Maryland Science Olympiad: Bottle Rocket 2012

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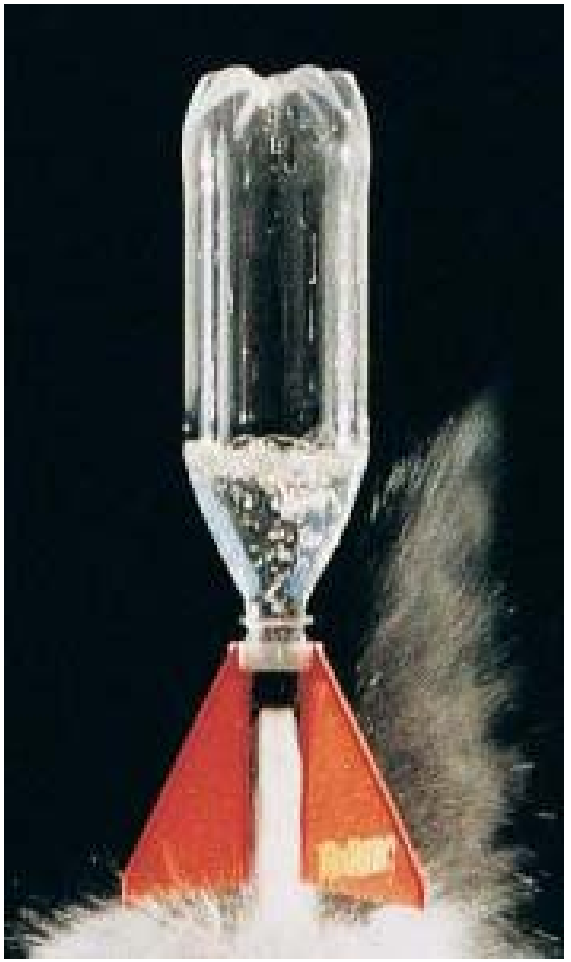
Overview

- Rules
- Four Key Areas
  - Propulsion
  - Flight
  - Recovery
  - Impact
- General Tips
- Examples/Wrap Up



Rules: General

- Use a one-liter (or smaller) soda bottle
- Only tape must be used to attach fins and other components to the pressure vessel. No glues of any type may be used on the pressure vessel. Glue may be used in other parts of the rocket assembly.
- Metal of any type and commercial model rocket parts are prohibited anywhere on the rocket.
- Students must wear safety glasses
- No off-the-shelf rocket parts
- No remote control

Rules: 1 Liter Bottle

- Each rocket's pressure vessel must be made out of a single 1-liter plastic **CARBONATED** beverage bottle with a neck/nozzle opening approximately 2.2 cm internal diameter
- (1/2 inch Schedule 40 PVC pipe should just fit inside the nozzle opening).
- Labels may be removed from the bottle but labels must be presented at the safety inspection.

Rules: Structural Integrity

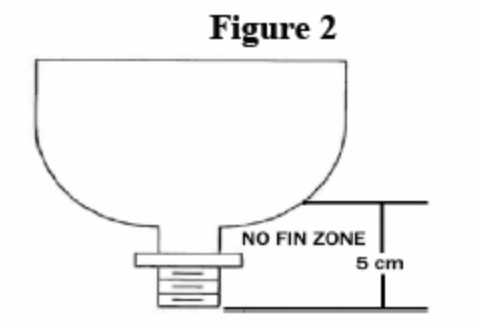
- The structural integrity of the pressure vessel (carbonated beverage bottle) cannot be altered.
- Examples of altering structural integrity include but are not limited to physical, thermal or chemical damage (e.g. cutting, sanding, using hot glues, super glues, spray paint).
- Damage to the structural integrity of the pressure vessel will result in a **safety** disqualification and the rocket will not be allowed to launch.
- Damage will be assessed by looking into the bottle through the nozzle for discoloration, bubbles, or thinning of the walls of the bottle.

Rules: No Stored Energy

- No explosives, **gases other than air**, electric or electronic devices, elastic powered flight assists, throwing devices, remote controls, **chemical reactions** or pyrotechnics may be used at any time.
- All energy imparted to the rocket at launch must originate from the water/air pressure combination (both provided by the event supervisor).

