Introduction to Flight

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Objectives

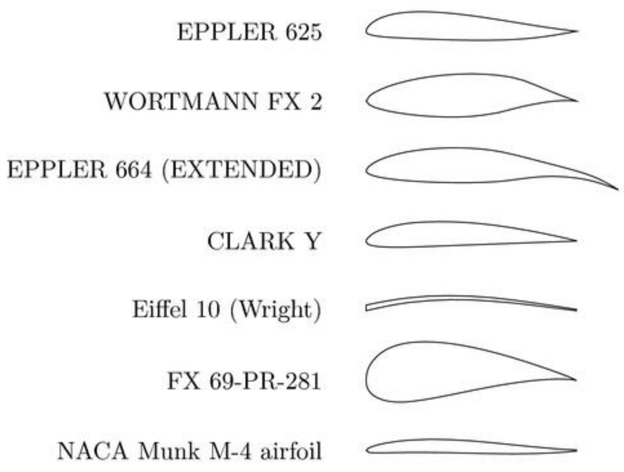
- Familiarity with common aircraft components and terminology
- Understand the aerodynamic forces and their causes
- Overview of design considerations

Similarities

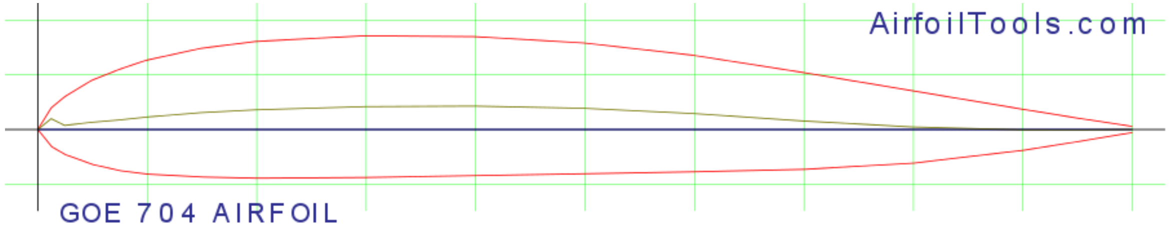
Wing

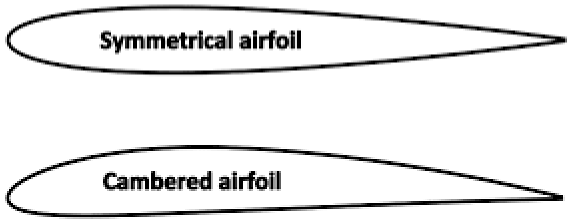
- Main source of lift for an aircraft
- Flaps and ailerons are <u>control surfaces</u>.
- Winglets often included for performance benefits

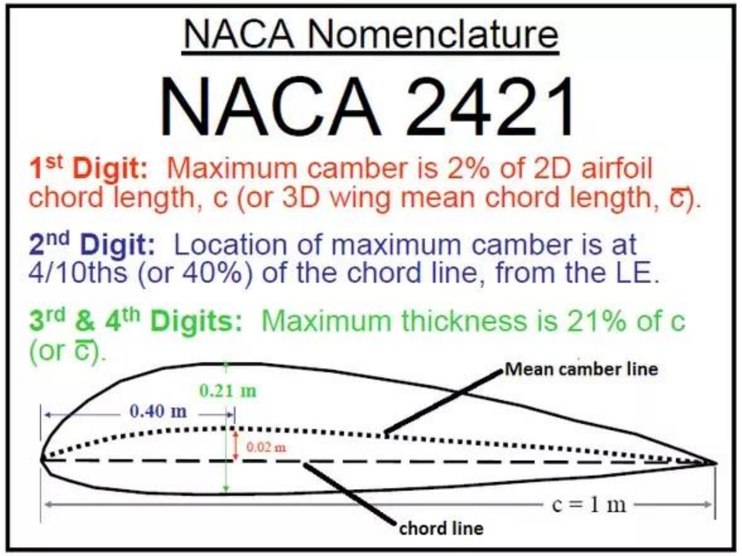
Wing (cont.)



