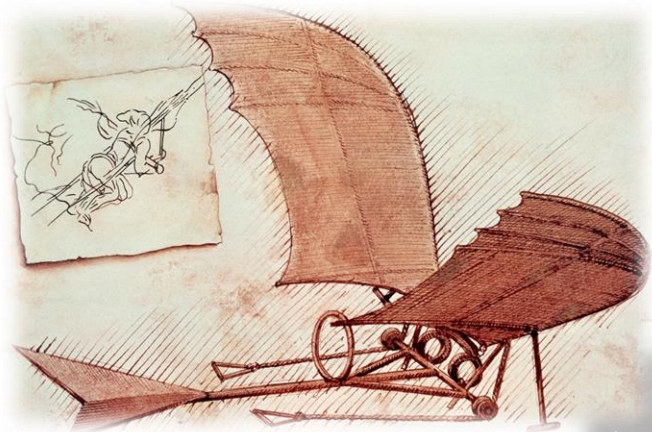
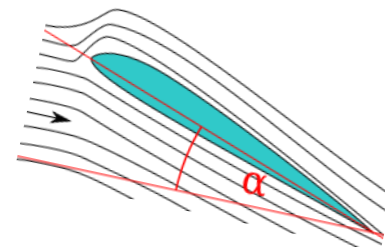
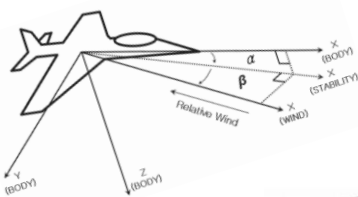
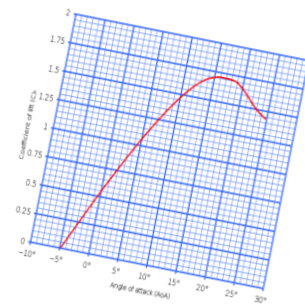
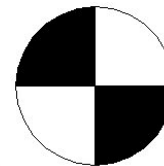


The Physics of Flight



$$f = ma$$



The Physics of Flight

Why and How Do Airplanes Fly?

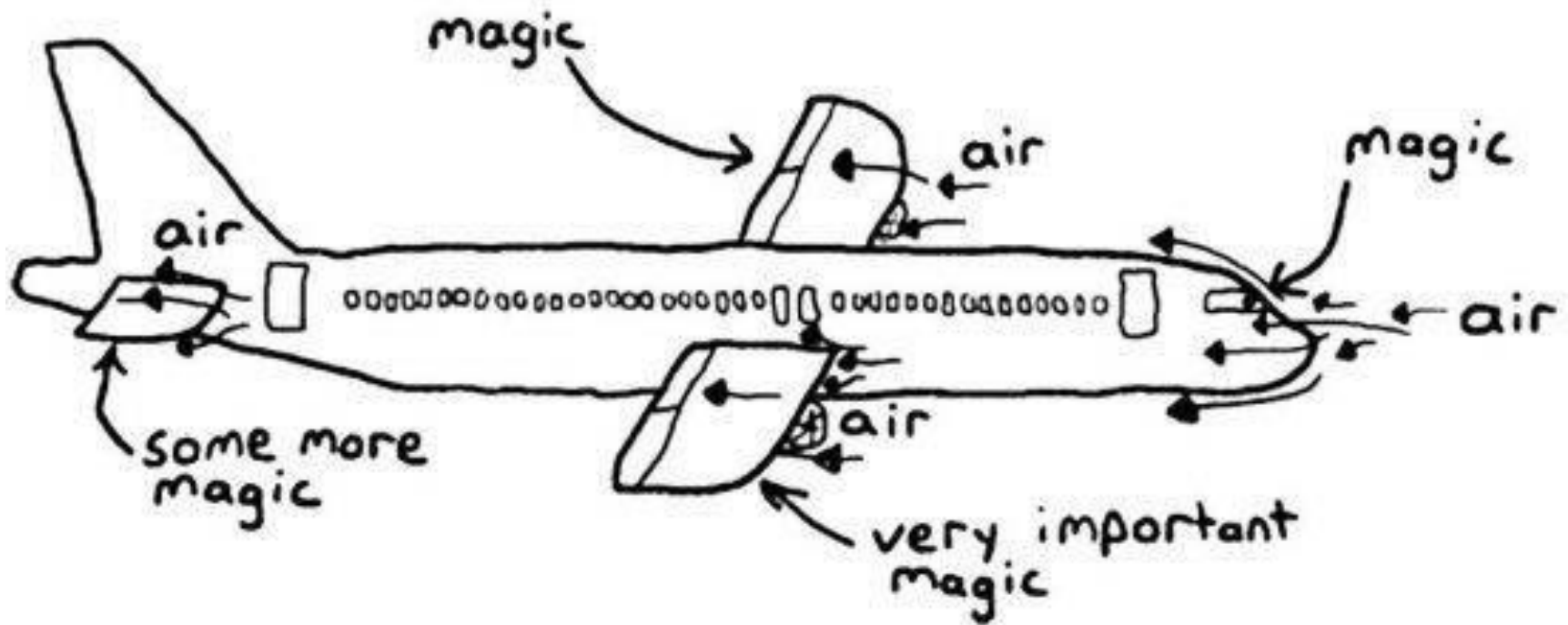
(adapted from Air Camp presentation)

What we'll talk about:

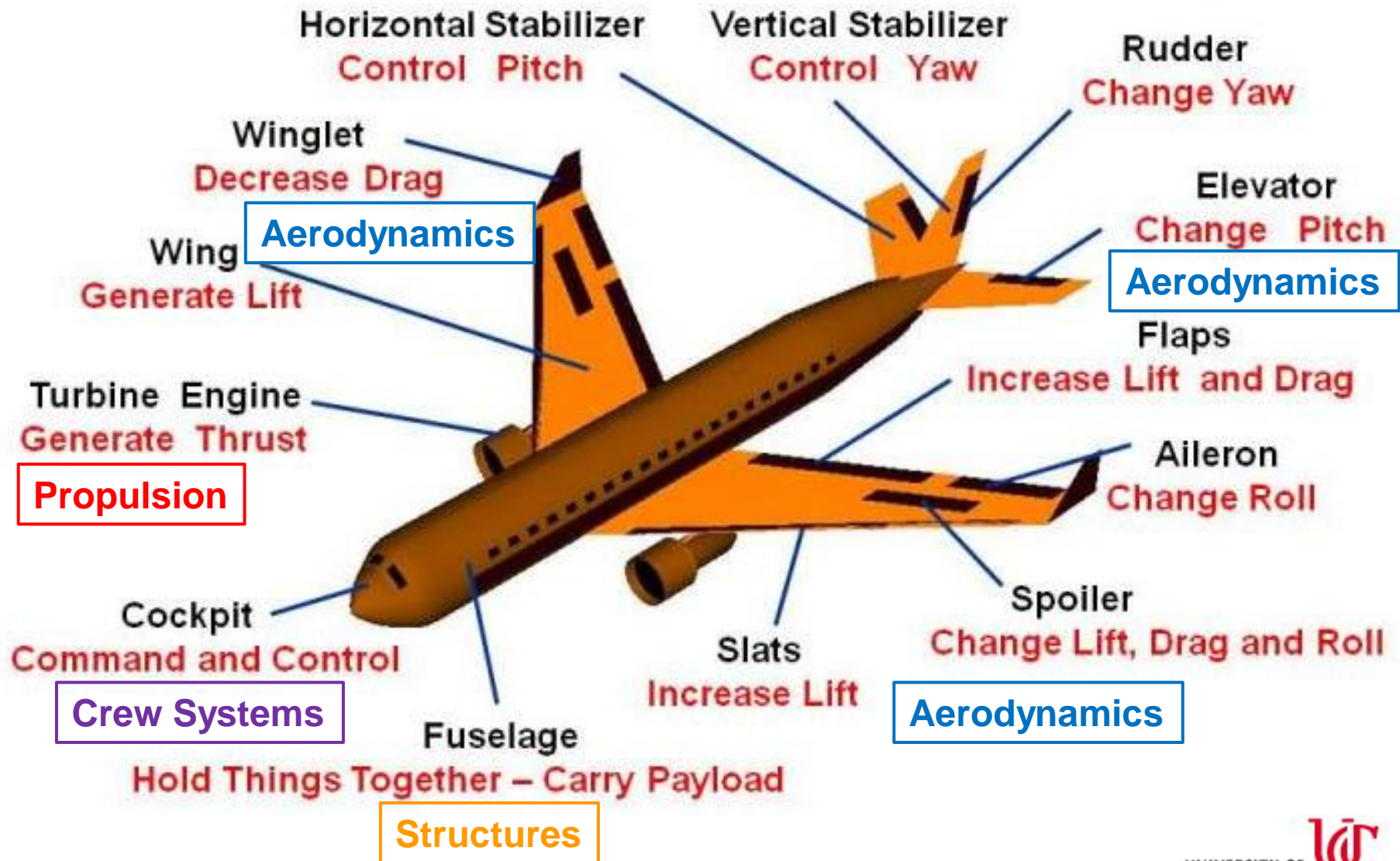
1. Physics
2. Forces
3. Stability
4. Control

Airplane Physics

how planes fly



Aircraft Performance

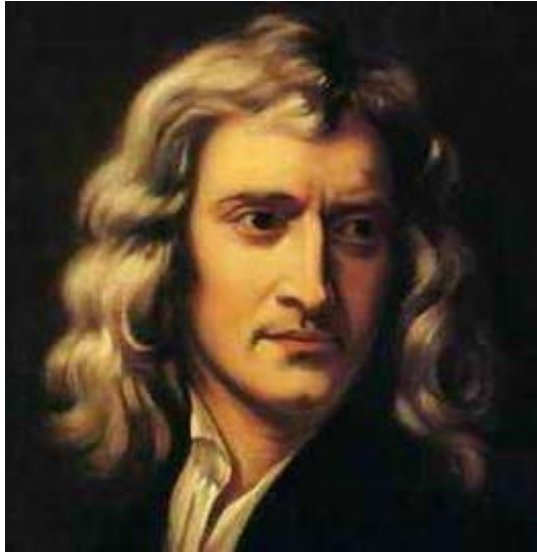


What is Physics?

It is the study of matter and its motion when acted upon by external forces, and the management of energy in explaining why and how an airplane flies

Newton's Laws of Motion

Sir Isaac Newton



1642 - 1726

I. A moving object will stay in motion unless you apply an external force to it.

II. Force = Mass x Acceleration

III. For every action there is an equal and opposite reaction.

What forces help an airplane fly?



