Horizontal Spin

Secondary Recovery System

- ☐ Tumble Recovery
- ☐ Streamer
- ☐ Parachute
- ☐ Glider
- ☐ Helicopter
- ☐ Drag Brakes
- ☐ Horizontal Spin

Parachute Description

Parachute Shape

- ☐ Circle
- ☐ Square
- ☐ Hexagon
- ☐ Octagon
- ☐ __________

Mass __________

Canopy Area __________

Color __________

Material:

- ☐ Plastic
- ☐ Cloth __________

No. of Shroud Lines __________

Shroud Line Length __________

Streamer Description

Material:

- ☐ Paper __________
- ☐ Plastic
- ☐ Cloth __________

Color __________

Length __________

Width __________

Mass __________

Glider Description

- ☐ Primary Vehicle
- ☐ Parasite on Rocket

Glider Type

- ☐ Boost-Glider
- ☐ Rocket-Glider

Glider Configuration

- ☐ Conventional
- ☐ Canard
- ☐ Flying Wing

Glide Mass __________

Horiz. Tail Area __________

Horiz. Tail Span __________

Horiz. Tail Chord __________

Length __________

Wing Span __________

Wing Area __________

Chord Length __________

CG (glide) __________

Wing Sweep Angle __________

Dihedral Angle __________

Vert. Tail Area __________

Vert. Tail Span __________

Vert. Tail Chord __________

Helicopter Description

No. of Blades __________

Blade Area (1 blade) __________

Blade Length __________

Blade Chord Length __________

Blade Mount Angle __________

Rotor Disk Area __________

Blade Position

- ☐ Carried Internally
- ☐ Hinged Near Front
- ☐ Hinged Near Rear

Blade Type

- ☐ Flat
- ☐ Chambered
- ☐ Symmetrical

Description of How Rocket Works

Special Construction Notes

Special Launch Preparation Proceedures

Parts List

APOGEE COMPONENTS

Rocket Sketch Sheet

Title:		
Designer		Date
Part No.	Sheet	Rev.

Rocket Name ____________________ Flight No. ______

Owner's Name ______________________________

APOGEE FLIGHT RECORD

Apogee Components

Pre-Launch Information

Date
Time of Launch
Location
Field Size
Elevation of Field

Launch Conditions

Temperature
Humidity
Atmospheric Pressure
Wind Direction
Wind Speed
Max. Gust Speed
Cloud Type

Model Information

Motors Used (No. / Type:)
1st Stage ____________________
2nd Stage ____________________
3rd Stage ____________________

Payload Used

Payload Mass
Liftoff Mass
Predicted Altitude
Predicted Duration

Launch Information

Method of Launch:
☐ Rod (Dia.) ________ ☐ Rail
☐ Tower ☐ Piston Launcher

Launch Angle & Dir.

No. Of Tries To Ignite Motor

Igniton:
☐ Successful Lift-Off
☐ Hung-up on Rod
☐ Caught on Igniter Clips
☐ Tip-Off (Went Horizontal)
☐ Motor Chuff
☐ Motor Failure
○ Side Wall Failure
○ Spit Nozzle
○ Forward Bulkhead (Blow Thru)

Cluster Ignition
☐ ___ Motors Did Not Ignite
☐ All Motors Ignited Successfully

Staged Models
☐ All Stages Ignited Successfully
☐ Stage #____ Did Not Ignite
☐ Stage #____ Had Motor Failure

Trajectory:
☐ Unstable
☐ Spinning But Straight
☐ Corkscrew/Barrel-Roll Ascent
☐ Straight-Up Flight
☐ Non-Vertical Trajectory
☐ Weathercocked Into Wind

Trajectory Angle & Dir.

