AMERICA'S NAVY

STEM for the CLASSROOM

Jets in Flight

Science Topic: Physics

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Discovery EDUCATION

Designing a Navy Jet Fighter

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Lesson Objectives

- Understand the Engineering Design Process
- Comprehend the basic principles of flight
- Apply the Engineering Design Process to aircraft design

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Navy Aviation

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Lesson Goal

Apply the principles of flight and the engineering design process to design and construct a model of a Navy jet fighter.

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Lesson Organization

- Part 1: Understanding and applying the basic principles of flight
- Part 2: Building a working prototype of a Navy jet fighter

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National Aeronautics and Space Administration

Airplane Parts and Function

www.nasa.gov

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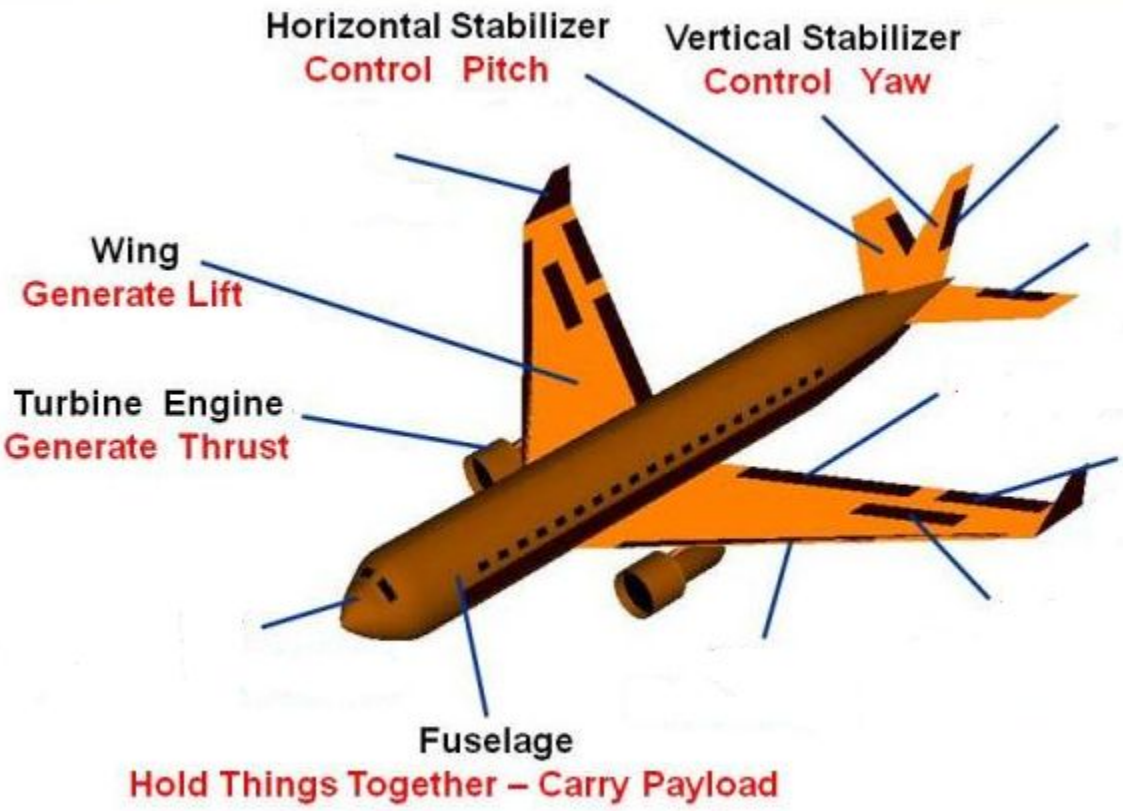
National Aeronautics and Space Administration

