LESSON LD05

ROCKET STABILITY

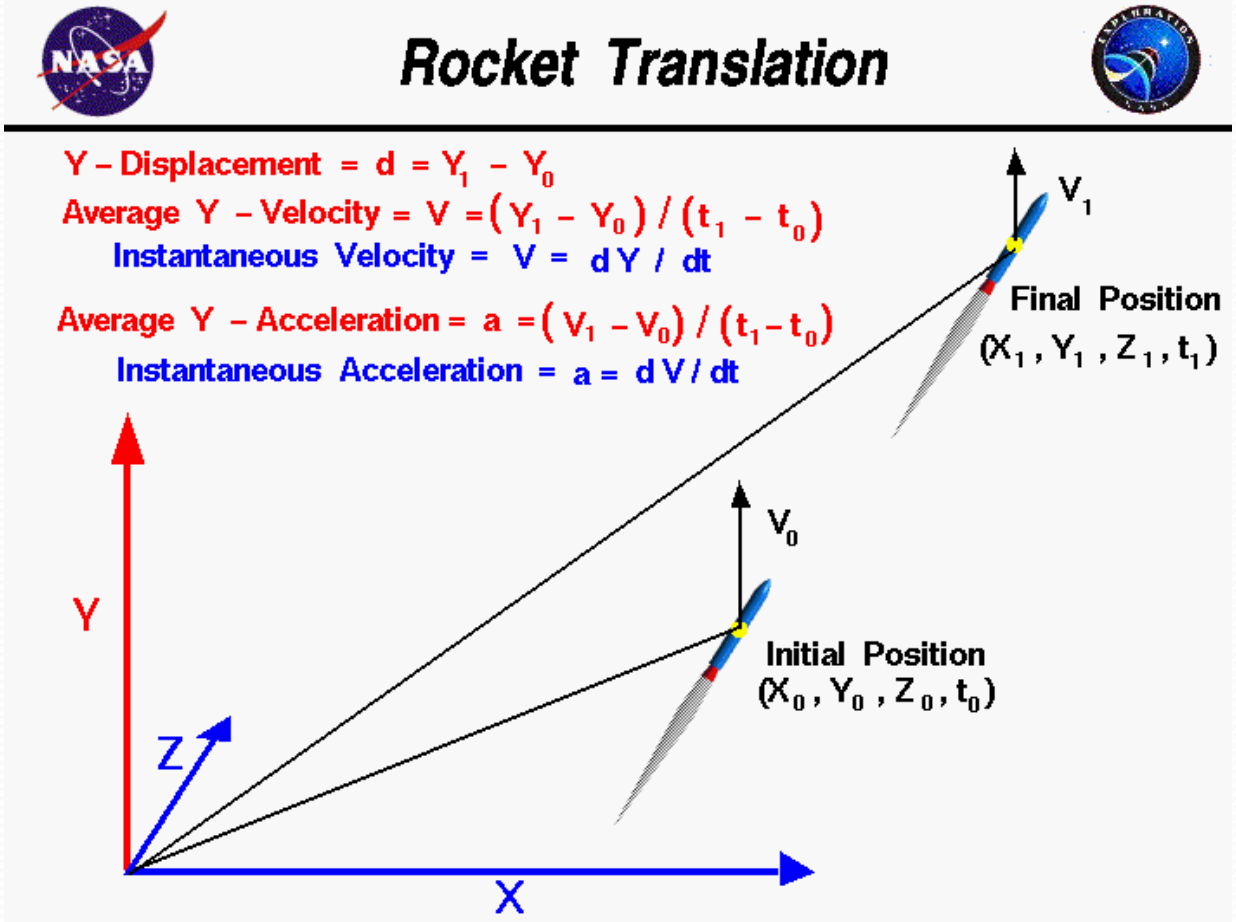
Rocket Stability

- During the flight of a model rocket, gusts of **wind** or thrust instabilities, can cause the rocket to "**wobble**", or change its attitude in flight.
- Poorly built or designed rockets can also become **unstable** in flight.
- This lesson is about what makes a rocket unstable in flight and what can be done to improve its stability.

