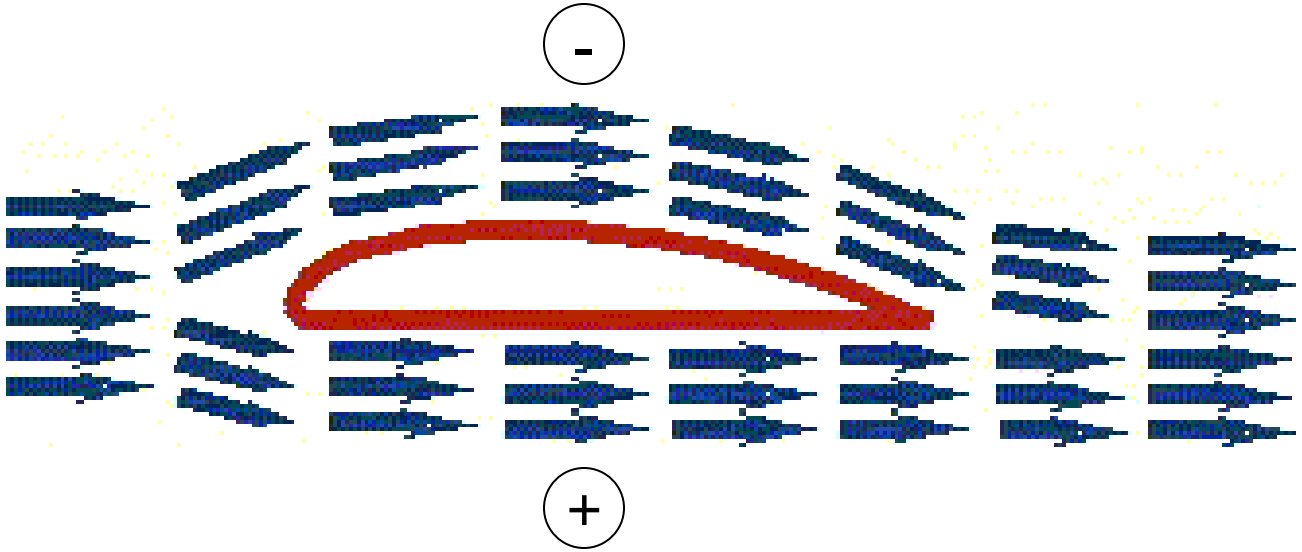
Some Airplane Basics

AE 1350

How Airplanes Fly

- The (too) simple version:
  - 1) Air “must” go faster over the top of wing (why?)
  - 2) Bernoulli’s principle implies that pressure will be lower on upper surface
    - Pressure + ½ * Density * Velocity^2 = Constant (“Static Pressure”)



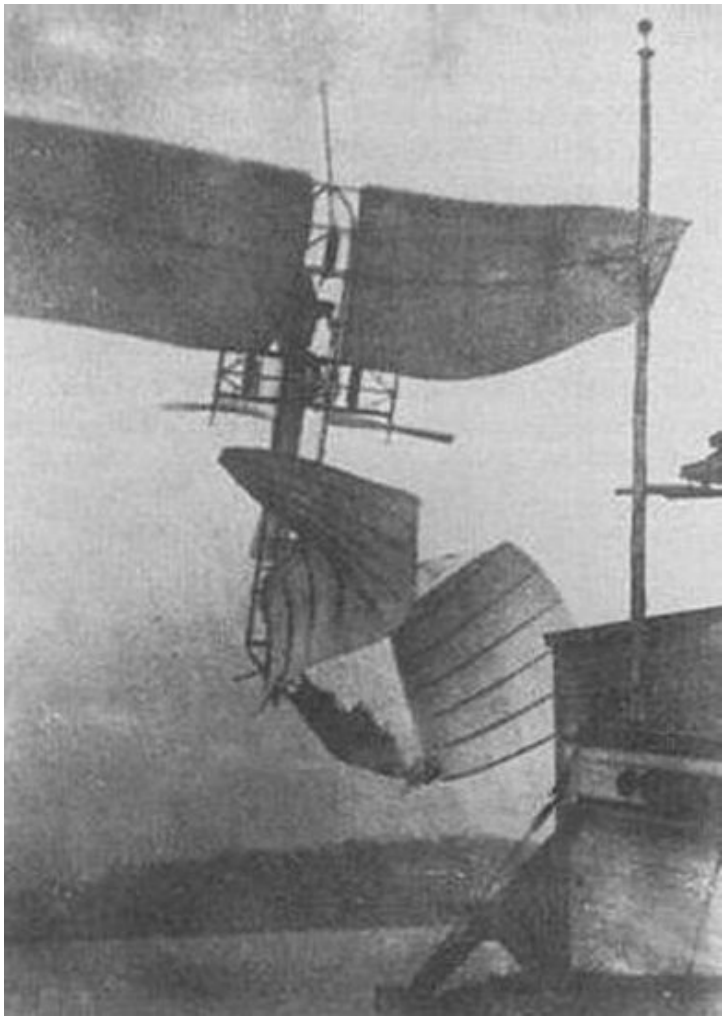
We Need Better

- How do airplanes without a wing of this shape fly?

- Why can airplanes fly upside down?

