The Ohio State University
College of Engineering

Buckeye Space Launch Initiative

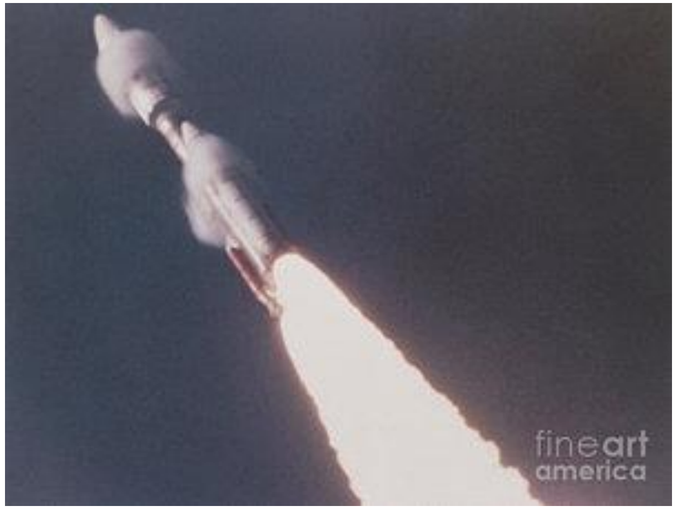
Aerodynamics and Propulsion

September 12

James Dai, Jonathan Winkler

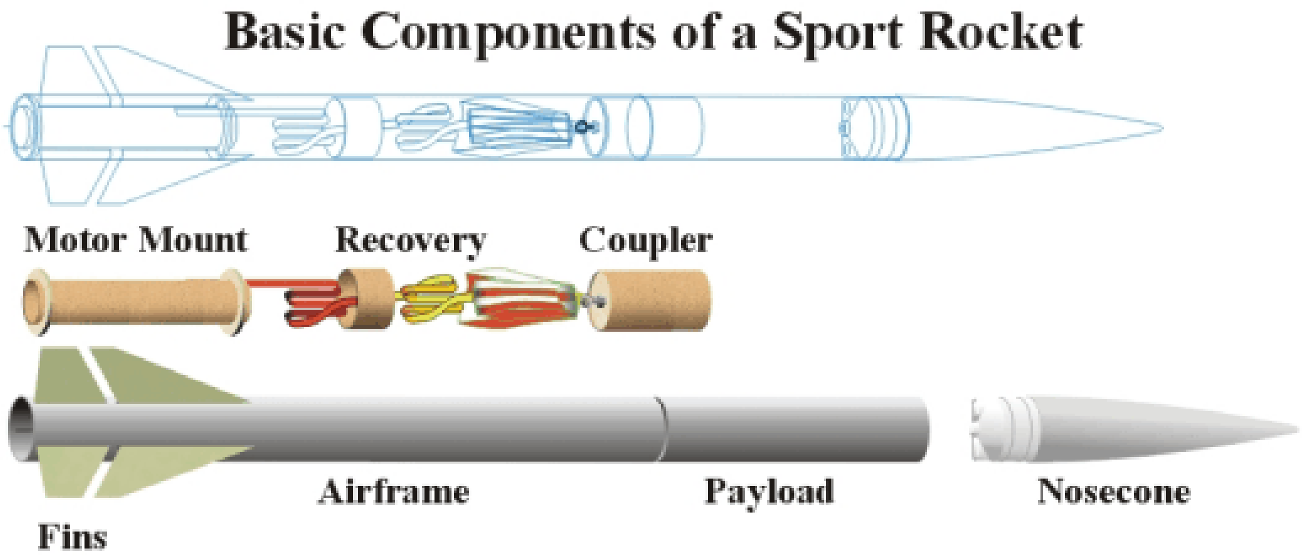
What are Rockets used for?

- Send payloads into orbit or deep space.
- Send payloads to high altitudes quickly
  - Weapon Applications
  - Scientific Payloads



