

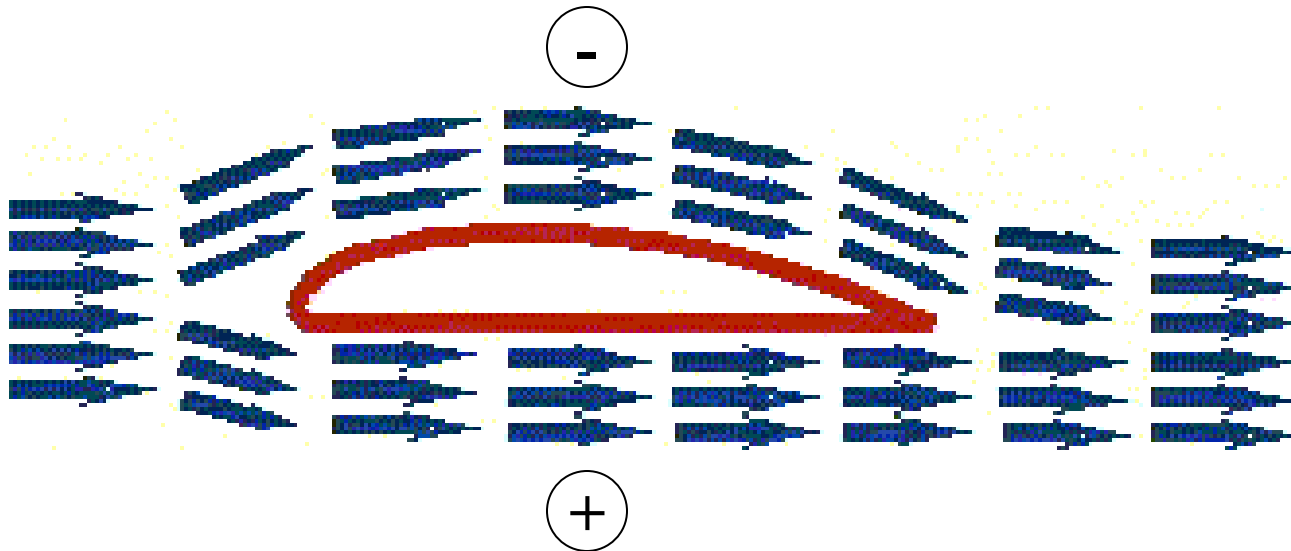


Some Airplane Basics

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
 - $\text{Pressure} + \frac{1}{2} * \text{Density} * \text{Velocity}^2 = \text{Constant}$ (“Static Pressure”)



We Need Better

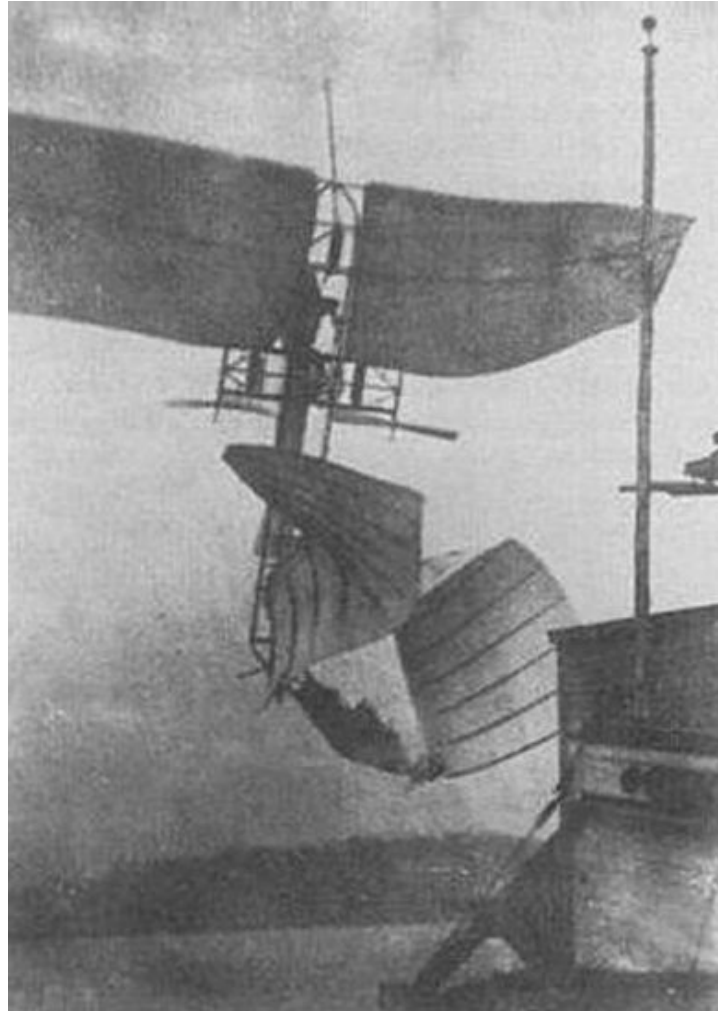
- How do airplanes without a wing of this shape fly?