- 2D airfoils define the 3D shape of wings

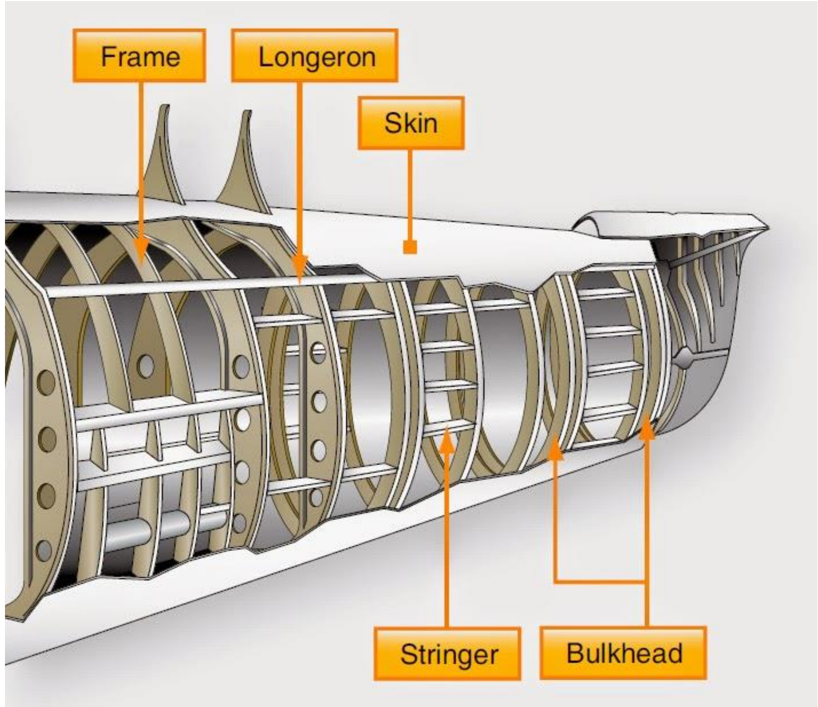






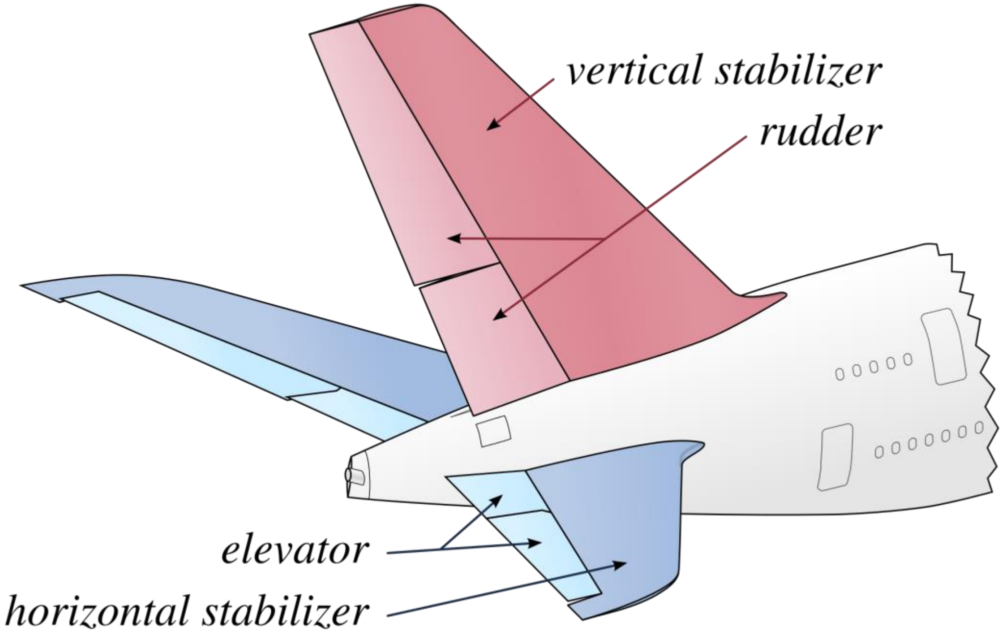
Fuselage

- Primary functions include passenger/cargo storage and structural integrity



Tail

- Major source of stability and control
- Components include vertical/horizontal stabilizers and rudder/elevator