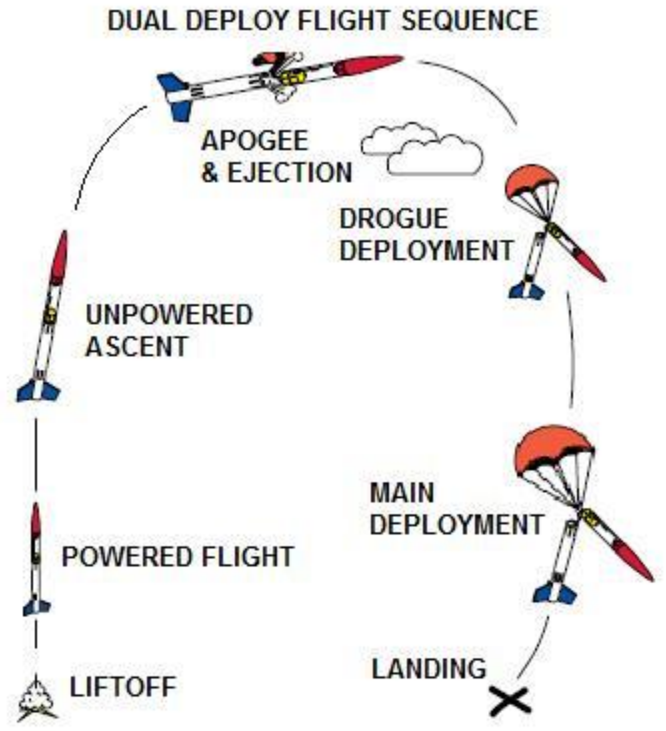
Rocket Anatomy

- Airframe
  - Nosecone
  - Body tube
  - Fins
- Internals
  - Parachutes and Shock Cord
  - Electronics bay
  - Motor tube and Motor



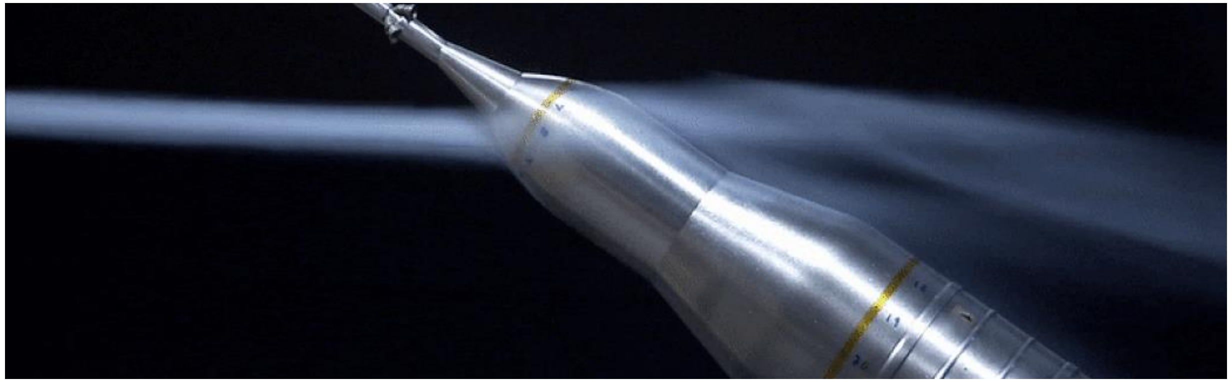
Rocket Launch Events

1. Rocket is prepared for launch
    1. Electronics are armed, motor is inserted, etc
2. Motor is ignited
3. Motor burns out
4. Coast to apogee
5. Drogue parachute deploys
6. Rocket deploys main parachute at preset alt
7. Rocket lands



Main Obstacles of Aerodynamics and Propulsion

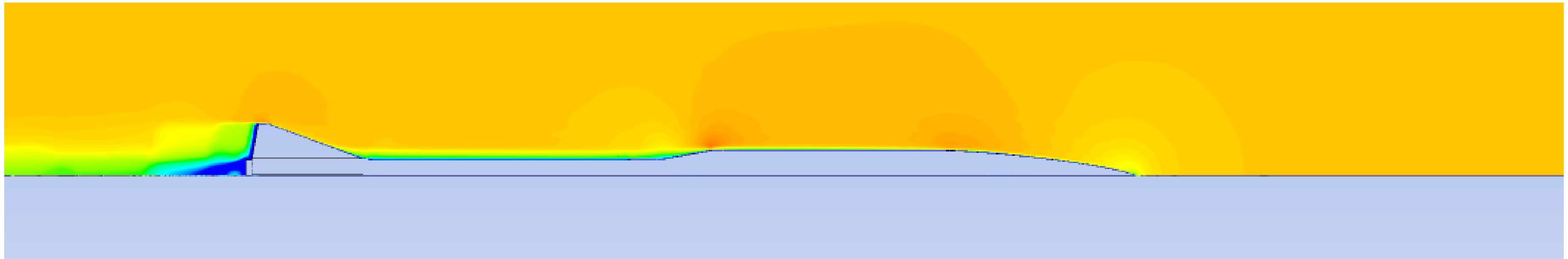
- Aerodynamics
  - Minimizing Drag
  - Maintaining stability
- Propulsion
  - Predicting Thrust
  - Optimizing fuel use

