Tech Report 1

Basic Training: Introduction to Model Rocketry

In this report, we will be reviewing the basics of model rocketry. We will start by looking at the basic components of a model rocket and what function each part serves. We will also review model rocket engines, their basic parts and functions, and we will also explain the coding system that is printed on the side of every model rocket engine. Then we will look at the basic flight profile of model rocket, including flight preparation, launch and recovery.

The Components of a Model Rocket

There are some basic components that are common to most every model rocket. The outer components are labeled in *Figure 1* below.

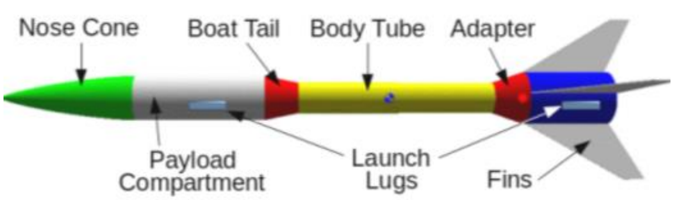

*Figure 1: Basic exterior components**

Nose Cone

The nose cone is the top of the model. It is the first part of the model to enter the air stream upon liftoff. Some nose cones are designed for efficiency, to allow the model to fly faster and/or higher. Other nose cones are decorative, to allow the model to take on the appearance of a space ship or other futuristic design.

Payload Compartment

The payload compartment can hold items used during experiments. This may include electronic payloads (such as altimeters and G-force recorders), cameras (both still and video), or perhaps a passenger such as an insect. Some payload bays are used to store raw eggs, to see if your skills as a rocketeer are good enough to recovery a raw egg intact.

Some payload compartments may be clear (as in the photo above), or they may be part of the body of the rocket. Not all rockets have payload compartments. It is an item that can be used dependent on the mission of the rocket.

Body Tube

The body tube is the basic airframe of the rocket, and in most models consists of a paper tube. The body tube has several important tasks. It acts as the main structure of the rocket, allowing a surface for the fins, launch lug and nose to attach. The inside of the body also holds the motor mount for the rocket, and as such is subjected to tremendous stress at the point of ignition. Another important task is that the body tube houses the recovery system until it is ready to be deployed (more on the motor mount and other components in just a few minutes).

Fins

The fins of a model rocket perform the same function as feathers on an arrow. They help keep the rocket flying stable and in a straight line. The design of the fin can have a large impact on both the stability and performance of the model. Some fins are even tilted at an angle, causing the model to spin and thereby increase the stability of the model.

The basic trapezoidal fin shape is defined by four specific terms as seen in *Figure 2* below.

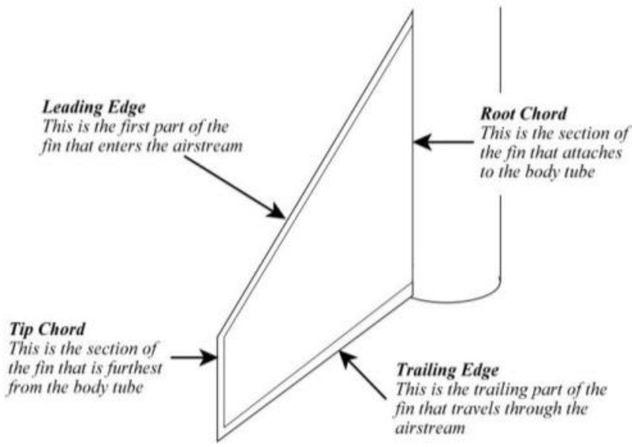

Figure 2: The parts of a fin

Launch Lug
The launch lug is a small tube that attaches to the body tube of the model. It is used in conjunction with a launch rod to start the model off in a straight path. This allows the model to build up enough speed so that the fins can take over the stability and keep the model flying in a straight path.

Even though the launch lug is the most common system used during launch, not all models use them. Some models are launch from towers and don't need launch lugs, helping reduce drag and making the model more aerodynamically clean. Other options include piston launching, pop-off lugs and launch rails instead of launch rods. Like all systems, there are tradeoffs between ease of use, reliability and performance.