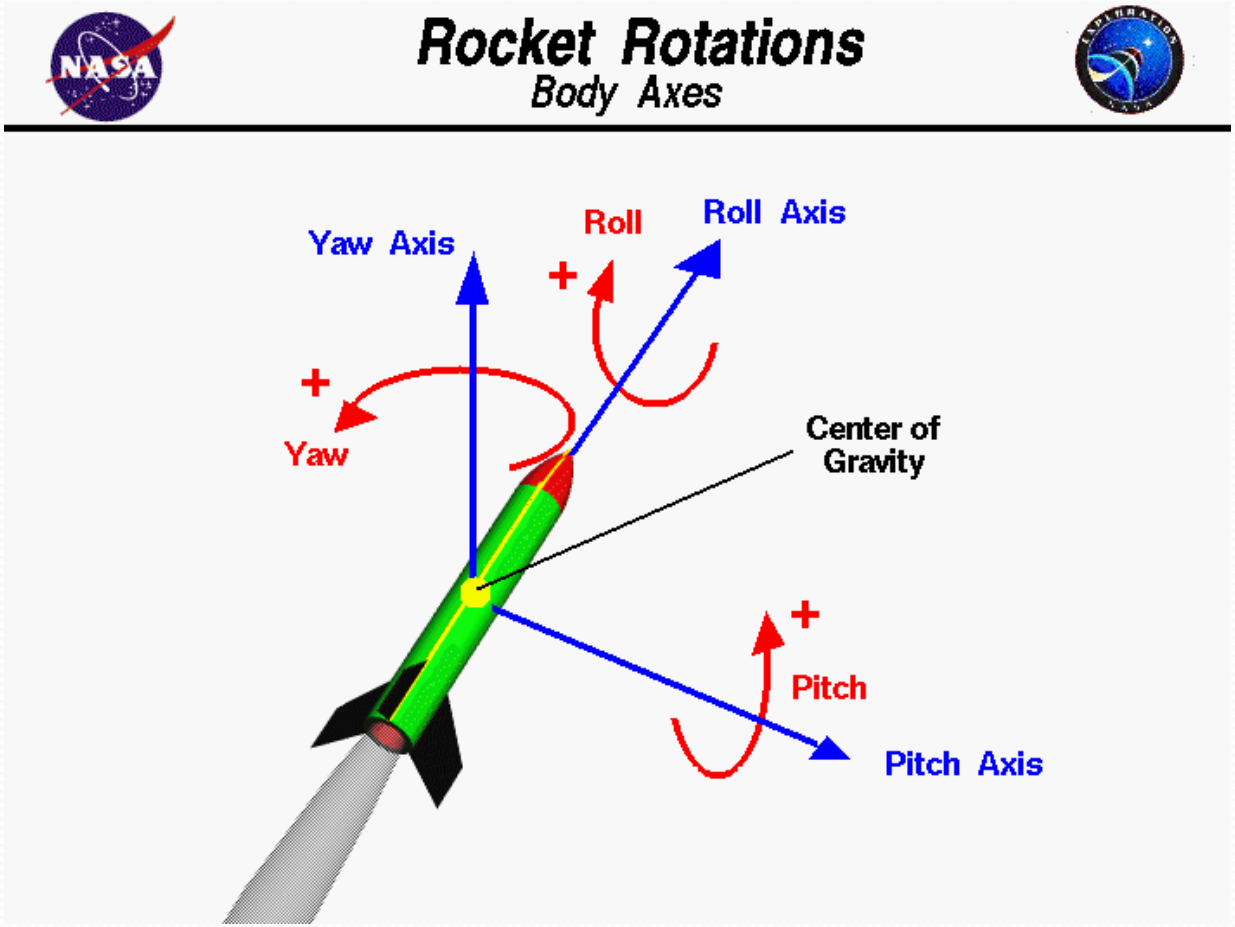
Translation and Rotation

- A rocket in flight can move two ways; it can **translate**, or change its location from one point to another, and it can **rotate**, meaning that it can roll around on its axis.