- Why can airplanes fly upside down?

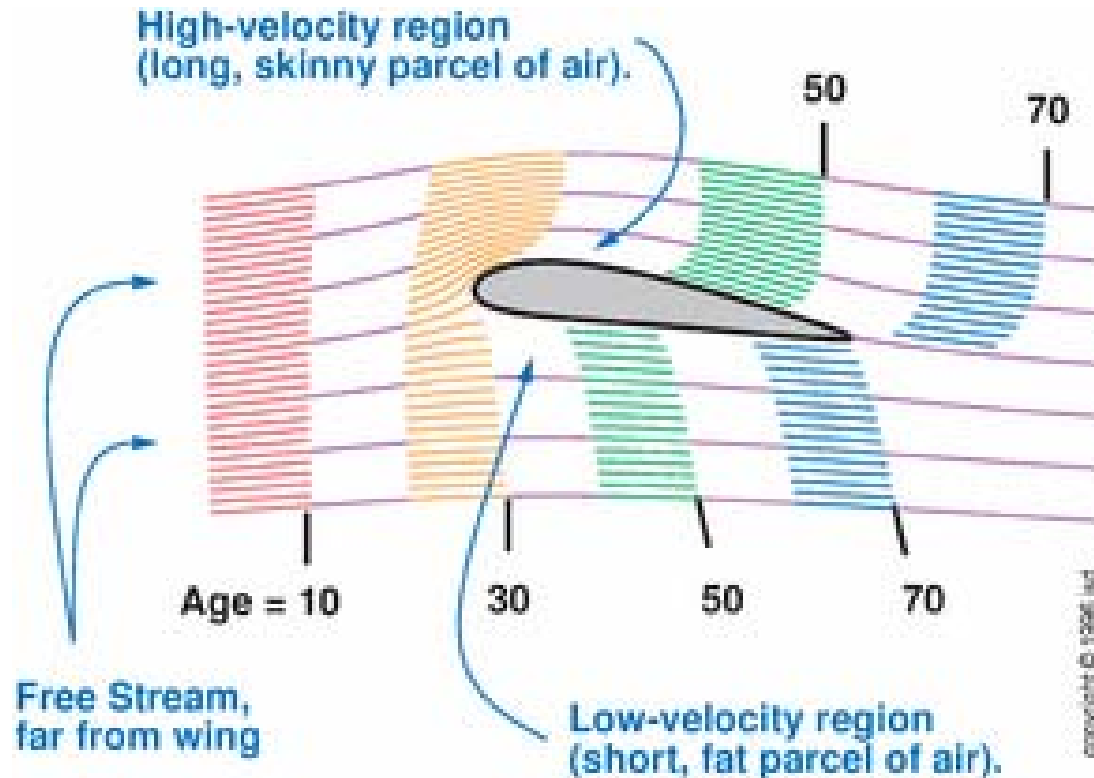
We Need Better

- 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

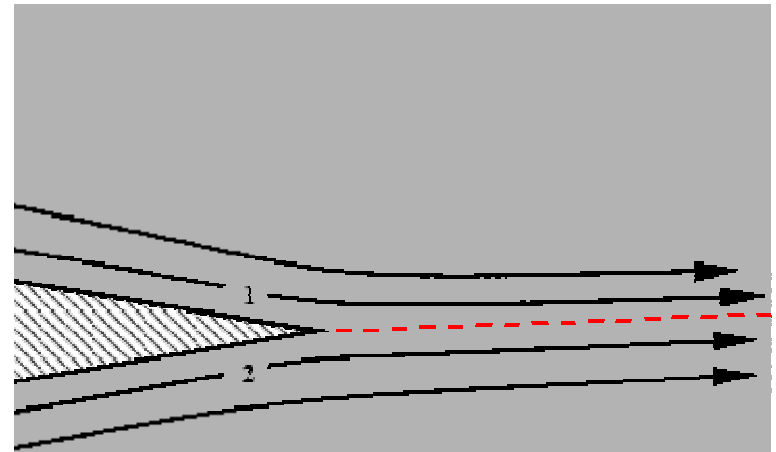
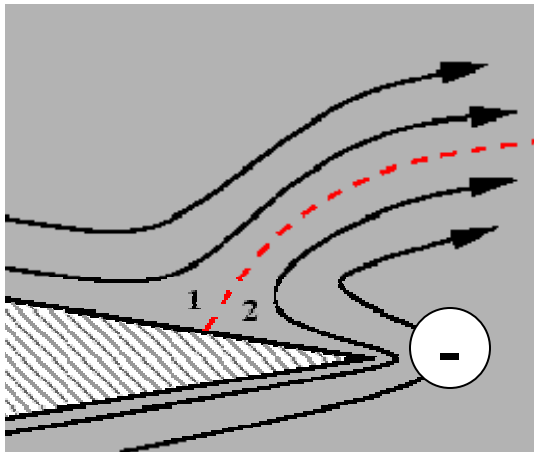
1. Lift generated to oppose Weight
 - Example: Wing with trailing edge
 - Weight kept to a minimum

