Understanding Rocket Stability Part 1 – Centre of Gravity

Learning Objective	In this lesson we will study the stability of model rockets using OpenRocket. We will discuss the forces acting upon a rocket during its flight and how its Centre of Gravity (CG) may be determined.
Grade Level	9 – 11

– Introduction –

To understand the stability of a model rocket flight it is important to visualize the rocket moving through the air during its upward trajectory.

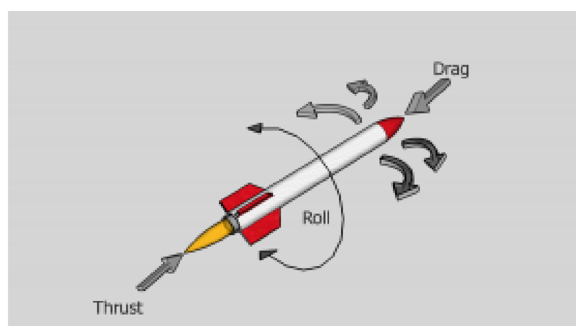

Figure 1 – Degrees of Freedom

After leaving the launch rod the rocket is essentially a free moving body in the air. The forces of wind, gravity and drag act upon the rocket affecting its intended upward flight.

Degrees of Freedom

Degree of Freedom (DOF) is defined as the number of independent parameters that define a mechanical configuration. For model rockets eight different degrees of freedom may be identified as shown in figure 1 (gravity not shown).

Thrust is the force provided by the motor and is responsible for moving the rocket upward. Drag is the force that opposes the upward motion and is determined by the aerodynamics of the rocket.

Roll is the motion that occurs when the rocket spins either left or right. The rocket may also pitch up or down, left or right and is shown by the curved arrows in the diagram.

Thrust, Drag and Gravity (not shown but affects the rocket at different points depending on the flight) are linear forces. The others are rotational forces with a rotational point. The roll rotation occurs along the axis that is straight down the centre of the rocket (assuming the rocket is symmetrical). For the pitch and yaw forces the rotational point is a point along the body of the rocket called the Centre of Gravity or CG.

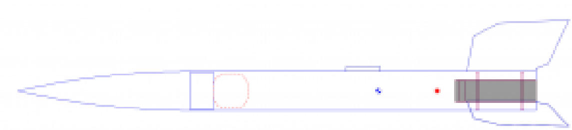

Figure 2 – Screen shot from OpenRocket

Determining CG

The easiest way to find the Centre of Gravity for your rocket is to balance it on a pivot such as a ruler. This is to be done when the preparation of the rocket is complete and it is ready to fly.

Thanks to modern software we may also use OpenRocket to determine our Centre of Gravity. Figure 2 shows a screen shot from OpenRocket of a simple rocket. The Centre of Gravity (CG) is shown by the blue circle.

You may also notice a red circle. This circle displays the Centre of Pressure of the rocket. What is important to note is that in order for a rocket to be stable it must have its Centre of Gravity ahead (closer to the nose cone) of its Centre of Pressure. We will go into more detail about Centre of Pressure in our next article.

Changing the CG

If you haven't already downloaded and run OpenRocket do so now. You may download it from http://www.openrocket.sourceforge.net. After running the program load "A simple model rocket" from the Open Example menu. Observe the Centre of Gravity and Centre of Pressure circles.

Open a component such as the Body Tube and change it's length. You will notice that the Centre of Gravity changes in relation to the Centre of Pressure as you lengthen and shorten the tube. You may even be able to shorten the tube so much that the CP moves ahead of the CG.

What we have learned so far

In this lesson we have just begun to scratch the surface in designing a stable rocket. Information regarding rocket design and stability has been with us for quite some time. Programs such as OpenRocket allow us to experiment with these concepts before we begin to build.

For part two of this lesson we will delve a little more into the balance between the Centre of Gravity and the Centre of Pressure.

Suggested Reading

The following is a list of some of the resources used in the writing of this article:

1. Handbook of Model Rocketry by G. Harry Stine and Bill Stine.
2. OpenRocket technical documentation