How a Rocket Translates



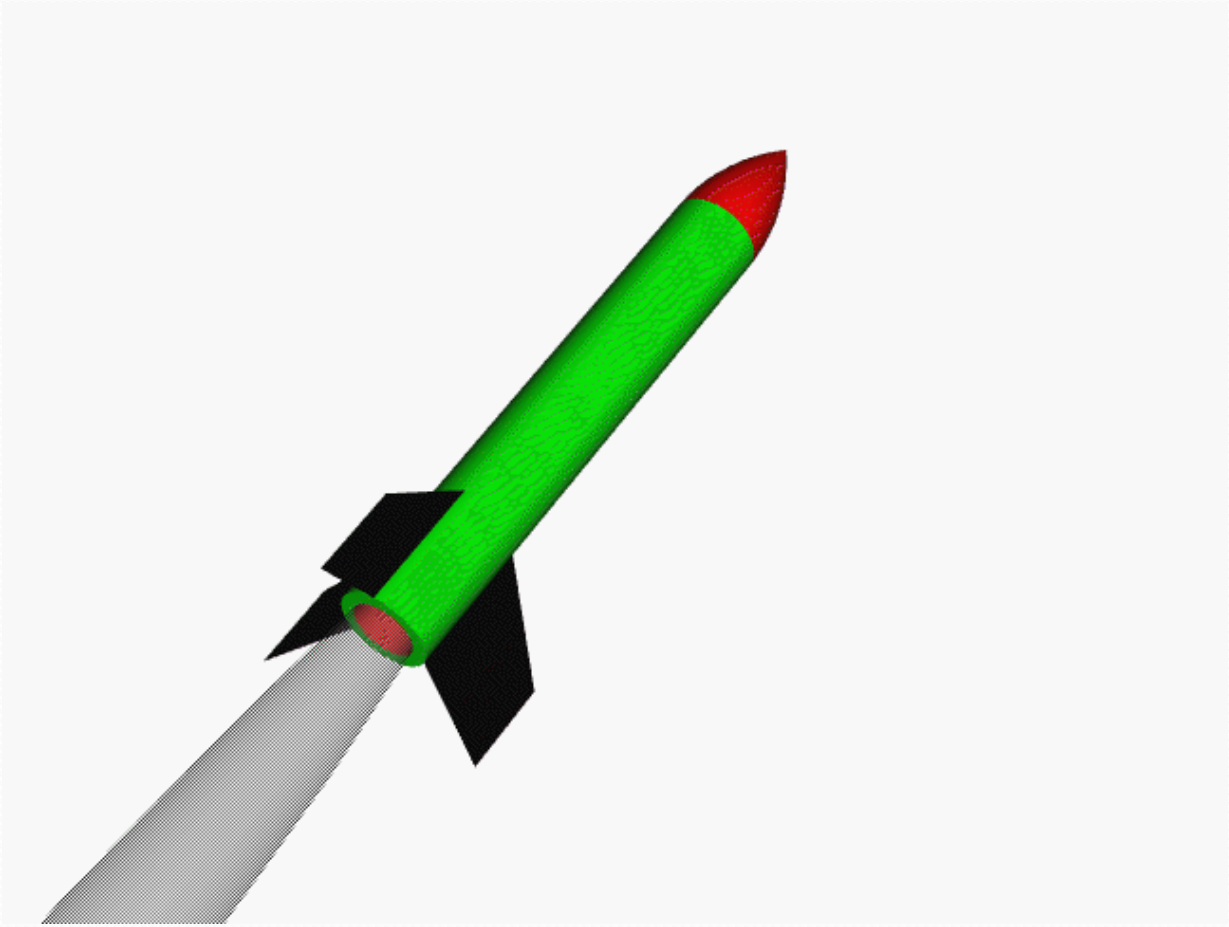
How a Rocket Rotates



Roll

- Most rockets are symmetric about a line from the tip of the nose to the center of the nozzle exit. We will call this line the **roll axis** and motion about this axis is called a **rolling motion**.
- The **center of gravity** lies along the roll axis.