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

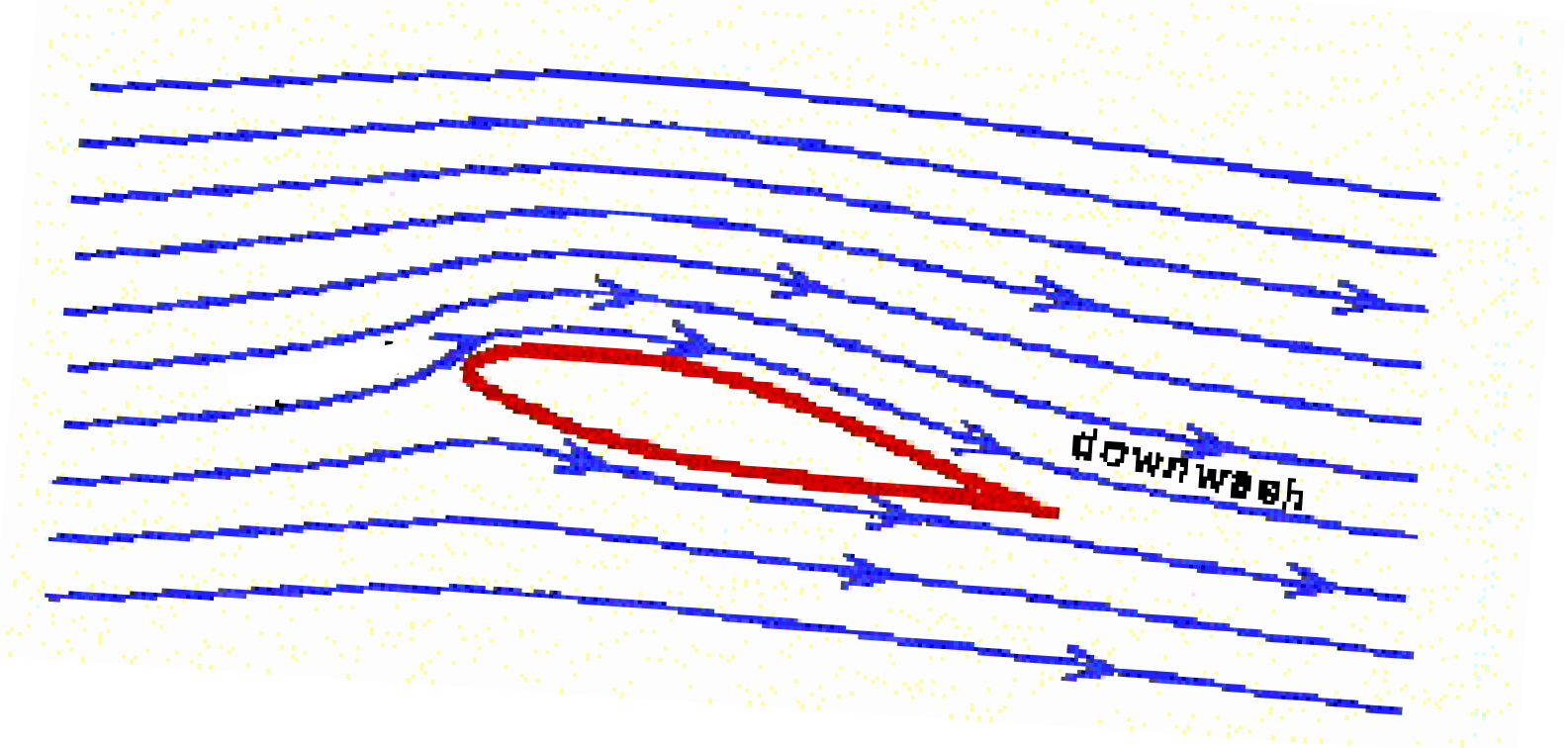
Kutta Condition

- 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



How Airplanes Fly

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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

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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!)



