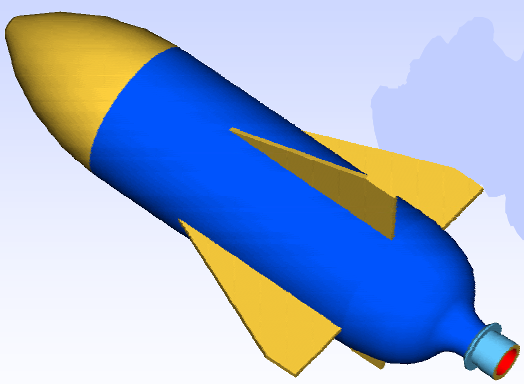
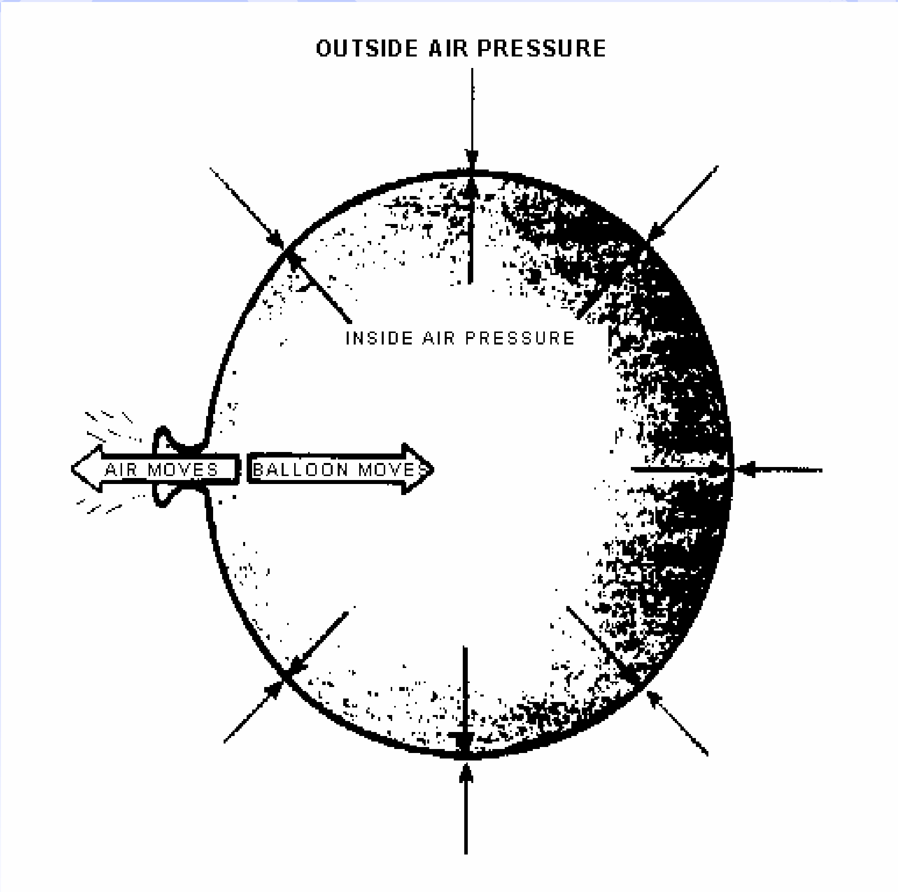
Principles of Rocketry



Water Rockets

BASIC CONCEPTS

What is a Rocket?



