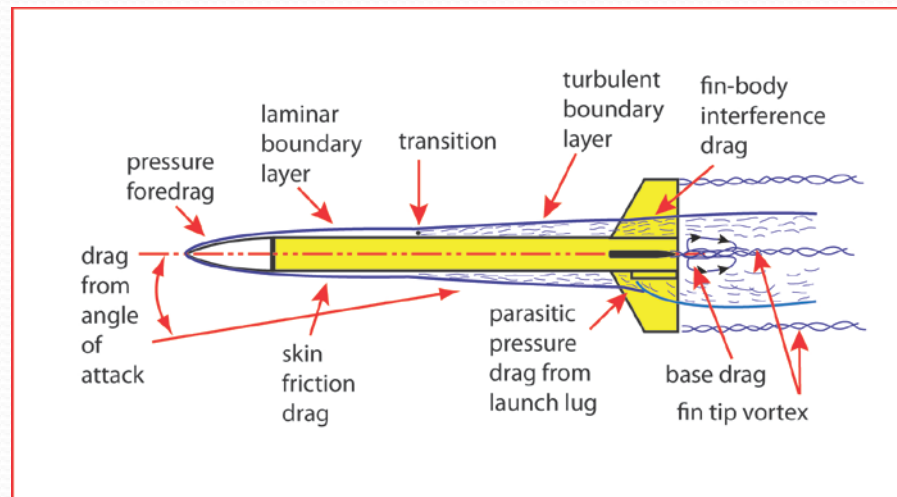


LESSON LD04

# AERODYNAMICS

# Definition

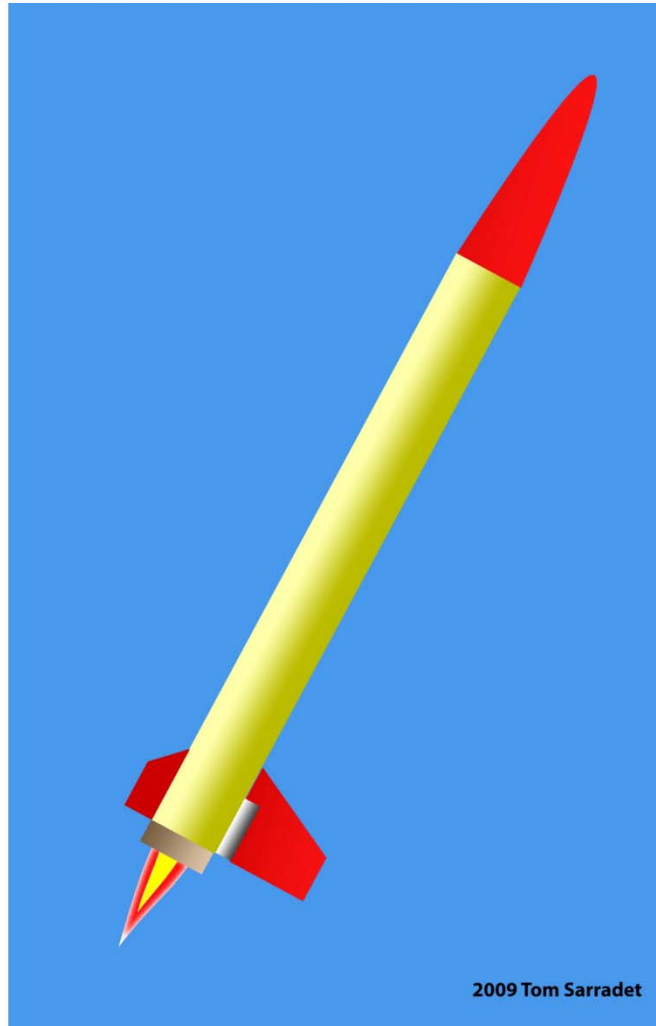
- **Aerodynamics** is the study of the motion of air, particularly when it interacts with a moving object.
- In physics the term **dynamics** customarily refers to the time evolution of physical processes.