The Components that Aren't Visible

Like any complex vehicle, some of the more important aspects are hidden below the surface, and a model rocket is no different. Here are some of the common components that you usually don't see (*Figure 3*).

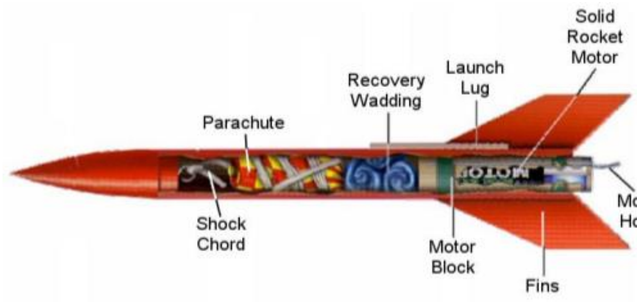

Figure 3: Internal rocket components

Recovery System
The recovery system allows the model to return safely to the earth so that it can be flown again. The two most common systems are parachutes and streamers, and these are stored inside the body tube during flight.

The parachute is probably the most familiar type of recovery system, allowing the model to float gently back to the earth. However, a parachute can be affected by wind and thermals (columns of rising hot air) that can be strong enough to carry the model far out of sight. One response to this is the use of a streamer.

The streamer is large enough to slow the model down (to avoid most damage to the model when it hits the ground) but the model falls in a mostly straight line, not being as affected by winds and thermals.

The recovery system is deployed when the motor fires an ejection charge, forcing the nose cone off the model and pushing the parachute or streamer out of the body tube. To keep the nose cone attached to the body tube and to help absorb the energy created by the ejection charge, an elastic band call a shock cord is used. In a typical model, one end of the shock cord is mounted inside the body tube, the other end is tied to the nose cone. The rocket will also use recovery wadding. This material is used to help absorb the heat of the ejection gases. This prevents the recovery material (such as plastic streamers/parachutes or nylon parachutes) from melting, allowing the system to fully deploy.

There are other recovery systems that you may see used in model rocketry. These include gliders, helicopters, featherweight and more.

Engine Mount
The engine mount is located at the very rear of the rocket, inside the body tube. The engine mount holds the solid rocket engine in place during launch and the ejection charge. If the engine mount fails during a launch, the model will not rise into the air, but instead the engine may come out the top of the model or some other undesirable event. If the engine mounts fails during the ejection charge, the model's recovery system will not deploy, and the model to return rapidly to earth.

The common components of the motor mount are described below (*Figure 4*).

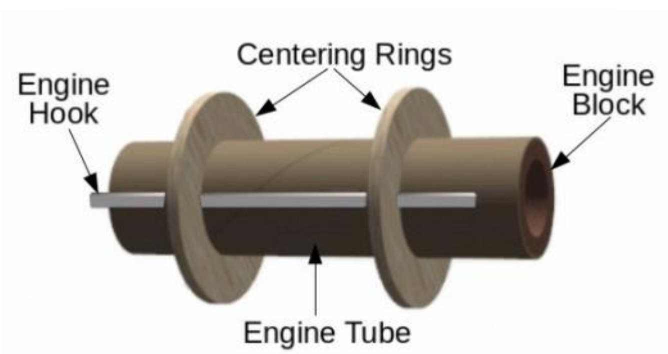

Figure 4: Engine mount components

Centering Rings
The spacing rings attach the engine tube holder to the inside of the body tube. They also center the engine tube inside the body tube, helping to ensure that the thrust developed by the engine is directed in a straight line, assisting in a straight and vertical flight path.

Engine Tube
The solid rocket engine slides inside of this tube. It makes up the bulk of the engine mount.

Engine Hook
The engine hook is a small metal strip that is designed to hold the engine in place within the engine holder tube. There is a small hook at each end that helps hold the engine in place. The engine hook is slightly bowed to allow the solid rocket engines to be removed and replaced rather easily.

Engine Block
An engine block can be used with or without an engine hook. It is a thick ring that is installed in engine tube that prevents the rocket engine from moving up inside the main body tube when the engine is ignited. It has a large opening to allow the ejection gases to pass through to deploy the recovery system.

