Rocket Stability Determination
(Swing Test)

A rocket that flies straight through the air is said to be *stable*. A rocket that veers off course or tumbles is said to be *unstable*. Whether a rocket is stable or unstable depends upon its design.

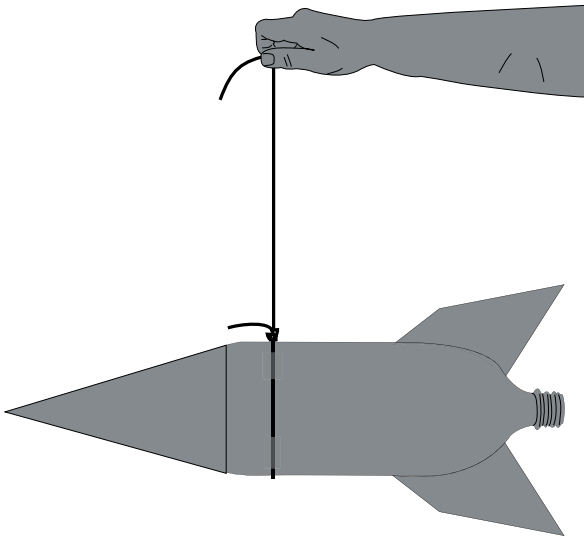
All rockets have two "centers." The first is the *center of mass*. This is a point about which the rocket balances. The picture to the right shows a rocket suspended from a string. The rocket is hanging horizontal. That means that it is balanced. The string is positioned exactly beneath the rocket's center of mass. (This rocket looks like it should really hang with its tail section downward. What you can't see in the picture is a mass of clay placed in the rocket's nose cone. This gives the left side as much mass as the right side. Hence, the rocket balances.)

The center of mass is important to a rocket. If the rocket is unstable, it will tumble around the center of mass in flight the way a stick tumbles when you toss it.

The other "center" of a rocket is the *center of pressure*. This is a point in the shape of the rocket where half of the surface area of the rocket is on one side and half on the other. The center of pressure is different from the center of mass in that its position is not affected by what is inside the rocket. It is only based on the rocket's shape.

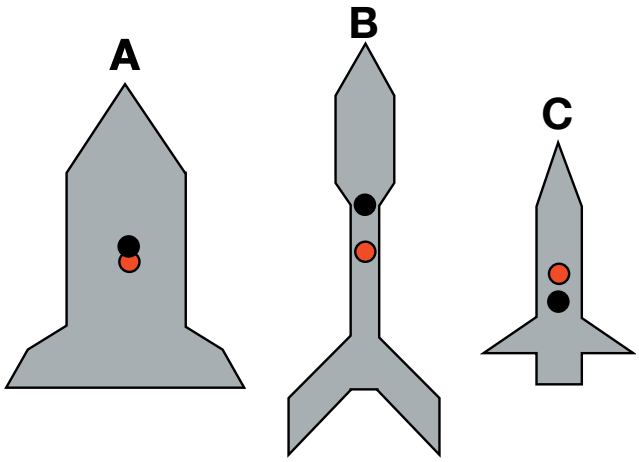
Air strikes the surface of the rocket as the rocket moves. You know what this is like. If you stick your arm outside a car window when it is moving, you feel pressure from the air striking your arm. The center of pressure of a rocket is the middle point. Half of the total pressure on the rocket is on one side of the point and half on the other.

Depending upon the design of the rocket, the center of mass and the center of pressure can be in different places. When the center of mass is in front of the center of pressure (towards the nose end), the rocket is stable. When the center of pressure is towards the front, the rocket is unstable.



When designing a stable rocket, the center of mass must be to the front and the center of pressure must be to the rear.