# Factors that Affect Aerodynamics

**The Object:**  
Shape & Size

**The Motion:**  
Velocity &  
Inclination to  
Flow



**The Air:**  
Mass, Viscosity,  
Compressibility

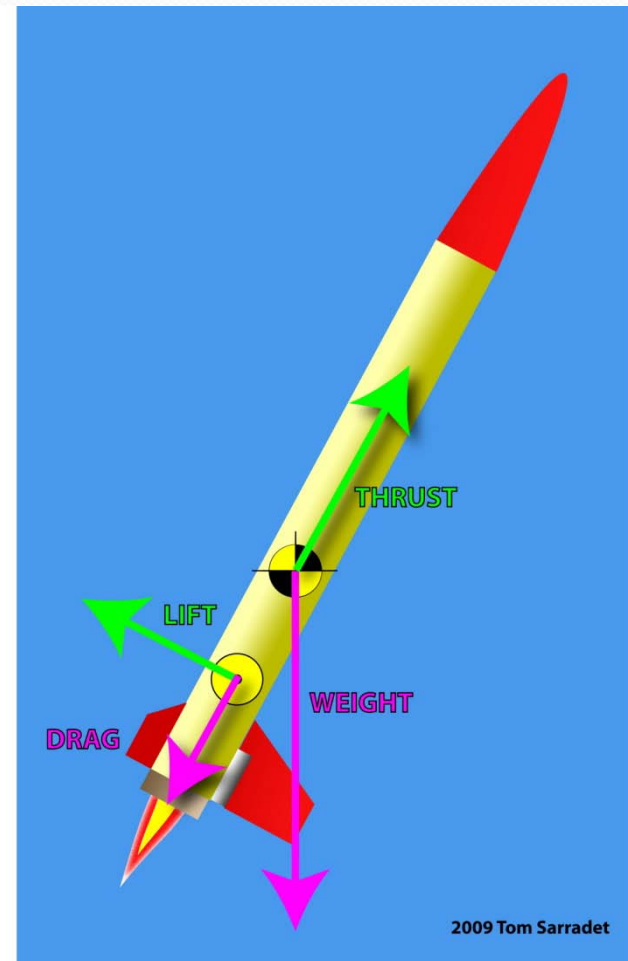


# Four Forces of Flight

- **Lift** is a force used to **stabilize** and **control** the direction of flight.
- **Drag** is the **aerodynamic force** parallel to the relative wind.
- **Weight** is the force generated by **gravity** on the rocket.
- **Thrust** is the **force** which moves the rocket **forward**.

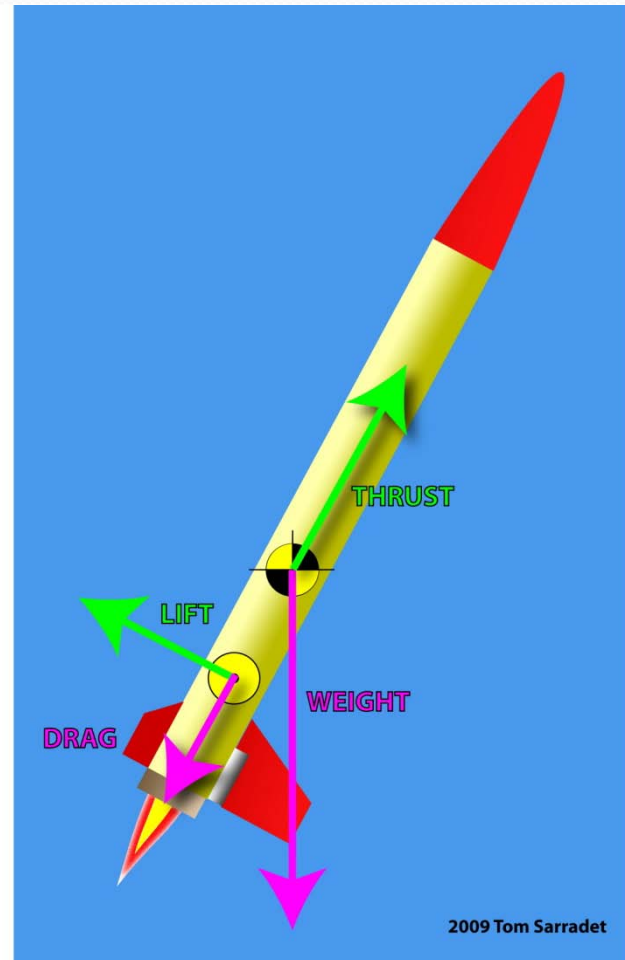
# Aerodynamic Forces

- **Aerodynamic forces** are generated and act on a rocket as it **flies through** the air.
- The lift and drag act through the **center of pressure** which is the average location of the aerodynamic forces on an object.