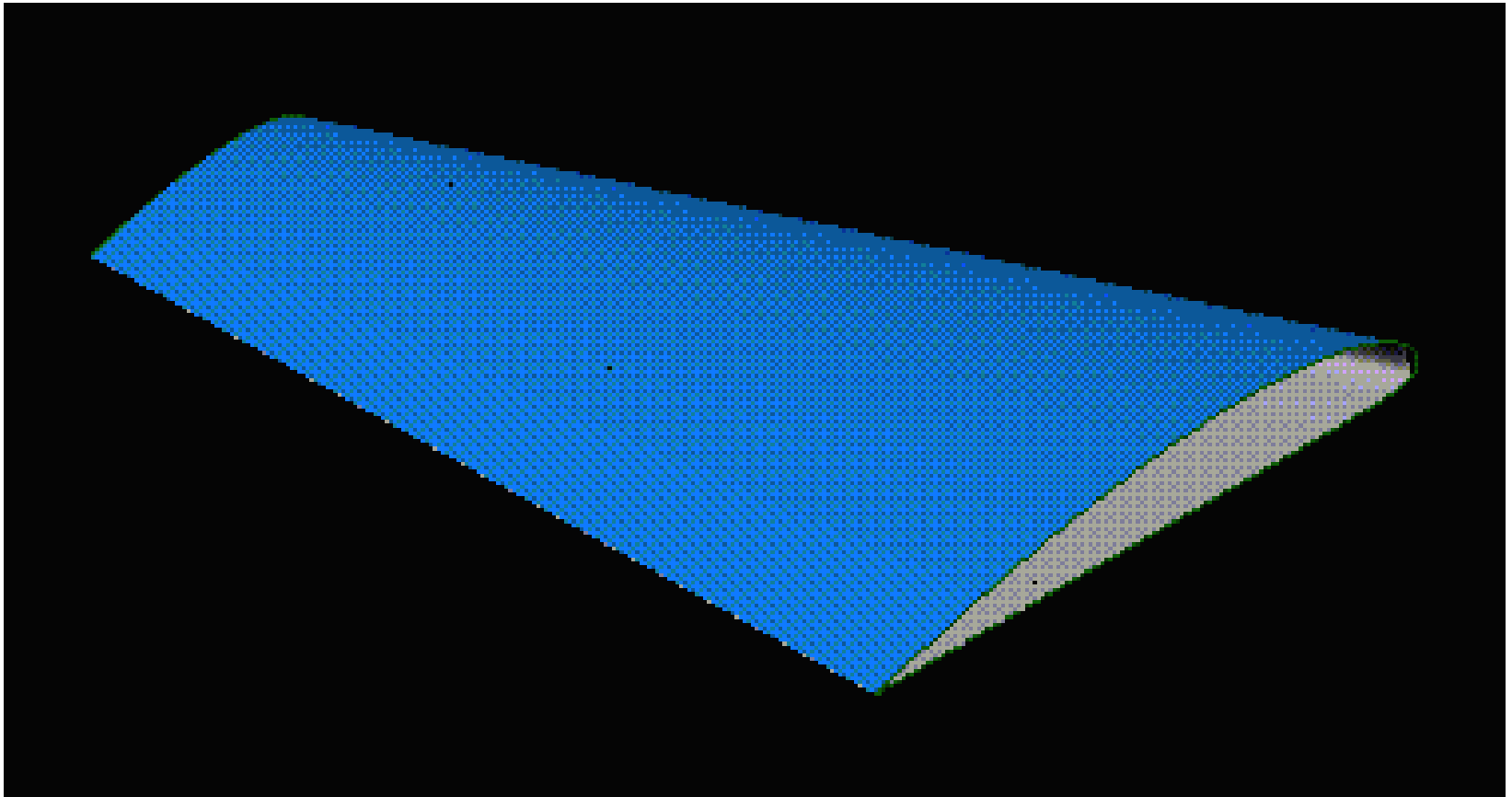
What forces don't help an airplane fly?



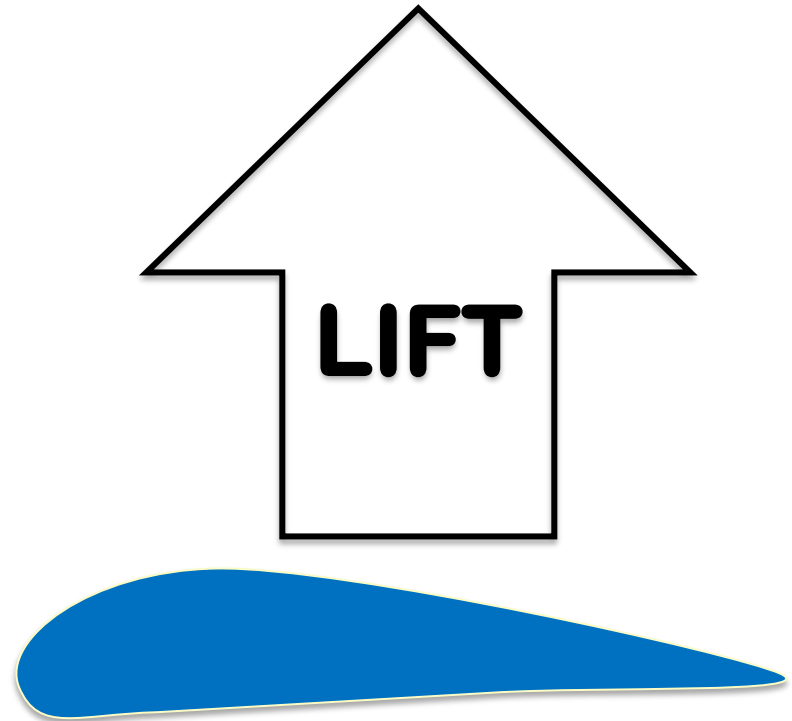
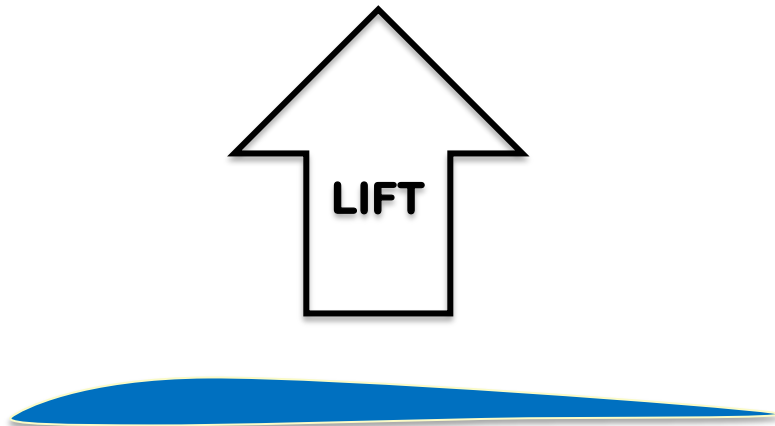
The “Four Forces of Flight”



Creating Lift



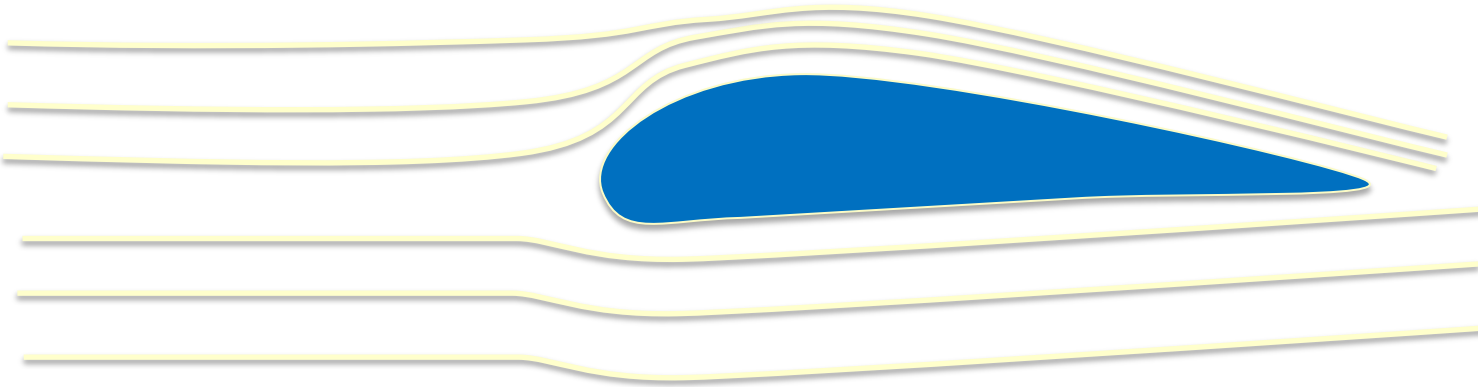
Creating Lift



Why does this happen?

Creating Lift

1. What is special about the shape?



2. What are the lines called?

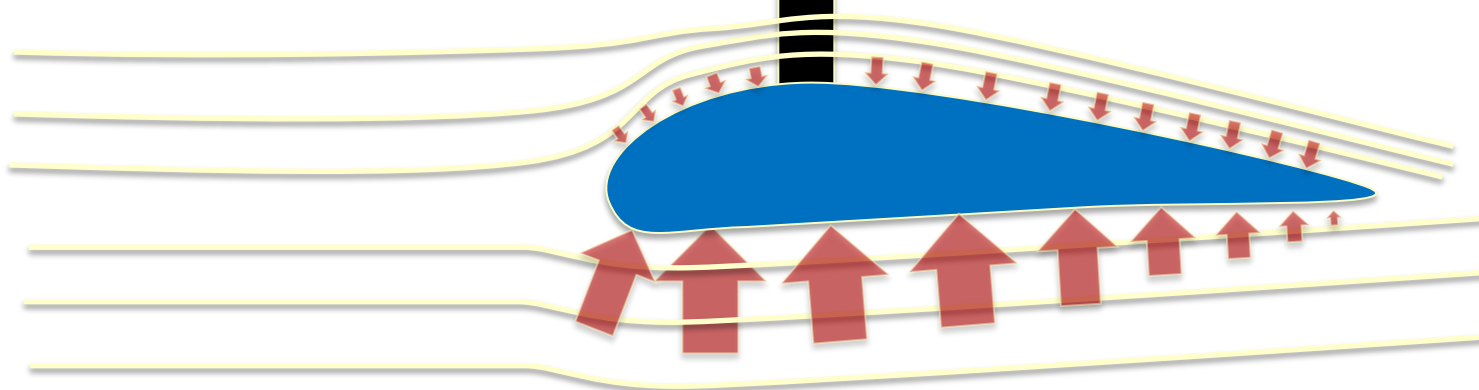
3. What can they tell us?

Creating Lift

Lift!