This concludes our look at the basic components of a model rocket. In the next section we will look at the basics of model rocket engines, how they are constructed and what those letters and numbers on the side of the engine mean.
The Black Powder Solid Model Rocket Motor

Most low power rocket engines are made from black powder propellants, while the high power rockets use composite materials. The mid-power rockets tend to see both types of propellants use. In this post, we are going to look at the black powder motors.

Black Powder Motors
The basic model rocket engine is made of a paper casing with clay caps on each end of the engine (*Figure 5*). The back of the engine has a nozzle molded from clay. The nozzle opens into the propellant. The electrical igniter is placed into the nozzle and pushed forward until it touches the

propellant. The most popular and inexpensive propellant on the market today is black powder. When the propellant is ignited, it burns from the back of the engine and moves to the front, expelling the hot gasses out through the nozzle and launching the model into the air.

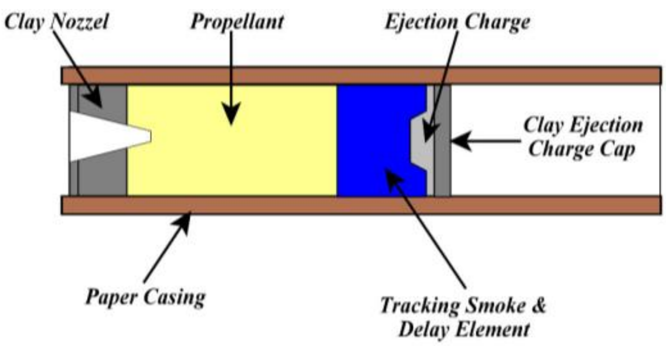

Figure 5: Black powder motor cut-a-way drawing

When the tracking smoke has been totally used up, a small charge called an ejection charge is fired, pushing off the clay end cap. The hot gases from this charge enter the body tube of the model and expand rapidly. This rapid expansion of the ejection charge gases pushes off the nose cone of the model, deploying the recovery device.

The Engine Coding System

All model rocket engines, regardless of the manufacturer, utilize the same coding system. This allows you to know the basic performance capabilities of the engine. That coding system is explained in *Figure 6*.

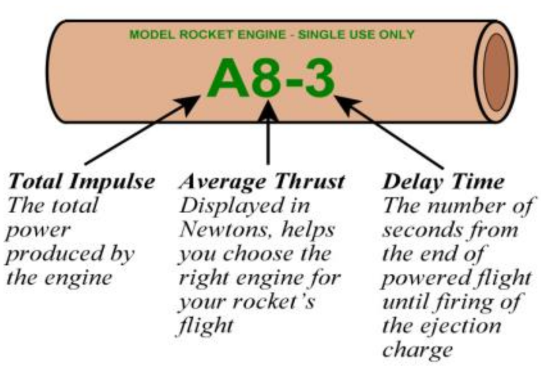

Figure 6: Motor markings

The chart in Figure 7 shows the total impulse classification for each letter code (in this case for 1/4A through G which includes low and mid-powered rockets). You should be aware that each time you increase the letter, the total impulse of the engine doubles. This means that a 'C' engine has twice the total impulse of a 'B' engine; a 'B' engine has twice the total impulse of an 'A' engine, and so on.

Code	Newton-seconds
1/4A	0.00-0.625
1/2A	0.625-1.25
A	1.25-2.50
B	2.20-5.00
C	5.00-10.00
D	10.00-20.00
E	20.00-40.00
F	40.00-80.00
G	80.00-160.00

Figure 7: Motor impulse chart for low to mid-power rockets

Pre-Flight

The flight of a model rocket begins during the pre-launch preparation. You should first inspect the model. Make sure that the fins are still tight against the body tube, the launch lug is still attached, the nose cone isn't too loose, and the recovery system is still attached to the rocket. You also need to check the motor mount, making sure that it hasn't become loose. The pre-flight should be done before every flight, whether the model is brand new or has hundreds of flights logged.