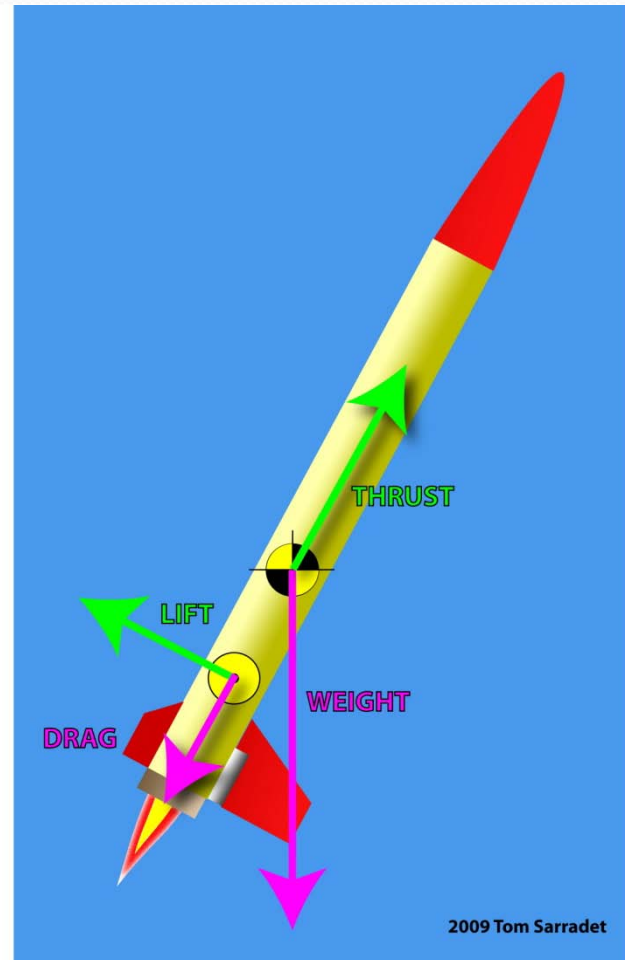
# Aerodynamic Forces

- Aerodynamic forces are **mechanical forces**. They are generated by the interaction and contact of the rocket with the air.
- For **lift** and **drag** to be generated, the rocket must be moving through the air.



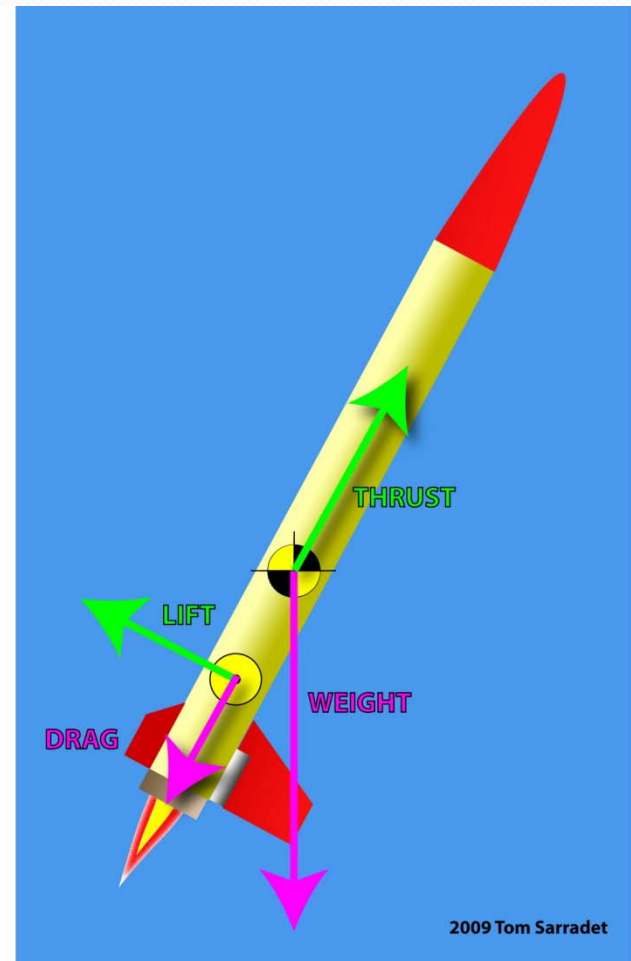
# Aerodynamic Forces

- **Lift** occurs when a flow of **gas** (the air) is turned by a **solid object** (the rocket).
- The flow is turned in one direction, and the lift is generated in the opposite direction.
- For a model rocket, the **nose, airframe**, and **fins** can become a source of **lift** if the rocket's flight path is at an **angle**.