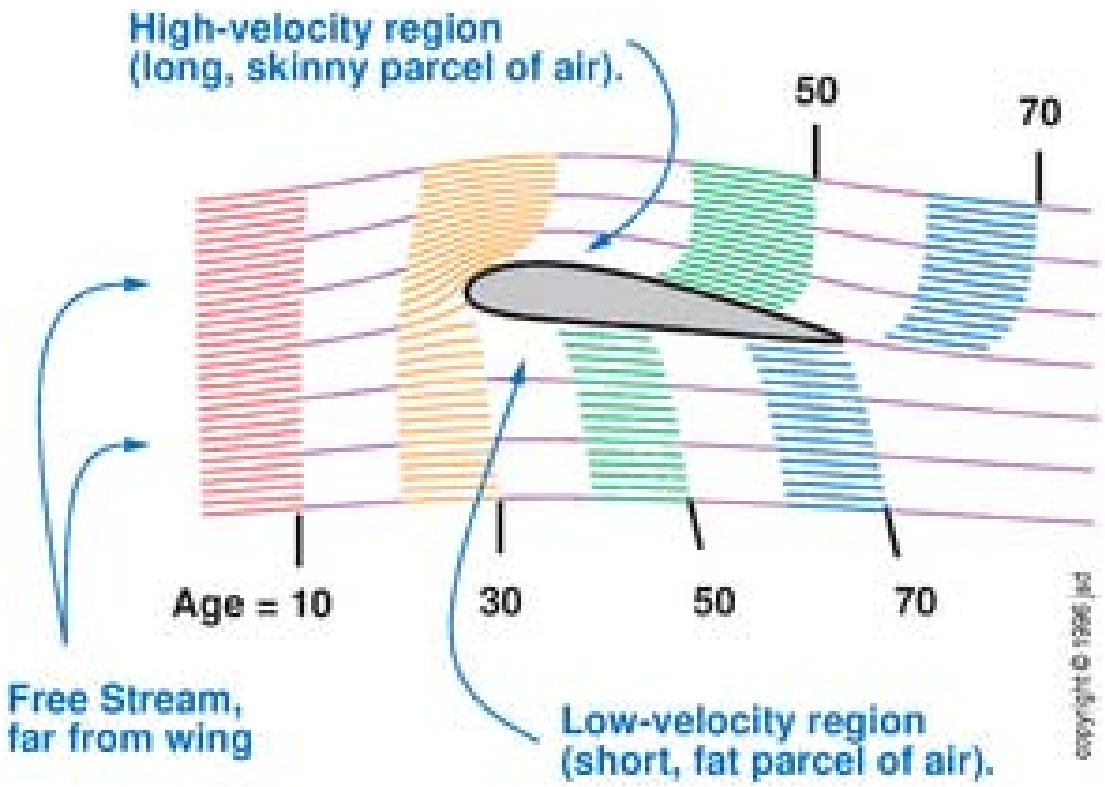
We Need Better

- Why did many airplanes with this shape not fly?



We Need Better

- The air going over top arrives BEFORE the air going under the bottom!



How Airplanes Fly

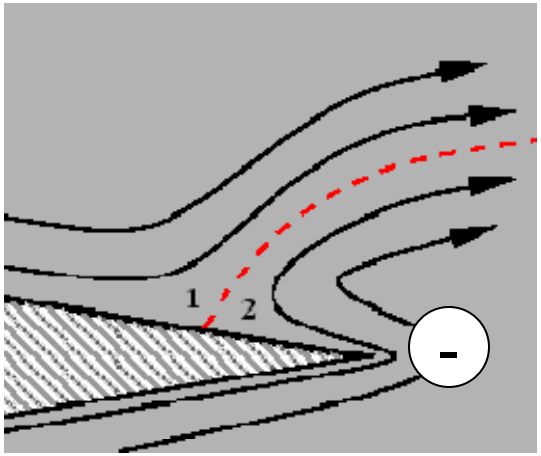
1. **Lift generated to oppose Weight**
   - **Example: Wing with trailing edge**
   - **Weight kept to a minimum**

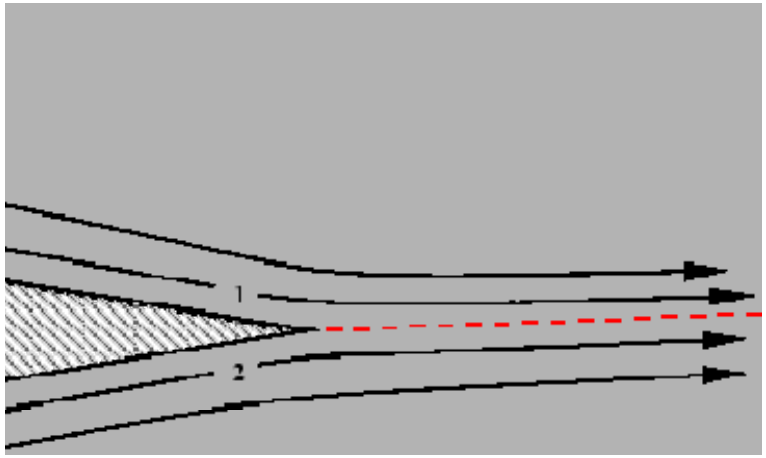
Airfoil: Shape of the Wing Cross-Section