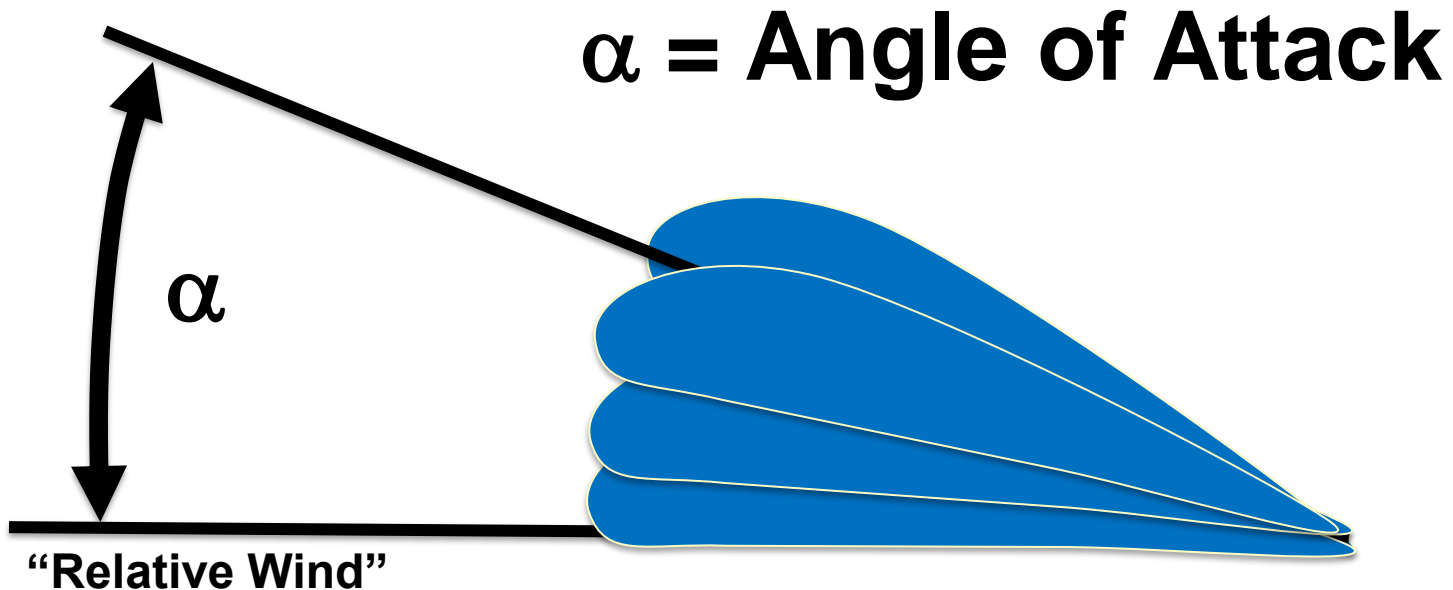


1. Speed of streamlines across the top? ***FASTER***
2. What happens to pressure? ***LOWER!***



3. Speed of streamlines across the bottom? ***SLOWER***
4. What happens to pressure? ***HIGHER!***

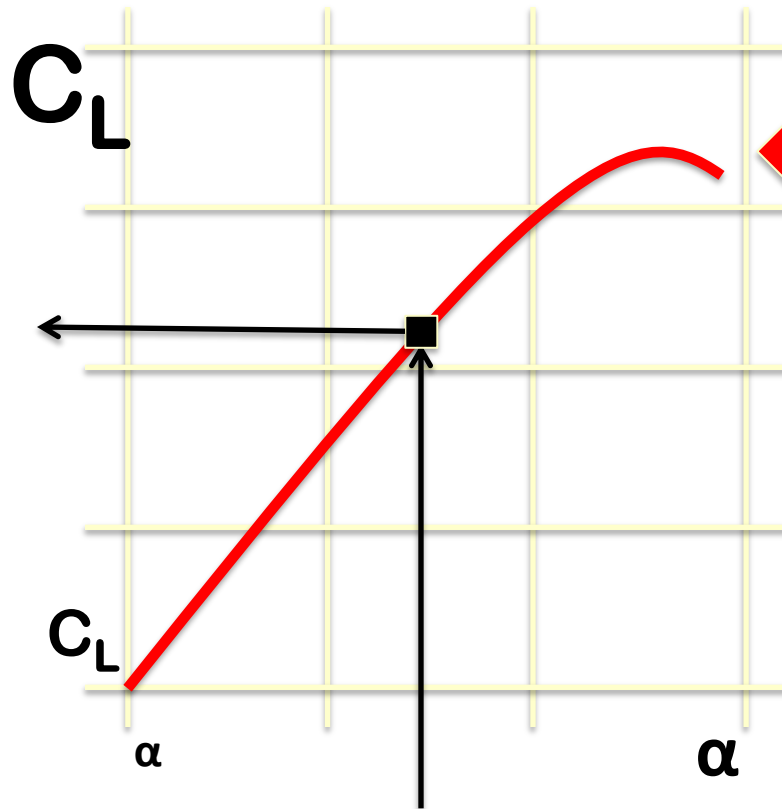
Creating Lift



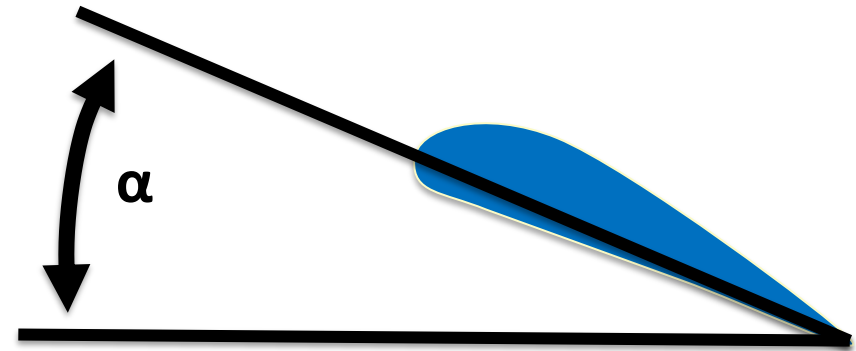
The “Lift Equation”:

$$\text{Lift} = \frac{\text{Lift Coefficient (C}_L\text{)} \times \text{Air Density} \times \text{Velocity Squared} \times \text{Wing Area}}{2}$$

Creating Lift



So...what happens here?



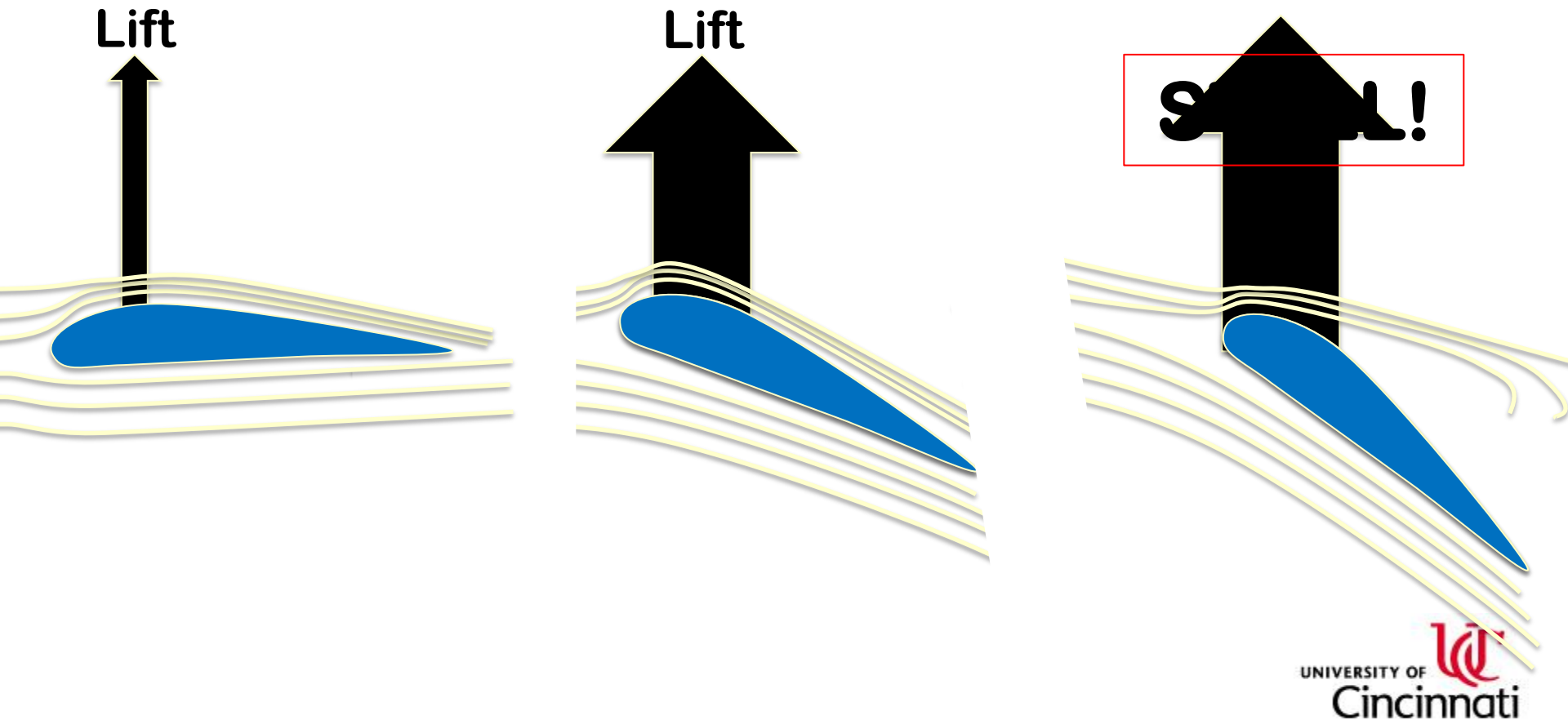
α = Angle of Attack
(AoA)

The “Lift Equation”:

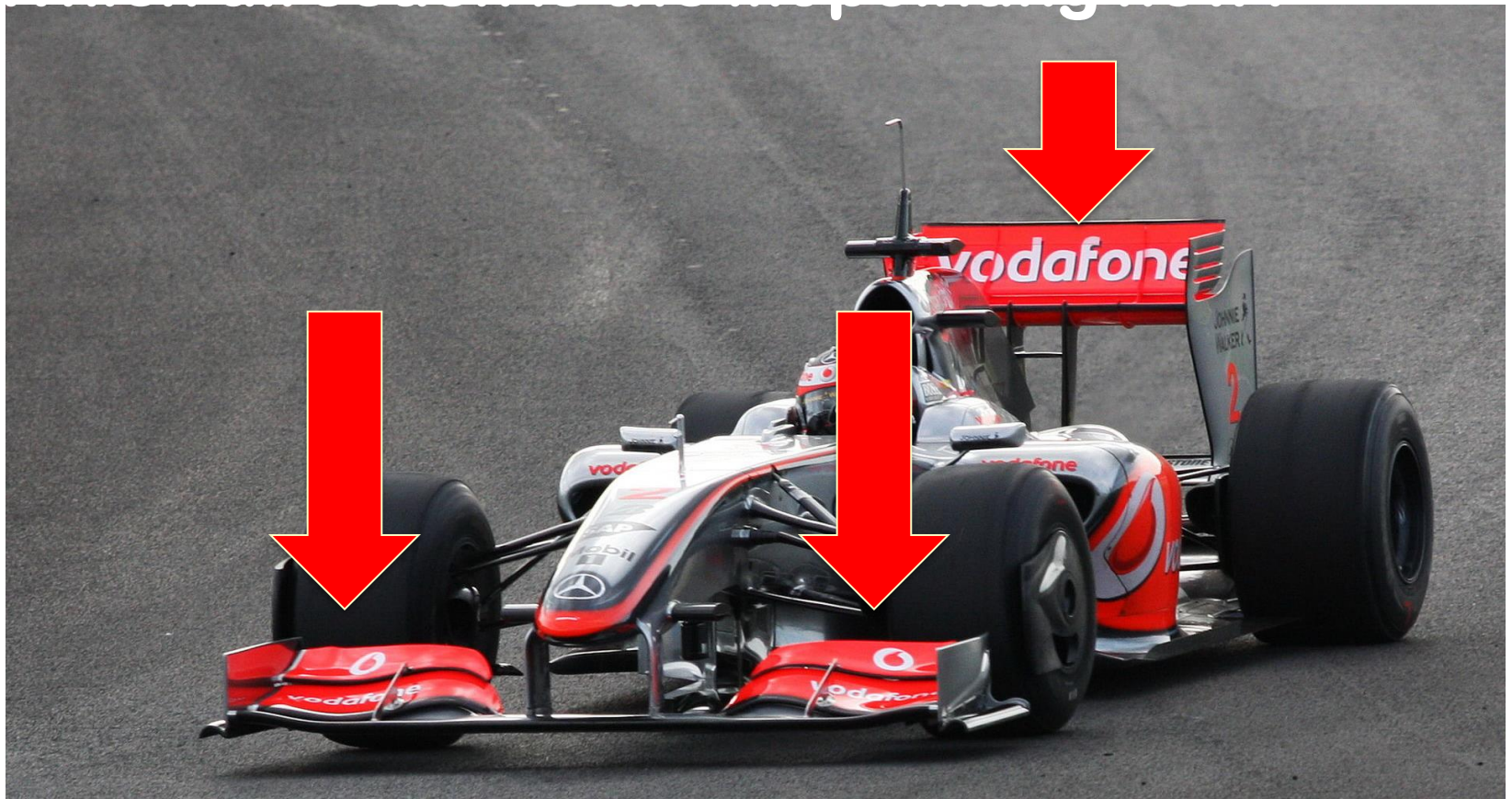
$$\text{Lift} = \frac{\text{Lift Coefficient } (C_L) \times \text{Air Density} \times \text{Velocity Squared} \times \text{Wing Area}}{2}$$

Creating Lift

Bigger α means MORE lift, right?