More Rules

- Commercial model rocket parts may not be used.
- All rockets will be launched using the launcher provided by the supervisor. To ensure rockets will fit on the launcher, fins and other parts added to the bottle must be 5 cm or higher above the level of the bottle's opening. Nothing, including tethers, may break this plane.



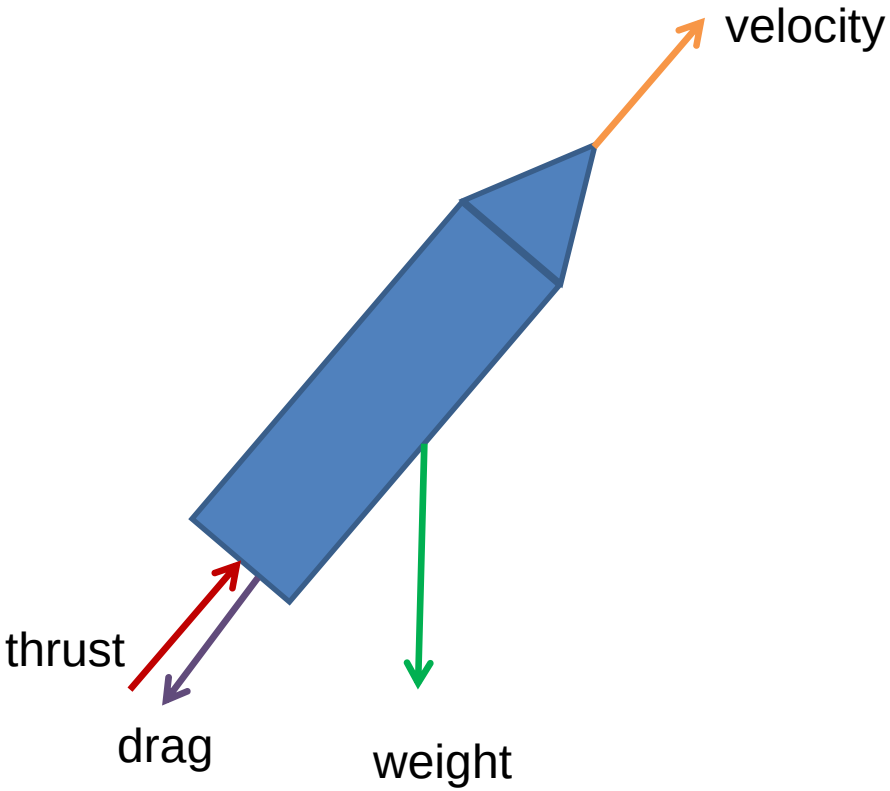
Rules: Recovery

- **No parts of the rocket should fall off or become separated during launch or flight.**

- **Parachutes (i.e. any recovery system that fills with air to function) cannot be used. Any other recovery system is allowed as long as all objects pertaining to the recovery system are in their lowest energy state at launch.**

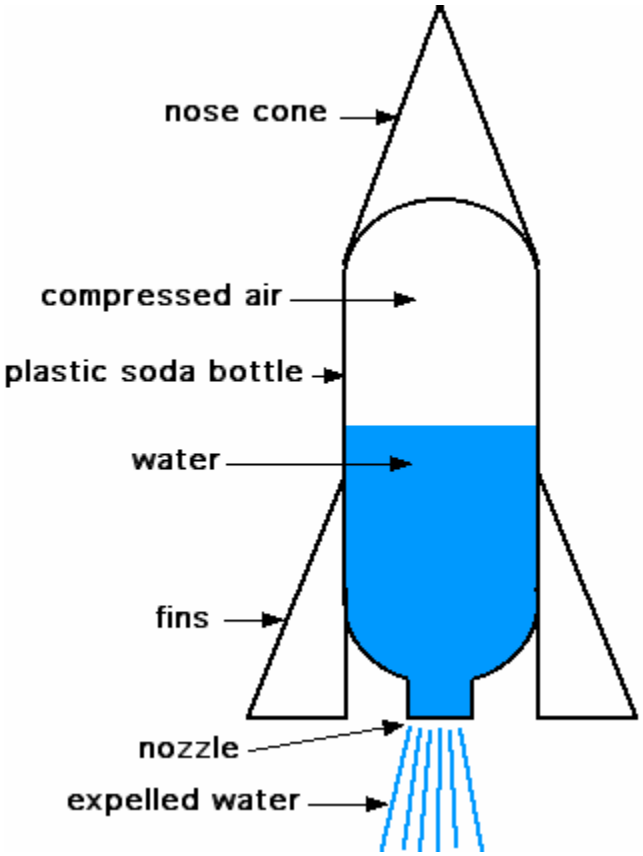
Propulsion: Goal

- Maximize Thrust!