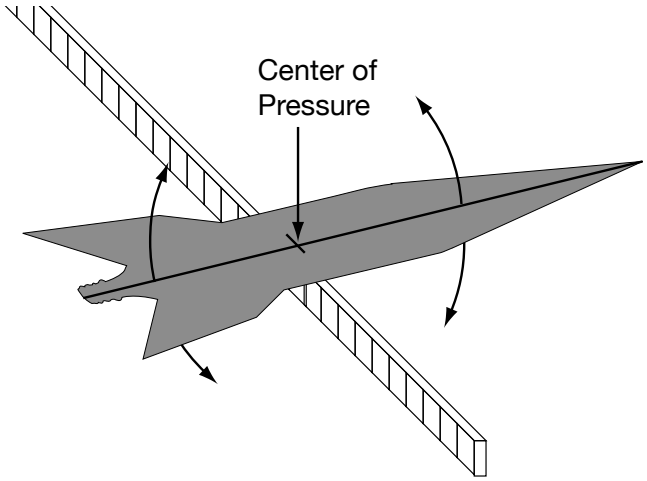
A simple way to accomplish stability is to place fins at the rear of the rocket and place extra mass in the nose. Look at the rockets below. Only one of the rockets is stable. The center of mass is shown with a back dot. The center of pressure is shown with a red dot. Which rocket will fly on course?



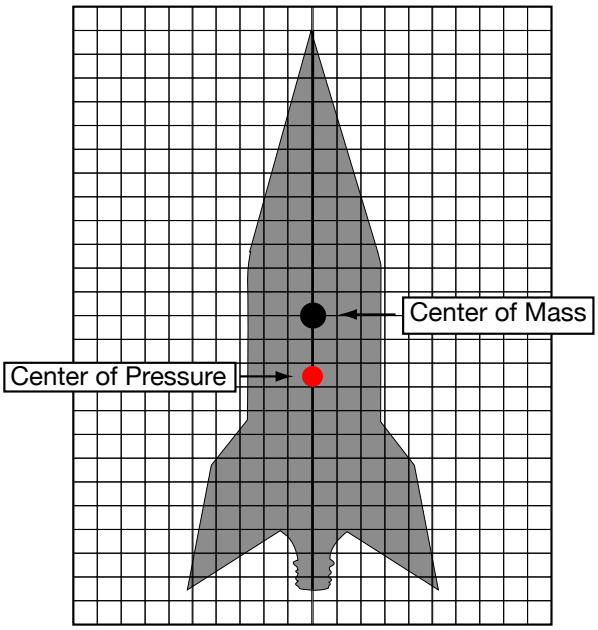
Rocket B is the most stable rocket. Rocket C will definitely tumble in flight. Rocket A will probably fly on a crooked path. Any cross winds encountered by the rocket as it climbs will cause it to go off course.

How to Determine Your Rocket's Stability

1. Draw a scale diagram of your rocket on the graph paper. Make it exactly to the shape of your rocket as seen from the side.
2. Tie a string loop snugly around your rocket so that you have one long end to hold. Except for the water needed for launch, your rocket should be set up exactly as it will be during launch.
2. Slide the loop until the rocket hangs horizontally. When it hangs horizontally, the string is at the rocket's center of mass. Mark that spot in the middle of your rocket on the scale diagram. Use a black dot.
3. Cut out a silhouette of your rocket from a piece of cardboard. Make it <u>exactly the same shape and size</u> of your rocket as seen from the side.
4. Balance the silhouette on the edge of a ruler. The center of pressure of your rocket is where the ruler is located. Mark that spot in the middle of your rocket on the scale diagram. Use a red dot.
5. If the center of pressure is before (towards the rocket's nose) the center of mass, add some additional clay to the rocket OR increase the size of the fins. Repeat the tests until the center of mass is in front.
6. Verify your design results by conducting a swing test. Balance the rocket again with the string. Use a couple of pieces of masking tape to hold the string loop in position.
7. Stand in a clear area and slowly start the rocket swinging in a circle. If the rocket is really stable, it will swing with its nose forward and the tail to the back.



Scale Diagram



In flight, the rocket will try to tumble around its center of mass. If the center of pressure is properly placed, the rocket will fly straight instead. More air pressure will be exerted on the lower end of the rocket than the upper end. This keeps the lower end down and the nose pointed up!

Swing Test