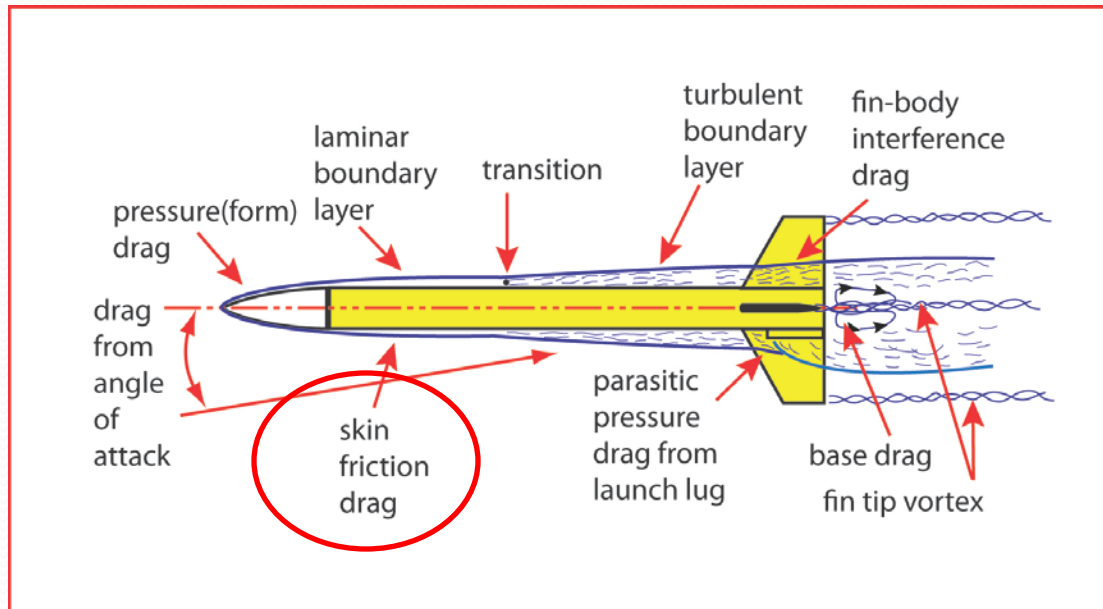
# Aerodynamic Forces

- When a solid body (**the rocket**) moves through a fluid (**gas or liquid**), the fluid **resists** the motion. The rocket is subjected to an **aerodynamic force** in a direction opposed to the motion which we call **drag**.



# Aerodynamic Forces

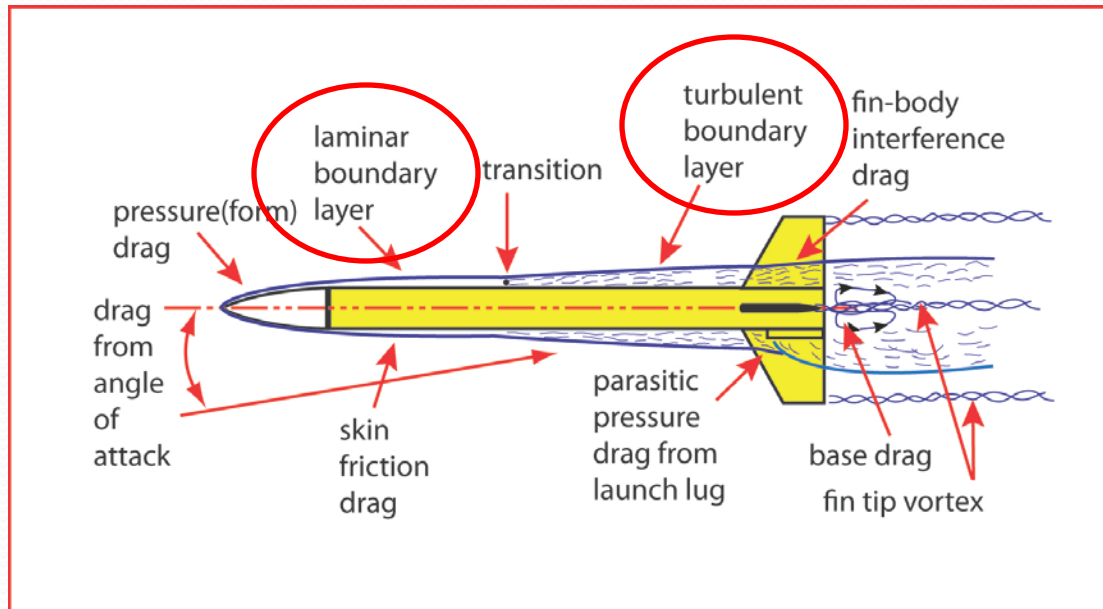
- **Drag** is **aerodynamic friction**, and one of the sources of drag is the **skin friction** between the molecules of the air and the solid surface of the moving rocket.