- The (too) simple theory tells us that to fly we need an airfoil with greater curve on the upper surface than the lower surface
- This is not correct
- What is required, is a trailing edge

Kutta Condition

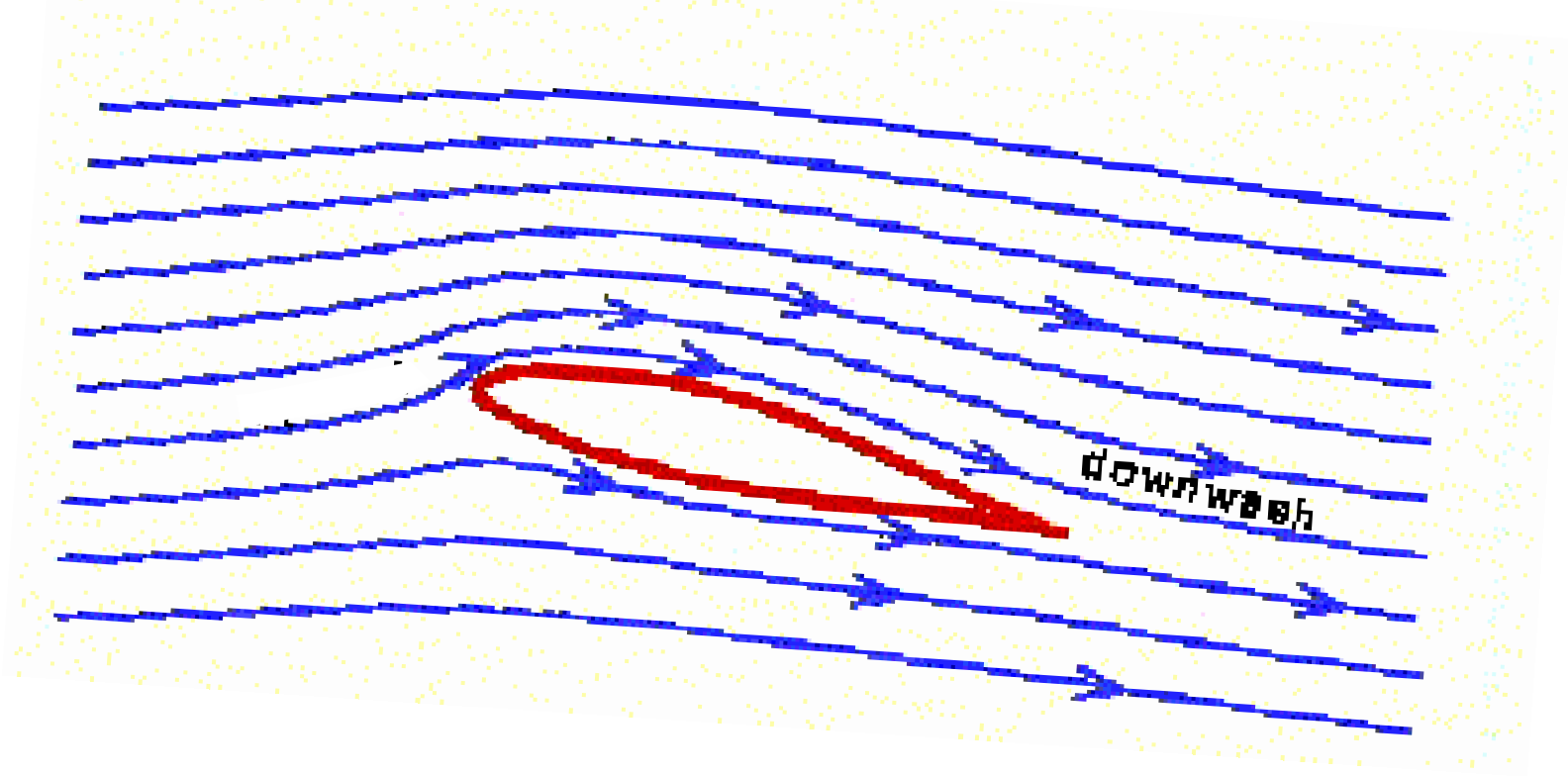
- Flow will tend to depart from trailing edge
  - If it didn't go straight off trailing edge, pressure would drop when going around sharp curve (something must make the flow turn!) – this "sucks" flow into the trailing edge