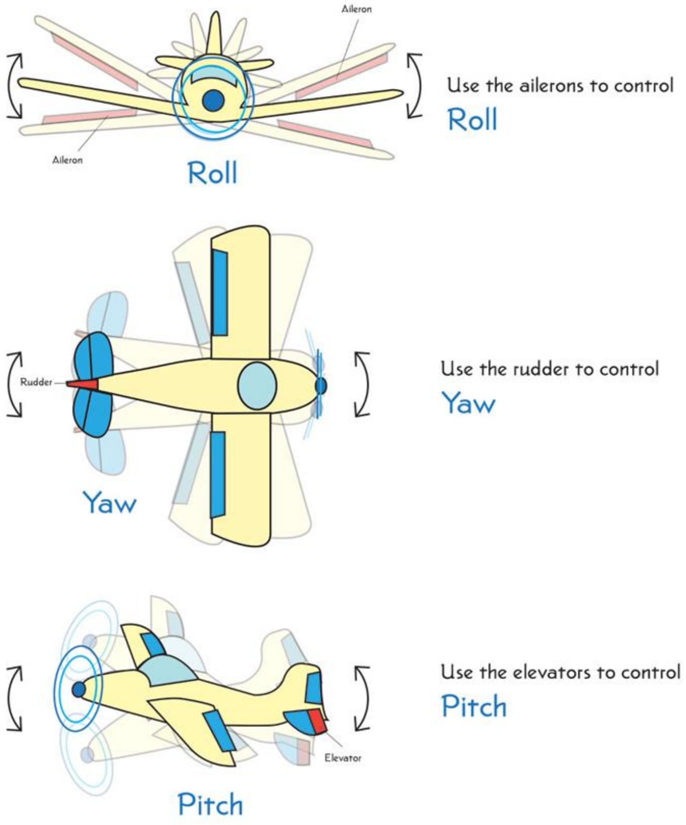


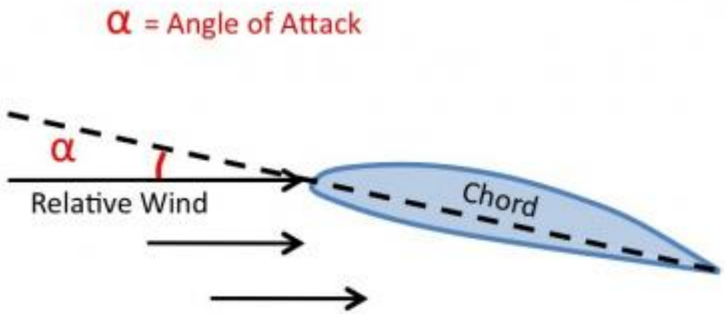
Motor and Propeller

- Generate thrust required for aircraft speed
- Each blade is just a small airfoil