Motor Preparation
Select a motor that will be adequate for the flight. The clay nozzle should be intact, and not deformed. A deformed nozzle will result in an underpowered flight at best, or loss of a rocket at worse.

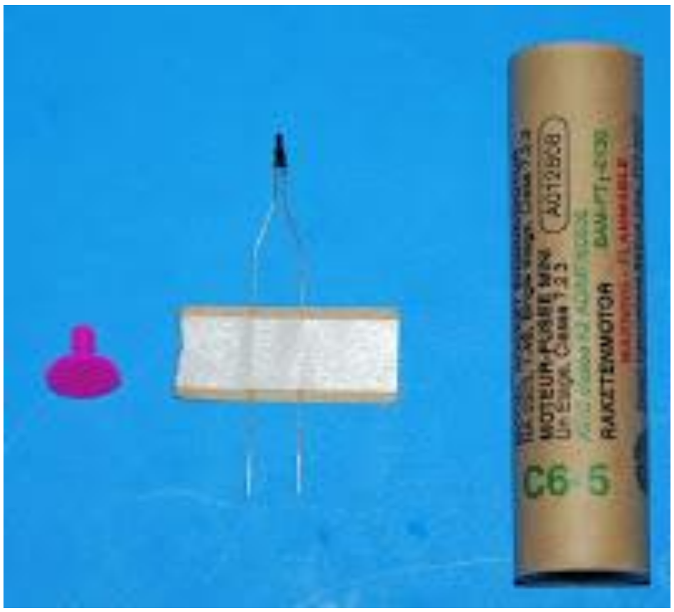

Figure 8: Motor, ignitor and plug

Select an igniter and check the end to ensure that it has enough pyrotechnic and that it is intact (*Figure 8*). Insert the igniter into the nozzle of the engine. Make sure you insert it until the igniter touches the propellant. If it does not touch the propellant, the motor will not ignite.

There are two popular methods to secure the igniter in place. Some motors come with a plastic plug that holds the igniter in place (*Figure 9*). If using the plastic plug make sure you select the right size. If you select a size that it too small, the plug will fall out and so will the igniter.

Figure 9: Motor prepped for flight

The second method is to take a small amount of wadding or tissue paper and roll it into a ball slightly larger than the nozzle opening. Push the waded ball into the nozzle opening, forcing the igniter to remain in contact with the propellant.

Regardless of what method you prefer, most rocketeers will use a small amount of masking tape to help secure the igniter in place. One nice thing is you can prep your motors whenever you want to; hours, days or weeks before you intend to fly. Many rocketeers will have all of their motors prepped and ready to go by the time they reach the flying field.

Motor Placement
When you insert the motor into the rocket, it needs to be held securely in place. This is usually done by one of two methods. The most common method is to use a metal band, called an engine hook, to hold the motor in place. When using an engine hook, make sure the motor is fully inserted, allowing the clip to hold the motor in place.

The second method uses a motor block and friction to hold the motor in place. In this method, a motor block or ring is glued to inside the motor mount tube to stop the motor from moving forward on ignition. The based of the motor is wrapped with masking tape. This causes a tight friction fit, stopping the motor from being ejected out the back of the model when the ejection charge is fired.

Recovery System Preparation

The most common type of recovery systems in use is the parachute. However, prior to inserting the 'chute, the recovery system requires that flame-proof wadding be inserted between the motor and the parachute. When inserting the wadding, make sure it is loosely crumpled. This will help the wadding absorb the heat of the ejection charge, and lessen the probability of your recovery system being melted together.

Packing the Parachute

There are about as many different ways to fold a parachute as there are rocketeers. I have found one method that seems to work well, resulting in consistently opening parachutes. It is also one of the more simple methods of packing a parachute.

First , smooth the 'chute down, so that it looks like a small round log. Next, fold the chute in half, and insert the folded end into the body tube. Lastly, insert the shroud lines and shock chord into the body tube. The idea behind this type of fold is that as the parachute exits the body tube, the open end of the 'chute will catch the air, causing the chute to fill with air and fully expand as it exits the body tube.