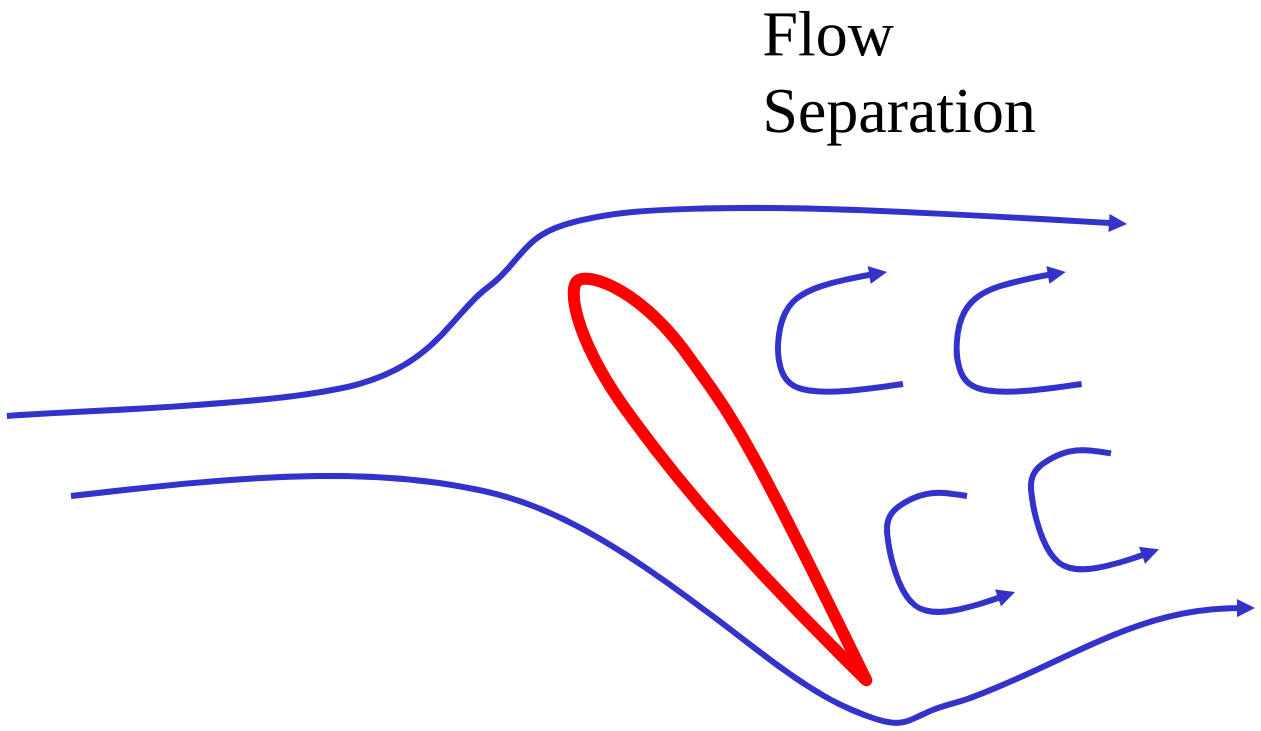
Generation of Lift

- Adjust angle of trailing edge to direct flow
- Deflecting air downward generates lift
- By pushing air down, airplane stays up



Take this too far, get a Stall

- Eventually the flow doesn't make the turn, and the flow separates – creating lots of drag, loss of lift, and turbulence



How Airplanes Fly

1. Lift generated to oppose Weight
   - Example: Wing with trailing edge
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2. **Thrust generated to oppose Drag**

Thrust Generated to Oppose Drag

- For propellers and jets:
  - Push air out the back of the airplane

How Airplanes Fly

1. Lift generated to oppose Weight
   - Example: Wing with trailing edge
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2. Thrust generated to oppose Drag
3. **Structure is strong/stiff enough**
   - **Stays together under maximum forces**
   - **Deflections low enough that aerodynamic forces still OK**

Structure Stiff/Strong Enough (without being too heavy!)

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC88-0059-002 Date: March 7, 1988 Photo by: Beasley

How Airplanes Fly

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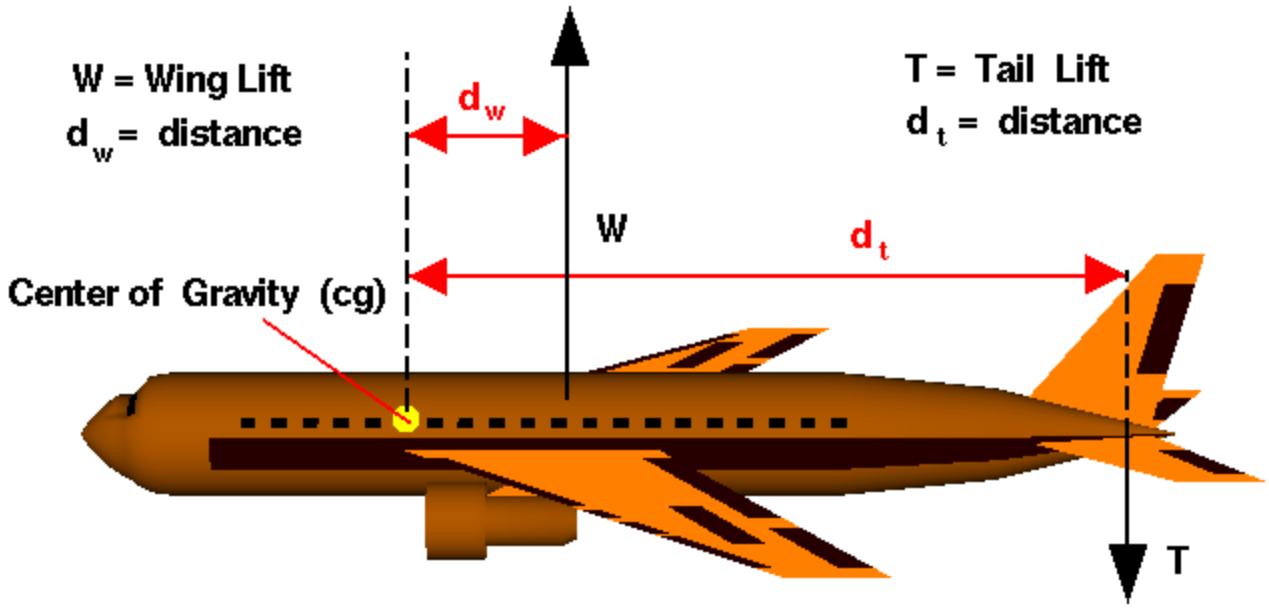
4. **Can be trimmed (moments brought to zero) i.e. “balanced”**