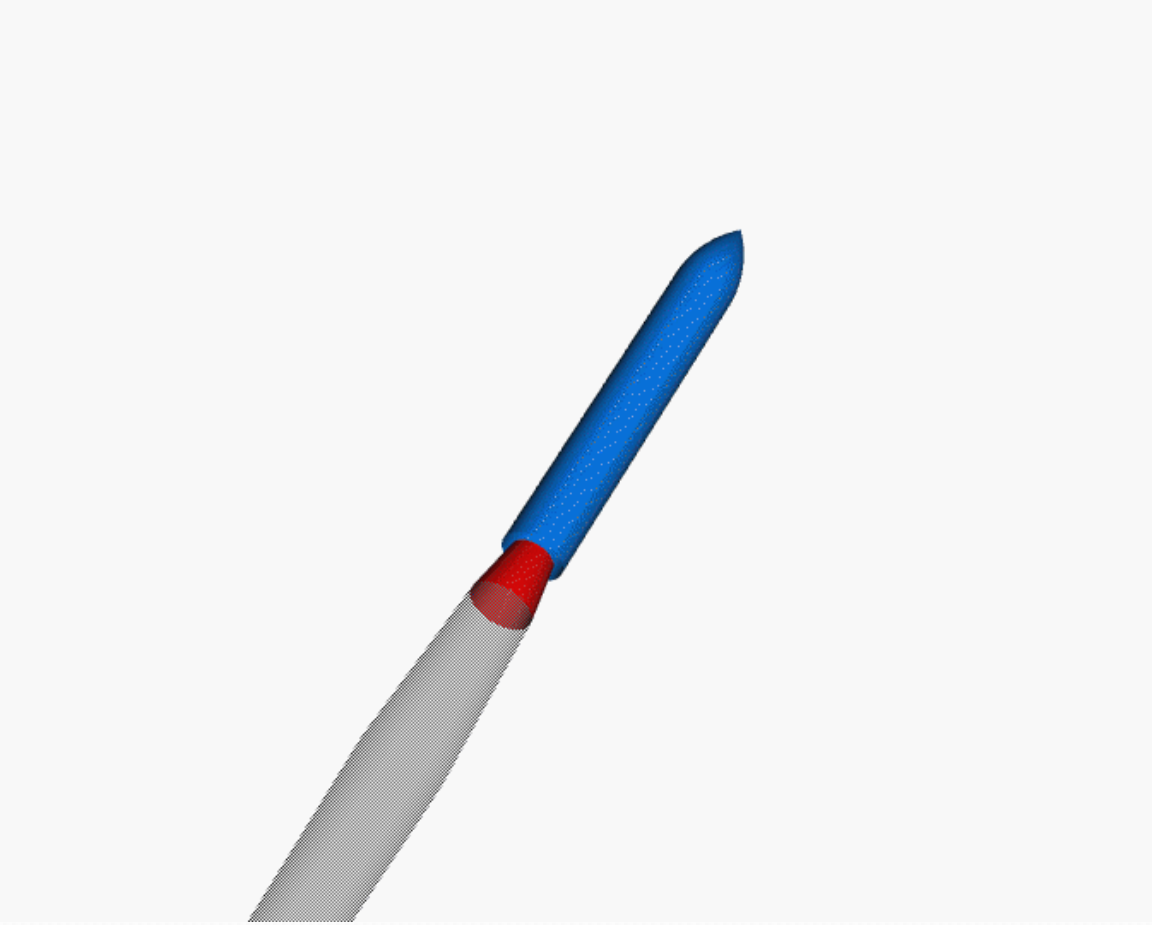
Roll



Yaw and Pitch

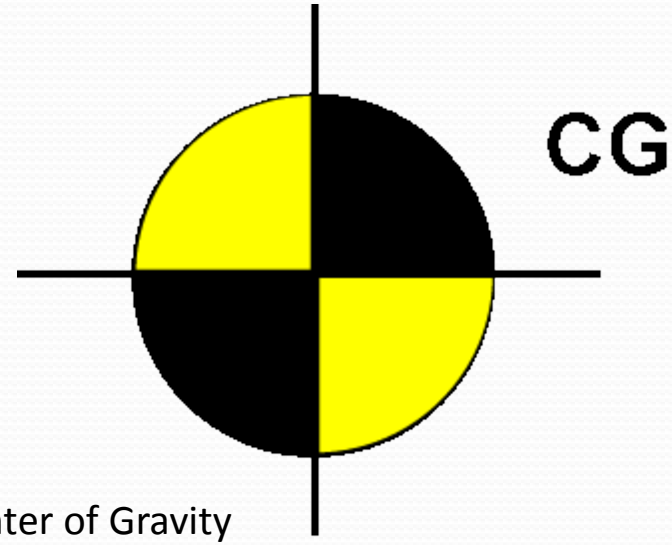
- When a rocket wobbles from **side to side**, this movement is called a **yaw motion**.
- A **pitch motion** is an **up or down** movement of the nose of the rocket.

Pitch



Center of Gravity - CG

- As a rocket flies through the air, it both **translates** and **rotates**. The rotation occurs about a point called the **center of gravity**, which is the average location of the weight of the rocket.