One last thought on packing the parachute. Unlike the motors, packing the 'chute should be just prior to launch. If the parachute has been packed inside a body tube for a couple of hours, the chances of it opening up are greatly diminished. You can sprinkle talcum powder or corn starch to help loosen up the plastic chutes and stop them from sticking. However, your best bet is not to pack your chute until you are ready to fly.

The Launch System

The launch system consist of two basic components, the launch pad and the electrical launch controller. The launch pad (*Figure 1*) is where the model sits while being made ready for flight.

Figure 10: Commercial launch pad

The launch pad will have some type of 'blast deflector' which directs the hot exhaust gases from the model rocket engine away from the ground. A rod is used to guide the model for the first three feet of the flight. This makes sure that the model begins it flight going straight up and allows the model to gain enough forward speed to allow the rocket's fins to take over. For model rockets the launch rods will come in two sizes, 1/8 -inch or 3/16-inch in diameter. The model rocket has a small tube (properly called a launch lug) that goes over the rod (*Figure 10*).

Launch Controller
The other part of the launch system is the electrical control system (*Figure 11*). All model rocket engines are ignited electrically. An electrical current is sent through the igniter. This heats up a small bit of pyrotechnic material, which in turn ignites the propellant. However, we need to make sure that the propellant only ignites when we allow it. To prevent an inadvertent ignition we use a safety key.

Figure 11: Launch controller

A safety lock or key is a necessary requirement on all model rocket launch systems. The key is removed from the system while the rocket engine is being connected to the system. This key ensures that the rocket engines are not fired accidentally. As long as the key is removed the electrical current cannot reach the igniter, thus preventing the engine from firing. Once everything is ready for launch and everyone has moved back to a safe distance, the key is placed back into the launch controller. If everything is connected properly, a small lamp (called a continuity light) that is part of the system should be lit. If the lamp doesn't come on, remove the safety key and check all of your connections.

With a model on the pad, a good continuity light and everyone moved to a safe distance from the pad, we are ready for a five second countdown (*Figure 12*).

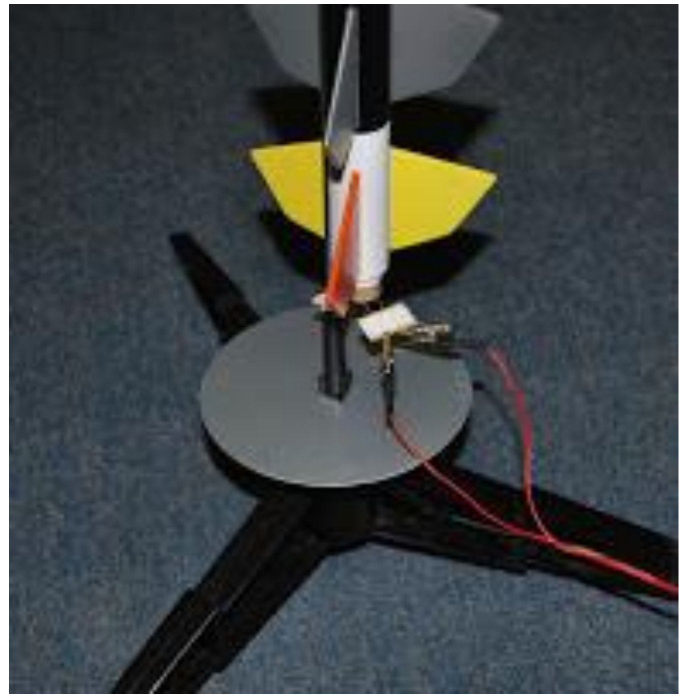

Figure 12: Rocket hooked up

At "zero" we press the launch button. The electrical current is sent to the igniter, the pyrotechnic on the end of the igniter fires and the propellant begins to burn with the hot exhaust gases exiting through the nozzle.