Creating Lift



Drag

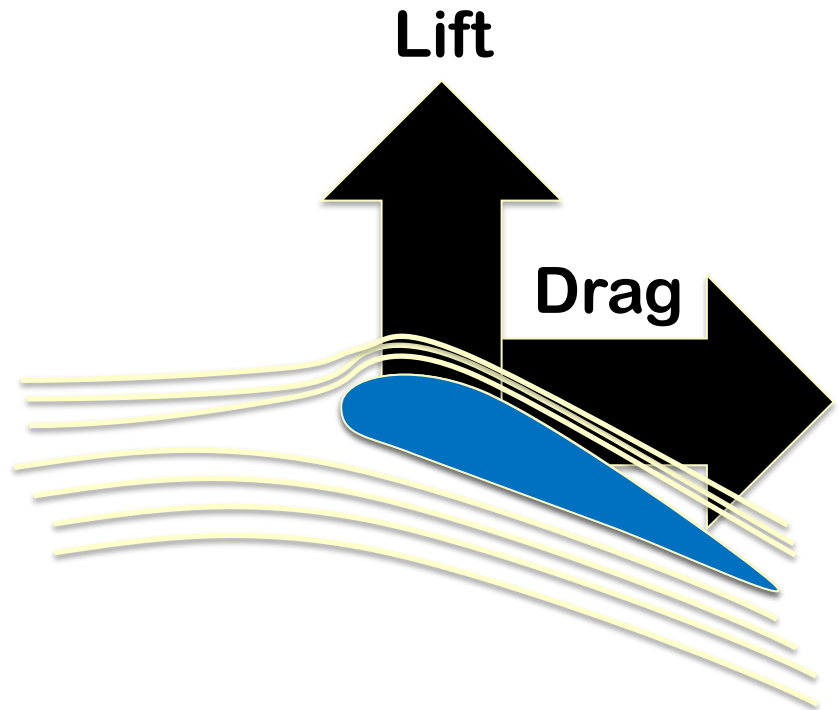
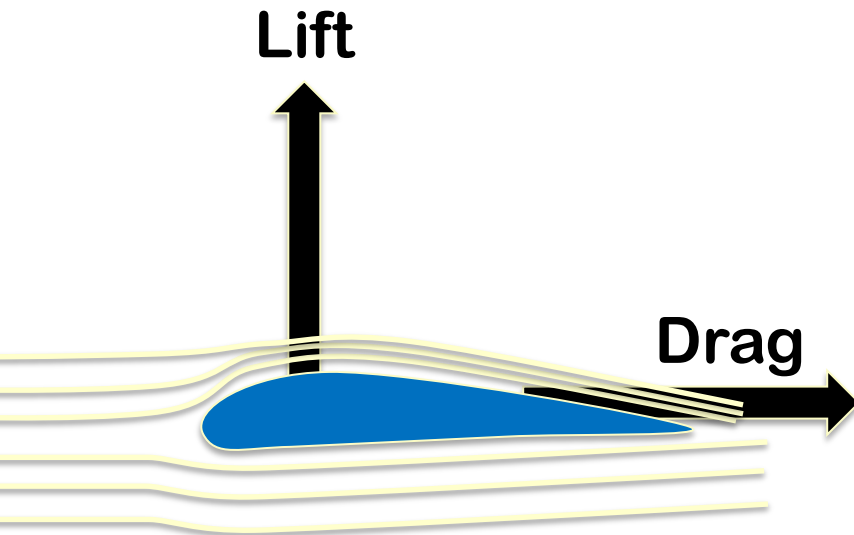
Five Varieties:

1. **Friction Drag**
2. **Form Drag**
3. **Induced (Lift) Drag**
4. **Wave Drag (High Mach Number)**
5. **Ram Drag**

Is Drag Good or Bad?

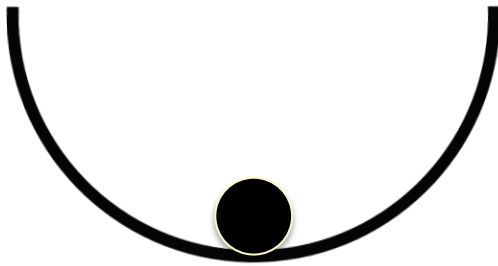


Drag

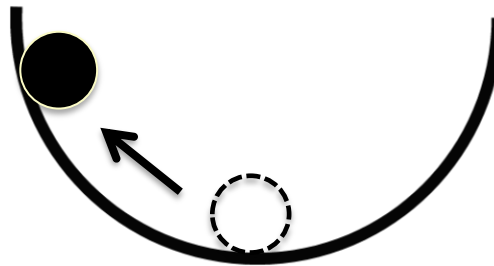


Stability

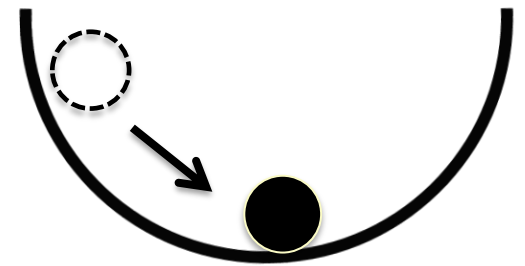
A Statically Stable System (“Positive”)



1. System at rest
“static”



2. System is
“disturbed”



3. Initial tendency to
return to start position.
Over time, settles out
at the start position

Stability

A Neutrally Static Stable System (“Neutral”)



1. System at rest



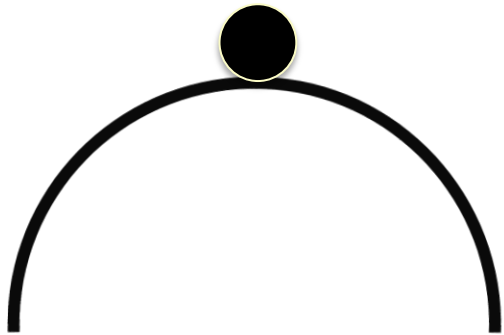
2. System disturbed



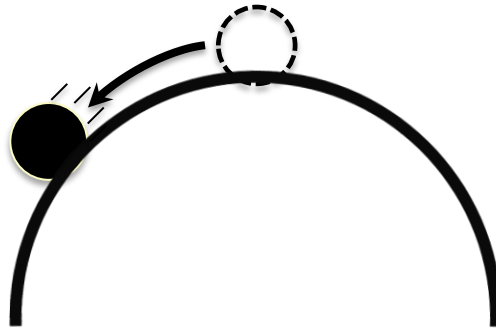
3. System **DOESN'T** return to initial condition, but establishes a **NEW** condition

Stability

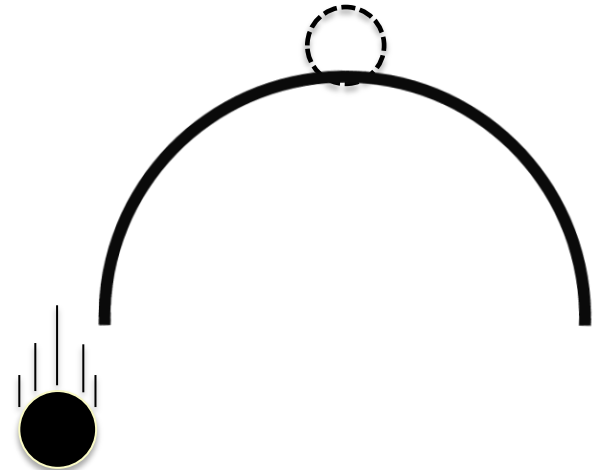
A Statically Unstable System (“Negative”)



1. System at rest



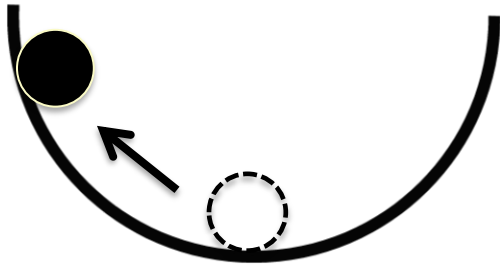
2. System disturbed



3. System continues
away from initial
condition

Stability

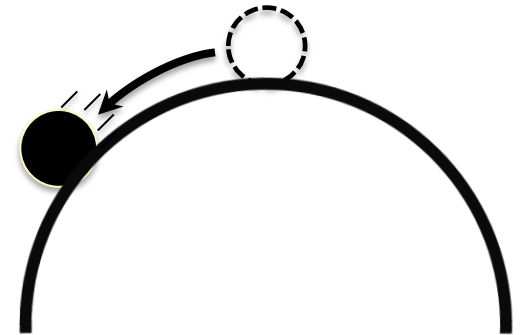
What kind of aircraft do you want to fly?



Positive



Neutral



Negative

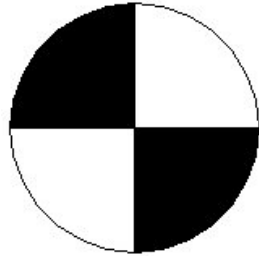
Are you sure?

Aircraft Stability



Stable or Unstable? Good or bad? Why?

Aircraft Stability



“Center of Gravity” (C.G.)

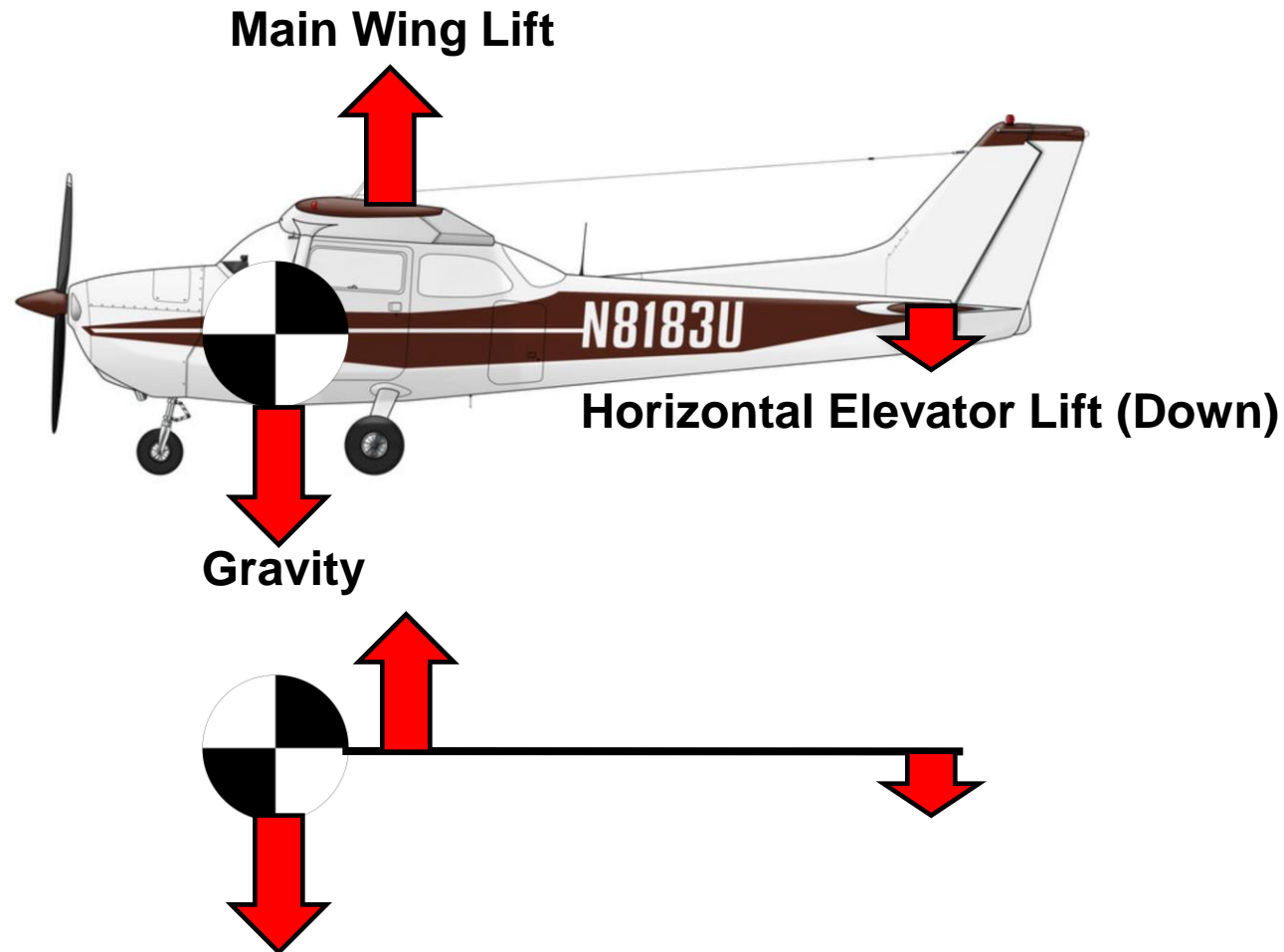
An imaginary point on a body of matter where, for convenience, the total weight of the body may be thought to be concentrated. Motion of the body occurs about the center of gravity.

