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What’s Important for Model Rocket Performance

(By James F. Myres)

I get many questions from beginning model rocket modelers that want to know how to design model rockets for the best altitude performance. This interest varies between those who just want to get the best performance from a custom designed rocket to those who are involved in Science Fair or school projects. Most often the focus of the questions are on design issues associated with aerodynamic shape such as the nose cone or fin shape and often the questions center on just length and diameter. In the following discussion, I'll try to unravel the issues about model rocket performance.

So What's Important?

To help divide the areas involved in model rocket performance, I've listed most of the factors that affect flight performance.

Gravity - A big factor. The only way to reduce gravity is to launch a rocket at an angle not perpendicular to the ground. Launching at an angle will increase the distance a rocket travels before coming back down. However, a rocket will not

reach its highest altitude unless it is launched straight up, perpendicular to the ground. I've brought the issue of gravity up to illustrate that the most important issue regarding model rocket performance is:

Weight - As you can't change gravity, you can get the same affect by reducing the weight. This is because the speed of the rocket at engine burnout is proportional to the weight of the rocket. The following simplified equation illustrates this:

$$v = (I * g)/W$$

Where as:
v = Max Velocity in Feet per Second
I = Total Motor Impulse in Pound Seconds
g = Gravity at 32.2 Feet per Second Squared
W = Weight of Rocket at Burnout in Pounds

In this equation gravity is a fixed constant. So only changing motor impulse or changing the weight of the rocket will affect the burnout velocity of the rocket.

To use this equation you can convert the typical motor impulse ratings of newton-seconds to pounds by dividing newton-seconds by 4.448. You can also convert typical rocket weight in ounces to pounds by dividing ounces by 16.

Power - Increasing the power has the same affect as reducing the weight. For instance let's apply the velocity formula to the following examples...

Rocket with an impulse of 5 newton-seconds equals 1.124 pound-seconds and 10 newton seconds at 2,248 pound seconds. Weight of 4oz equals .25 pounds.

Applying the formula v = (I * g)/W yields:
(1.124 * 32.2) /.25 = 144.77 feet per second

Change the impulse to 2.248 changes the result to:
(2.248 * 32.2) /.25 = 289.54 feet per second

As you can see, doubling the total impulse or cutting the weight in half has the same affect of doubling the velocity.

The above burnout velocity calculations do not take in to account the effect that aerodynamic drag has on the velocity. In the following section we will begin to deal with this issue.

Aerodynamic Drag

Aerodynamic drag can have a significant impact on the velocity of a rocket in flight.

For instance, the calculation of drag force is:

D = 0.5 * p * (V^2) * Cd * ((r ^ 2) * 3.14159)

Where as:
D = Drag
p = Air density in kg/m3
v = Max velocity in feet per second
Cd = Drag coefficient
r = Diameter of rocket divided by 2

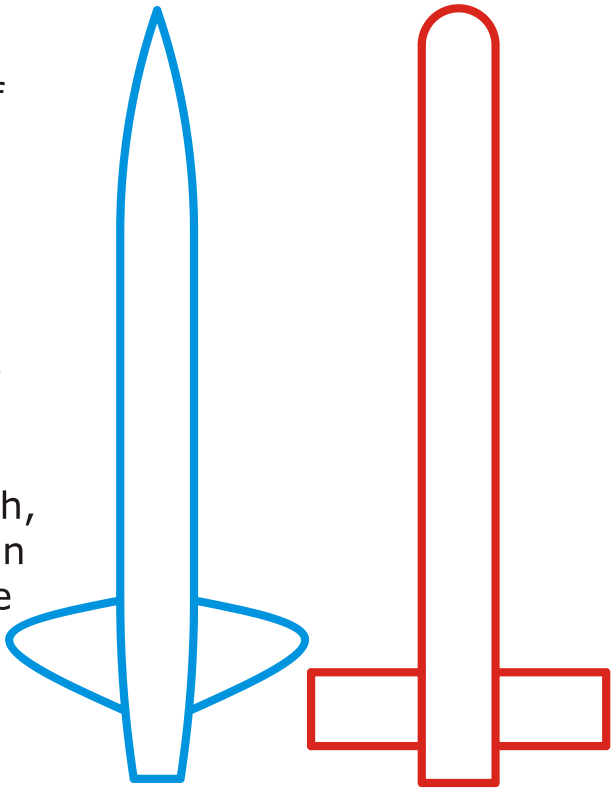
The velocity has the greatest affect on drag in this calculation since it is squared. However, as the earlier equation for velocity is calculated separately, we will consider this to be a constant in this calculation.

Air Density - Air density is about .97 at sea level and 70F. There is little that you can do about it other than launch on a hot day or take a trip up to the mountains where the air is less dense to launch.

Drag Coefficient - The drag coefficient is usually less than 1. Most rockets fall between .5 and .75. Only a very bad design would exceed 1. We will discuss this in some detail in the following section.

Diameter of the Rocket - In the above calculation, the diameter is divided in two, then the result is squared and multiplied by 3.14159 or PI. This calculation will give you the area the rocket faces into the wind or how much the air is displaced.

Independent of the velocity value, the diameter of the rocket is the single largest factor in drag force calculations. The drag nearly quadruples as the rocket diameter only doubles.



Aerodynamic Shape - The single factor which describes the shape of model rocket and the finish is the drag coefficient.

Take a look at the 2 rocket designs on the right. The one on the left looks considerably sleeker than the one on the right.

Based on a rocket with a good finish, the design on the left would come in with a .5 Cd (drag coefficient) while the one on the right would come in with a .75 Cd value.

So What Does All This Mean?

Aerodynamic shape has an impact on the drag force the rocket sees in flight. However, the diameter of the rocket has a larger impact on drag calculations.

It is understood that the height the rocket is able to obtain is based on velocity over time. The import factors in the velocity are the weight and power of the rocket.

To achieve better performance from a rocket and higher altitude flights, focus on weight and power, first, then rocket diameter and lastly aerodynamic shape.

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