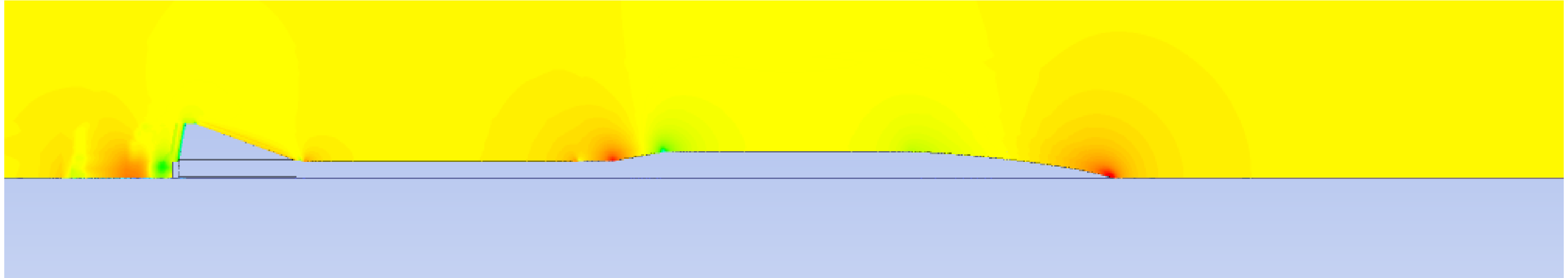


Aerodynamics - Drag

- What is Drag?
  - Pressure Drag
  - Skin Friction Drag
- Drag equation

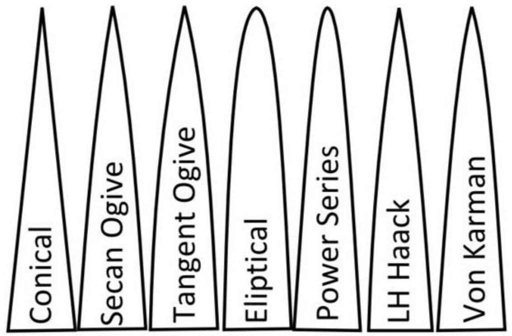
$$D = \frac{1}{2}\rho V^2 S C_D$$





Modern Shape of a Rocket

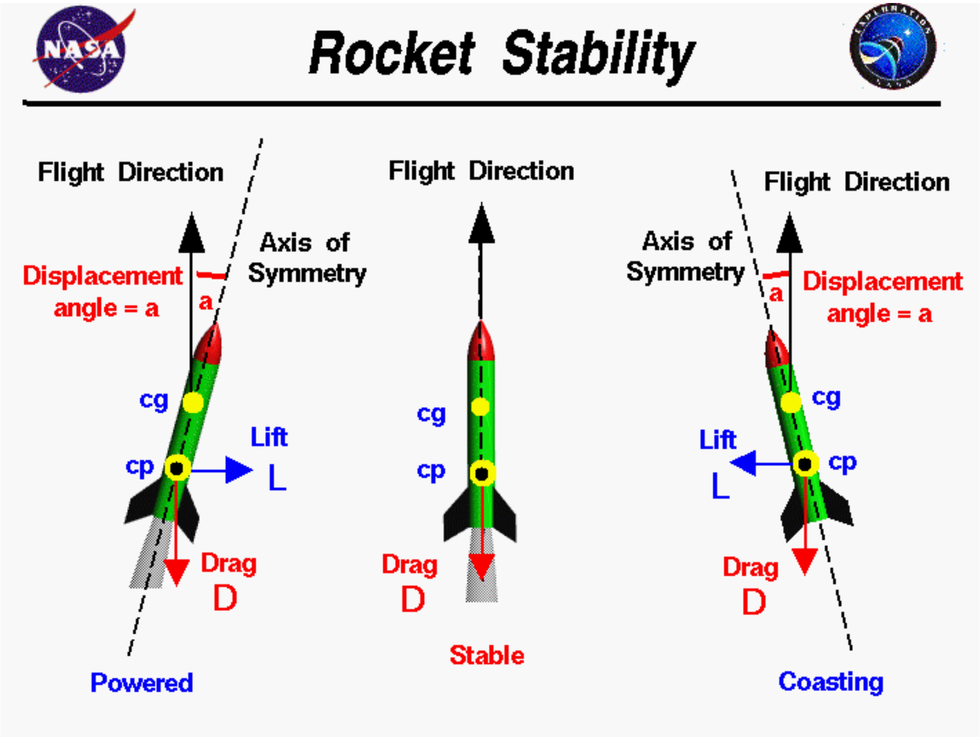
- Nosecone
  - Splits airflow around vehicle
  - Airflow maintains speed
  - Different nosecones for different airflow