Aircraft Stability – Pitch “Axis”



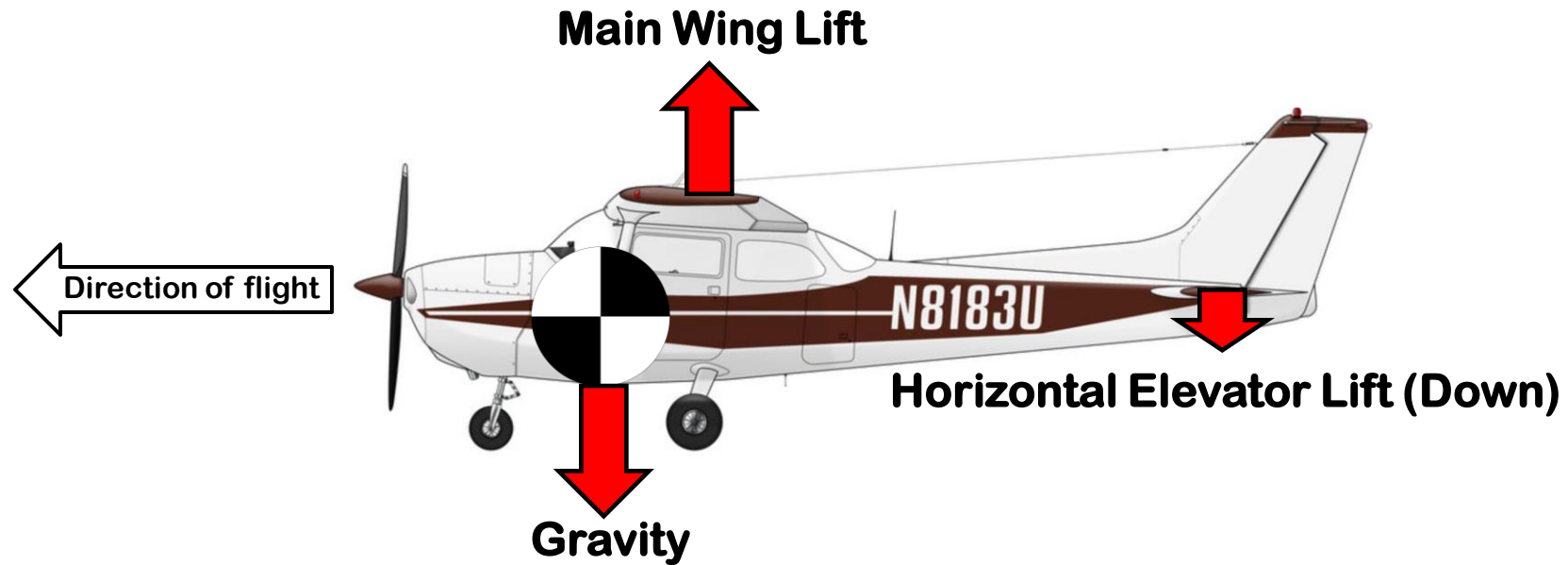
Where would you place the C.G.?

Aircraft Stability – Pitch “Axis”

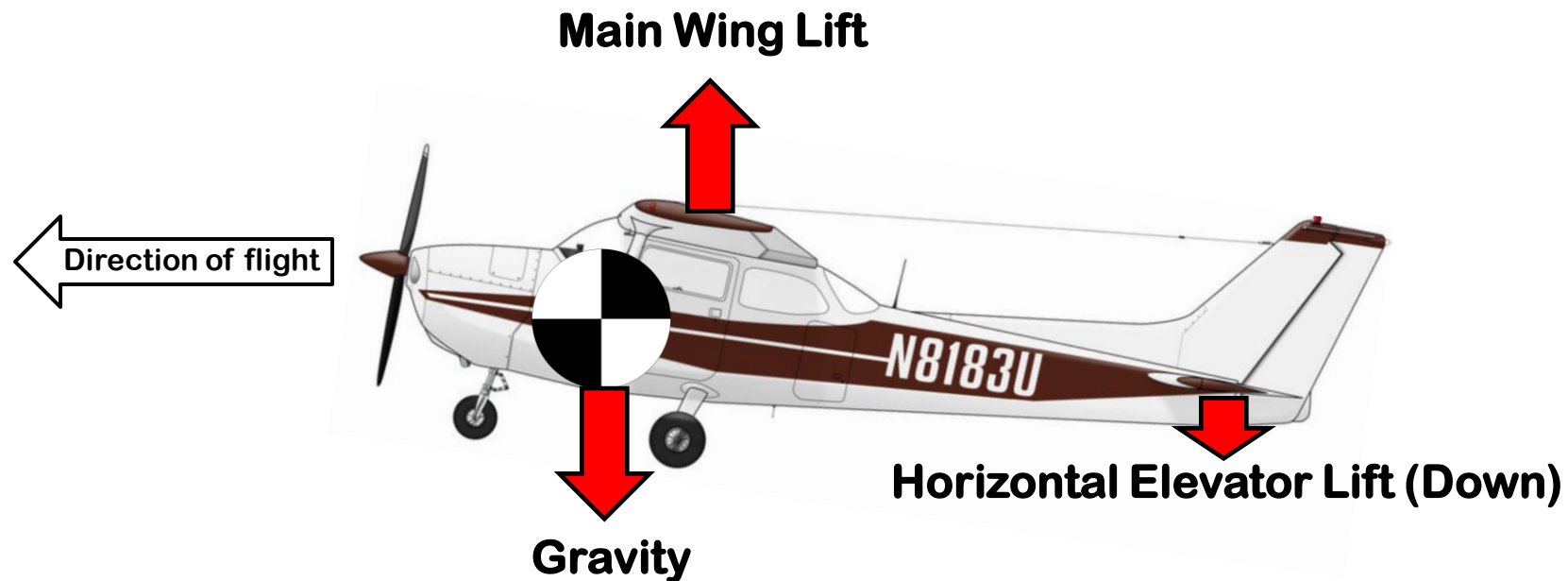


The objective is “balance” of the forces so that the torque is zero. This is “trimmed flight.”

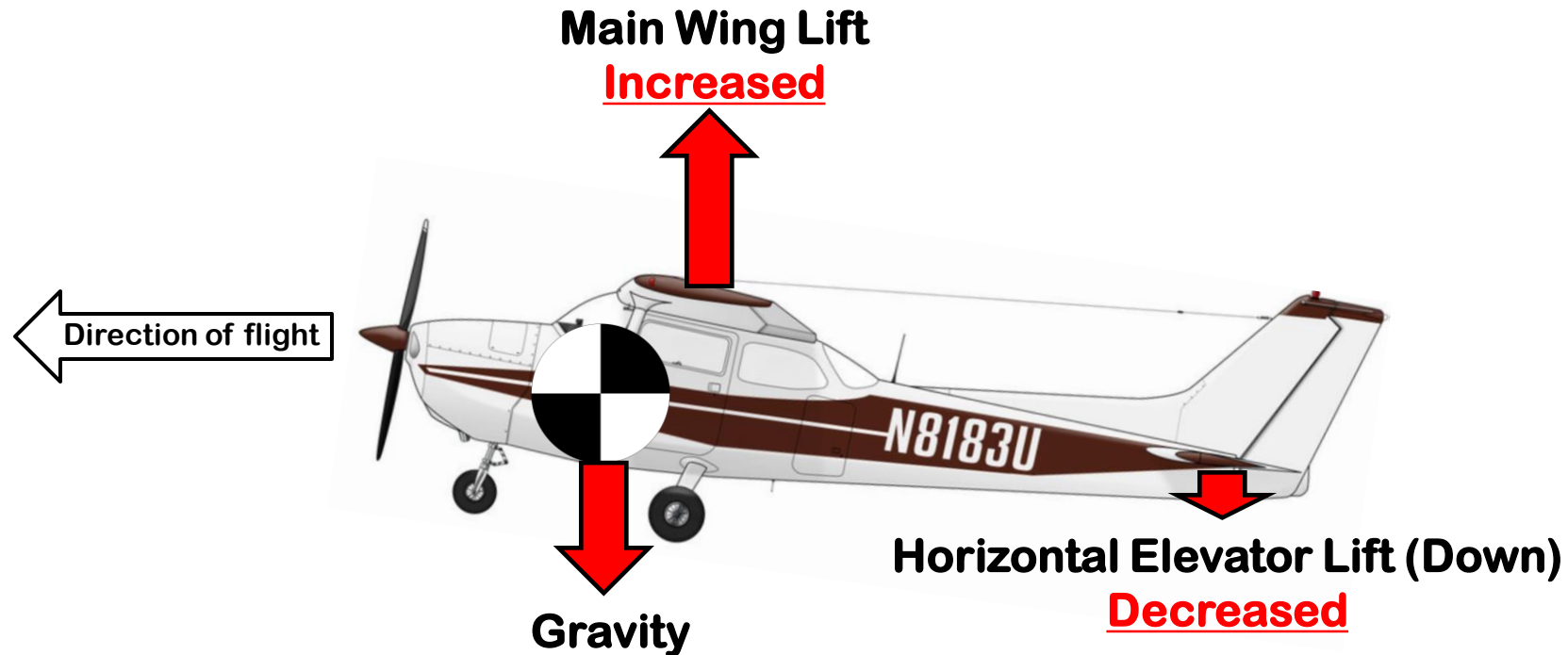
Cruising along...



