Rocket Stability

The rocket stability is determined by the relative position of the center of pressure to the center of gravity. The center of pressure is the point where the aerodynamic forces are applied, and the center of gravity is the point where the gravitational force is applied.

As the center of gravity is the point where the gravitational forces occur, we can see it as an axis around what the rocket will turn. If we put a force above the center of gravity, the rocket nose will go in the force direction (force applied on the left side of the rocket will make the nose go to the right). If we put a force under the center of gravity, the rocket nose will go in the opposite force direction.

Here are some illustrations of the different possibilities:

First case:

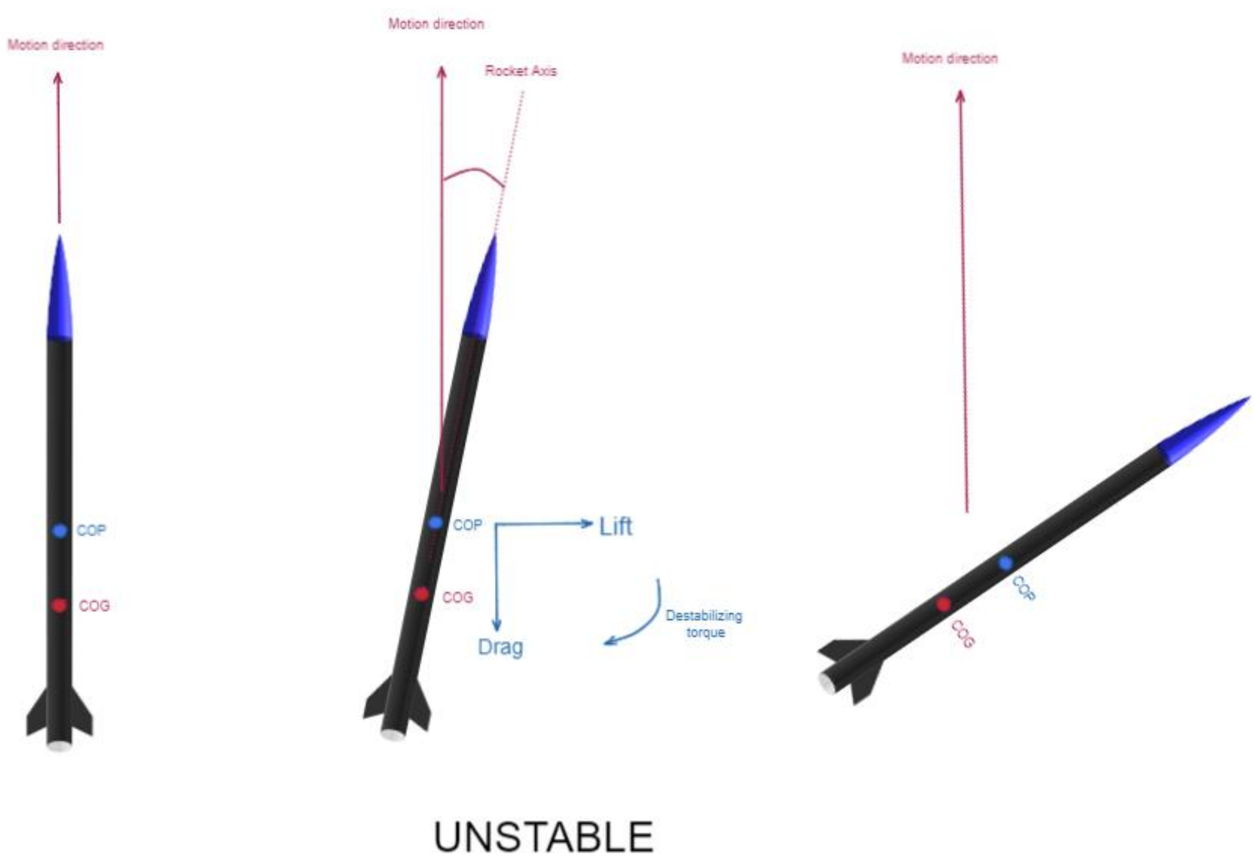

Figure 1 Unstable scenario

In this case, the center of pressure is above the center of gravity.