Airplane Parts and Function

Vital for Flight



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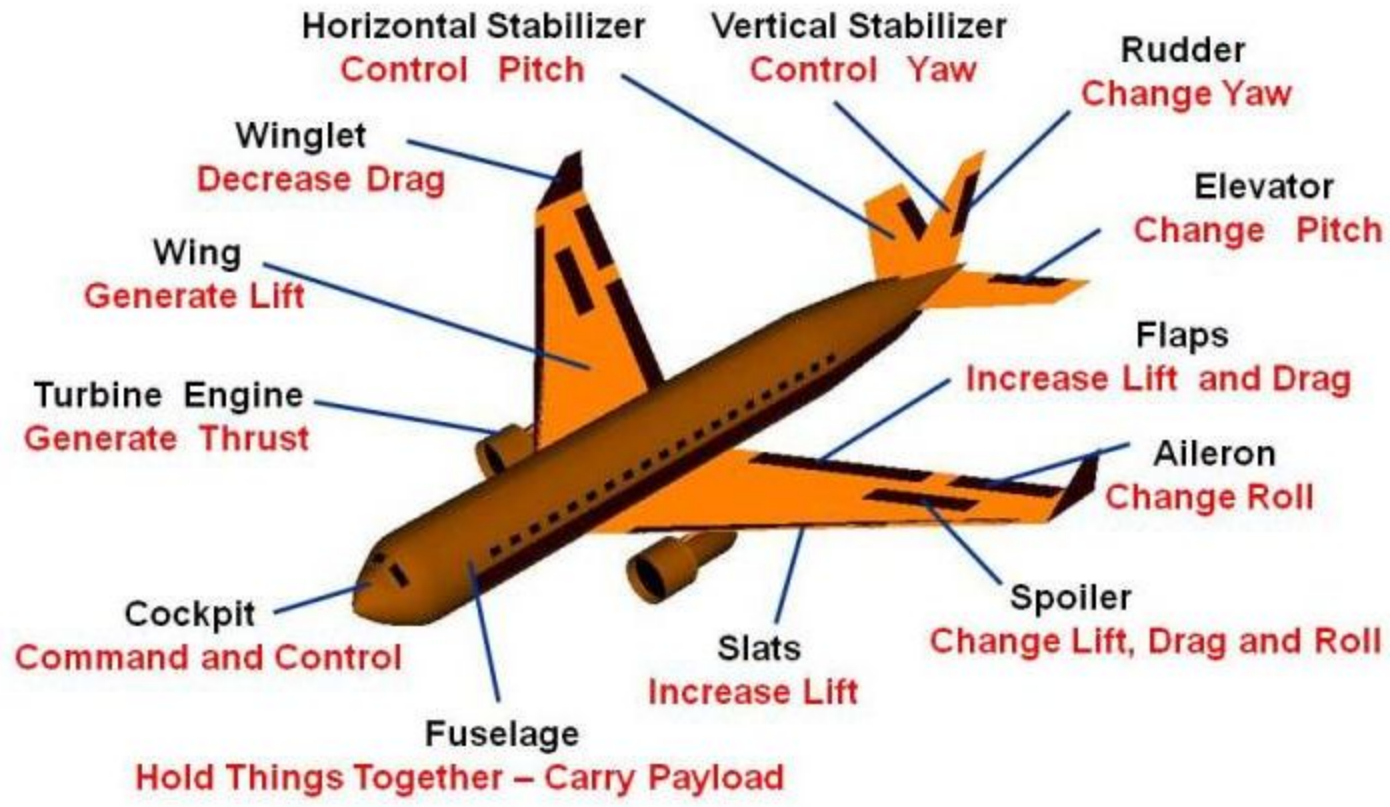
National Aeronautics and Space Administration

NASA

Airplane Parts and Function



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Part 1: The Principles of Flight

- Forces acting on an aircraft in flight
  - Thrust: the force that propels an aircraft forward
  - Drag: air resistance that produces a force in the opposite direction of thrust
  - Weight: gravitational force
  - Lift: upward force acting in the opposite direction of weight