Flight Mechanics

- 3 types of control surfaces
- Angle of attack



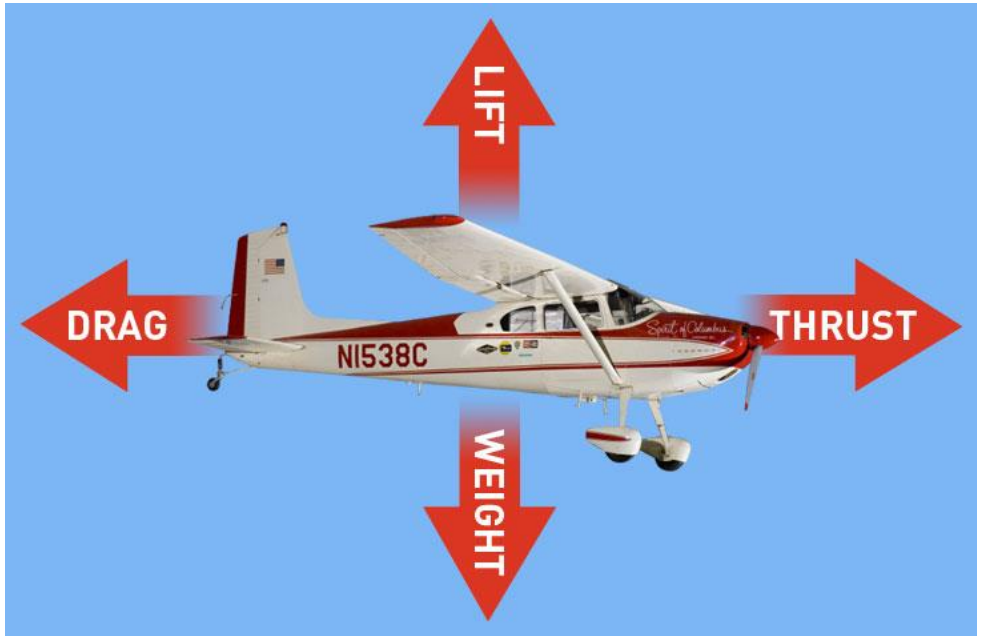


Review of Aircraft Components

- Overall aircraft structure is formed by fuselage, wing, tail, and motor
- Control surfaces are used to control aircraft pitch, yaw, and roll maneuverability
- Airfoils are 2D cross sections of aerodynamic surfaces designed to generate lift

Aerodynamic Forces

- Airplanes are influenced by four aerodynamic forces while in flight
- Constant velocity flight is referred to as “cruise”



Weight

- Always directed downward, based on aircraft size and material

Weight

Table 2.2-3 Weight breakdown for some representative aircraft. All weights in kg.

System	B-747-100	% weight	C-5A	% weight
Wing	40,200	11.450	37,048	11.234
Tail	5,417	1.543	5,592	1.696
Airframe	31,009	8.833	52,193	15.826
Landing gear	14,596	4.157	17,046	5.169
Nacelle	4,703	1.340	3,838	1.164
Propulsion system	4,352	1.240	3,087	0.936
Flight controls	3,120	0.889	3,143	0.953
Auxiliary power unit	815	0.232	484	0.147
Instruments and navigation	674	0.192	333	0.101
Hydraulics and pneumatics	2,296	0.654	1,956	0.593
Electrical system	2,404	0.685	1,495	0.453
Avionics	1,873	0.534	1,871	0.567
Furnishings	21,748	6.195	3,539	1.073
Air conditioning	1,647	0.469	1,179	0.357
Anti-icing	188	0.054	106	0.032
Load and handling system	104	0.030	124	0.038
Operating empty weight	134,934	38.434	133,028	40.338
Dry engine weight	16,173	4.607	13,137	3.984
Empty weight	151,106	43.041	146,164	44.321
Take-off gross weight	351,076	100.0	329,785	100.0

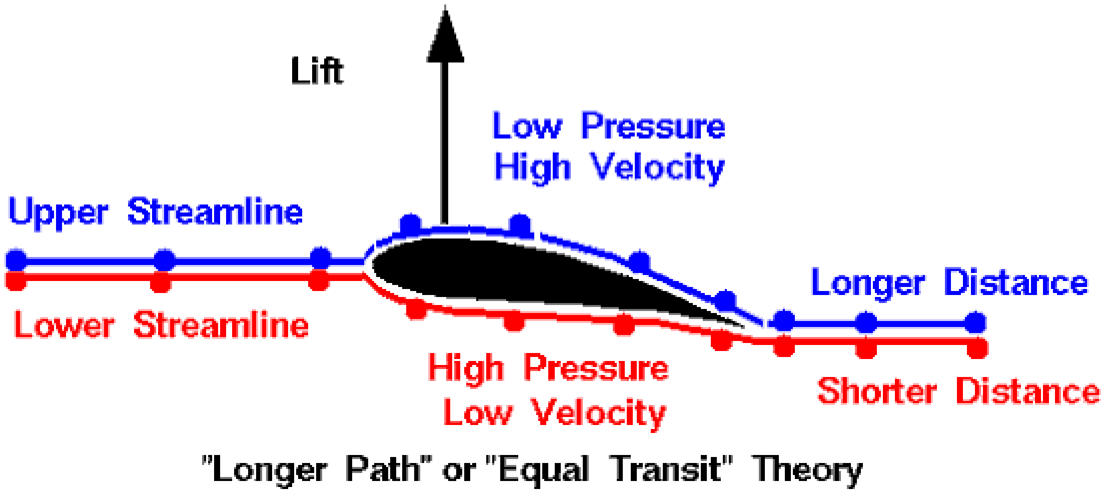
Thrust

- Thrust is a combination of battery, motor, and propeller
- Thrust must be larger than drag in order to accelerate
- Larger propellers and motors generate more thrust, but require more battery weight
- Tradeoffs need to be made when sizing the propulsion system