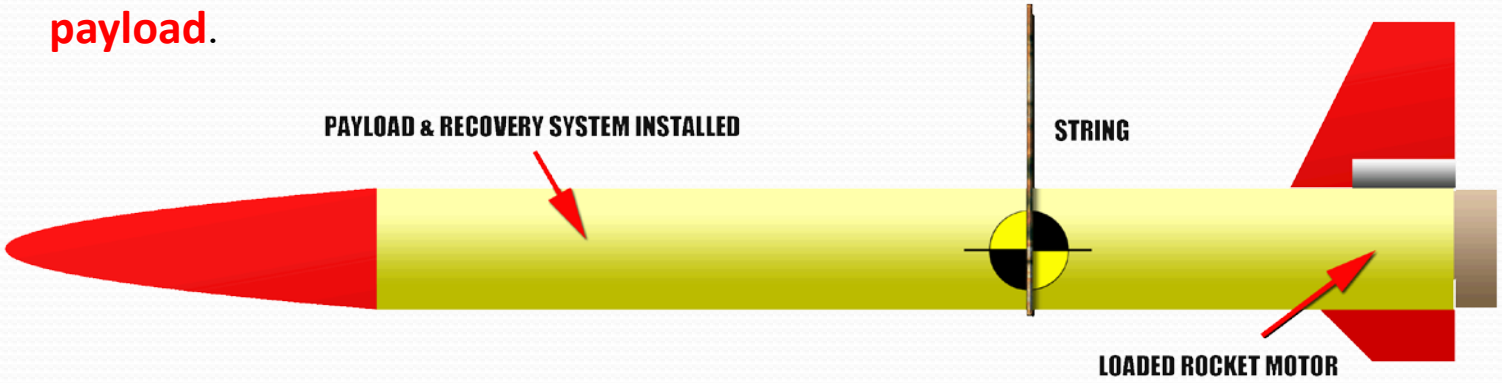
Symbol for Center of Gravity

Typical Location of CP

How to Determine CG

1. Load the motor, recovery system, and payload.

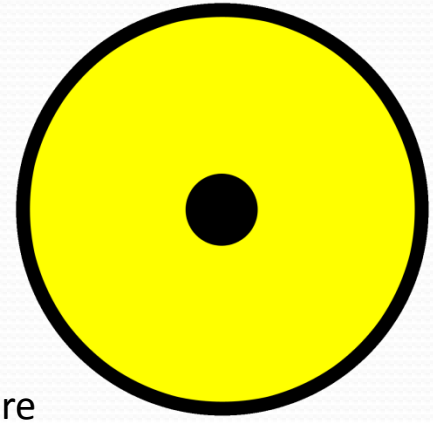
3. The location of the string is at the center of gravity.



2. Tie a string around the airframe and adjust it until the rocket is horizontally balanced.

Center of Pressure - CP

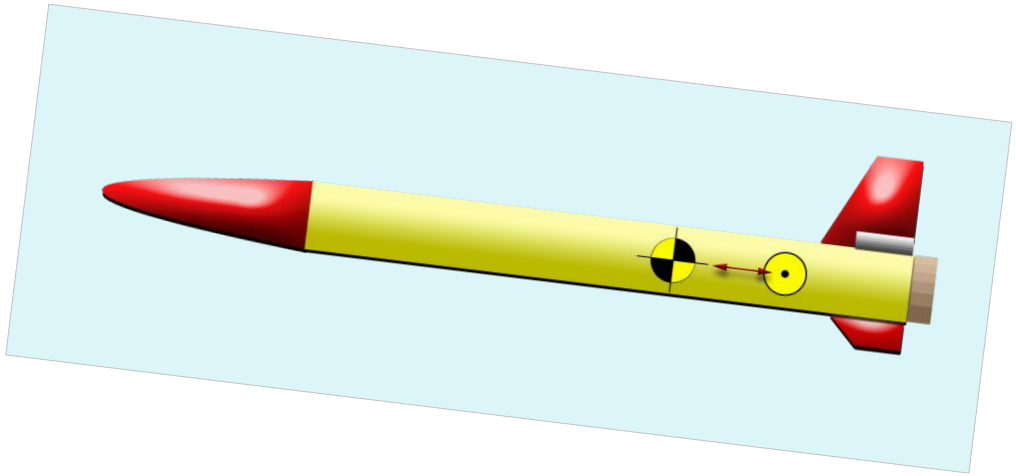
- The **average location of the pressure** on the rocket is called the **center of pressure.**
- The parts of the rocket that influences the location of the center of pressure the most are the **fins**.