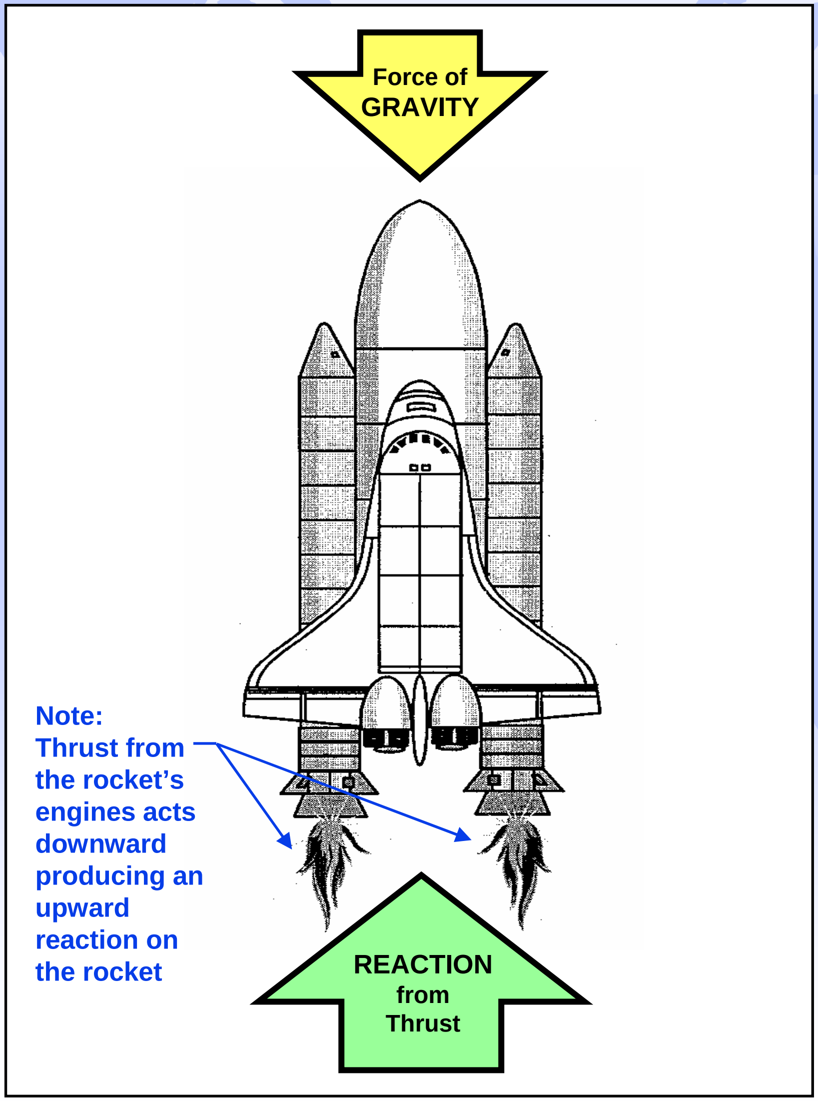
- **A chamber enclosing a gas under pressure.**
- **A balloon is a simple example of a rocket.**

Rubber walls compress the air inside. Air escapes from the small opening at one end and the balloon flies.

Newton's Three Laws

- 1. **Objects at rest** will remain at rest and **objects in motion** will remain in motion in a straight line unless acted upon by an unbalanced force.
- 2. **Force** equals **mass** times **acceleration.**
- 3. Every **action** has an equal and opposite **reaction**.

1. Objects at Rest, in Motion



- **At Rest:** Forces are balanced. The force of gravity on the rocket balances with that of the launch pad holding it up.