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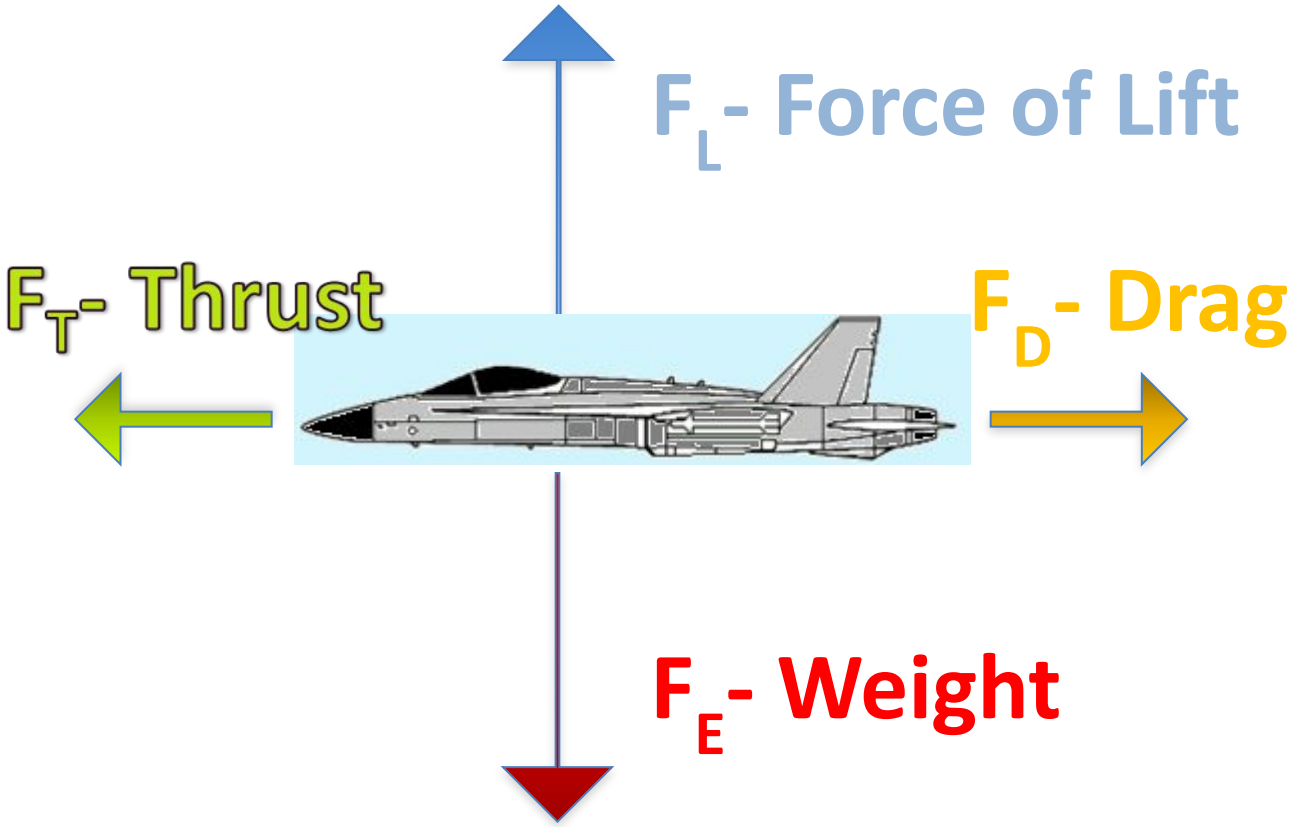

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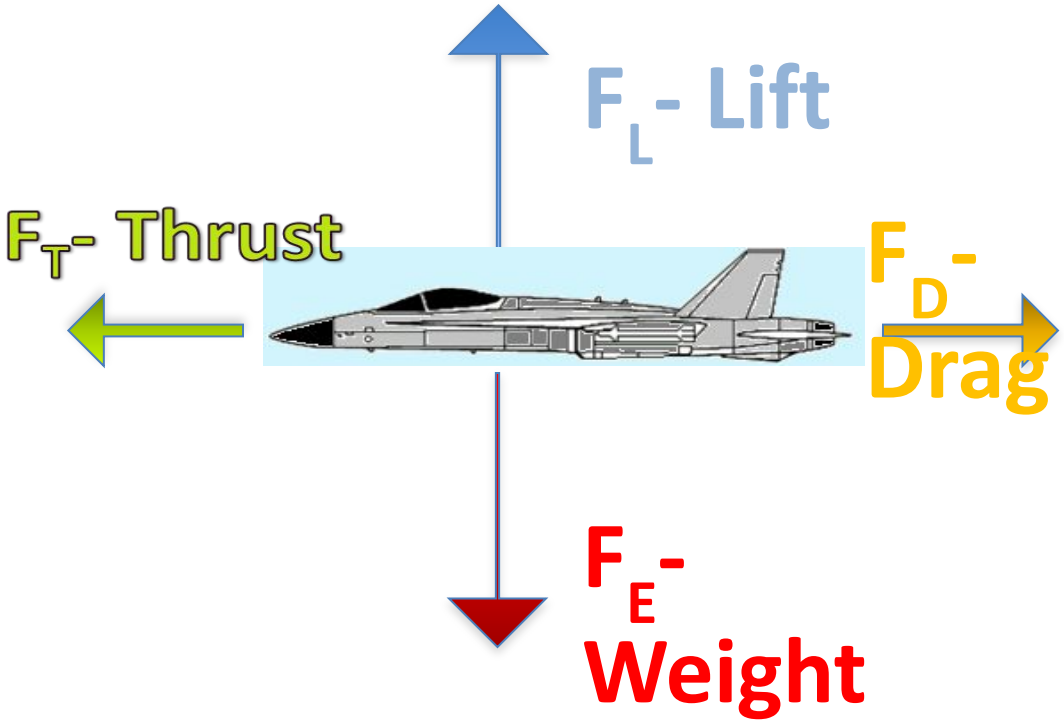
- Flight is achieved by shifting the balance between the opposing forces