Must be Trimmed or “Balanced”

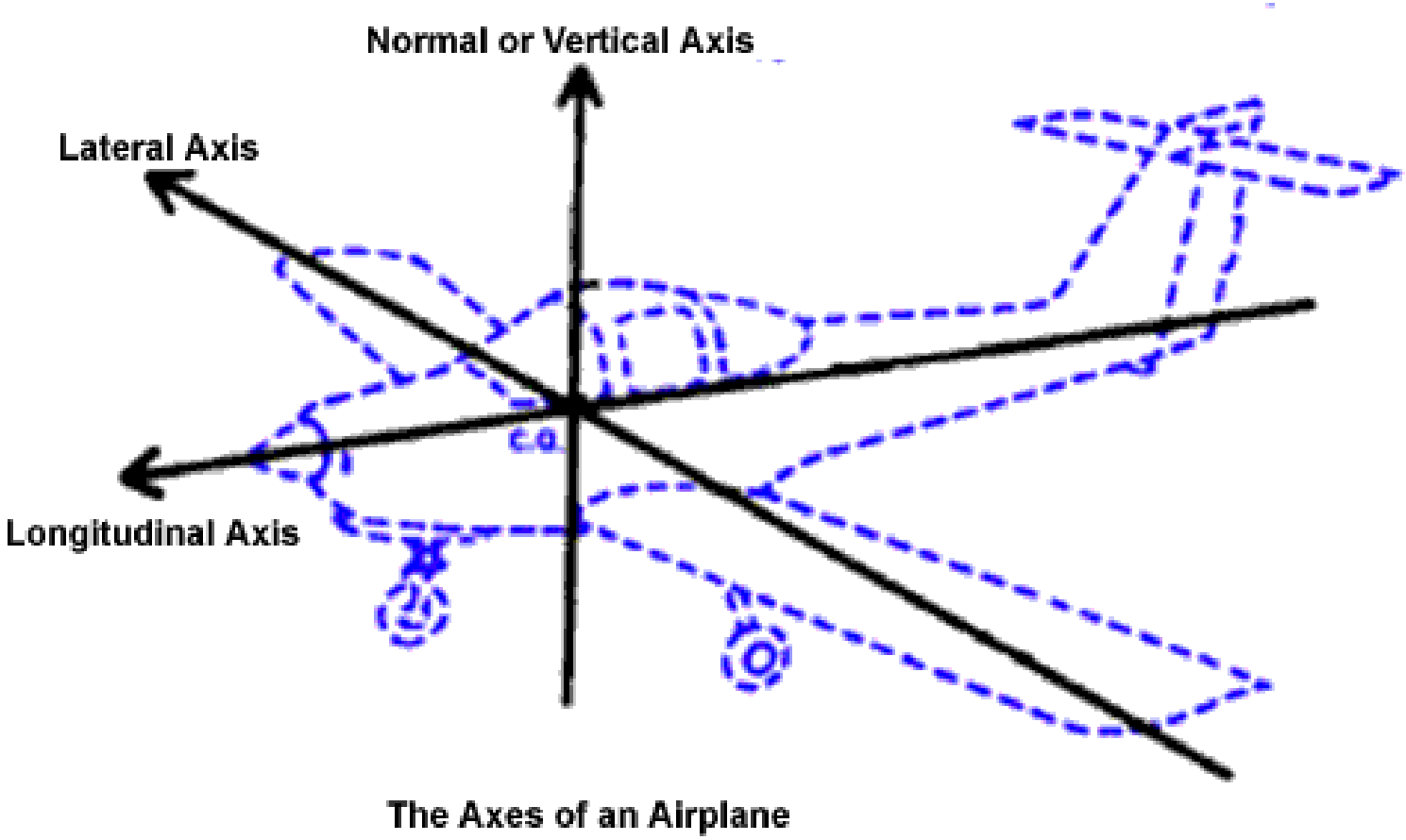


For trimmed flight, no rotation about cg.

Equation: $(\overleftarrow{W} \times \overleftarrow{d_w}) + (\overleftarrow{T} \times \overleftarrow{d_t}) = 0$