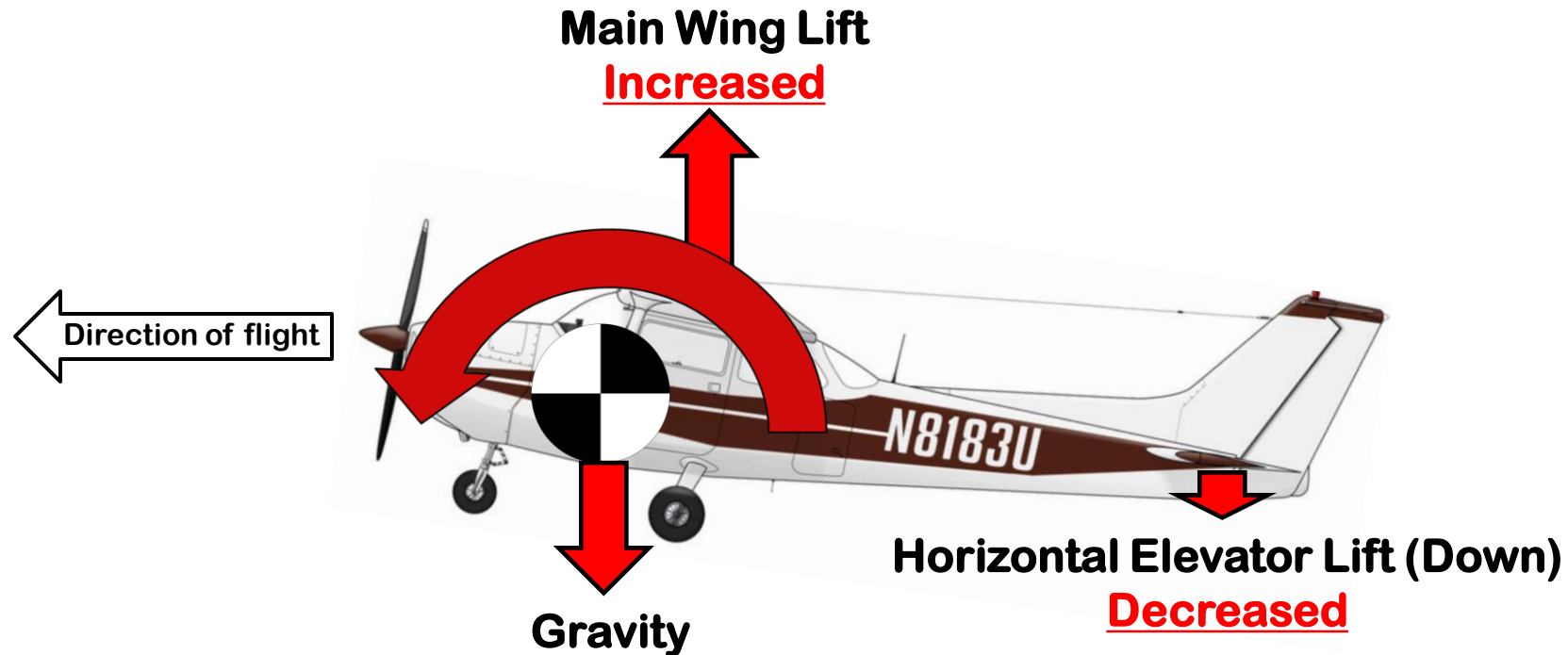
Wind gust causes nose to pitch up...what happens in this case?



Wind gust causes nose to pitch up...what happens in this case?

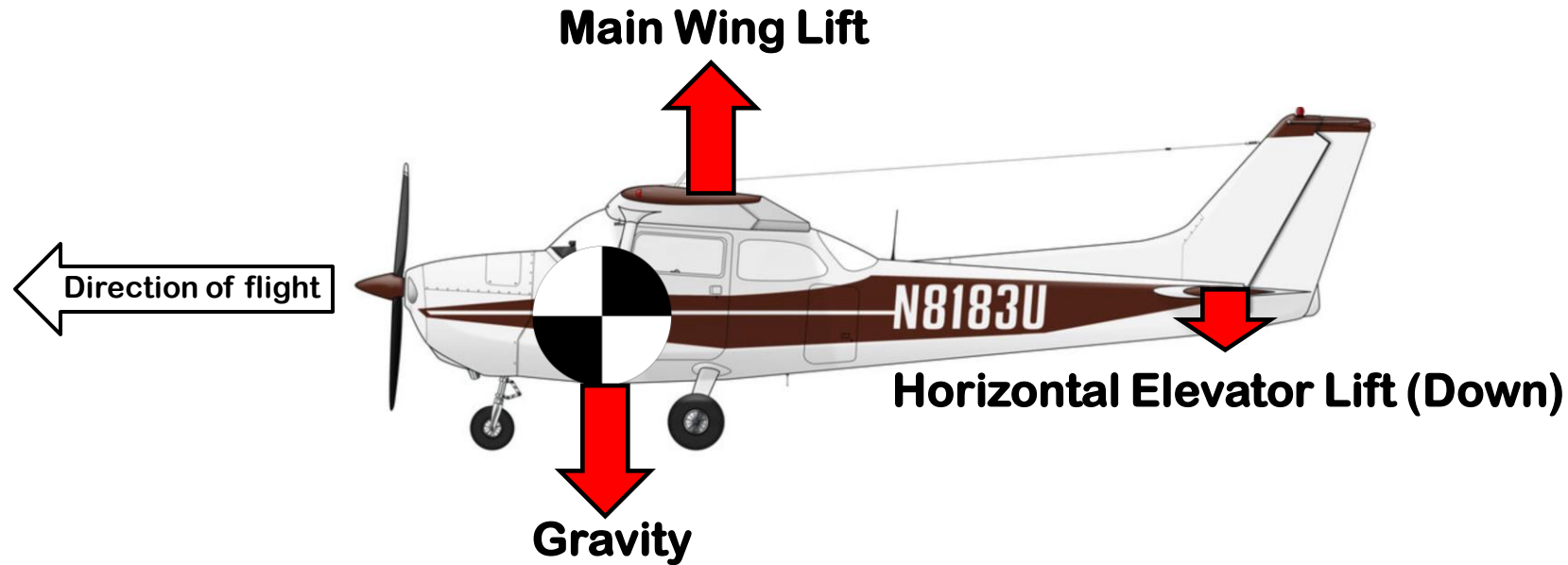


Wind gust causes nose to pitch up...what happens in this case?



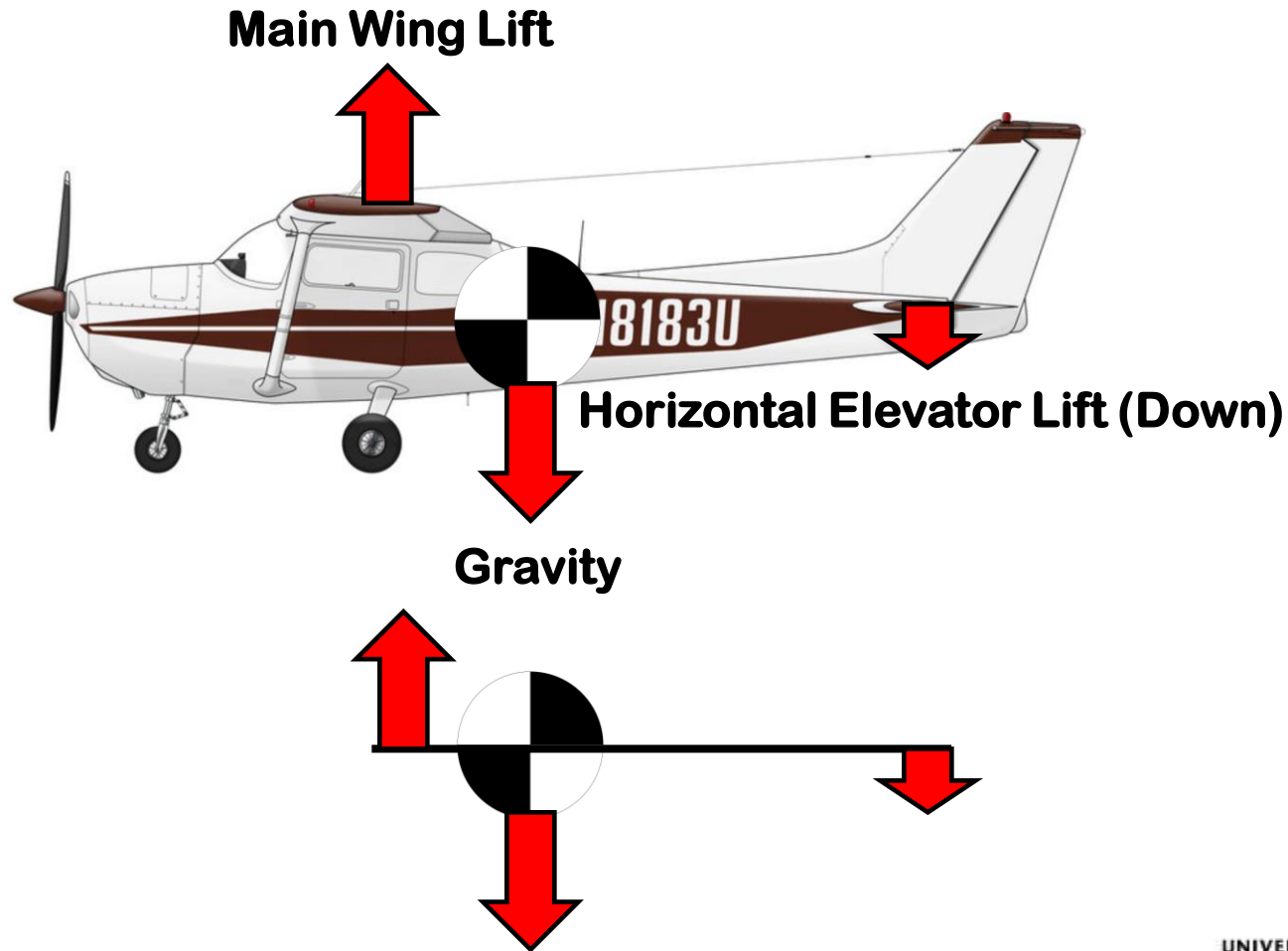
The imbalance between lift and horizontal elevator forces creates a “restoring moment” and the nose pitches back down

Back to Trimmed Flight!

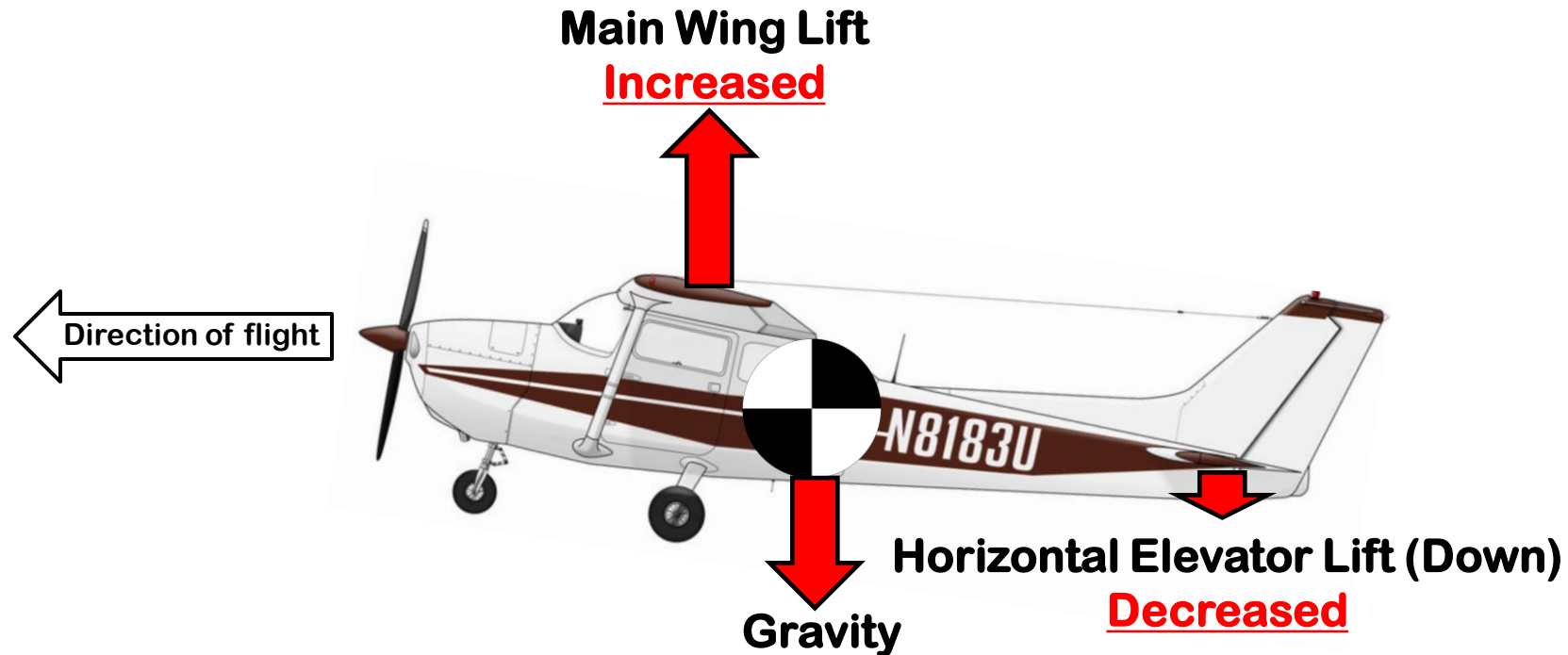


This is the result of “pitch axis positive static stability”—and a good thing!