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- Thrust is produced in one of two ways:
  - Transfer of momentum when gases are ejected to the rear of the plane through jet engines
  - Launching a plane with a catapult from the deck of an aircraft carrier

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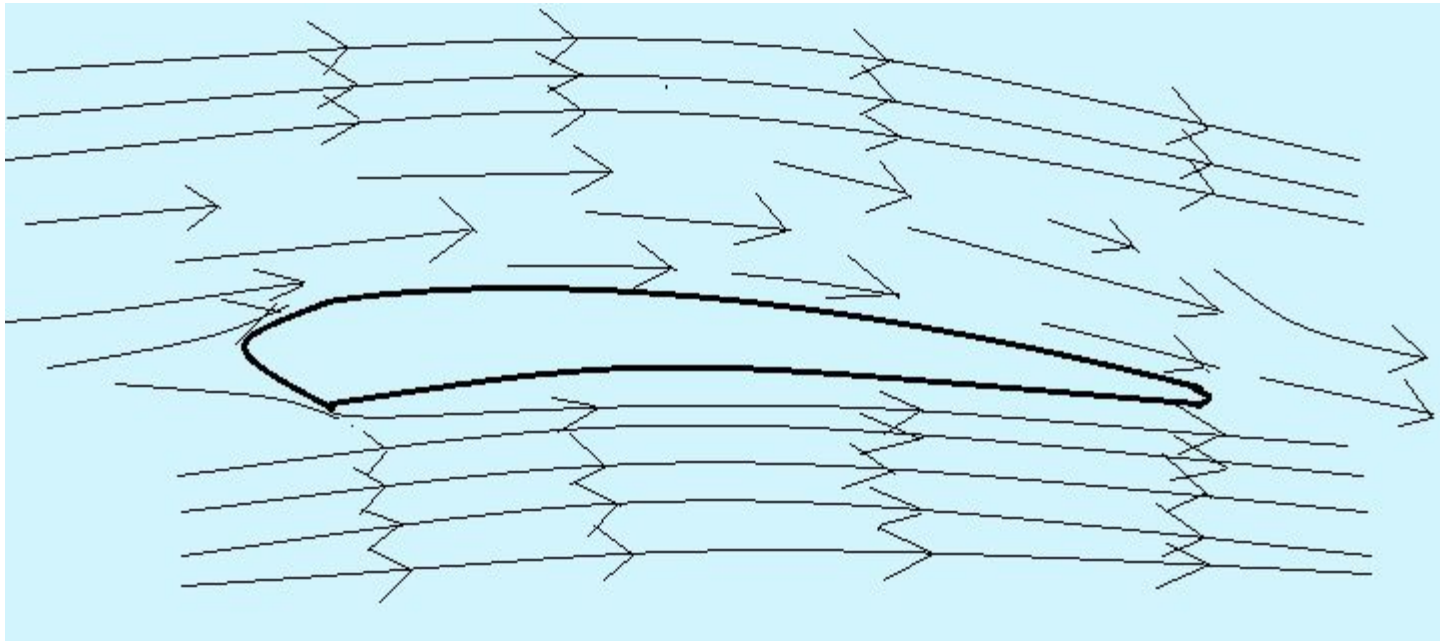
Lift is the upward force created as air passes over and beneath the wings of an aircraft