# Aerodynamic Forces

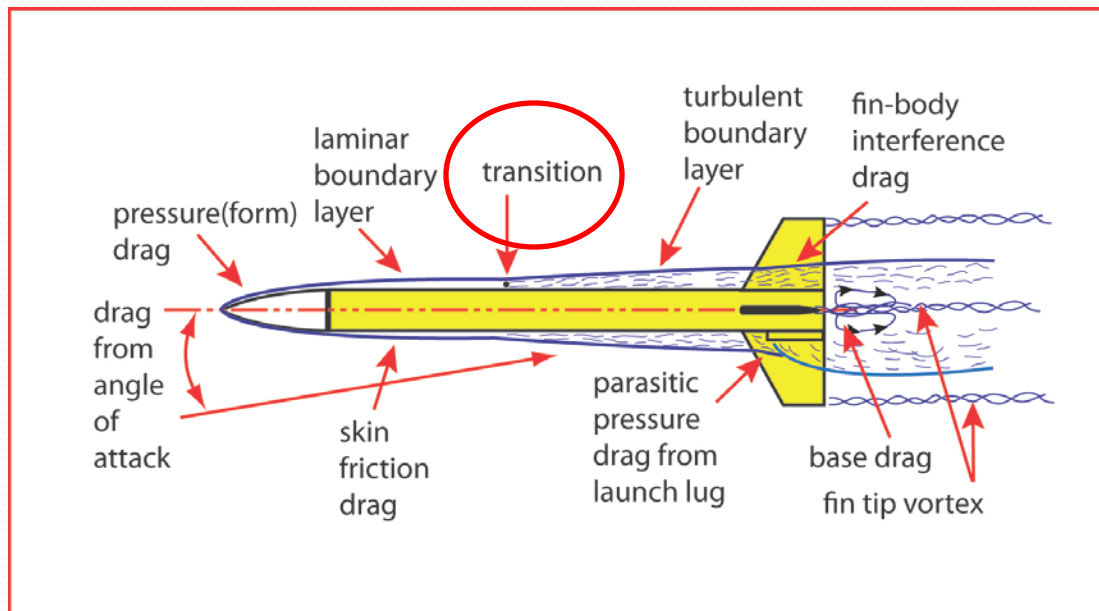
- A **boundary layer** is the layer of air in the immediate vicinity of the rocket's surface.

Boundary layers can be **laminar** (smooth flow) or **turbulent** (swirling).