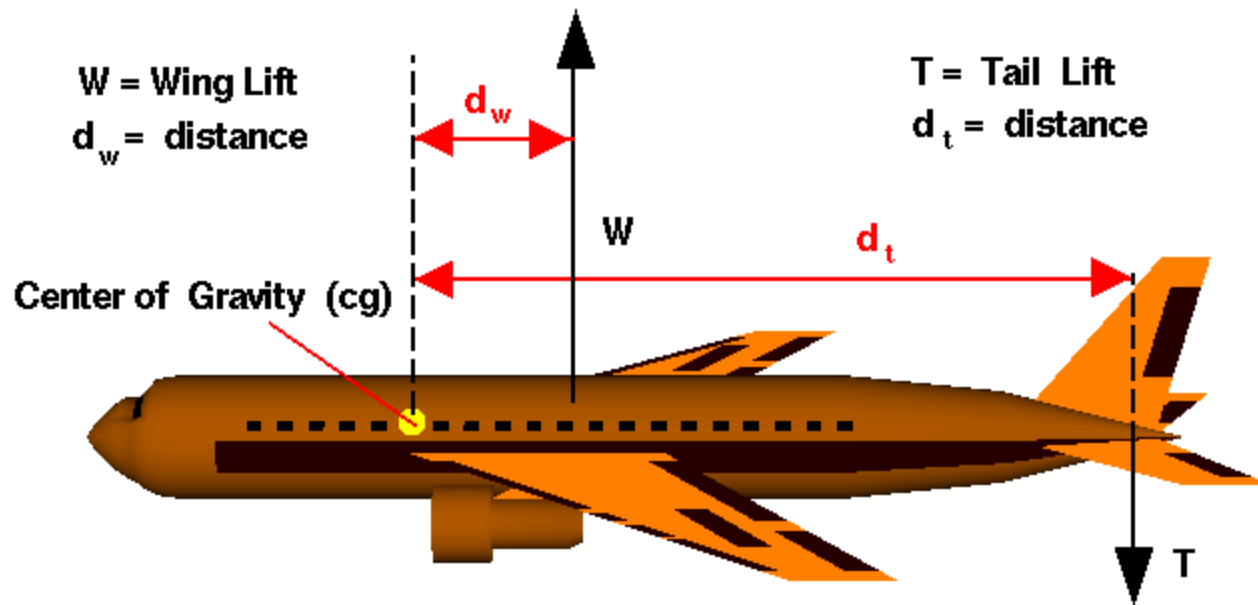
NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/gallery/photo/index.html>
NASA Photo: EC87-0014-8 Date: 1987

Daedalus Project's Light Eagle - Human powered aircraft

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

Must be Trimmed or “Balanced”

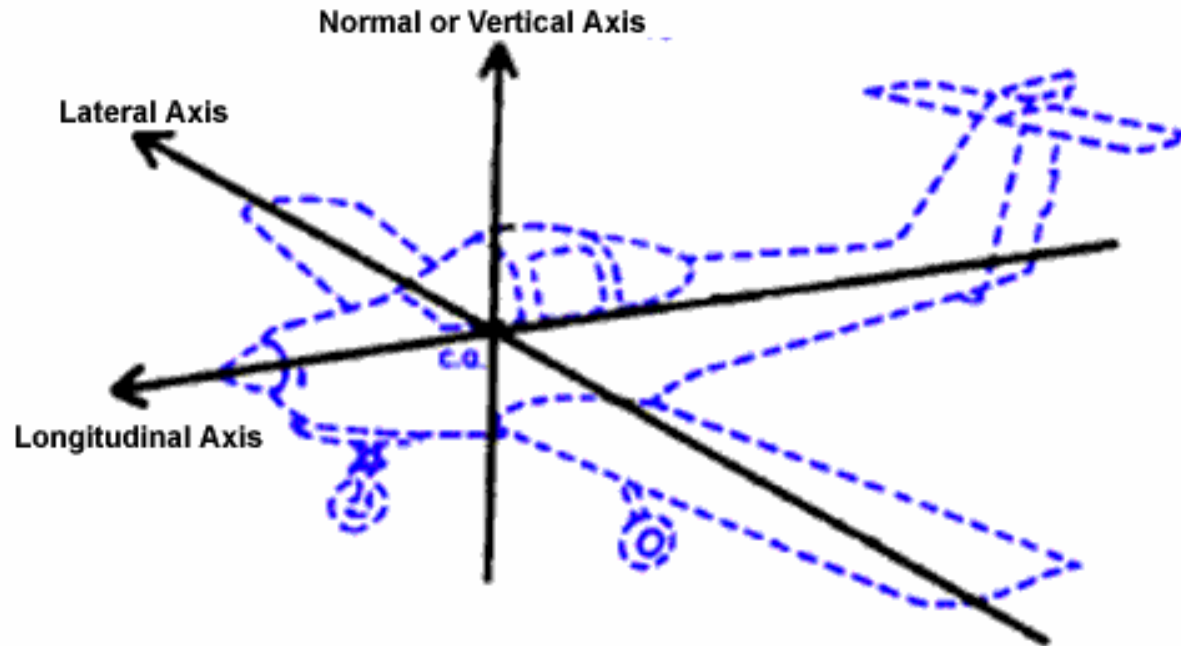


For trimmed flight, no rotation about cg.