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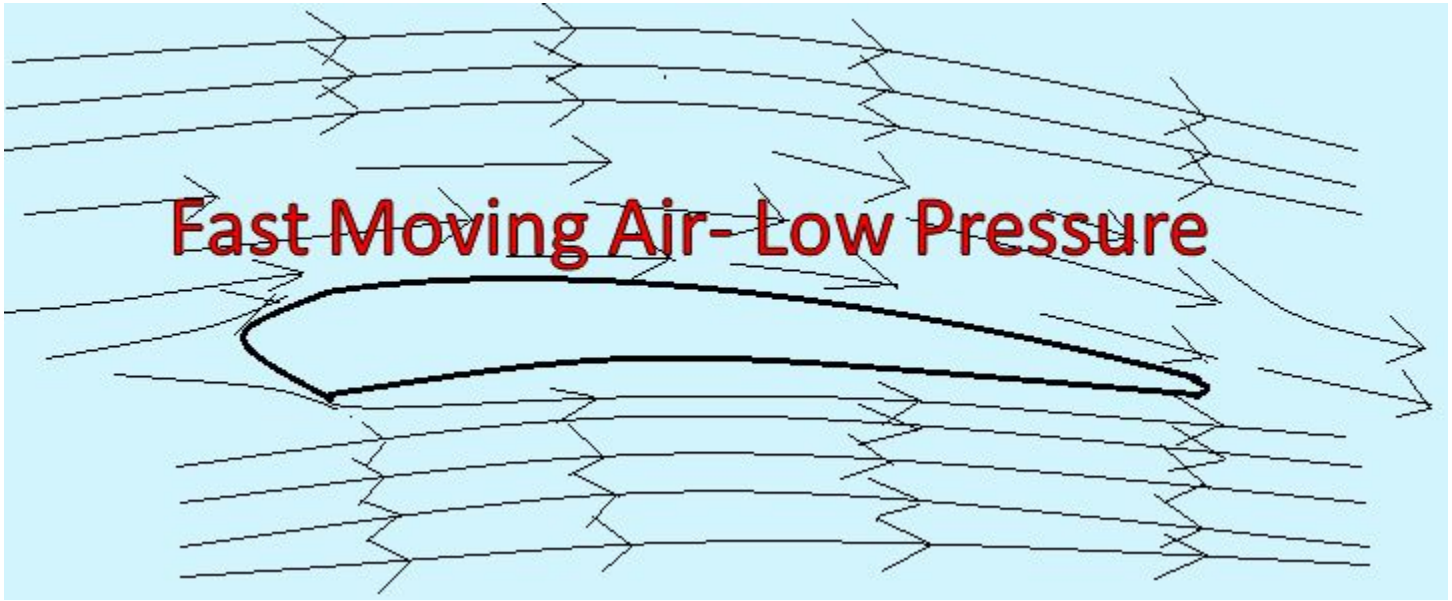
- Bernoulli's Principle:
  1. Fast moving air at the top edge of the wing creates a zone of low pressure



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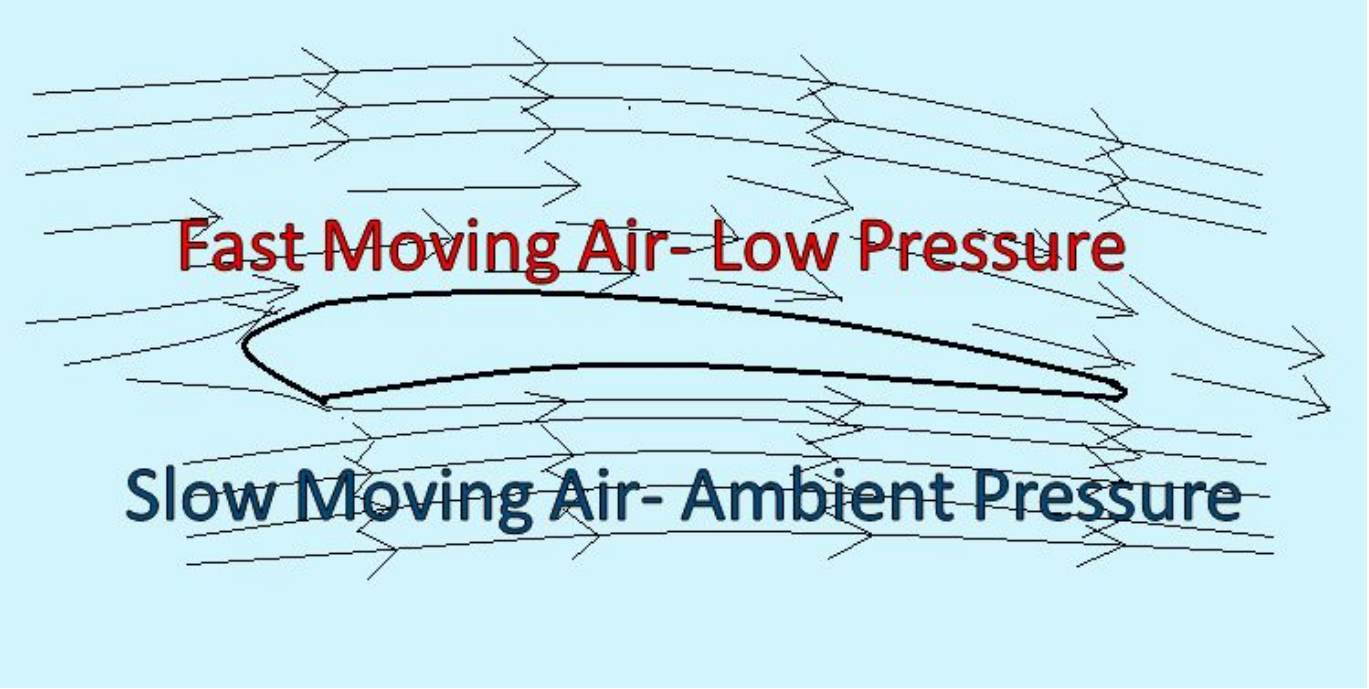
- Bernoulli's Principle:
  2. Slow moving air along the bottom edge of the wing has the same pressure as the air at the front of the wing (Ambient Pressure)