Symbol for Center of Pressure

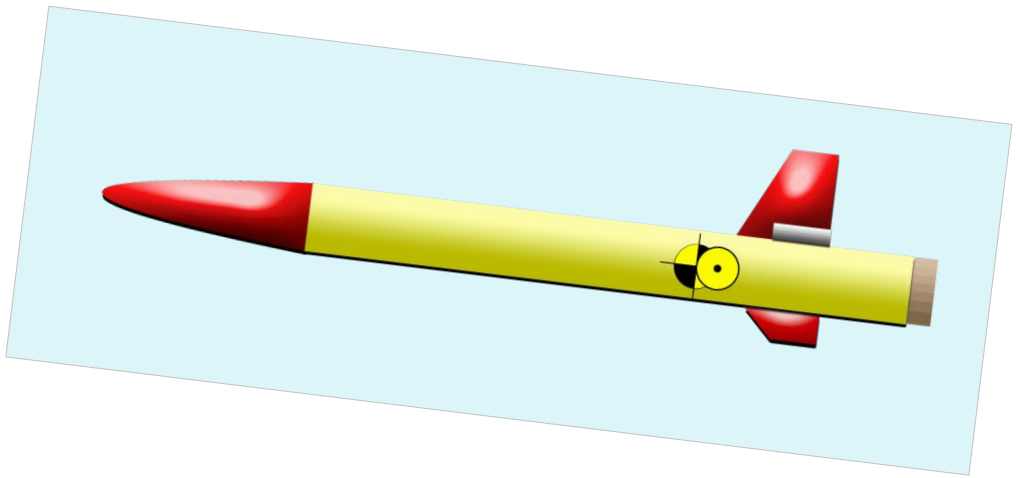
Building a Stable Rocket

If the **center of gravity is in front of the center of pressure**, the rocket will return to its initial flight conditions if it is disturbed. This is called a **restoring force** because the forces "restore" the rocket to its initial condition and the rocket is said to be **stable**.

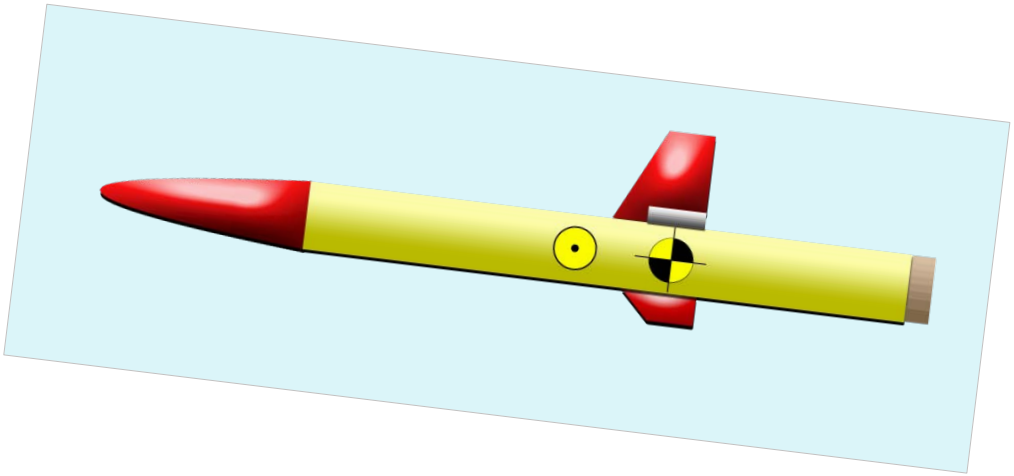


If the center of gravity and the center of pressure are in the same location, it is called **neutral stability**.

A rocket with **neutral stability** may make a stable or unstable flight depending on the forces acting on it.



If the **center of pressure is behind the center of gravity**, the lift and drag forces maintain their directions but the direction of the torque generated by the forces is reversed. This is called a **de-stabilizing force**. Any small displacement of the nose generates forces that cause the displacement to increase. Such a flight condition is **unstable** .