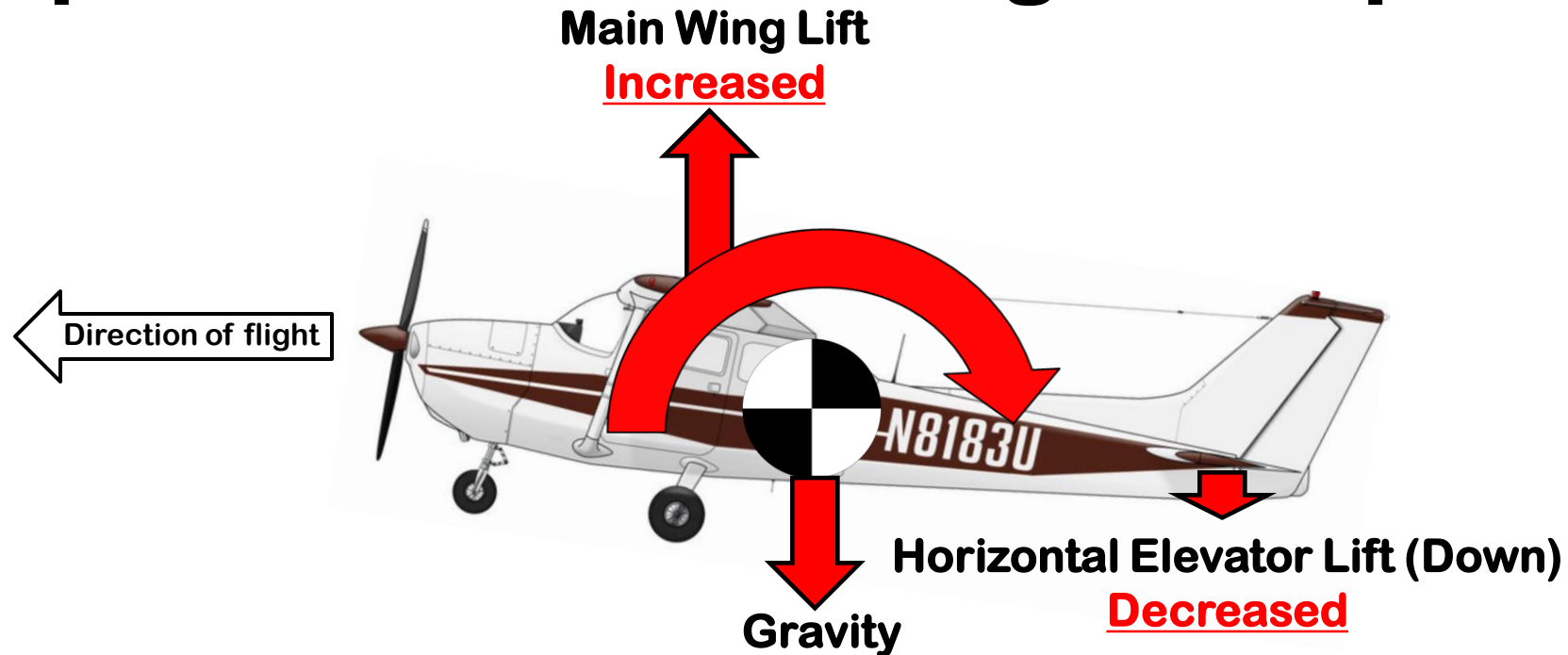
What has changed here...what do you think will be the result?



Wind gust causes nose to pitch up...what happens now?

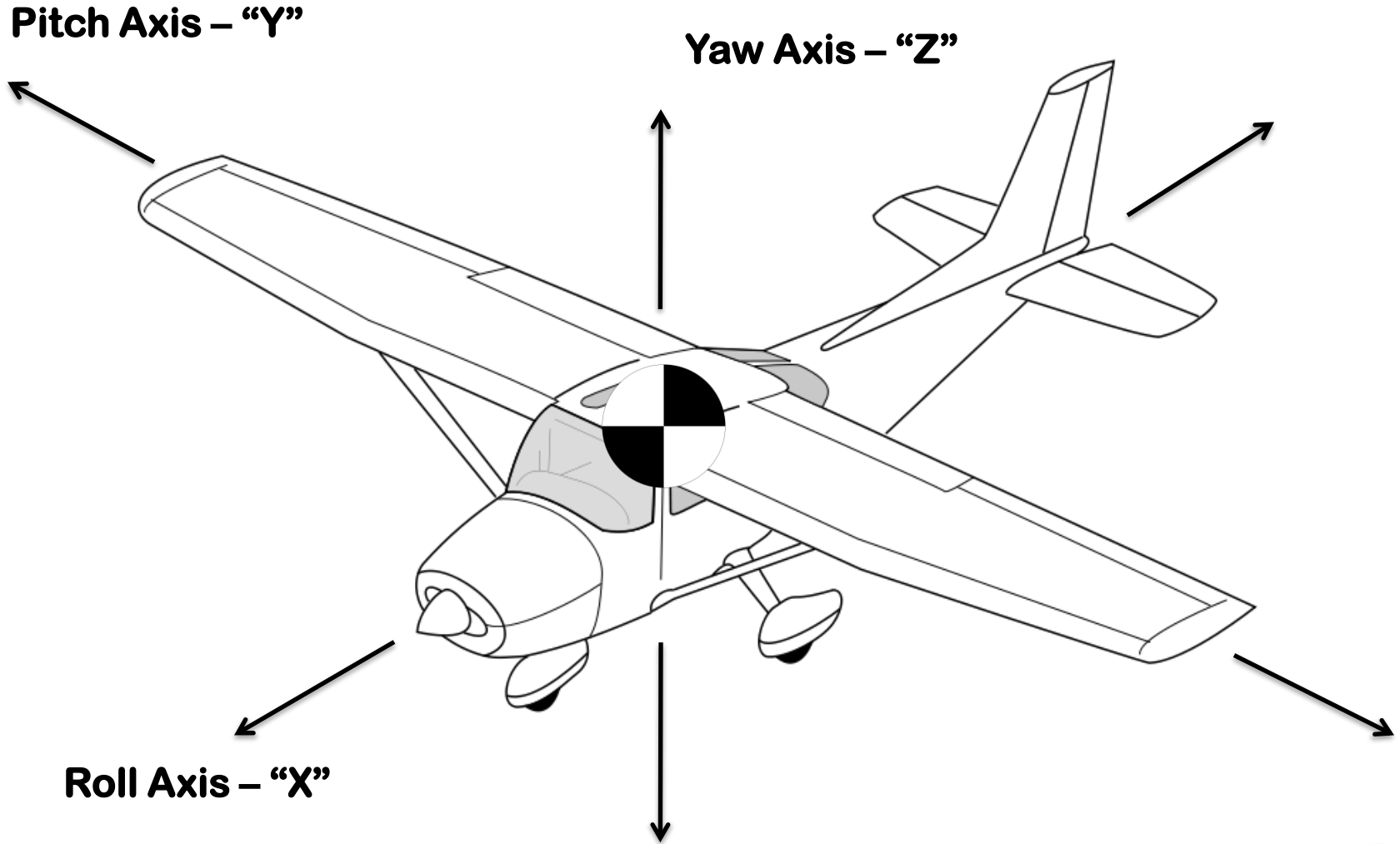


Nose will keep pitching up until pilot does something to stop it!

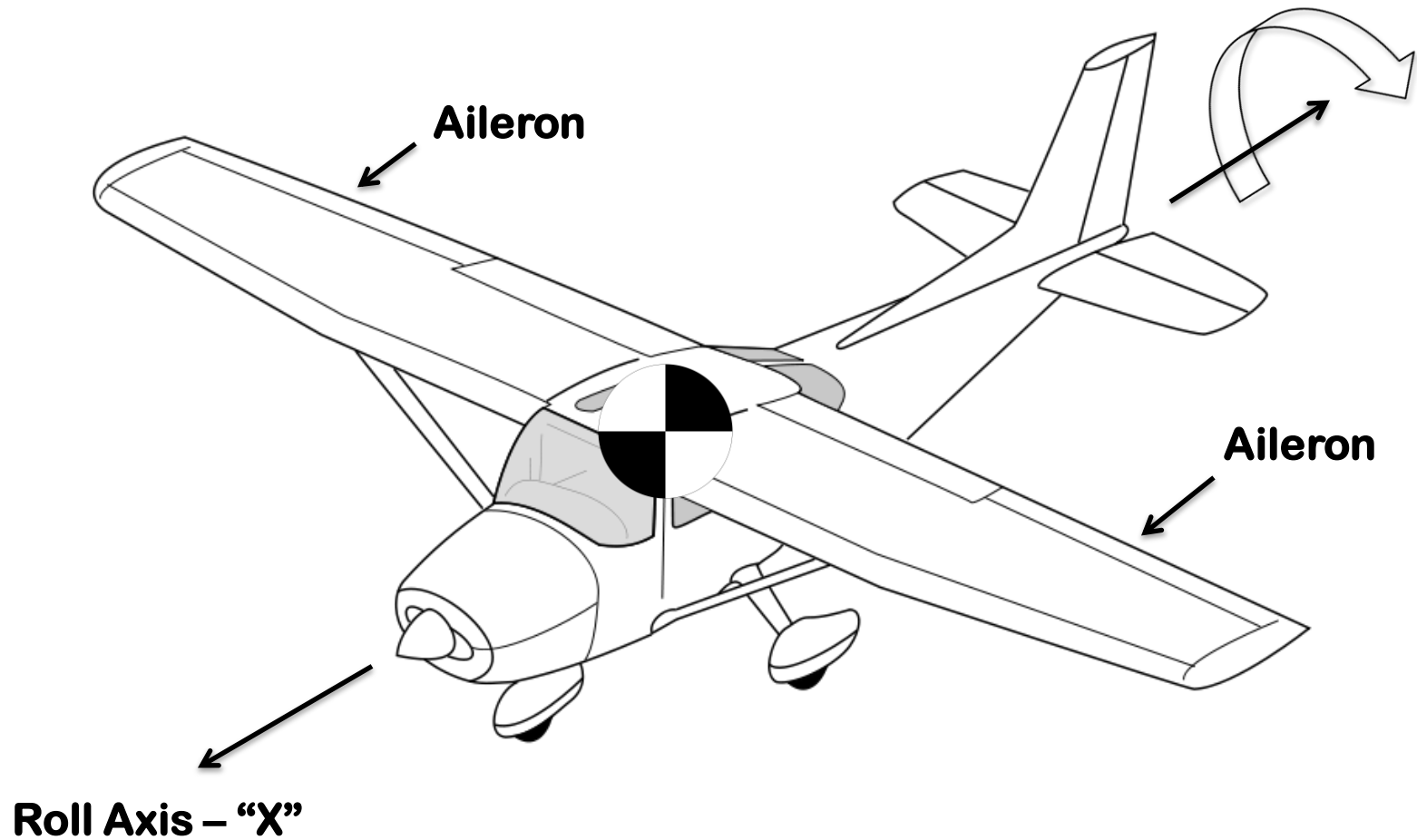


Impossible to “trim” the aircraft!