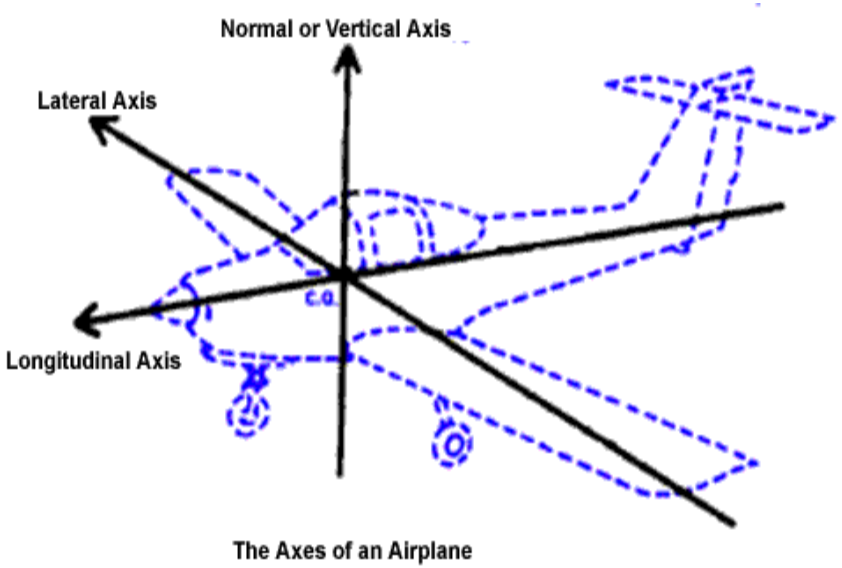
(Lift of Wing x distance from cg) + (Lift of Tail x distance from cg) = 0

Axes of an Airplane



The Axes of an Airplane

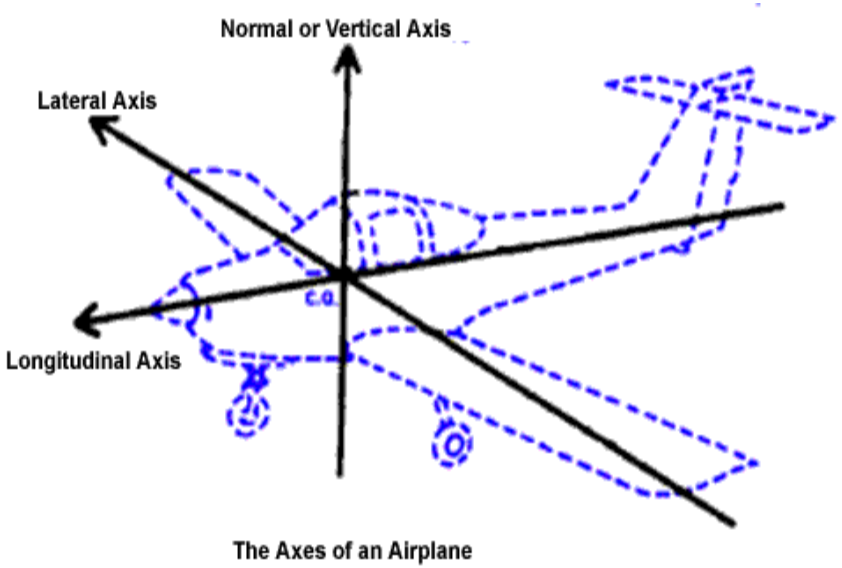
Roll



The Axes of an Airplane

- The **longitudinal axis** extends lengthwise through the fuselage from the nose to the tail.
- Movement of the airplane around the longitudinal axis is known as **roll** and is controlled by movement of the ailerons.

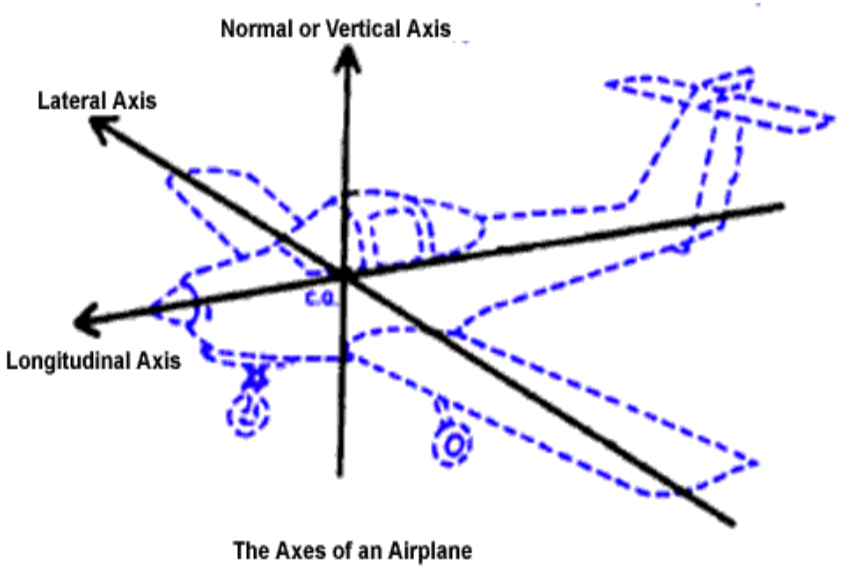
Pitch



The Axes of an Airplane

- The **lateral axis** extends crosswise from wingtip to wing tip.
- Movement of the airplane around the lateral axis is known as **pitch.**
- Pitch is controlled by movement of the elevators.

Yaw



The Axes of an Airplane

- The **vertical or normal axis** passes vertically through the center of gravity.
- Movement of the airplane around the vertical axis is yaw.
- Yaw is controlled by movement of the rudder.