Correcting Unstable Flight

To move the Center of Gravity:

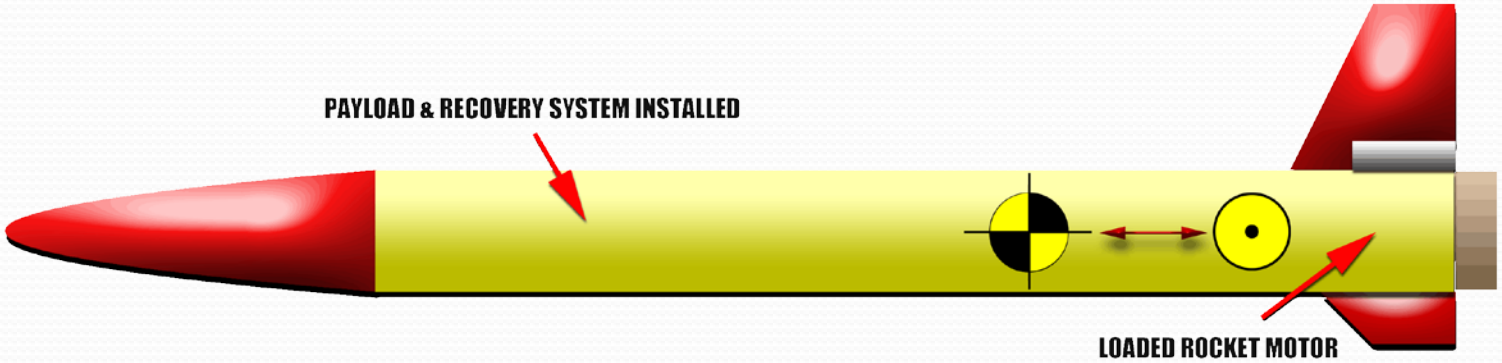
- **Add or remove weight in the nose cone.**
- **Redistribute the Payload**
- **Increase or decrease airframe length.**

To move the Center of Pressure:

- **Increase or reduce the fin size.**
- **Change the shape of the fins.**
- **Change the location of the fins.**
- **Increase or decrease airframe length/diameter.**