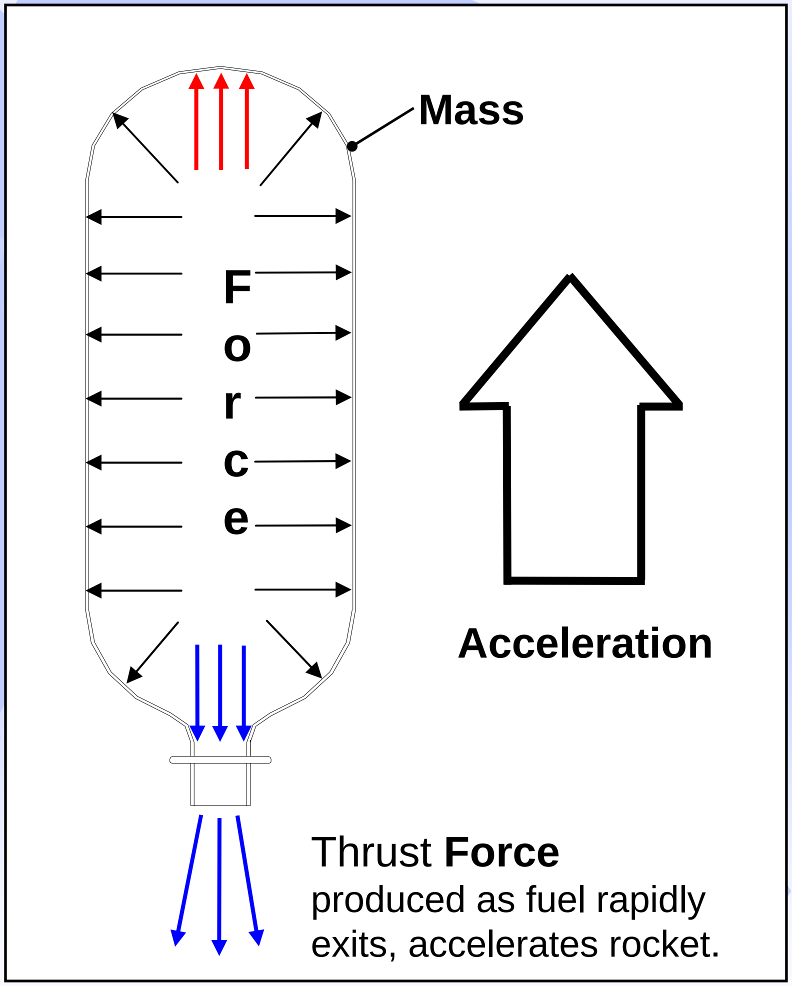
- **In Motion:** Thrust from the rocket unbalances the forces. As a result, the rocket travels upward (until it runs out of fuel).

2. F=mA

- **Force** equals **mass** times **acceleration**. The pressure created inside the rocket acts across the area of the bottle's throat and produces force (thrust). Mass represents the total mass of the rocket, including its fuel.

- The mass of the rocket changes during flight. As fuel is rapidly used and expelled, the rocket weighs less and accelerates.

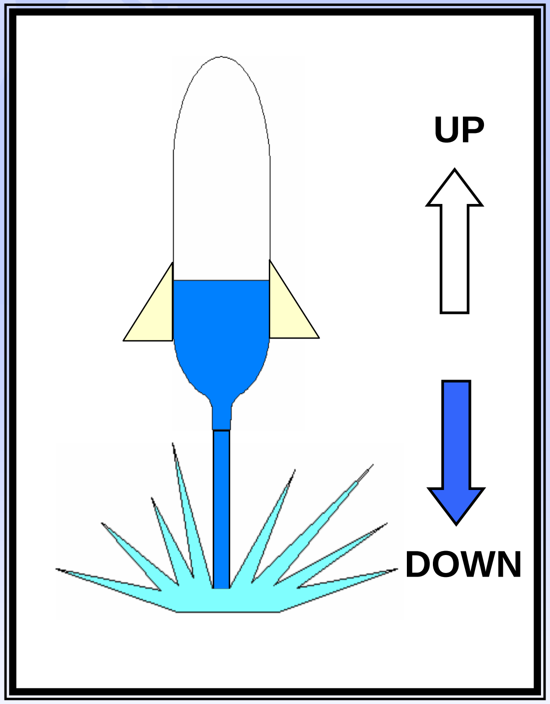
- Thrust continues until the engine stops firing.



3. Action and Reaction

☞ A rocket takes off only when it expels gas. **Action:** The rocket pushes the gas out of the engine. **Reaction:** The gas pushes up on the rocket.

☞ The Action (**Thrust**) has to be greater than the **weight** of the rocket for the reaction (liftoff) to happen.



(Bottle & Water Mass) X (Bottle Velocity)

EQUALS

(Ejected Water Mass) X (Ejected Water Velocity)

Essentially, the faster the fluid is ejected, and the more mass that is ejected, the greater the reaction force on the bottle.