Flight
With the ignition of the solid rocket engine and the first movement up the rod begins the flight of the rocket. The propellant begins to burn and exits through the nozzle, thrusting the model upward through the power ascent stage. When the propellant finishes burning, the model is moving very rapidly and continues to coast upward toward apogee. During this time the delay charge begins burning, sending a trail of smoke out through the nozzle. The smoke trail is seen from the ground, allowing easier tracking of the rocket. When the delay has completed burning the last section of the engine is set to fire the ejection charge. The rocket is ready to transition from the flight phase to the recovery phase (*Figure 13).*

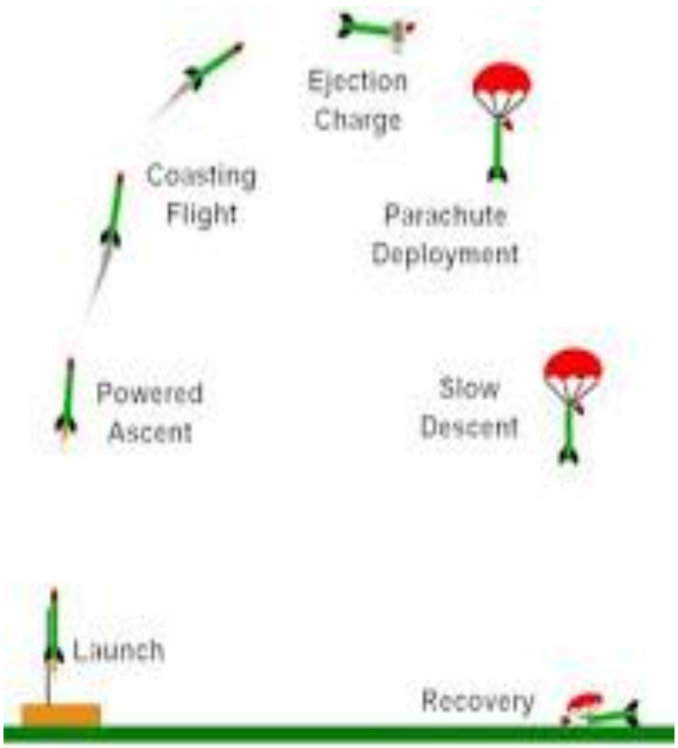

Figure 13: Typical Rocket Flight

Recovery

To begin the recovery phase the ejection charge fires sending a burst of hot gas into the body of the rocket. The heat from the gas is absorbed by the recovery wadding, preventing the heat from melting the parachute together. The gases are expanding inside the body, pushing the parachute towards the front of the rocket. The pressure inside the body tube forces the nose cone away from the rocket. As the nose cone moves away from the rocket the parachute follows, being attached to the nose cone by the parachute's shroud lines. The energy of the nose cone is absorbed by the shock chord, keeping the nose cone and parachute attached to the rocket. The parachute fills with air, opening up and slowing down the rocket. With the parachute fully deployed the rocket drifts slowly back down to Terra firma. The rocket lands gently and can be made ready to fly again in just a matter of minutes.

** The conical transitions noted in the drawing are labeled as “boattail” (going from a larger diameter to a smaller diameter body tube) and “adapter” (going from a smaller diameter to a larger diameter body tube). These may also be referred to as transitions, adapters, etc. The terminology used in this document was taken from the report, “The Theoretical Prediction of the Center of Pressure” by James S. and Judith A. Barrowman.*

If You Enjoy Rocketry, Consider Joining the NAR

If you enjoy model rocketry and projects such as the Arduino Launch Control System, Project:Icarus, The Dyna-Soar and others, then consider joining the National Association of Rocketry (NAR). The NAR is all about having fun and learning more with and about model rockets. It is the oldest and largest sport rocketry organization in the world. Since 1957, over 80,000 serious sport rocket modelers have joined the NAR to take advantage of the fun and excitement of organized rocketry.

The NAR is your gateway to rocket launches, clubs, contests, and more. Members receive the bi-monthly magazine "Sport Rocketry" and the digital NAR Member Guidebook—a 290 page how-to book on all aspects of rocketry. Members are granted access to the "Member Resources" website which includes NAR technical reports, high-power certification, and more. Finally each member of the NAR is cover by $5 million rocket flight liability insurance.

For more information, visit their web site at https://www.nar.org/