$$\text{Equation: } (\overleftarrow{W} \times \overleftarrow{d}_w) + (\overleftarrow{T} \times \overleftarrow{d}_t) = 0$$

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

Axes of an Airplane

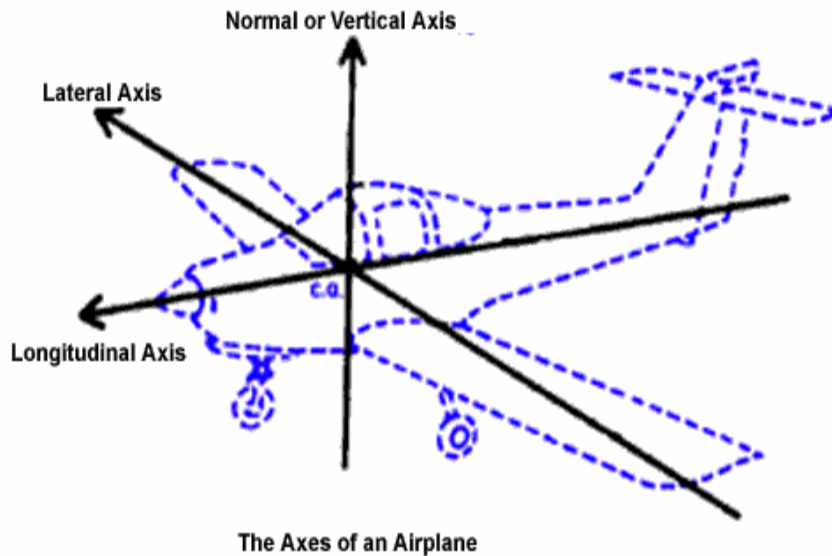


The Axes of an Airplane

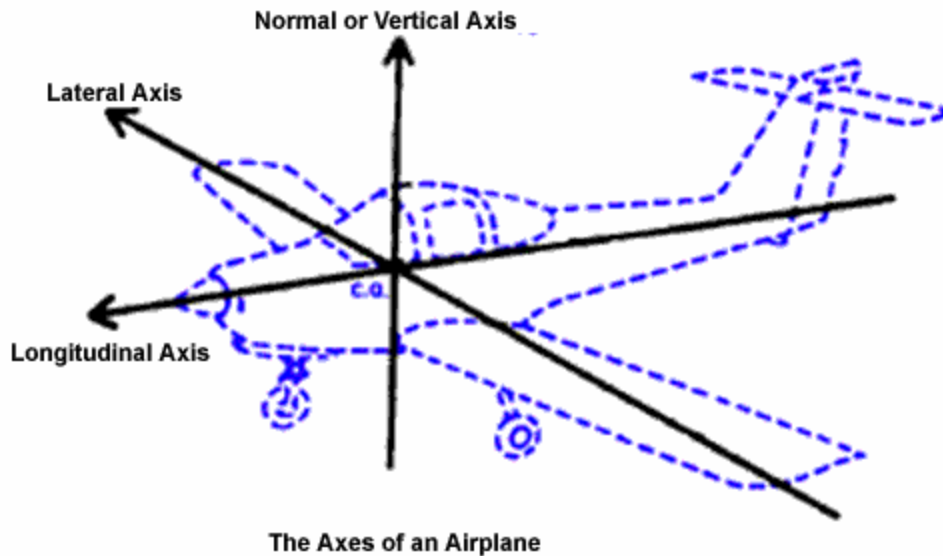
Roll

- The **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.