Water Rockets

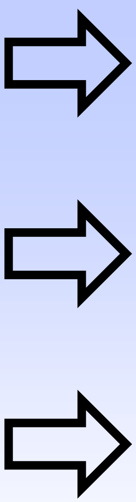
DESIGN CONSIDERATIONS

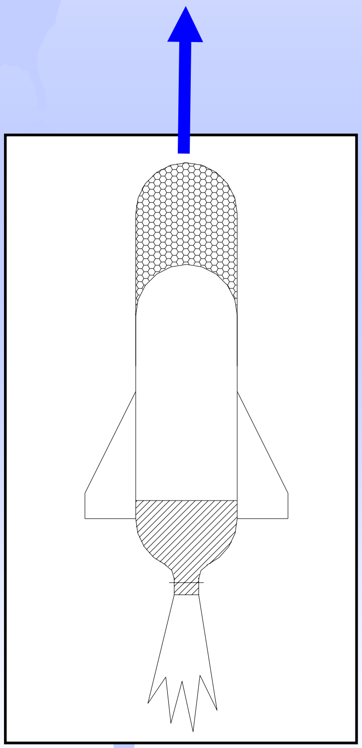
Inertia

<u>Inertia</u> is the tendency of an object to resist any change in motion. It is associated with the mass of an object.

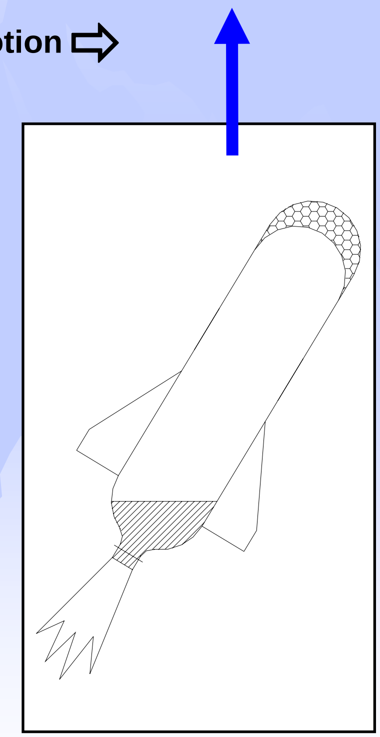
⇦ Desired Path of Motion ⇨
(Trajectory)

Wind Direction





A bottle rocket that is <u>HEAVIER</u> has <u>MORE</u> Inertia, because it has <u>MORE</u> mass. <u>MORE</u> Inertia will offer <u>GREATER</u> resistance to a change in direction. Therefore the wind will have <u>LESS</u> effect on a bottle with <u>MORE</u> *INERTIA*.



A <u>LIGHTER</u> bottle rocket has <u>LESS</u> inertia,because it has LESS mass. <u>LESS</u> inertia means the rocket will have <u>LESS</u> resistance to change in direction. Consequently, the wind has a <u>GREATER</u> effect on the rocket's path of motion.

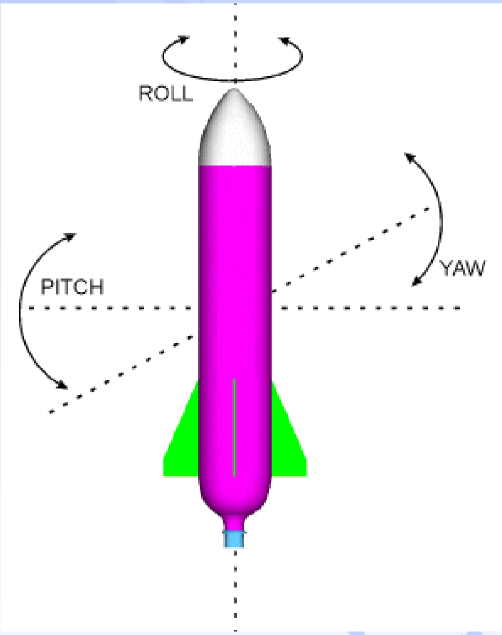
Center of Mass

The Center of Mass is the exact point about which all of the mass of an object is perfectly balanced.

☞ All matter, regardless of size, mass, or shape has a center of mass.

☞ Around this point is where an unstable rocket tumbles.