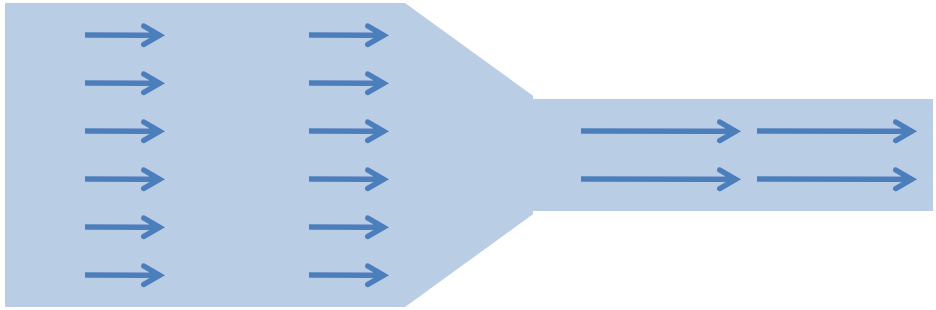
Propulsion: Energy Input

- All about energy conversion!
- Potential energy is stored in compressed air (60 psi) inside the reservoir
- The water is incompressible and does not store energy
- Energy is released when water is forced out of the nozzle



Propulsion: Nozzle

- Water speeds up as it exits through the narrow end of the bottle, *per Bernoulli*.



$$V_1 \times A_1 = V_2 \times A_2$$

Propulsion: Rocket Equation

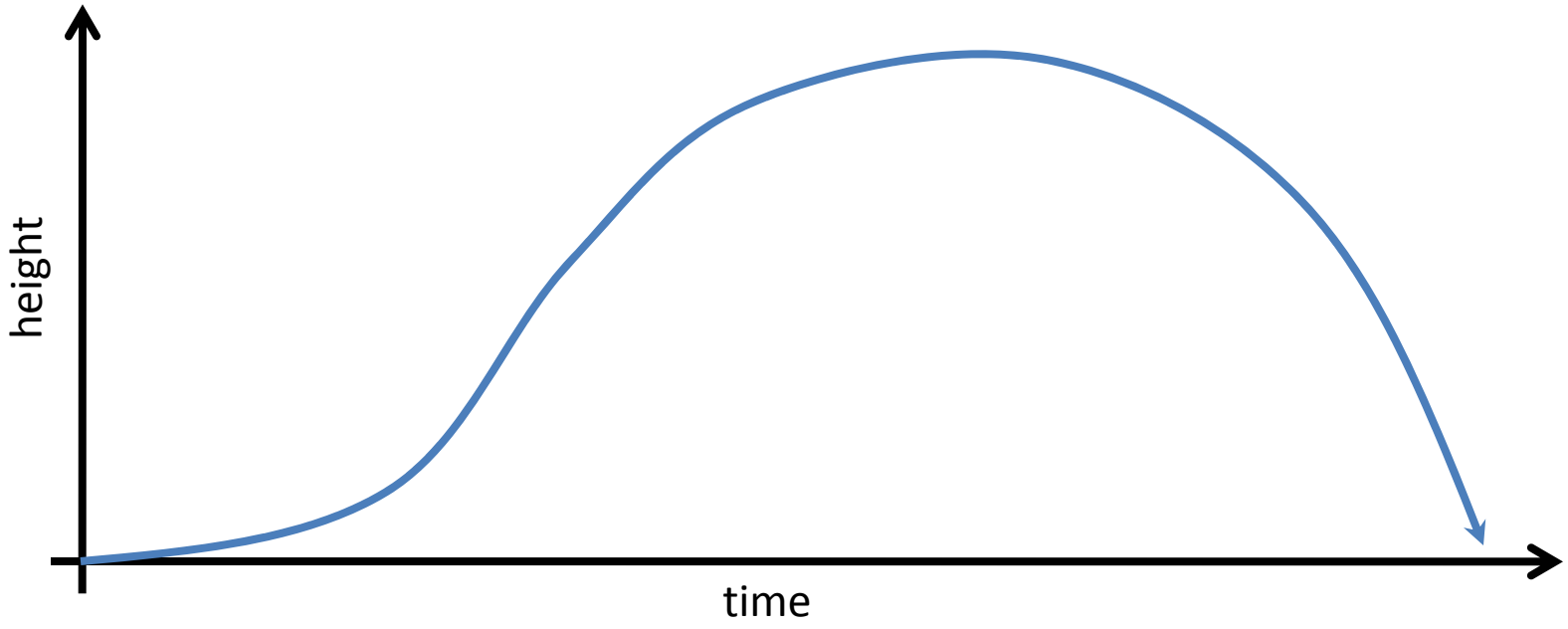
- Acceleration of the rocket depends on the speed and mass of the exhaust (i.e. water) ejected. *Per ideal rocket equation*