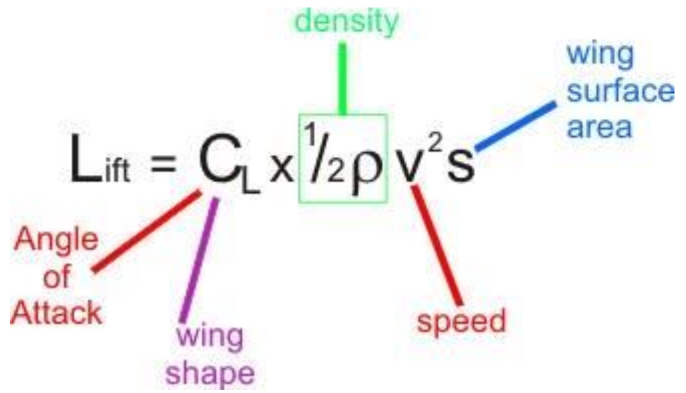
Lift

- Generated lift force must be greater than aircraft weight in order to takeoff
- Pressure difference leads to upward lifting force (Force = pressure*area)
- Bernoulli's equation:

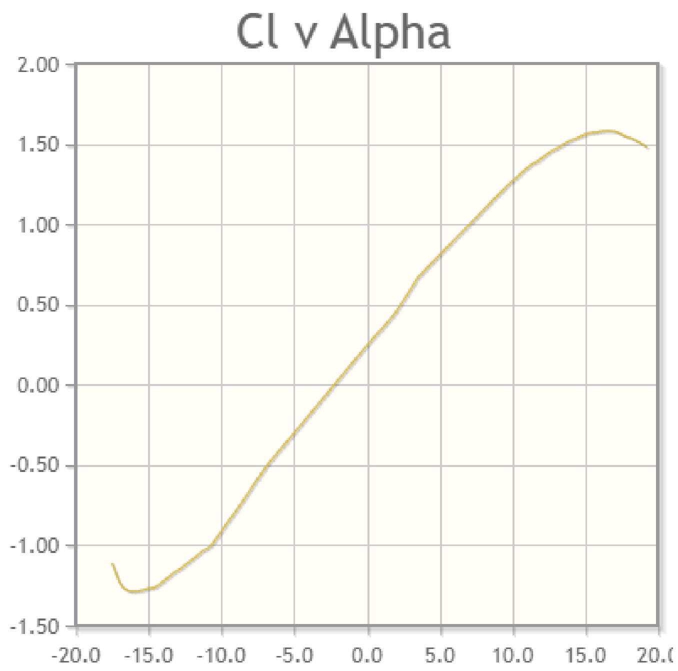
$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

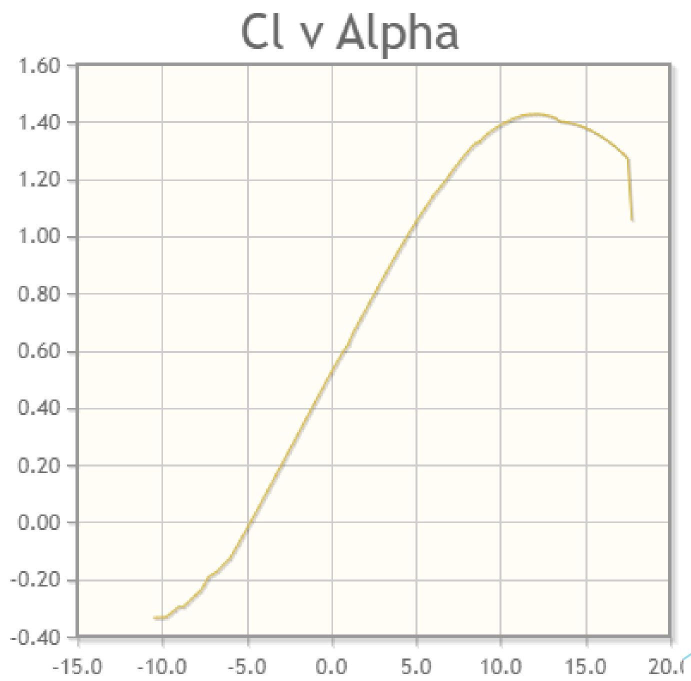


Calculating Lift



- Air density, aircraft speed, and wing surface area are all simple physical parameters
- Lift Coefficient is often determined from online airfoil databases