- Spinning and tumbling takes place around one or more of three axes: roll, pitch, and yaw
- Any movement in the pitch and yaw axes directions can cause the rocket to go off course

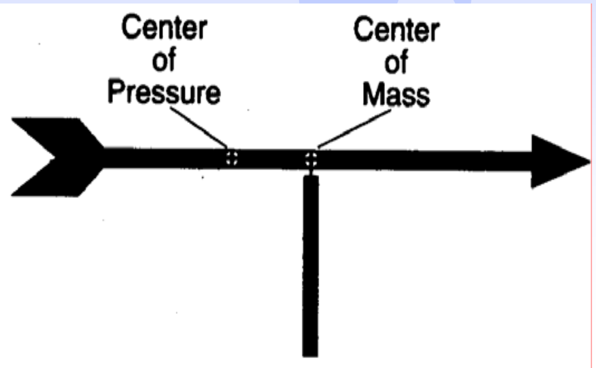


Center of Pressure

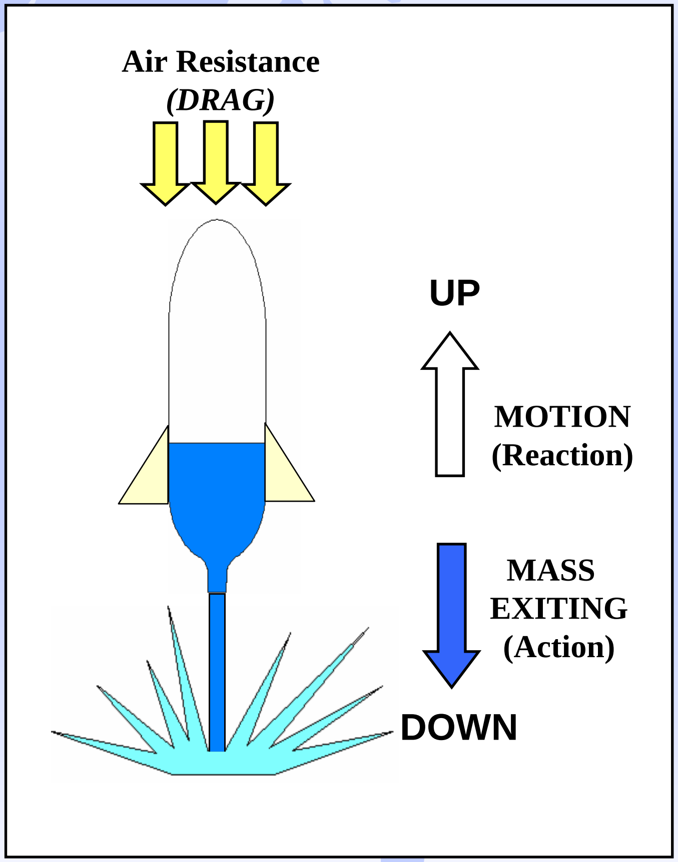
The Center of Pressure (CP) is the location where the ‘pressure forces’ acting on a rocket are balanced. The CP exists only when air is flowing past the moving rocket. (Based on surface area)

- Flowing air pushing against the rocket, can cause it to roll and sway around the most stable point (CM).

- It is important that the CP of the rocket is located toward the **tail** and the CM is located toward the **nose**.