Recovery Information

Ejection Occurred:
☐ During Ascent
☐ At Apogee
☐ While Descending
☐ Model On Ground

☐ Ejection Failure
○ Fast Delay Burn
○ Slow Delay Burn
○ Delay Didn't Burn
○ Weak Ej. Charge

Recovery Device
☐ Did Not Deploy
☐ Partially Deployed
☐ Deployed Fully

Parachute Descent
☐ Stable Descent
☐ Some Swaying of Load Under Canopy
☐ Tangled Lines Caused Spiral Descent

Reason For Recovery Device Failure
☐ Damaged Chute ☐ 2nd System Failure
☐ Improper Set-up ☐ Tight Nose Cone
☐ Chute Separated ☐ Obstruction In Tube
☐ Motor Ejected ☐ Other____________
☐ Ejection Failure ____________

☐ Unplanned Separation Occurred

Descent Speed
☐ Caught Thermal
☐ Slow
☐ Average Speed
☐ Very Fast
☐ Ballistic Trajectory to Ground

Landing
☐ Soft Landing ☐ Landed in Tree
☐ Hard Landing ☐ Caught on Wire
☐ Water Landing ☐ Landed on Building
☐ Crash Landed ☐ Drifted Out-of-Sight

Recovery
☐ Full Recovery ☐ Model Not Recoverable
☐ Model Lost ☐ Part of Rocket Lost

Dist. & Direction From Pad Model Landed

Last Known Position of Lost Model

Helicopter Flight Recovery

Deployment
☐ Full Deployment
☐ Partial Deployment
☐ Did Not Deploy
☐ Blade(s) Broke at Deployment

Cause of Deployment Failure
☐ Burn String Didn't Burn Thru
☐ Excessive Friction in System
☐ Misalignment of Parts
☐ Improper Set-up
☐ Other ____________

Spin Direction
☐ Clockwise Rotation
☐ Counter-Clockwise Rotation
☐ No Rotation

Descent
☐ Upside-Down Descent
☐ Flip-Flop Descent
☐ Descended Horizontally
☐ Proper Descent Orientation
☐ Model Showed Precession

Tracking Data

Flight Duration

Altitude Tracking Data
Elevation Angle #1 ____________
Azimuth Angle #1 ____________
Elevation Angle #2 ____________
Azimuth Angle #2 ____________
Baseline Length ____________
Comp. Altitude #1 ____________
Comp. Altitude #2 ____________
Avg. Altitude ____________
Closure Error % ____________

Glider Flights

Trajectory
☐ Unstable ☐ Looped During Coast
☐ Spinning Climb ☐ Climbed at Angle
☐ Corkscrew ☐ Straight-up Boost
☐ Thrusting Loop ☐ Horizontal Flight

Transition Phase
☐ Pod Separated During Ascent
☐ Pod Did Not Separate
☐ Red Baron
☐ Transition Mechanism Failure
☐ Proper Transition Occurred

Cause of Mechanism Failure
☐ Burn String Didn't Burn Thru
☐ Excessive Friction in System
☐ Misalignment of Parts
☐ Improper Set-up
☐ Other ____________

Longitudinal Stability in Glide
☐ Steep Dive
☐ Shallow Dive
☐ Good Glide
☐ Shallow Stall
☐ Deep Stall

Roll Stability
☐ Rolled Left
☐ No Roll
☐ Rolled Right

Lateral Stability
☐ Yawed Left
☐ No Yaw
☐ Yawed Right

☐ Model Flew Inverted

Turn Information ☐ Left
☐ Flat Turn ☐ Straight ☐ Tight Turn
☐ Sprialing Dive ☐ Right ☐ Wide Turn

Post Flight Information

Flight Damage
☐ No Damage ☐ Minor Damage
☐ Scuffed Paint ☐ Major Damage

Describe any Damage to Model

☐ Damage Unknown - Model Lost

Flight Grade
☐ Excellent ☐ Mediocre
☐ Good ☐ Poor

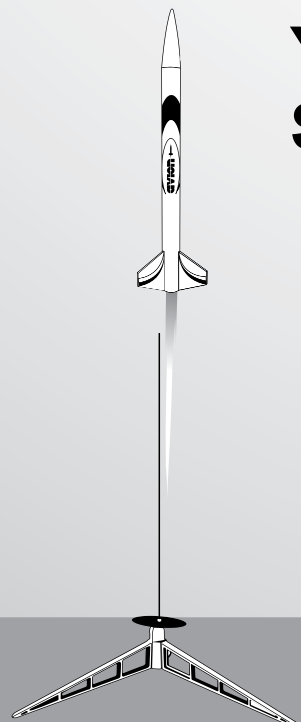
Additional Flight Description

Lessons Learned
(ways to improve next flight)
(why flight might have gone bad)