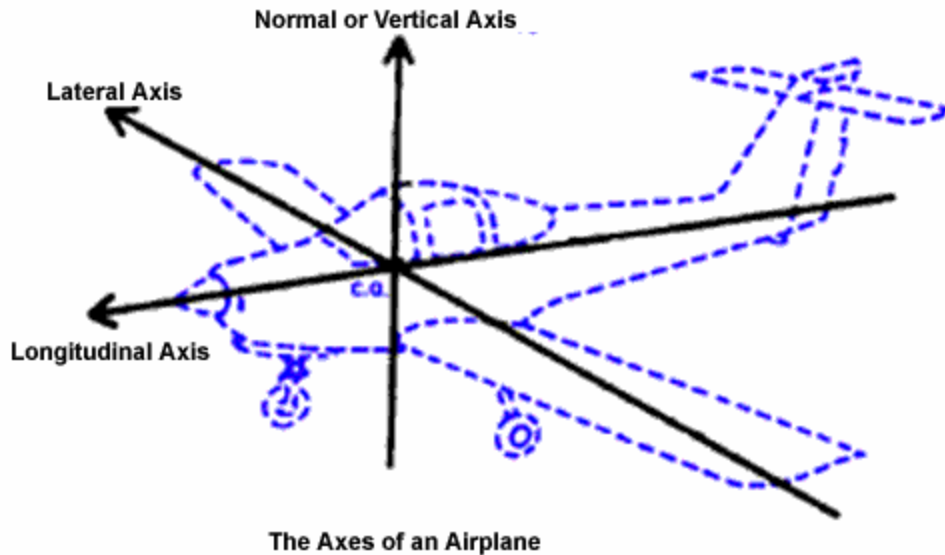


Pitch



- The **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 **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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5. Either stable OR controllable

Must be Stable OR Controllable (Both not required)



Stable

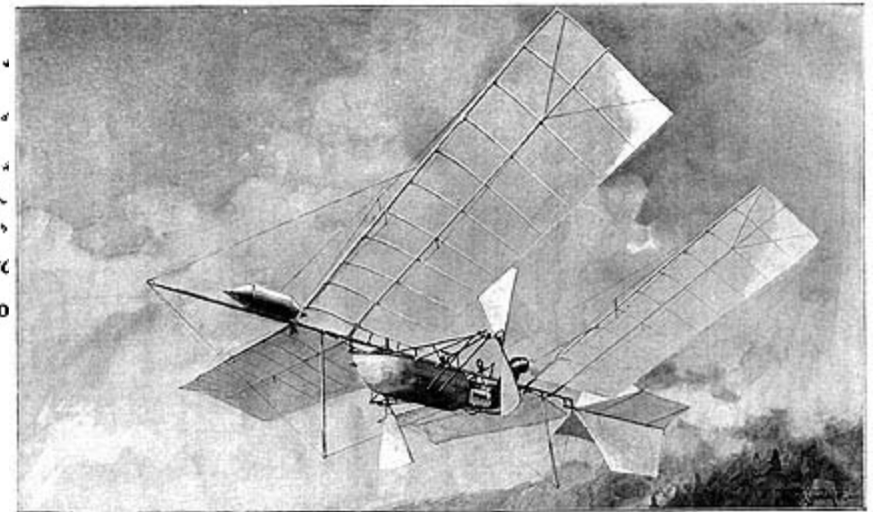
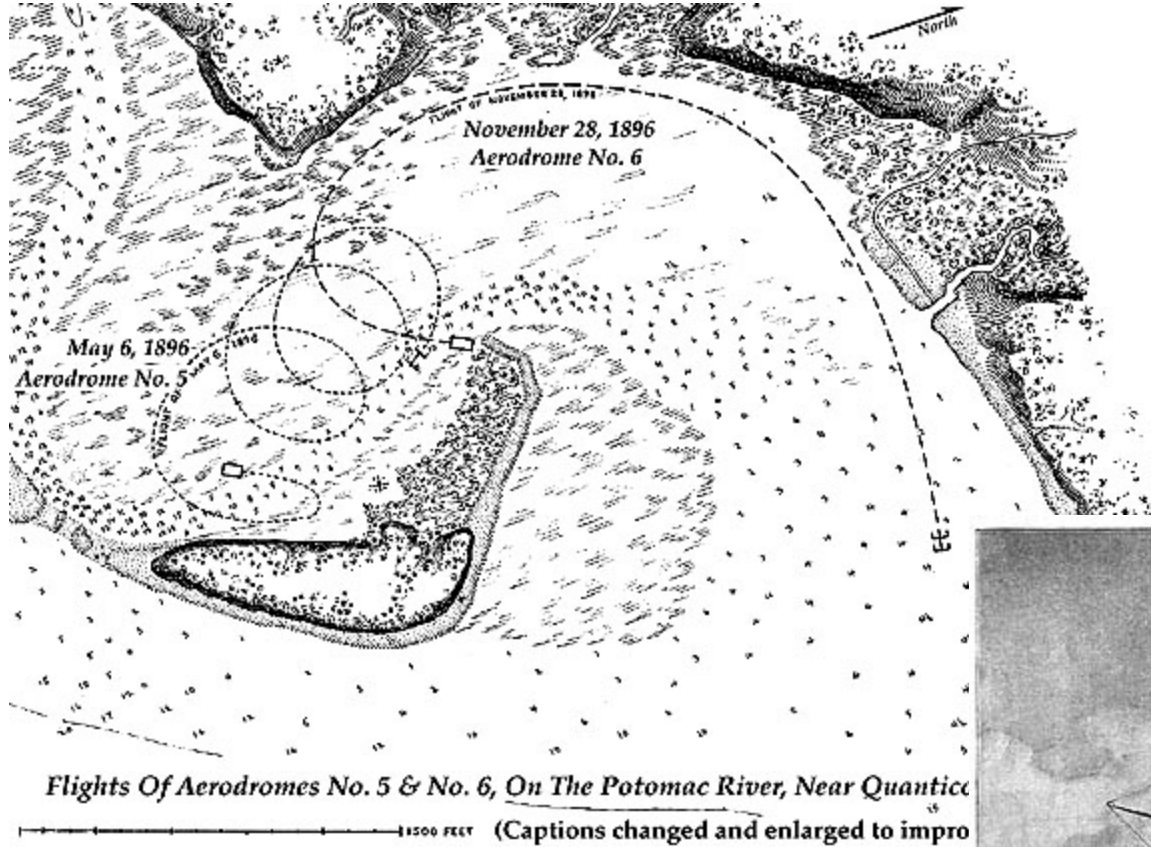
If perturbed from equilibrium flight, will return to equilibrium