DRAG

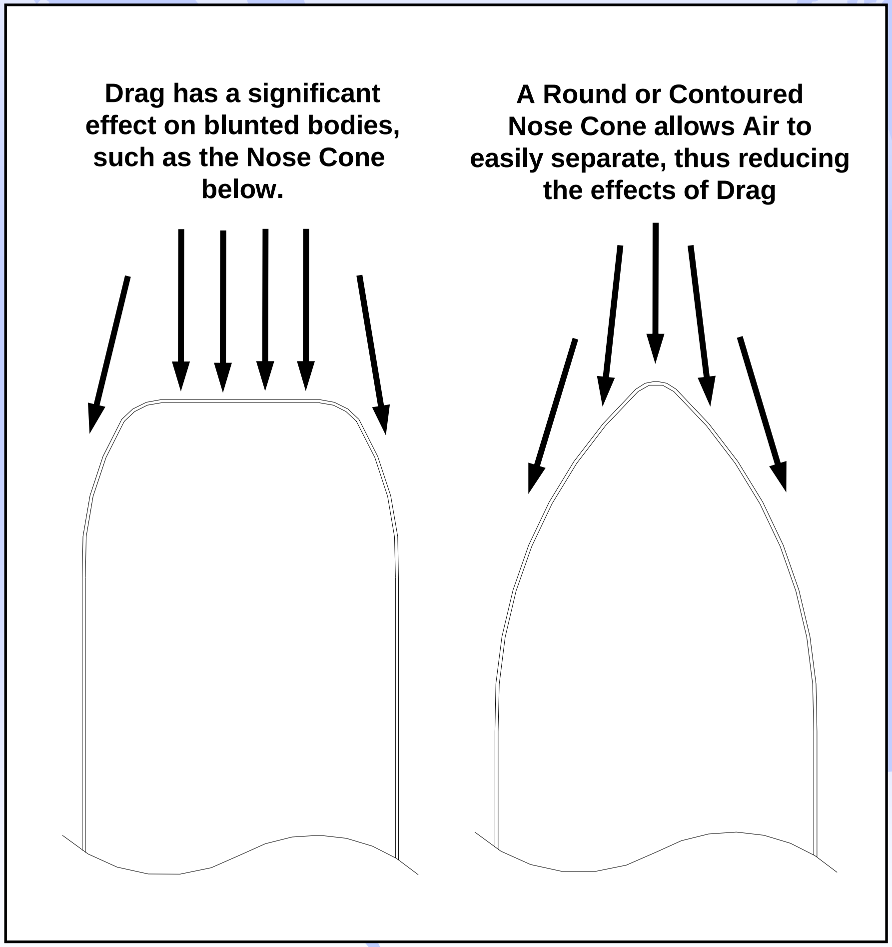


DRAG = Air Resistance

Air Resistance causes friction which ***slows down*** the Rocket. Friction always works in the opposite direction of the Rocket's motion.

(Even when a rocket is **descending**, drag counteracts the rocket's motion!)

TIPS: REDUCING DRAG

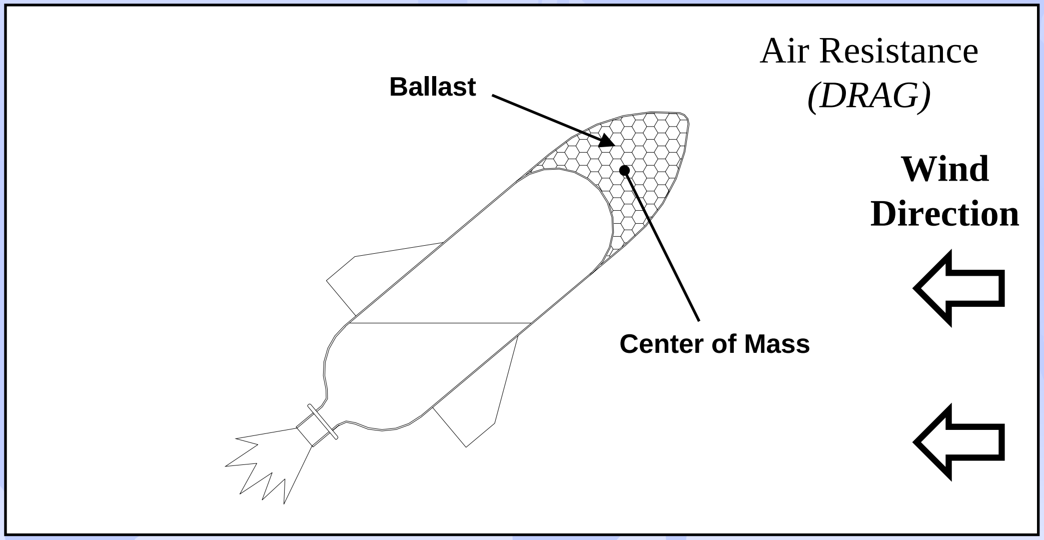


More **AERODYNAMIC** **or pointed nose cone:** This causes the air to "part" around the bottle.

More Aerodynamic fins: Thinner, more streamlined fins reduce drag. Position fins toward the tail of the rocket (moves CP!).