The rocket is going upward, which means that the aerodynamical forces are applied on the top side of the rocket.

Therefore, if the rocket is destabilized as shown on the second picture, the left side of the rocket becomes the top side.

This means that the aerodynamical forces generate a force on this left side and that this force can be divided in two directions: from left to right there is the lift force, from up to down there is the drag force.

As the center of pressure is above the center of gravity, the rocket nose will go in the force direction. Therefore, the lift force will make the rocket nose go to the right as shown on the last picture.

Finally, in this configuration, a perturbation generates a bigger perturbation. This is why this configuration is unstable.

Second case:

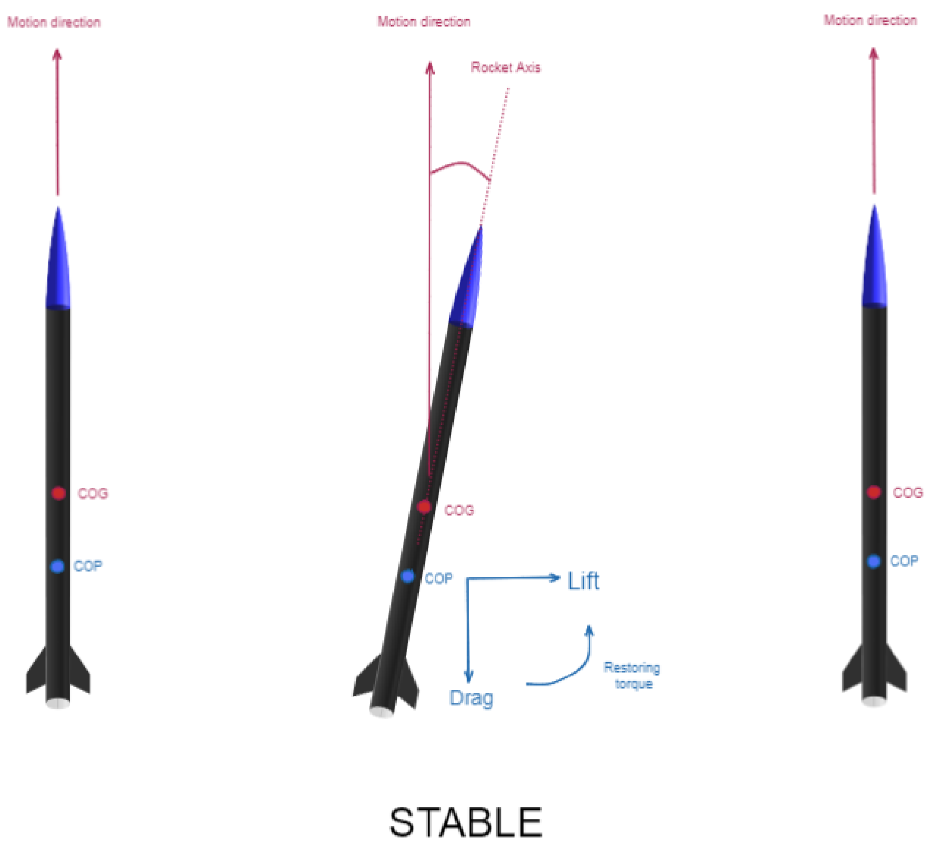

Figure 2 Stable scenario

In this case, the center of pressure is under the center of gravity.

The same perturbation occurs on the rocket. Therefore, the same forces (lift and drag) are applied on our system.

The difference this time is where these forces occur. Indeed, the lift force still goes in the same direction but this time, this force is applied under the center of gravity.

Therefore, the rocket nose goes in the opposite direction, meaning from left to right as shown in the third illustration.