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



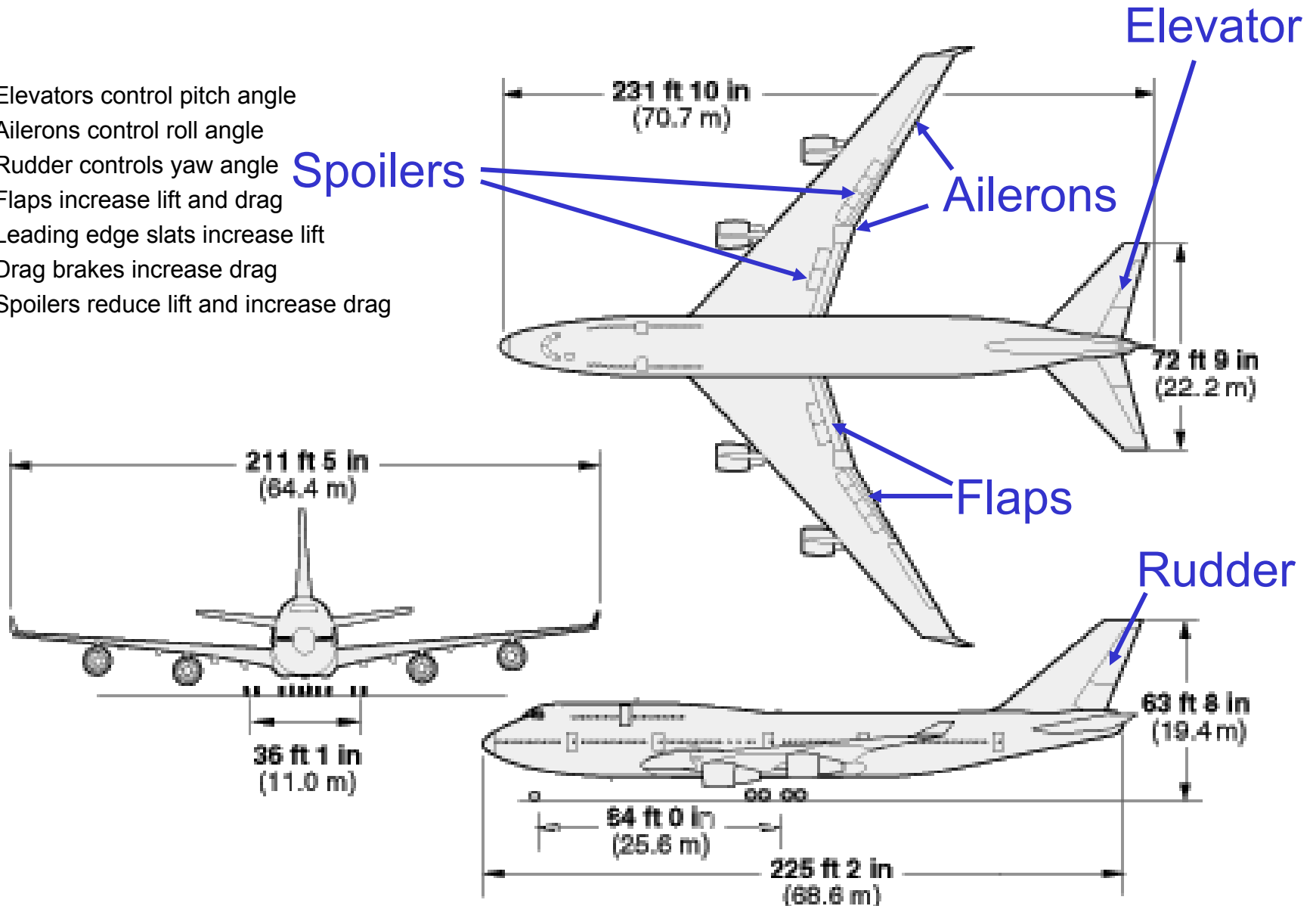
The first successful flight on December 17, 1903
Unstable, highly controllable (think windsailing)