BALLAST

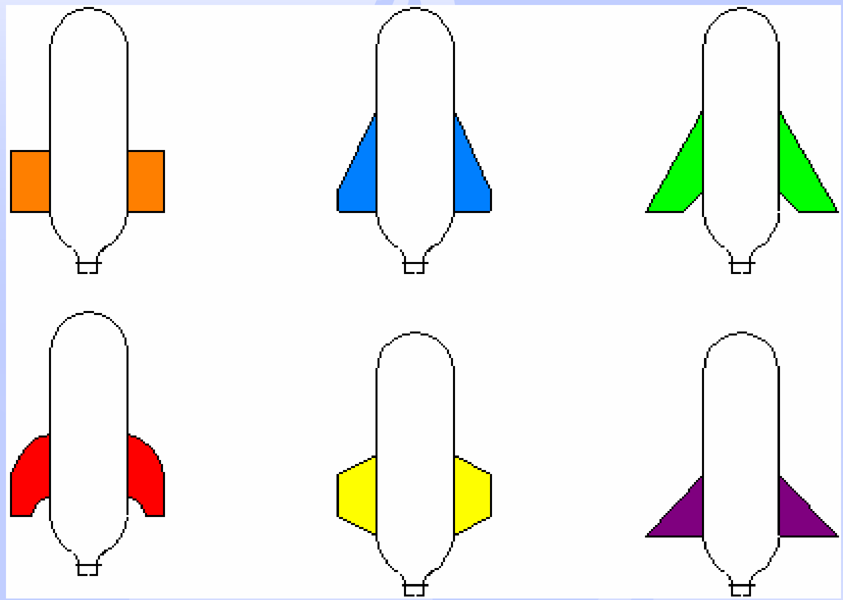
BALLAST: any mass added to a vehicle to improve *STABILITY* and increase *INERTIA.*



☞ **Stability:** Ballast towards the nose cone will shift the **center of mass** forward.

☞ **Inertia:** More weight (**ballast**) increases inertia and will prevent a bottle's path of motion (*or* Trajectory) from being prematurely overcome by DRAG & WIND FORCES........***CAREFUL! Too much Ballast will make the vehicle too heavy (Newton's 3rd Law).***

Rocket Fin Shapes



- **Square/Trapezoidal** Fins yield MORE stability, but create MORE ***drag***.
- **Triangular/ Epsilon** Fins introduce LESS ***drag***, but yield LESS stability.

Stability

How can you increase Rocket Stability?

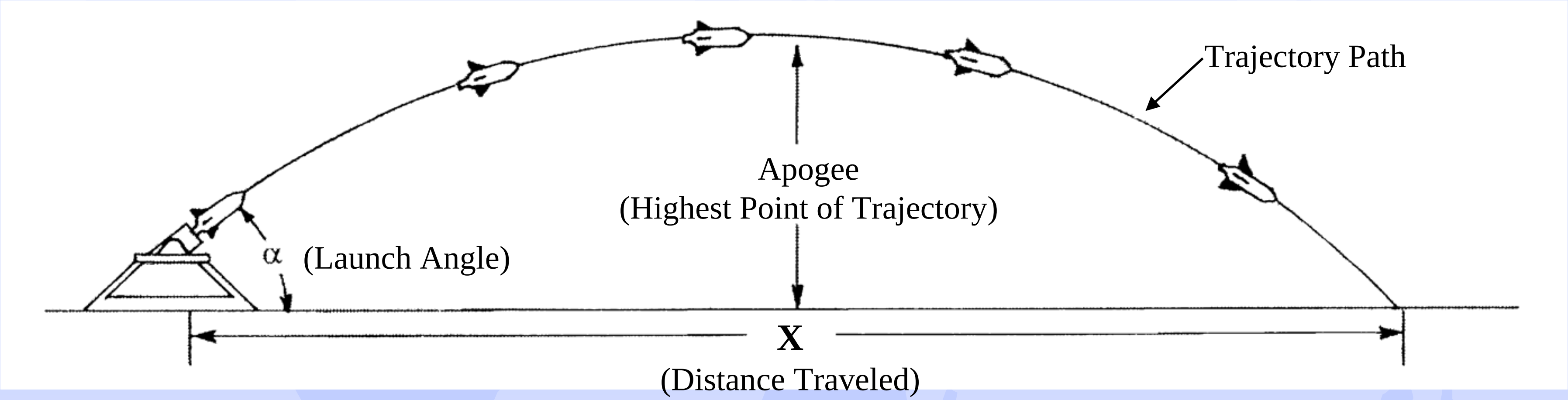
- **Lengthen** the rocket (This moves the **center of mass** further forward than the **center of pressure**)
- Add **mass** to the nose cone or nose piece
- Bend the fins to cause it to **spin**,

  Caution! (Spinning the rocket will consume energy. This energy will not be used to gain any more altitude)
- Extend **fins** towards the end of the rocket.
- Heavy rockets have **more inertia** and therefore more stability

Watch Out! *Too much weight will not allow the rocket to travel fast enough and it will prematurely run out of thrust, therefore, preventing it from reaching its intended destination*.