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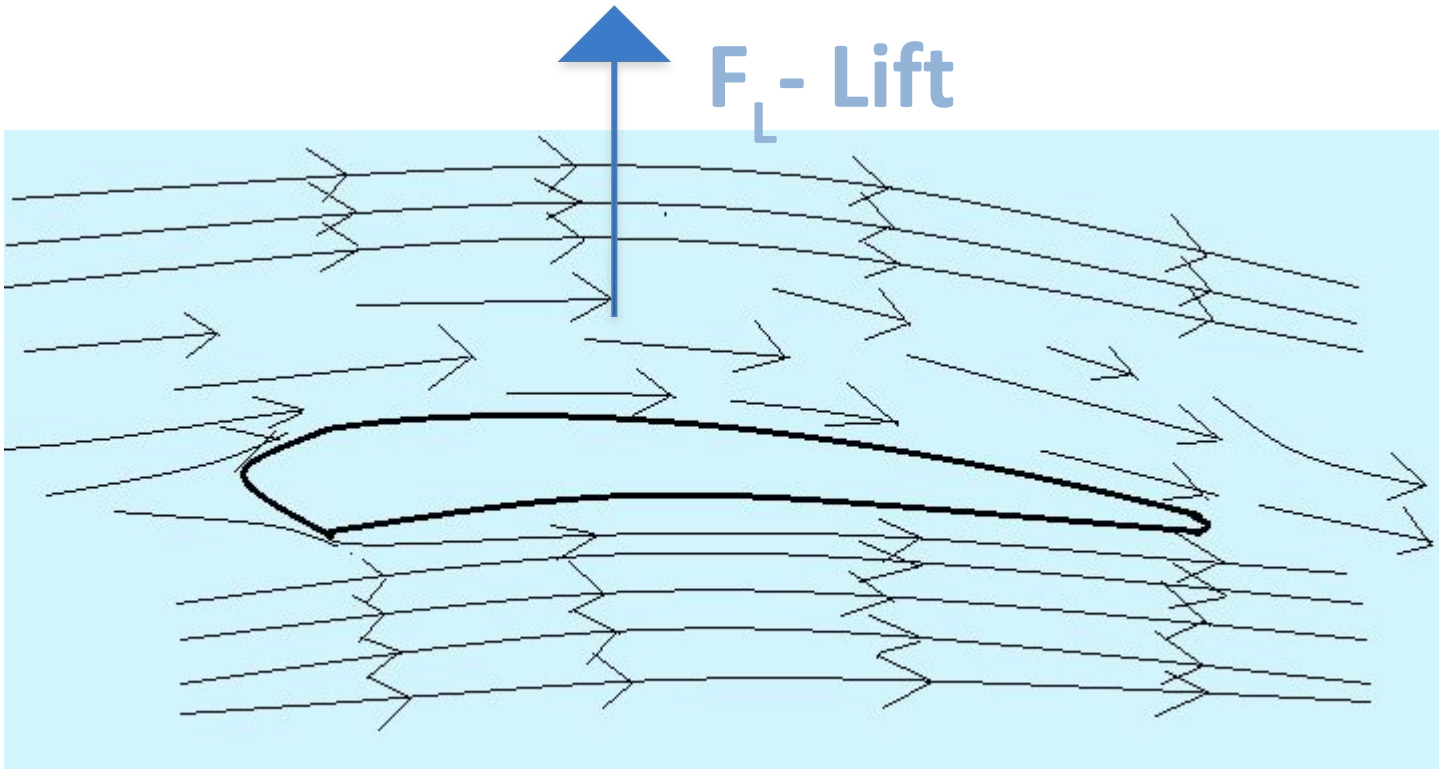
- Bernoulli's Principle:
  3. The difference in pressure creates the force of lift