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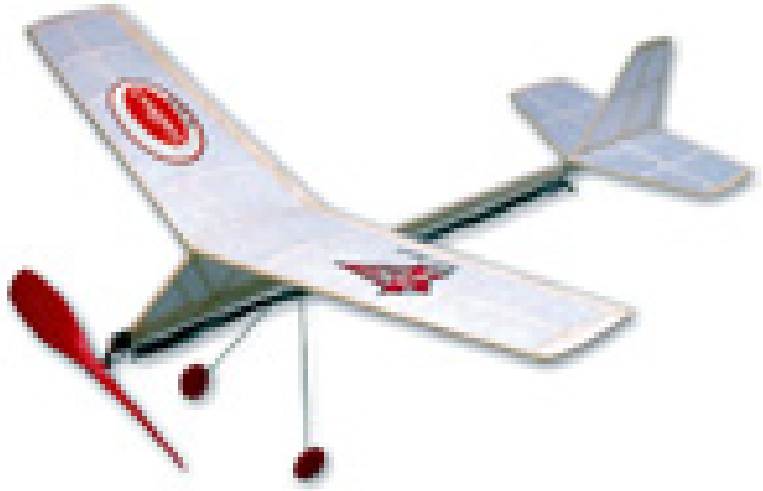
   - Deflections low enough that aerodynamic forces still OK
4. Can be trimmed (moments brought to zero)
   i.e. “balanced”
5. **Either stable OR controllable**

Must be Stable OR Controllable (Both not required)



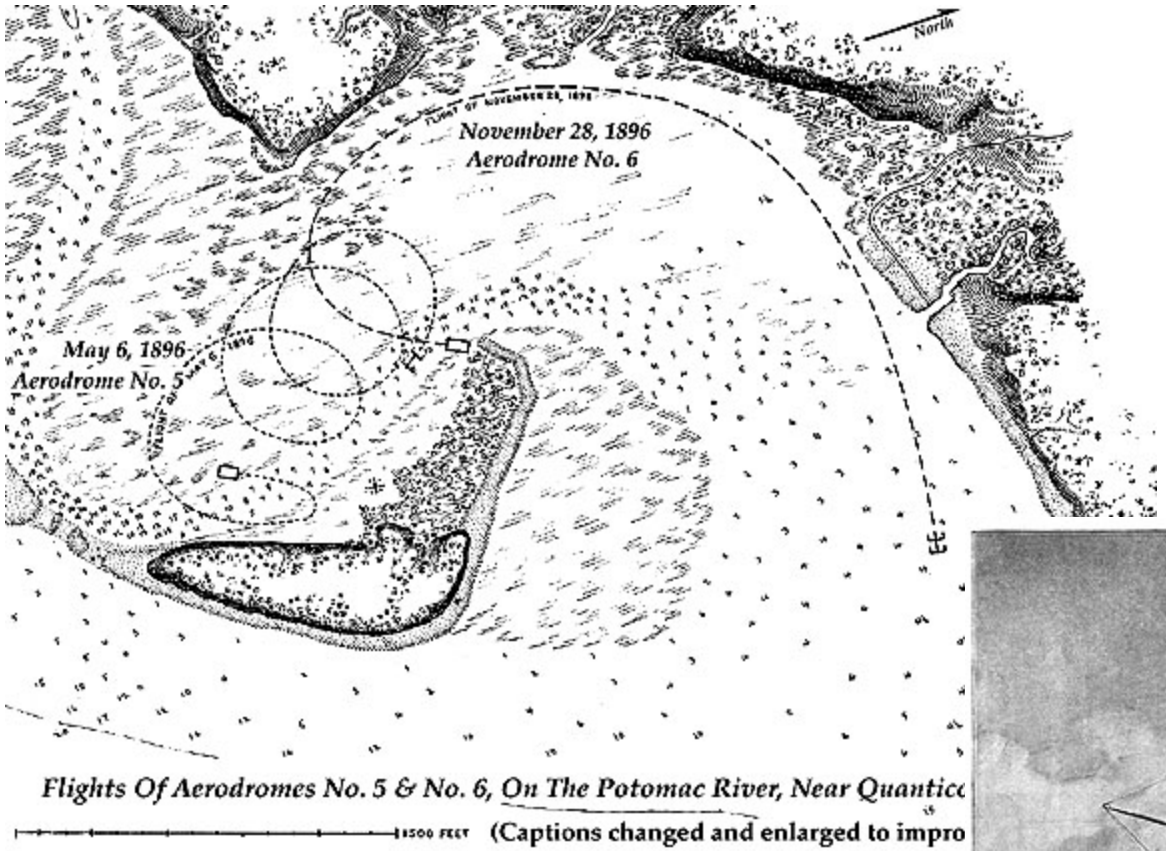
Stable

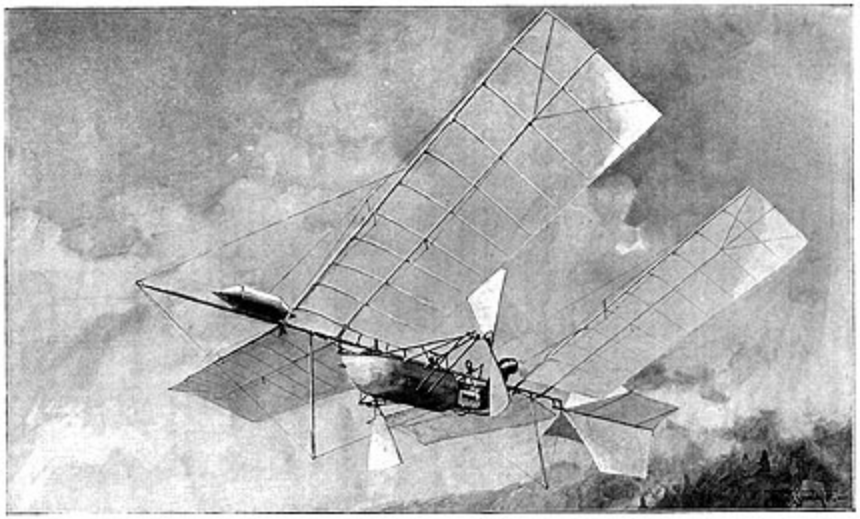
If perturbed from equilibrium flight, will return to equilibrium