- Body
  - Cylinder keeps pressure even across body
  - Efficient housing for all sensitive components
  - Main structure (discussed more in that subsystem)
- Fins
  - Adds drag, but required for stability

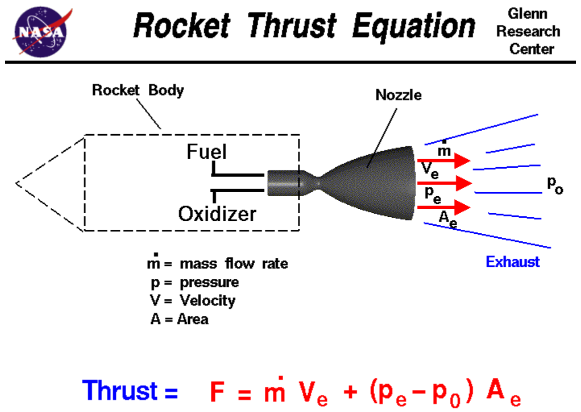
Aerodynamics - Stability

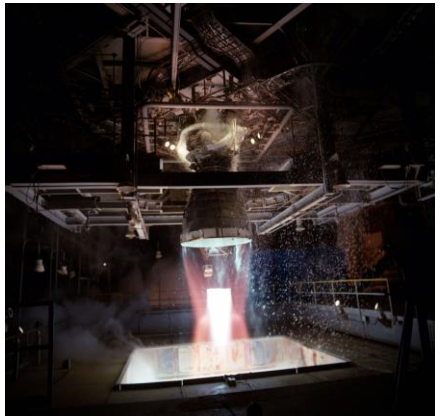
- What is stability?
  - In an ideal world, it would always be stable
  - In the real world, we deal with perturbations
  - Changes with velocity
- How do we know it's stable?
  - C_p vs C_g
  - Calibers of stability
- How do we make a rocket stable?
  - Adjust fin area
  - Relocate internal mass



Propulsion

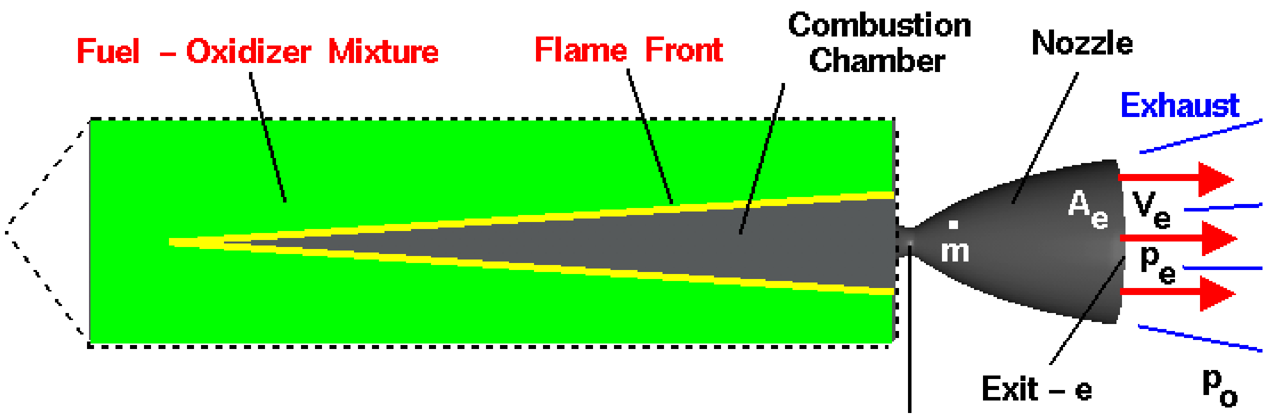
- Works by ejecting mass at a high velocity
  - Newton's laws
  - $Isp = \frac{Total\ Impulse}{Weight} = \frac{F}{\dot{m} * g_0}$
  - $\Delta v = Isp * \ g_0 * \ln\left(\frac{m_0}{m_f}\right)$
- Three Main Kinds
  - Liquids
    - Most difficult to make, most efficient
  - Hybrids
    - Between solid and liquid in terms of complexity and efficiency
  - Solids
    - Less efficient than hybrids and liquids, much simpler
    - Most used at our scale