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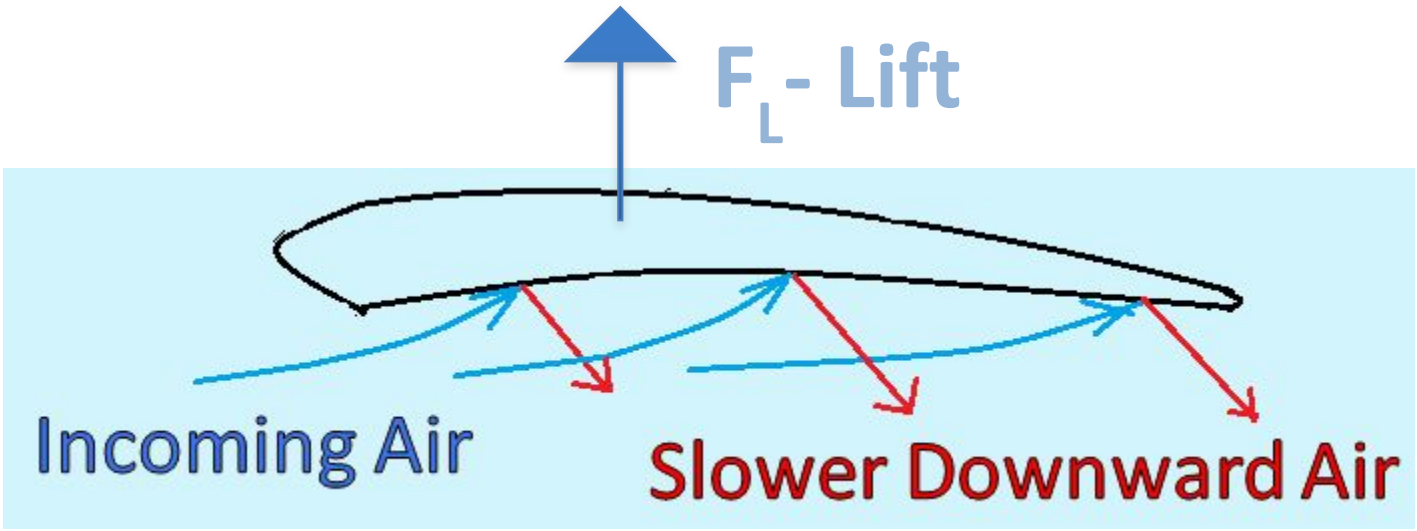
- Lift Momentum: additional upward force is generated incoming air deflects off the bottom of the wing and transfers momentum to the wing



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Lift Formula

$$F_L = \frac{1}{2} \rho v^2 C_l A$$

- F_L - Force of lift
- r - Density of air
- v - Velocity
- A - Total area of wings
- C_l – Coefficient of lift

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Lift Formula

$$F_L = \frac{1}{2} \rho v^2 C_l A$$

- Scenario 1:
  The total wing area on an F/A-18A is 409 ft^2. What is the total lift force exerted on the aircraft while it flies at 1027 ft/s (700 mi/hr) in air of density .00254 sl/ft^3 (.0817 lb/ft^3) and the lift coefficient of 1.8?

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Lift Formula

$$F_L = \frac{1}{2} \rho v^2 C_l A$$

- Scenario 2:
  Suppose the F/A-18C is flying at gross weight 51890 lb (23,537 kg). Given C_l of 1.00, wing area of 409 ft^2, and air density of .00254 sl/ft^3 (.0817 lb/ft^3), at what speed must it fly in order to maintain its level of flight?

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Resources

- http://www.av8n.com/how/htm/4forces.html
- http://www.aerotraining.com/reference/AC%2061-23C_Chapter_1_Canada.pdf
- http://www.grc.nasa.gov/WWW/k-12/BGA/Sheri/the_lift_equation_act.htm
- http://www.fighter-planes.com/info/f18.ht
- http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html

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Part 2: Designing a Prototype

You are an engineer tasked with building a model (prototype) of a small, lightweight aircraft that can carry a small camera (10-25 grams). The Navy plans to use this model in covert operations to collect intelligence. Naval Operations specifications require you to design a catapult to launch the prototype which must fly a minimum horizontal distance of 100 feet while remaining airborne for a minimum of 15 seconds. You may use only approved materials provided by the Navy as described in the Resources List. Maintain a record of your design process in a journal for post-Design assessment.