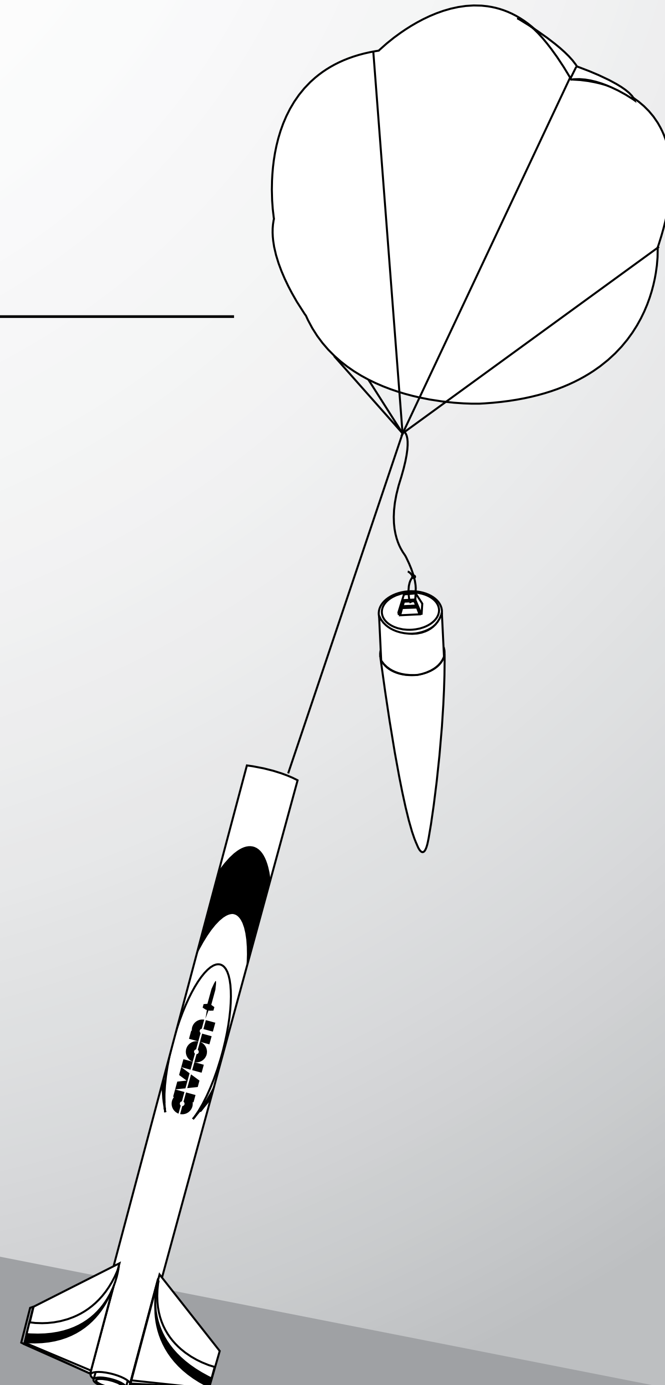
Congratulations!

Name: ____________________

Date: ____________________



You Have Had A Safe And Successful Launch!



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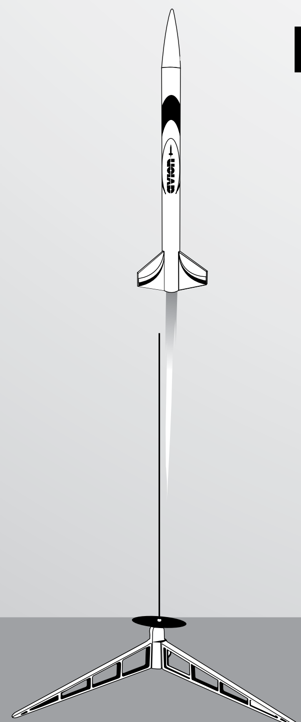
Oops!

Name: ______________________________

Date: ______________



Better Luck Next Time!

APOGEE COMPONENTS

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Congratulations!

Name: ____

Date: ____________________

You Had The Highest Flight!

Apogee Components

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