Controllable

Pilot can change vehicle direction at will (also useful for trimming)

First Successful Airplane Flight





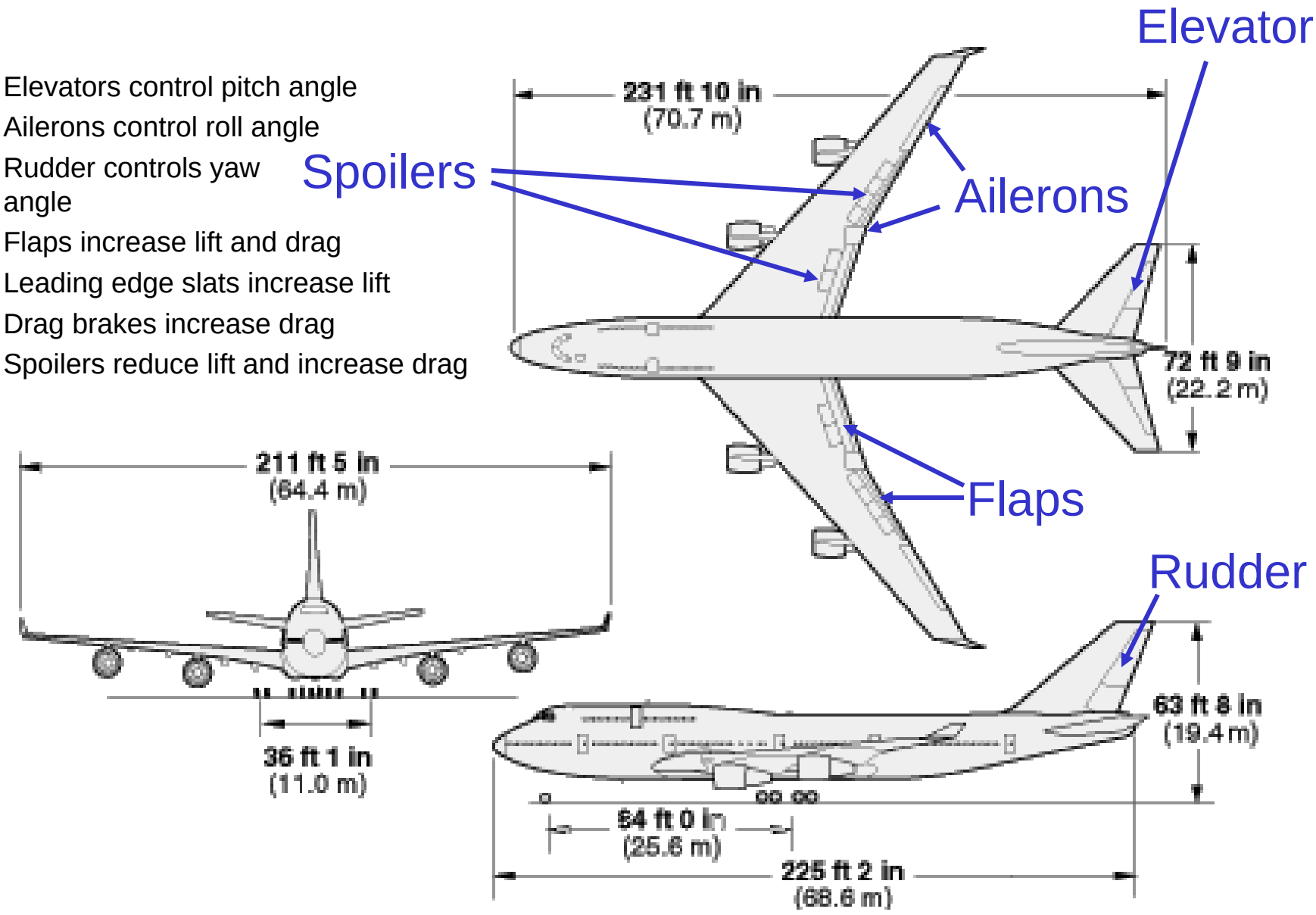
Samuel P. Langley
Steam power, 30 lbs., 25 mph
The first successful flights in 1896

First Human-Carrying Airplane

The first successful flight on December 17, 1903
Unstable, highly controllable (think windsurfing)

Aerodynamic Controls

- Elevators control pitch angle
- Ailerons control roll angle
- Rudder controls yaw angle
- Flaps increase lift and drag
- Leading edge slats increase lift
- Drag brakes increase drag
- Spoilers reduce lift and increase drag



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Disciplines