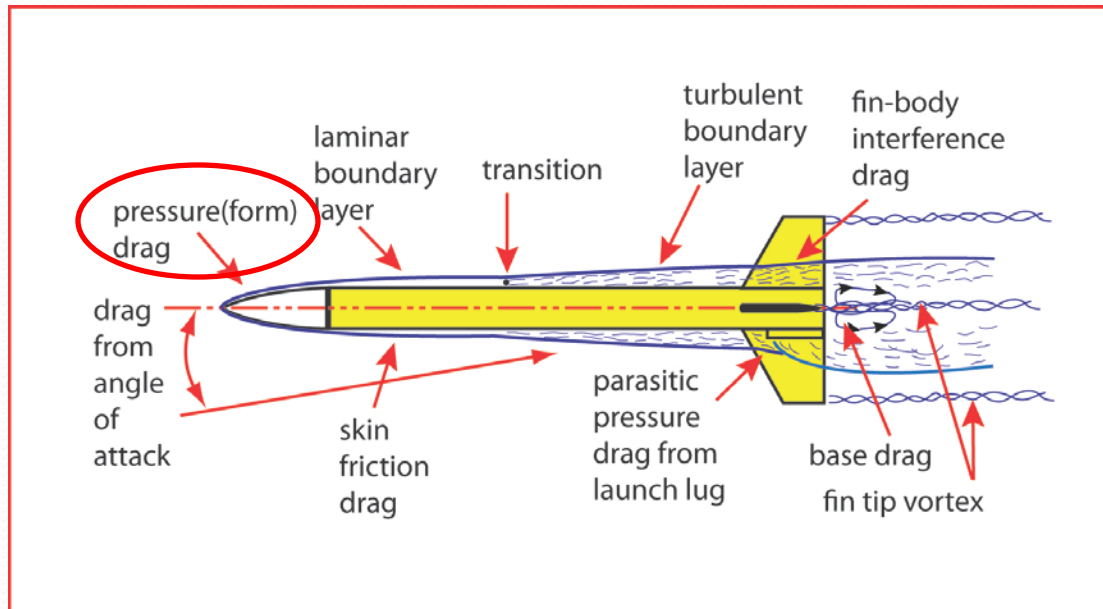
# Aerodynamic Forces

- The **point** in which a laminar boundary layer becomes turbulent is called the **transition**.



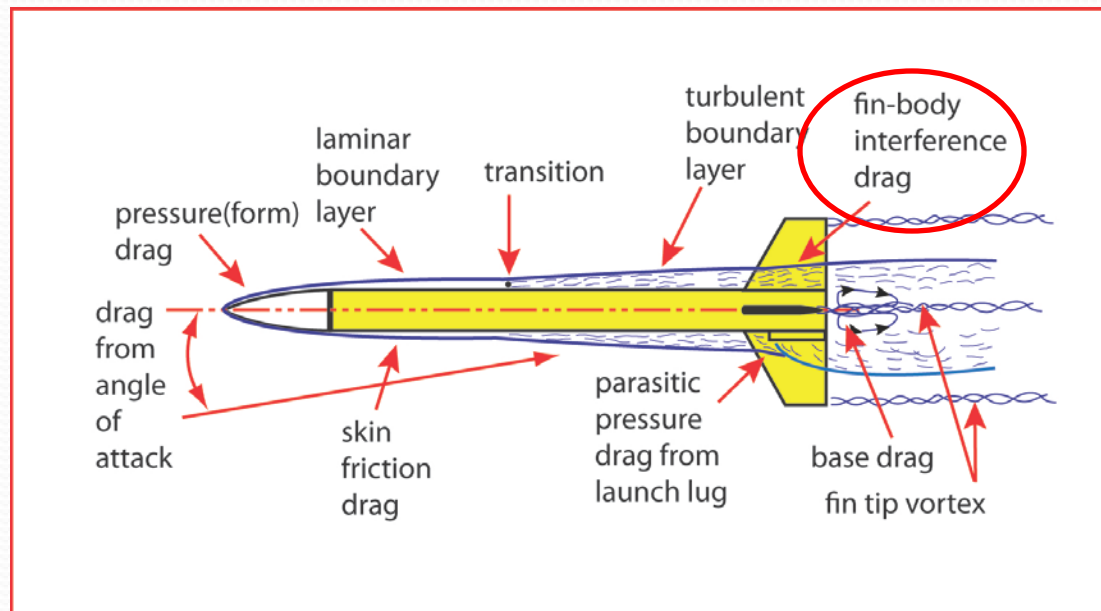
# Aerodynamic Forces

- **Drag** is also **aerodynamic resistance** to the motion of the object through the fluid. This source of drag depends on the **shape** of the rocket and is called **pressure or form drag**.