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

Parts of an Airplane

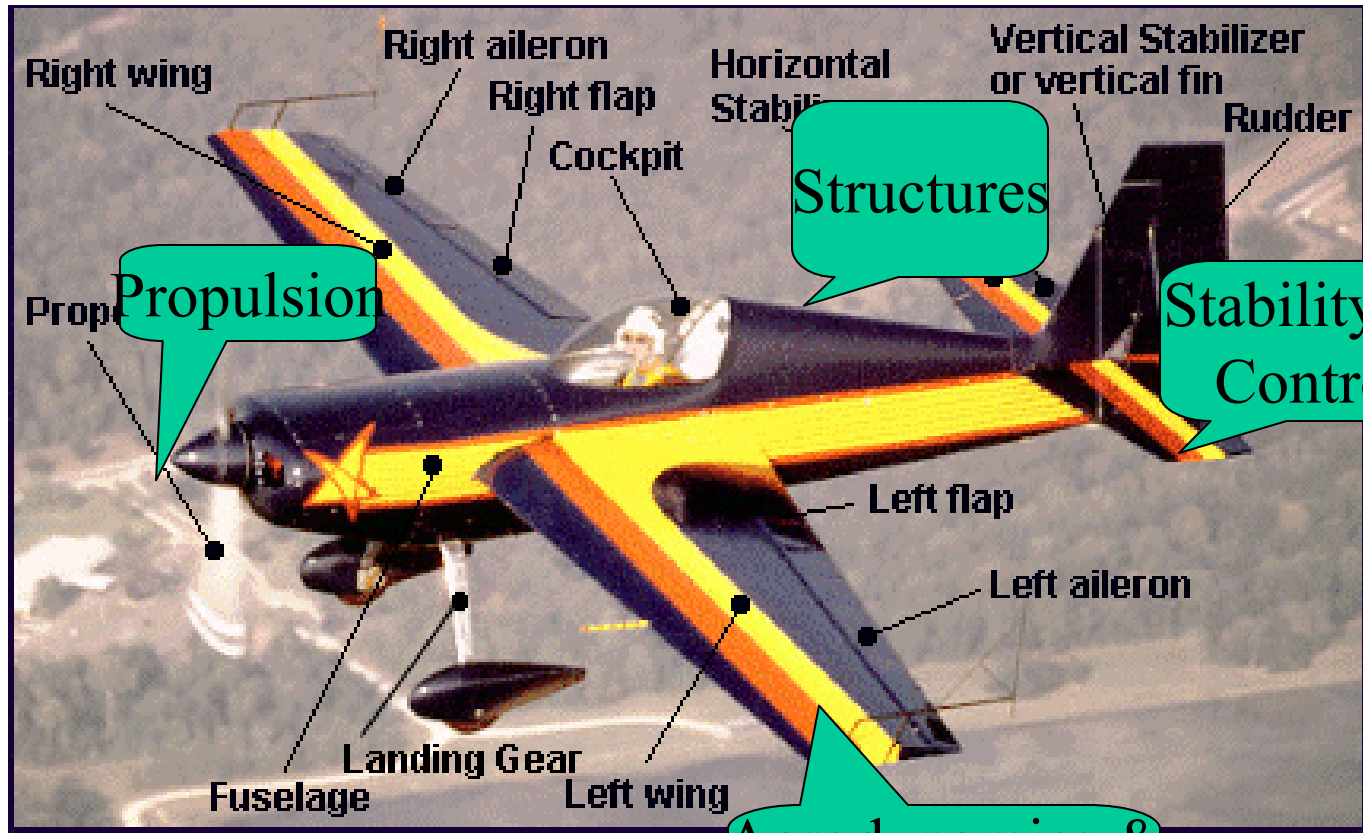
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Disciplines



Design

Propulsion

Structures

Stability &
Control

Aerodynamics &
Performance