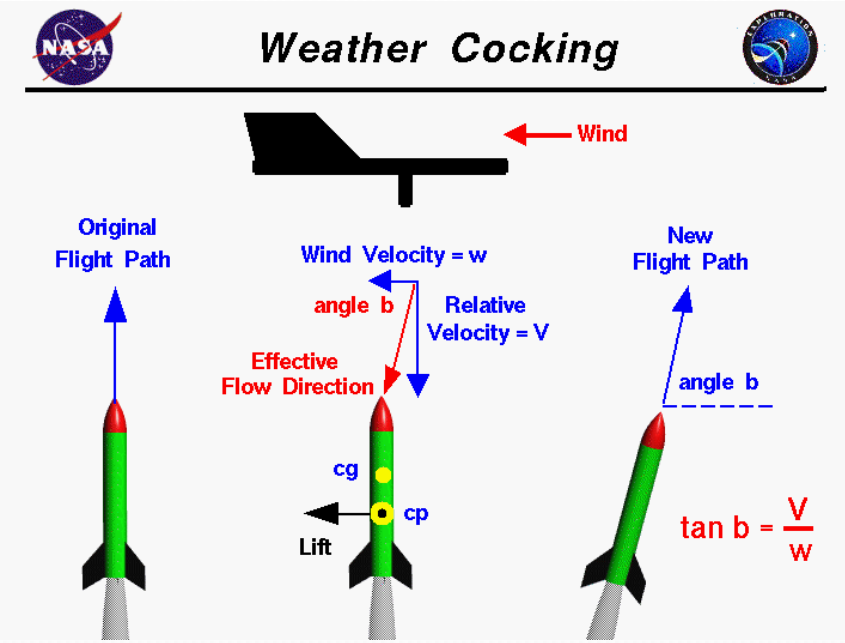
One Caliber Stability

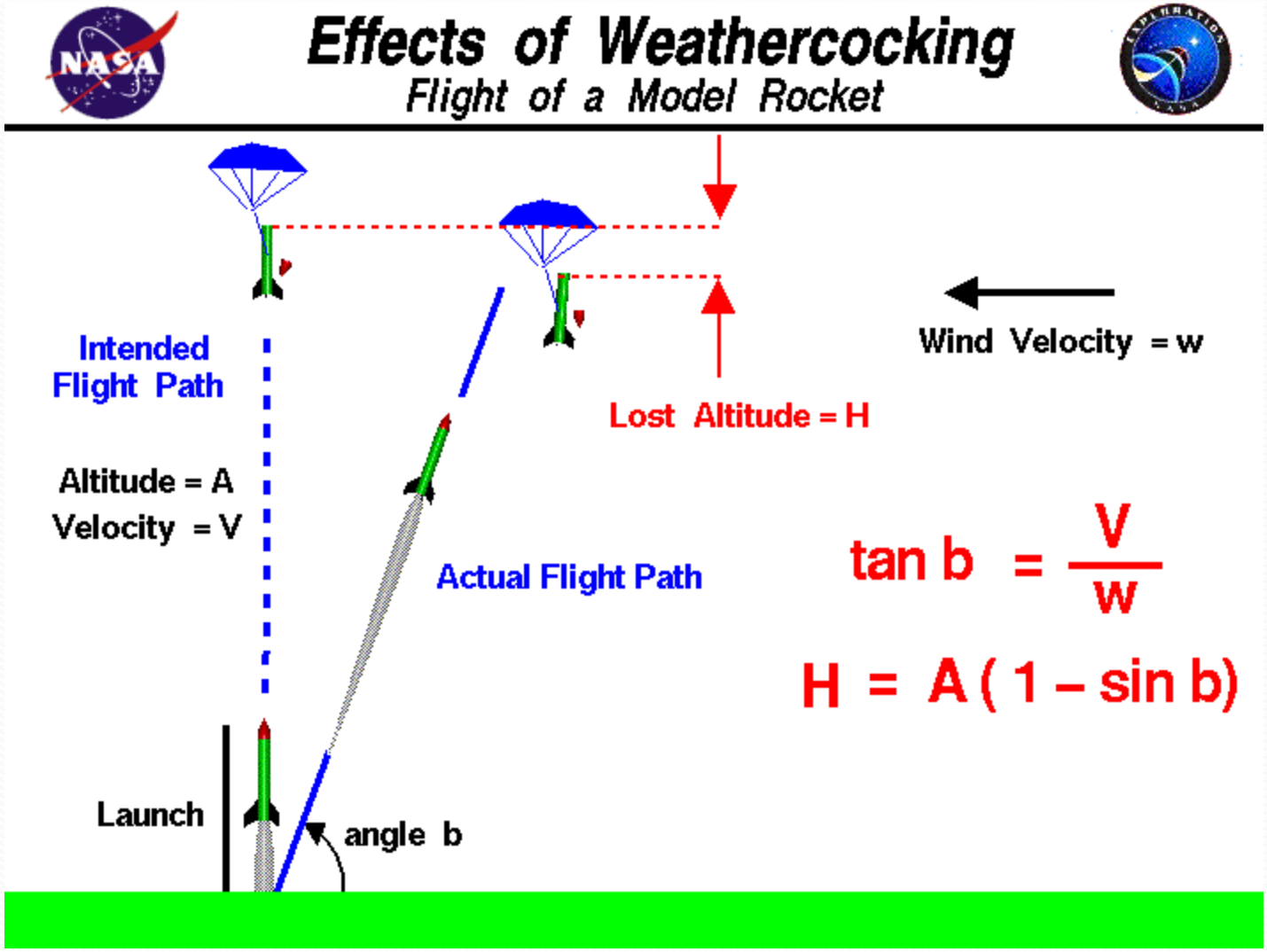
The best separation between the center of gravity is for the CP to be at least **one body tube diameter** in front of the CG. This is called **one caliber stability**.



Weather Cocking

- Following the liftoff of a model rocket, it often **turns into the wind**. This maneuver is called **weather cocking** and it is caused by forces, such as a strong wind, pushing on the side of the rocket's fins.




Effects of Weathercocking
Flight of a Model Rocket
Intended Flight Path
Altitude = A
Velocity = V
Actual Flight Path
Lost Altitude = H
Wind Velocity = w
tan b = V / w
H = A (1 – sin b)
Launch
angle b

Causes of Weather Cocking

- Rockets with long airframes experience weather cocking, especially during the coast phase.
- Large fins present a larger surface area for the wind.
- Rockets with a center of gravity that is far in front of the center of pressure.

Tube Fins

- Using tube fins reduce weather cocking because of the aerodynamic side profile.
- Tube fins should be used carefully because these types of rockets tend to be unstable.