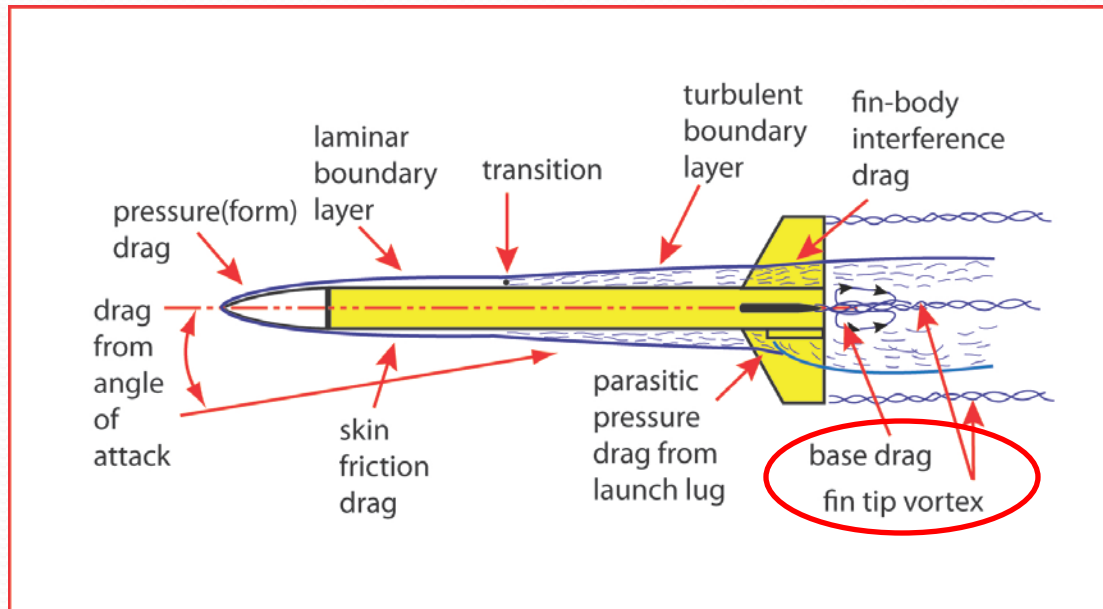
# Aerodynamic Forces

- **Interference drag** occurs whenever two surfaces meet at sharp angles, such as at the fin roots. Interference drag creates a **vortex** which creates drag. Fin fillets reduce the effects of this drag.



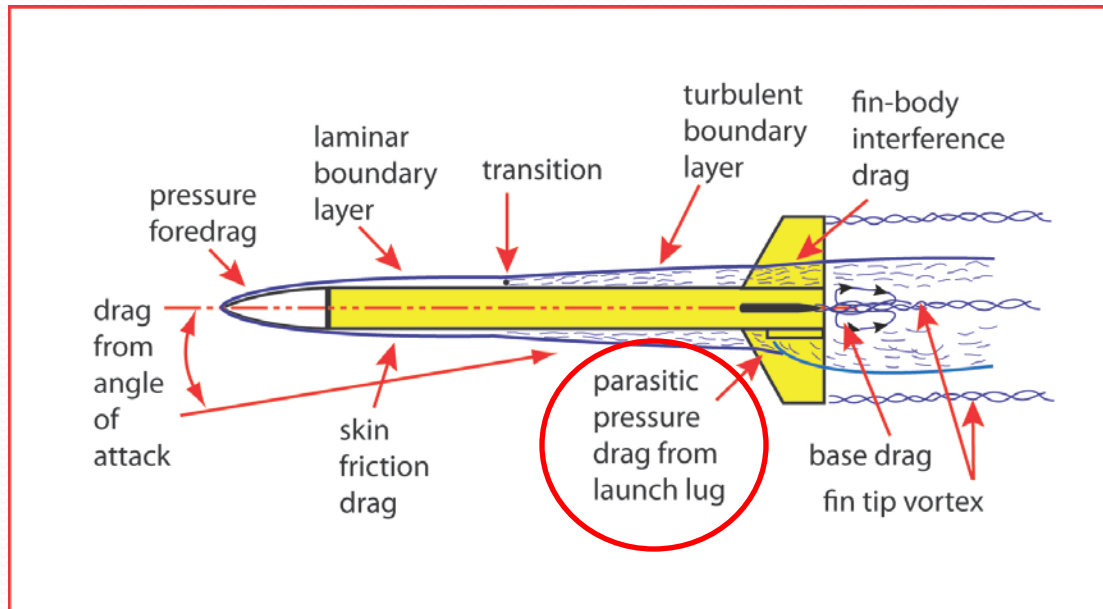
# Aerodynamic Forces

- Air passing by the tips of the fins form a **fin tip vortex**. Accelerating the air into this vortex causes **drag** on the fins, and a **low** pressure area behind them. Tapered fin tips reduce this drag.