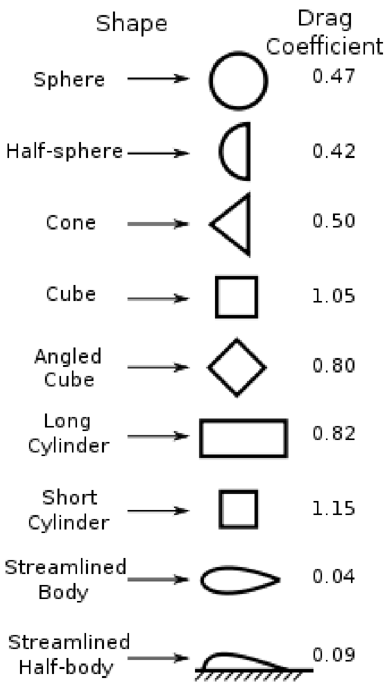


Drag

- Drag is the force resisting aircraft motion
- During cruise, drag = thrust. In order to accelerate, drag < thrust
- Total drag is a combination of three separate drag components:
  1. Form drag
  2. Skin friction drag
  3. Induced drag

Form Drag

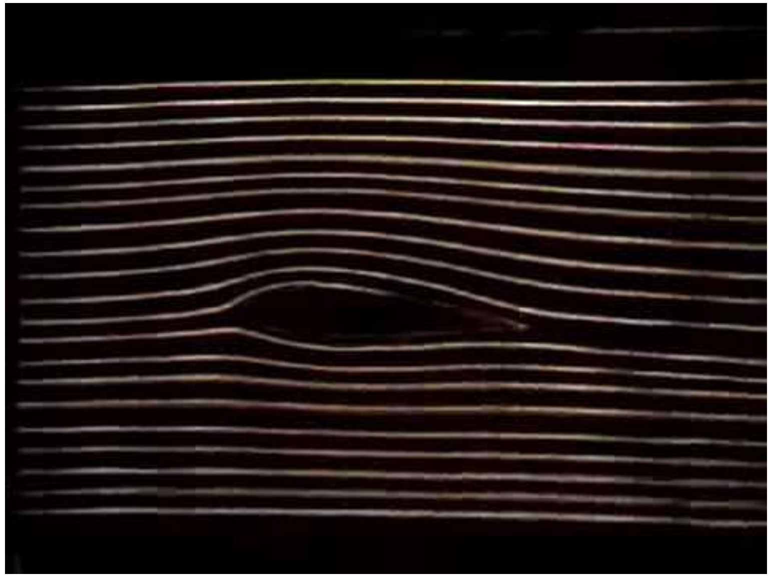
- Determined by the exterior shape of the aircraft
- Corresponds to overall resistance experienced moving a shape through air



Measured Drag Coefficients

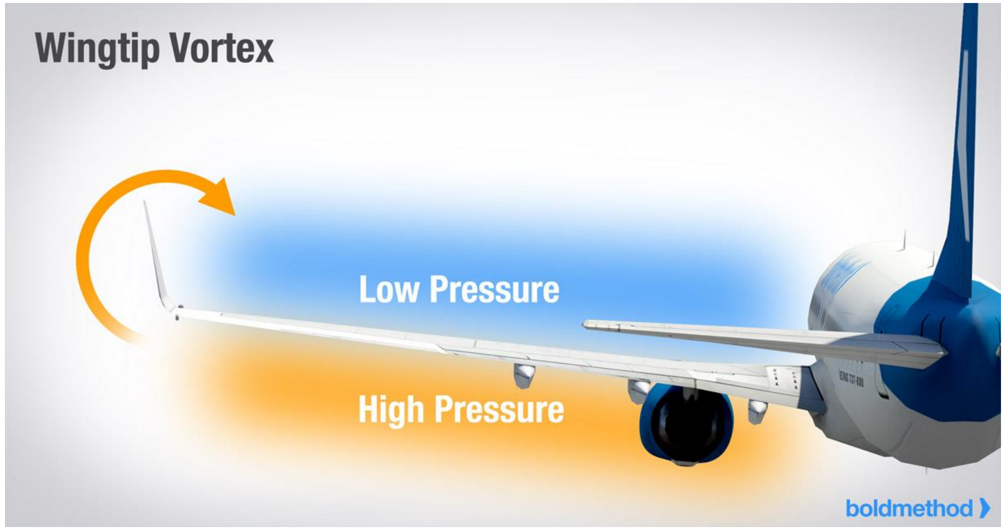
Skin Friction Drag

- Similar to how sliding an object across the ground generates an opposing friction force, moving an object (airplane) through air particles generates a small friction resistive force
- Determined by the smoothness of aircraft exterior