Finally, when a perturbation occurs, an aerodynamical force compensate the perturbation and the rocket retrieve its first direction. This is why this configuration is stable.

Third case:

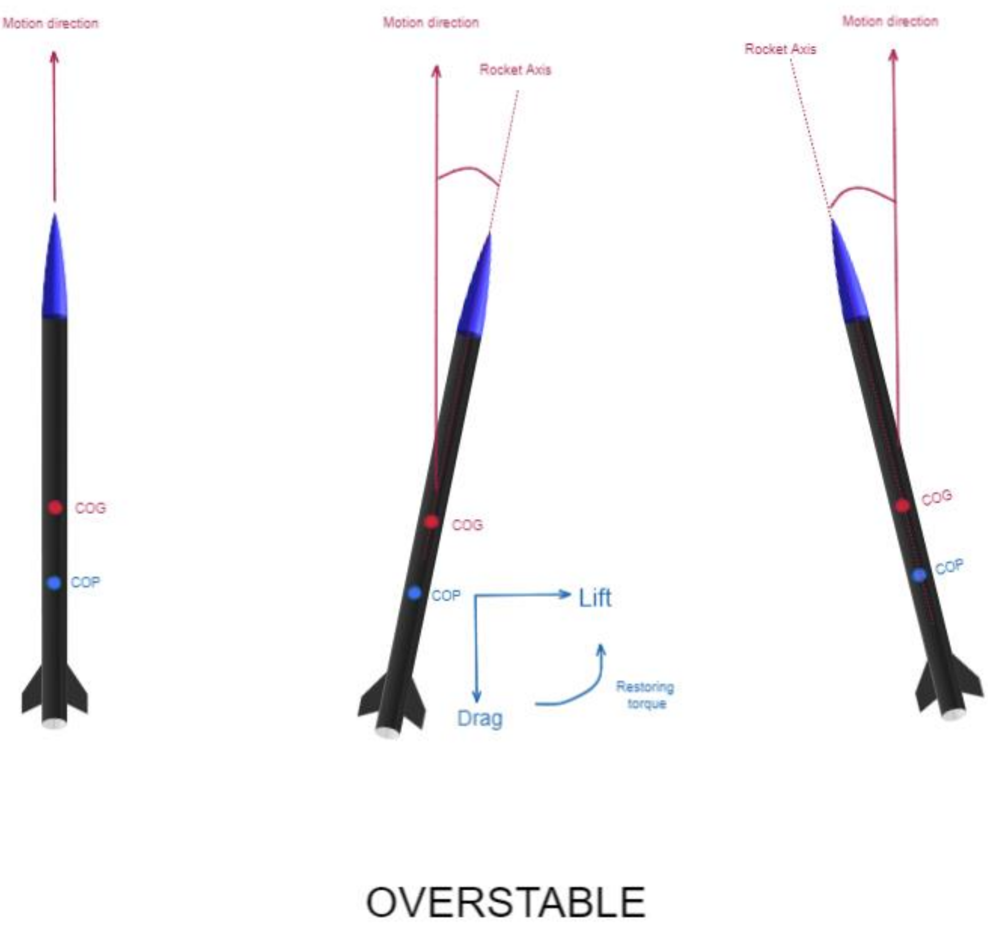

Figure 3 Overstable scenario

In this case, the center of pressure is under the center of gravity.

The difference between this case and the previous one is the intensity of the lift force.

The lift force still goes from left to right and still applies under the center of gravity so that the rocket nose goes from right to left.

However, this time, the compensation given by the lift force is too high, making the rocket nose go further than its first direction.

Therefore, the rocket now goes to the left. However, the lift direction changes too (as the top side of the rocket is now the right side). Therefore, the rocket nose will go left again, but as the intensity of this compensation is still too high, it will go further than the first direction again.

Finally, the rocket will enter a vibration phase that will lead to its destruction, or at best, to a big loss of performances. This is what we call an overstable system.