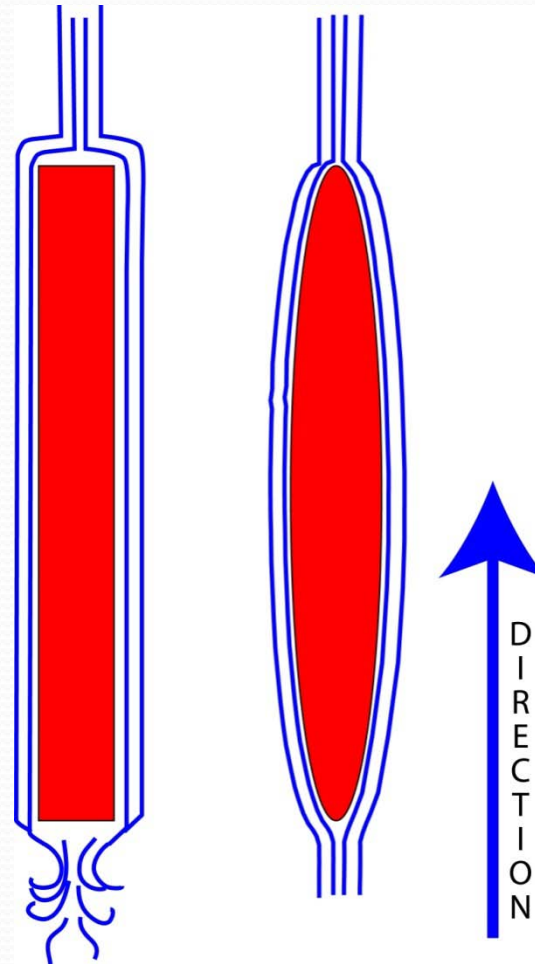
# Aerodynamic Forces

- **Parasitic Drag** is produced by objects like the launch lug. The launch lug can account for **30%** of all drag. Cutting the lug's leading edge to 45 degrees reduces drag.



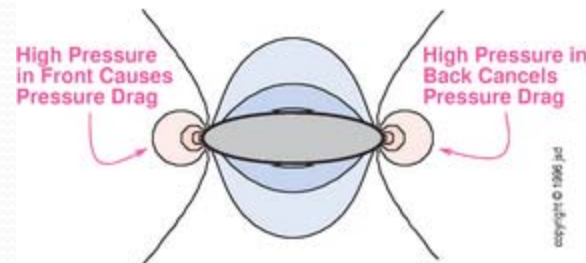
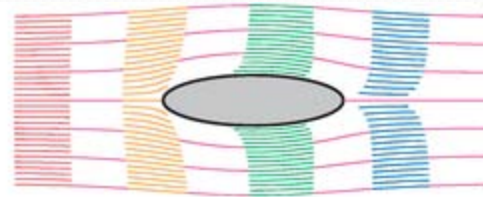
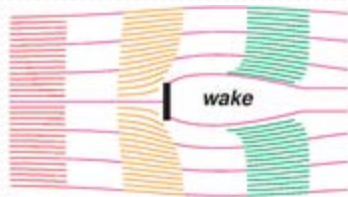
# Airfoil Fins

- A model rocket's fin that is **square** on the edges creates a lot of **drag** and **turbulence**.
- If the fin's leading and trailing edges are sanded in a **round shape**, called an **airfoil**, it reduces the drag.



# Airfoil Fins

- **airfoil shape fins** creates high pressure behind the fin and **pushes it forward**, cancelling out most of the pressure drag caused by the fins. This is called **pressure recovery**.



# Weight

- Weight is the force generated by the **gravitational** attraction on the rocket.
- The gravitational force is a **field force**; the source of the force does **not** have to be in physical contact with the object.
- Gravity affects the rocket whether it is **stationary** or **moving** (up or down).



# Thrust

- **Thrust** is the force applied to the rocket to **move it** through the air, and through space.
- **Thrust** is generated by the **propulsion system** of the rocket through the application of Newton's Third Law of Motion.
- The direction of the thrust is normally along the **longitudinal** axis of the rocket through the rocket's **center of gravity**.