Induced Drag

- Induced drag is a side effect of lift generation
- Only acts on the wing tips, resulting in higher span wings being more efficient (one reason why competition limits wingspan)
- Winglets can reduce this effect



Parasitic Drag

- Often times, form drag and skin friction drag will be combined into “parasitic drag” which is simply the sum of the two
- This is often referred to in textbooks as Cd_0

Calculating Drag

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

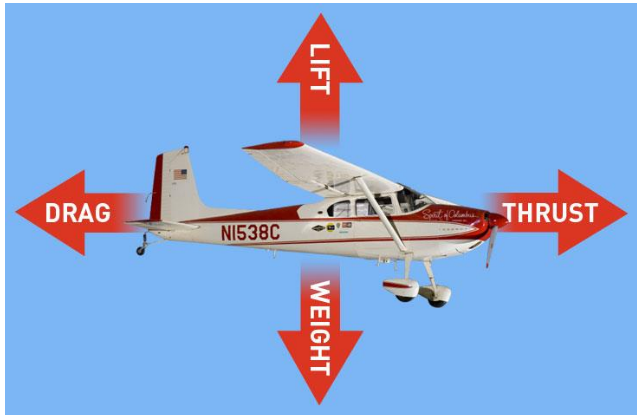
- Notice, the drag equation is almost the exact same as the lift equation!
- Only difference is using the total drag coefficient instead of the lift coefficient
- What does this say about the relationship between lift and drag?
- $Cd = Cd_{Form} + Cd_{Friction} + Cd_{Induced}$

Lift/Drag Ratio

- As lift and drag are the two most important forces acting on an aircraft, L/D is a common parameter used to represent aircraft efficiency
- High altitude gliders can have L/D exceeding 50
- Most commercial/military aircraft have L/D more in the range of 10-20
- A higher L/D ratio is always desirable from an aerodynamic perspective, but design limitations often place limitations on this efficiency in order to meet performance requirements

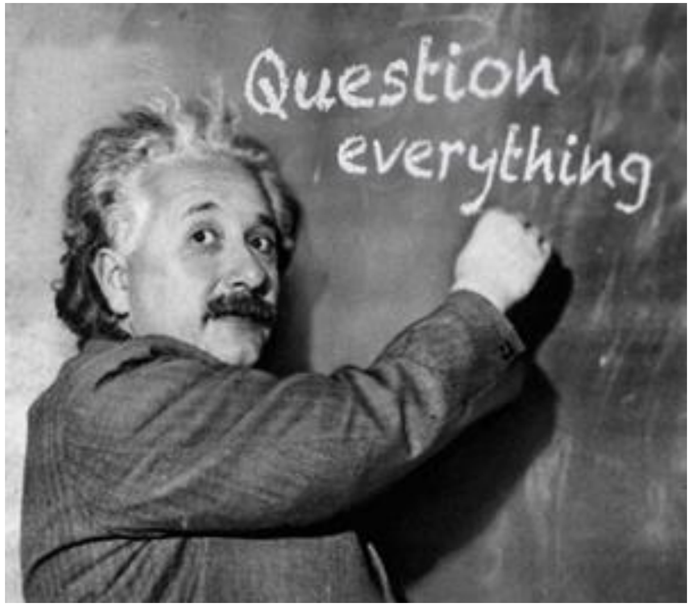
Summary of Aerodynamic Forces

- Lift = Good
- Drag = Bad
- Thrust and lift are generally design points determined early in the conceptual design process
- Drag on the other hand, is constantly able to be lowered and improved to improve vehicle performance
- Drag reductions can come from many different areas



Questions

- Any questions?
- If any arise in the future, please do not hesitate to reach out to myself or any other leads



Future Resources

- Future lectures in aerodynamics, potentially diving deeper into specific important topics or topics of interest
- Sub-team meetings
- Textbooks available for checkout from UW libraries (list coming soon)