Propulsion- Solids

- Propellant
  - “Holds” energy
  - Geometry changes as it burns
  - Acts as combustion chamber
- Nozzle
  - Accelerates flow thanks to aerodynamic magic
  - Mostly designed already; can be bought

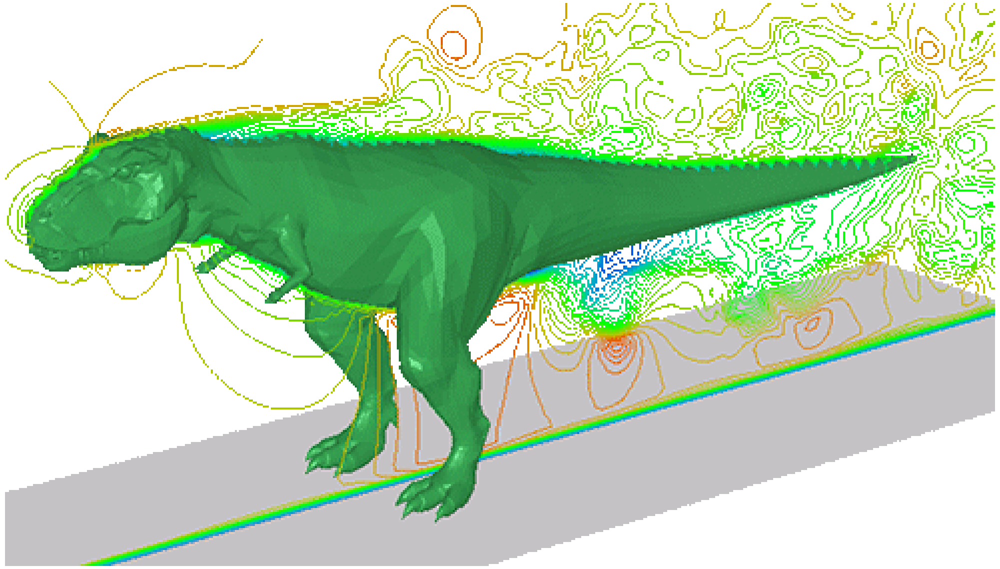


Past

- Sub-team Tasks
  - Design components (Nosecone, Fins)
  - Characterize performance (Cd, Thrust, Etc
- Techniques
  - Barrowman's equations (OpenRocket)
  - Computational Fluid Dynamics (CFD)
  - Testing

Future

- Aerodynamics
  - Improving CFD techniques
  - More scaled tests
- Propulsion
  - More static testing
  - Expand into Hybrid Engines



Terms

- Aerodynamics Terms
  - Pressure Drag: Drag due to pressure differential between front and back of rocket
  - Skin Friction Drag: Drag due to friction at the surface of a rocket's body
  - Wave Drag: Drag due to shockwave formation
  - Coefficient of Drag: Dimensionless variable that characterizes the drag for each particular rocket
  - Stability: The tendency for the rocket to return to a nominal flight path after a perturbance
  - Caliber: Margin of stability $(X_{C_g} - X_{C_p})$ in units of body diameters
  - Center of Mass: The point where all mass on the rocket acts (no moment due to gravity)
  - Center of Pressure: The point where all aerodynamic forces exert a moment of zero
  - Max-Q: The point in launch where the rocket experiences the maximum pressure, which typically occurs at motor burnout

Terms

- Propulsion Terms
  - Specific Impulse: How efficient a rocket motor or engine is
  - Total Impulse: The classification for how powerful a motor is
  - Delta-V (Δv): The change in velocity resulting from motor burn
  - Propellant: High energy chemical compound that accelerates exhaust to provide thrust
    - Ammonium Perchlorate Composite Propellant (APCP) is the commercial standard for propellants, and it is what we use
  - Core: Cylinder of open air in motor that acts as a combustion chamber
  - Grain: Sections of propellant that are combined to create motors (see GIF)
  - Motor Casing: Aluminum tube that houses propellant grains. Acts as structural support for motor
  - Nozzle: A component that accelerates exhaust, which increases thrust

Questions

Future Meetings

Sub-System Introductions: Scott E0024

19th Sept. 6:00 pm – Structures

26th Sept. 6:00 pm – Recovery

3rd Oct. 6:00 pm – Avionics

Website: u.osu.edu/rocket

Facebook: @spacelaunchinitiative

Open Rocket Tutorial

- http://openrocket.info/

Commercial Standards

- Commercial parts follow standard diameter and length increments
- Motors:
  - 24mm
  - 38mm
  - 54mm
  - 75mm
  - 98mm
- Body Tubes:
  - 2”
  - 3”
  - 4”
  - 5”
  - 6”