$$\Delta v_{rocket} = v_{exit} \ln \frac{m_0}{m_1}$$

$$v_{rocket} \propto \Delta mass, v_{exit}$$

Propulsion: Changing Pressure

- Of course, the pressure of water in the tank decreases as more and more water is expelled
- This means less force and less acceleration upward over time. The entire time the rocket is flying gravity is pulling it down



Propulsion: Wrap Up

- Want to maximize expelled mass (water), but need sufficient volume (air) to store energy
  - **Fill about halfway with water**
- Good opportunity for young investigators!
  - Make a barebones rocket
  - Test at different fill levels

Flight: Goal

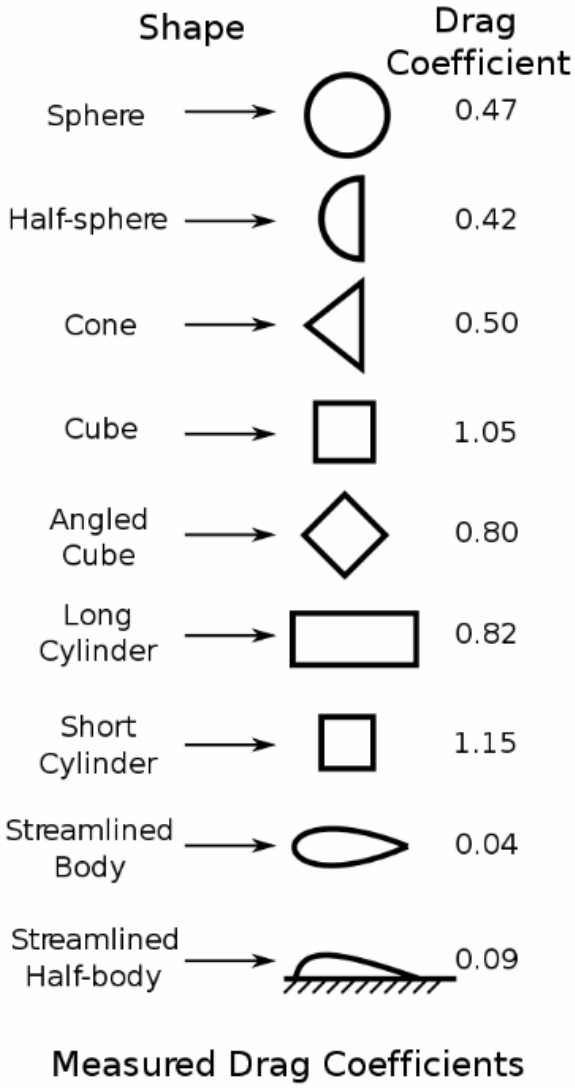
- Minimize Drag!
- Maximize Stability!