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Resources List

- 1 large foam meat tray per student (unused)
- 1-2 foam plates per student
- 1 glue gun per 3 students (with glue sticks)
- 2-3 bamboo skewers per student
- 1 roll of scotch tape per 3 students
- 1 dowel rod per 4 students (cut in halves or quarters)
- 1 Office Store Rubber Band per student
- 1 pair of scissors per 2 students (or retractable carpet razors)
- 1 ruler per 2 students
- 1 cardboard sealed container per student (ex: Eggo, ½ gallon milk) cleaned.
- 1 hammer per class
- Small glob of clay per student
- Weights: 10 to 25 grams per group

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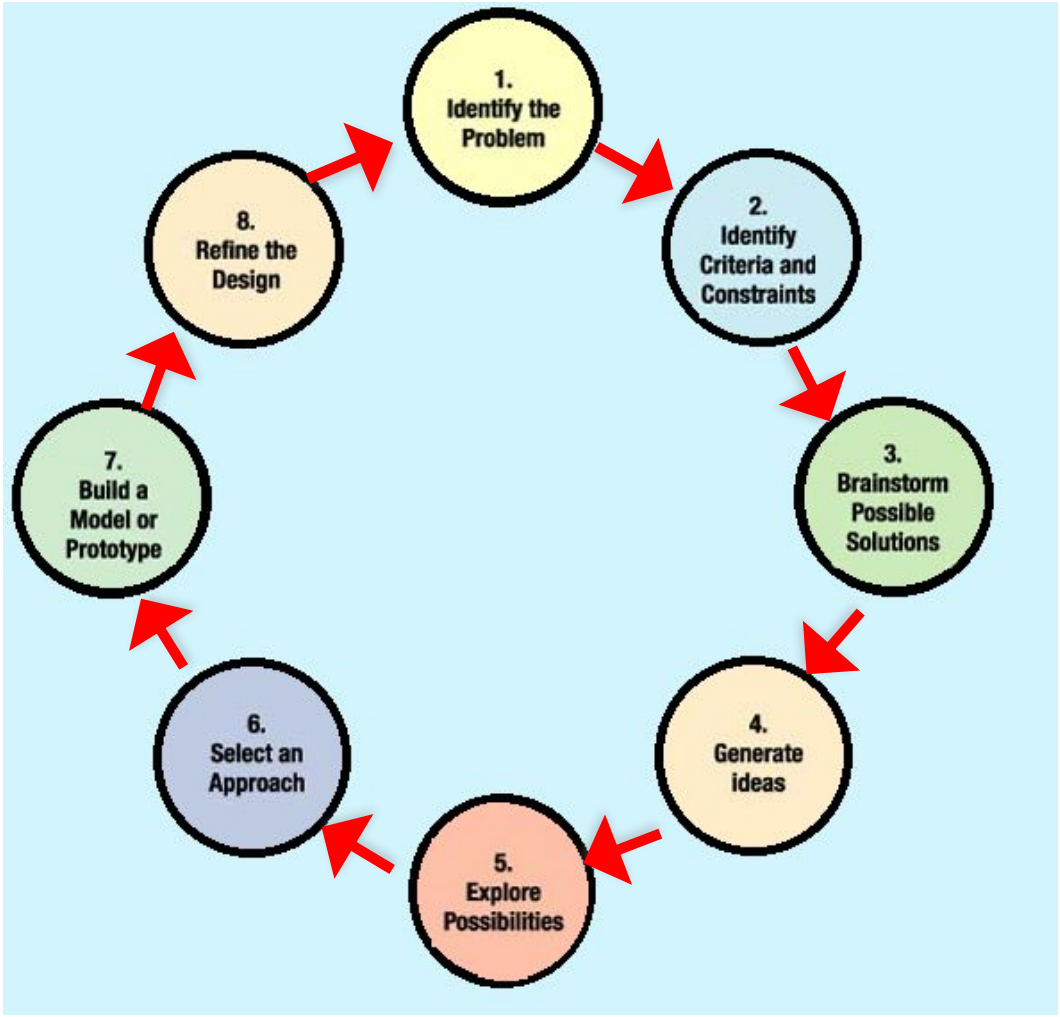

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Step 1: Identify the Problem

- Create a small, lightweight model aircraft that can carry a small camera (10-25 grams) to collect intelligence information for the Navy.

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Step 2: Identify Criteria and Constraints

- Fly at least 100 feet horizontally
- Maintain flight for at least 15 seconds
- Construct a catapult device
- Others?

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Complete the remaining steps of the engineering design process and demonstrate how your prototype meets the Navy's specifications.

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