TRAJECTORY

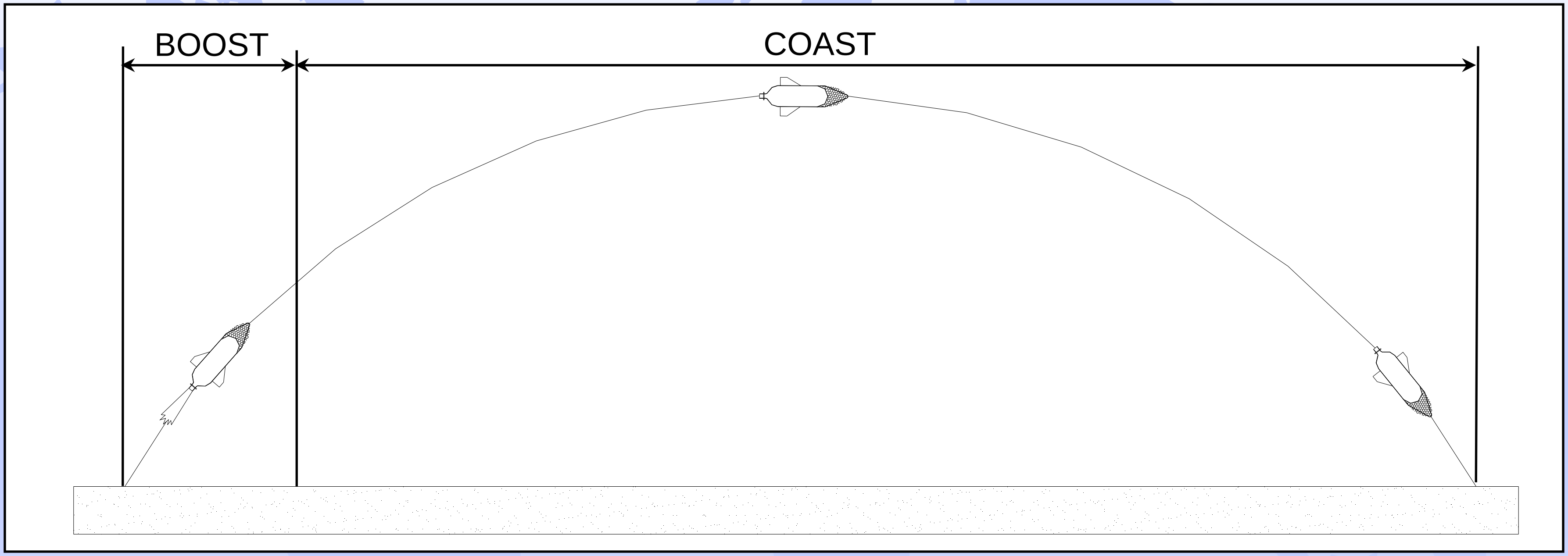
<u>Trajectory</u> is the curved path of an object traveling through space.
NOTE: Even objects thrown or launched vertically have a trajectory.



<u>Factors that Affect Bottle Trajectory:</u>

- Newton's 3 Laws of Motion
- Flow Rate of Fuel Existing
  - Bottle Internal Pressure
  - Air/Fuel Volumes
  - Air/ Fuel Densities
- Mass of Bottle
- Air Resistance/Drag Affects
  - Atmosphere Pressure/Temp
  - Bottle Aerodynamics
- Gravity

TRAJECTORY PHASES



BOOST PHASE

The **Boost Phase** of a rocket refers to the initial period in which the rocket produces THRUST to power itself forward. Water Rockets are considered to be under **Boost Phase** up until the last drop of water is expelled.

COAST PHASE

The **Coast Phase** of a rocket refers to any period during flight that the rocket is not being actively powered. Water Rockets enter into Coast Phase immediately after Boost Phase ends; the rocket will remain in **Coast Phase** until it impacts the ground.

Water Rocket Design Competition for

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