Flight: Minimize Drag

- Drag Equation:

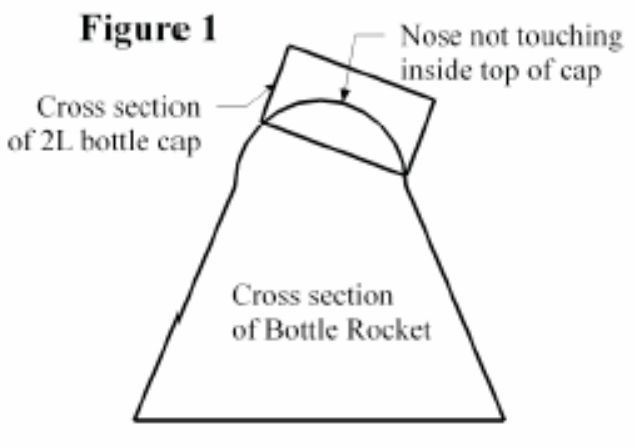
$$F_d = \frac{1}{2}\rho v^2 C_d A$$

- Can control drag coefficient
- Build a nose cone!



Rules: Rocket Nose

- The nose of the rocket must be rounded or blunt at the tip and designed such that when a standard 2 liter bottle cap **(~3.1 cm diameter x 1.25 cm tall) is placed on top of the nose, no portion of the nose touches the inside** top of the bottle cap (see Figure 1). Teams must not use a nose that is sharp, pointed, or consisting of a rigid spike regardless of the material used.



Flight: Maximize Stability

Center of Gravity/Pressure

- Rocket will naturally want to pivot about its **center of gravity.** For stable flight, **center of drag** forces needs to be below the center of gravity, otherwise the rocket will topple.

Aerodynamic Stability

- Vertical fins will resist lateral motion
- Maximize area while minimizing leading edge (drag)
- Tapered foil shape will minimize drag

Flight: Wrap Up

- Use a conical or cylindrical nose cone
- Don’t add too much extra “girth”
- Place fins as low as possible on the rocket body
- Fins can be long
  - More area is better, but not too wide
- Taper if possible (sand)

General Tips

- Low net weight = good
- Fins near nozzle = good
- Balsa wood fins = good
- Find the ideal water level for your rocket.
  - 100% air will give you the maximum potential energy, it has very little mass and therefore very little momentum to carry the rocket.
  - 100% water will have great mass, but very little potential energy to give it momentum.

General Tips

- Keep it simple
- Paint has mass
- Tape has mass
- Students have the most opportunity to gain flight time in the **RECOVERY** phase, so guide them in that direction
- BRING TWO ROCKETS
  - Multiple launch opportunities
- Take advantage of these!

Supplies

- The launcher
- A small air compressor with the correct connections for the launcher
- 1-liter bottle
- At least one 1/8” sheet of balsa wood
- An x-acto knife or other razor blade
- A pair of sharp scissors
- A metal ruler
- A fine point black sharpie
- At least one role of masking or painters tape
- One role of thread or small diameter fishing line
- A piece of cardboard to use as a cutting surface

A conceptual design

- Pressure vessel
  - One 1-liter bottle
- Capsule/nose cone
  - The top of the second 1-liter bottle
  - It may be useful to leave excess material to provide directionally biased drag
- Fins
  - Outline fins using the sharpie and metal ruler
  - Cut pieces of balsa wood using the x-acto knife, metal ruler, and cutting surface
  - Mark the fin placement on the pressure vessel using the sharpie, thread, and ruler. Try to space them evenly around the pressure vessel,.
  - Tape the fins to the pressure vessel

Scoring

- Rockets with construction or safety violations will not be launched due to safety.
- Teams that are unable to launch a rocket because of construction violations will receive participation points only.
  - a. Ranking within each tier is determined by the combined greatest time aloft of both rocket flights. If a team only launches one rocket then that team will receive only the flight time for that launch.
  - b. Tiers: Teams with a Tier 1 rocket and a rocket with a violation are scored as if they had only one rocket.
    - i. Tier 1: Rockets launched without construction or competition violations.
    - ii. Tier 2: Any Launch with competition violations.
  - c. Ties are broken by the greatest time aloft by a single rocket.

Resources

- Contact Info:
  - Morgan Trexler: morgana.trexler@jhuapl.edu
  - Matt Trexler: matthew

- **Bottle Rocket DVD** available on the Official Science Olympiad Store or Website at http://www.soinc.org.trexler@arl.army.mil