Aircraft Control (3 Axes)

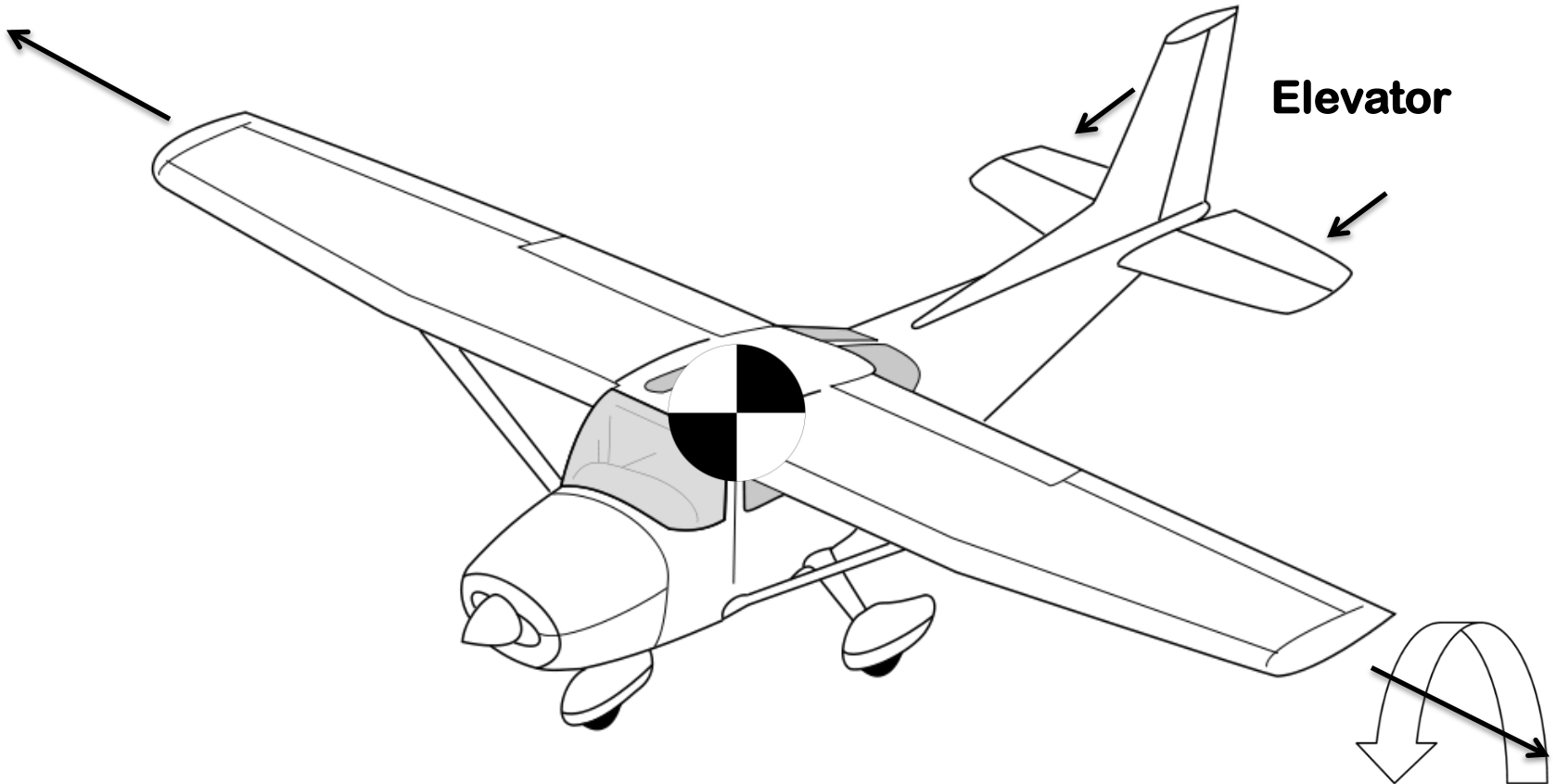


Aircraft Control (Roll)

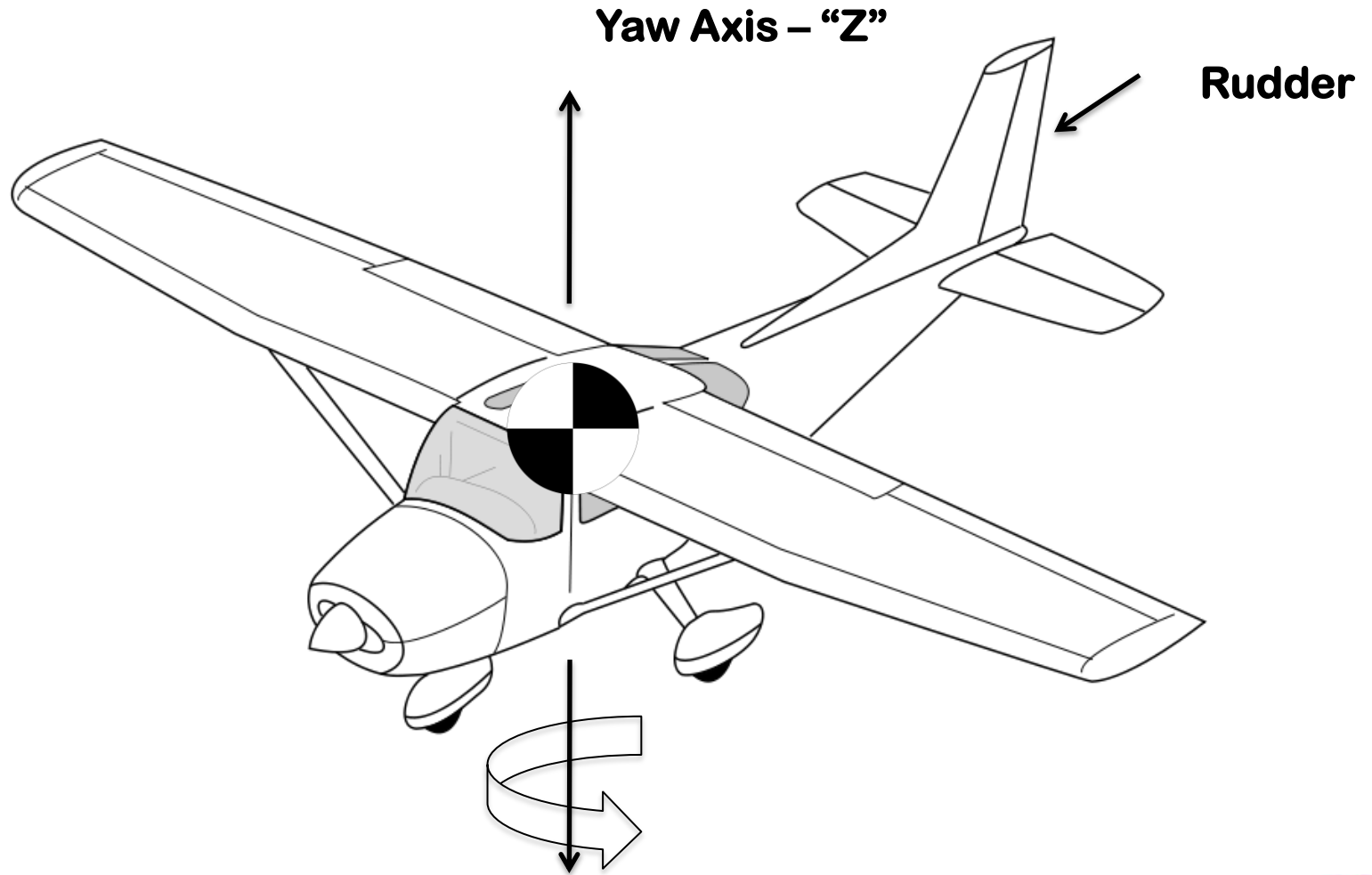


Aircraft Control (Pitch)

Pitch Axis – “Y”

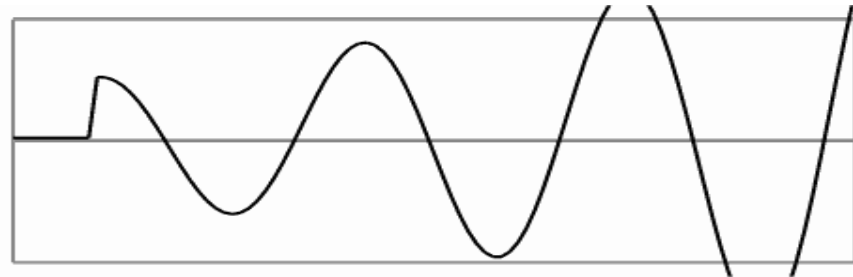
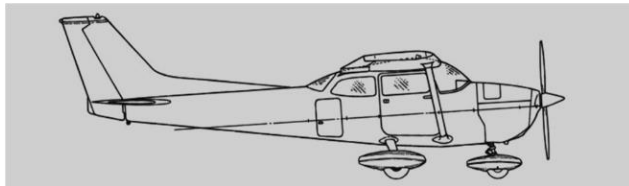
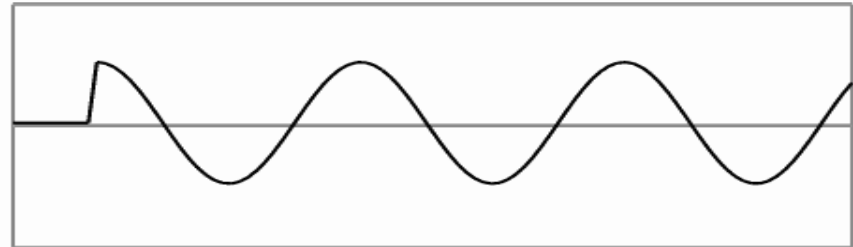
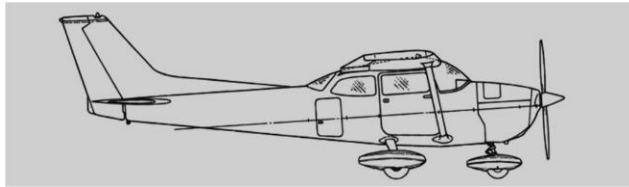
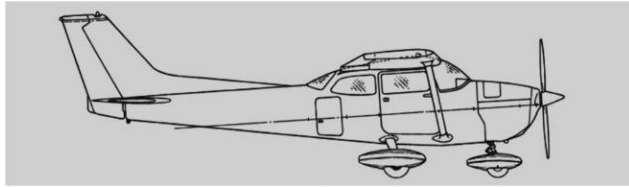


Aircraft Control (Yaw)



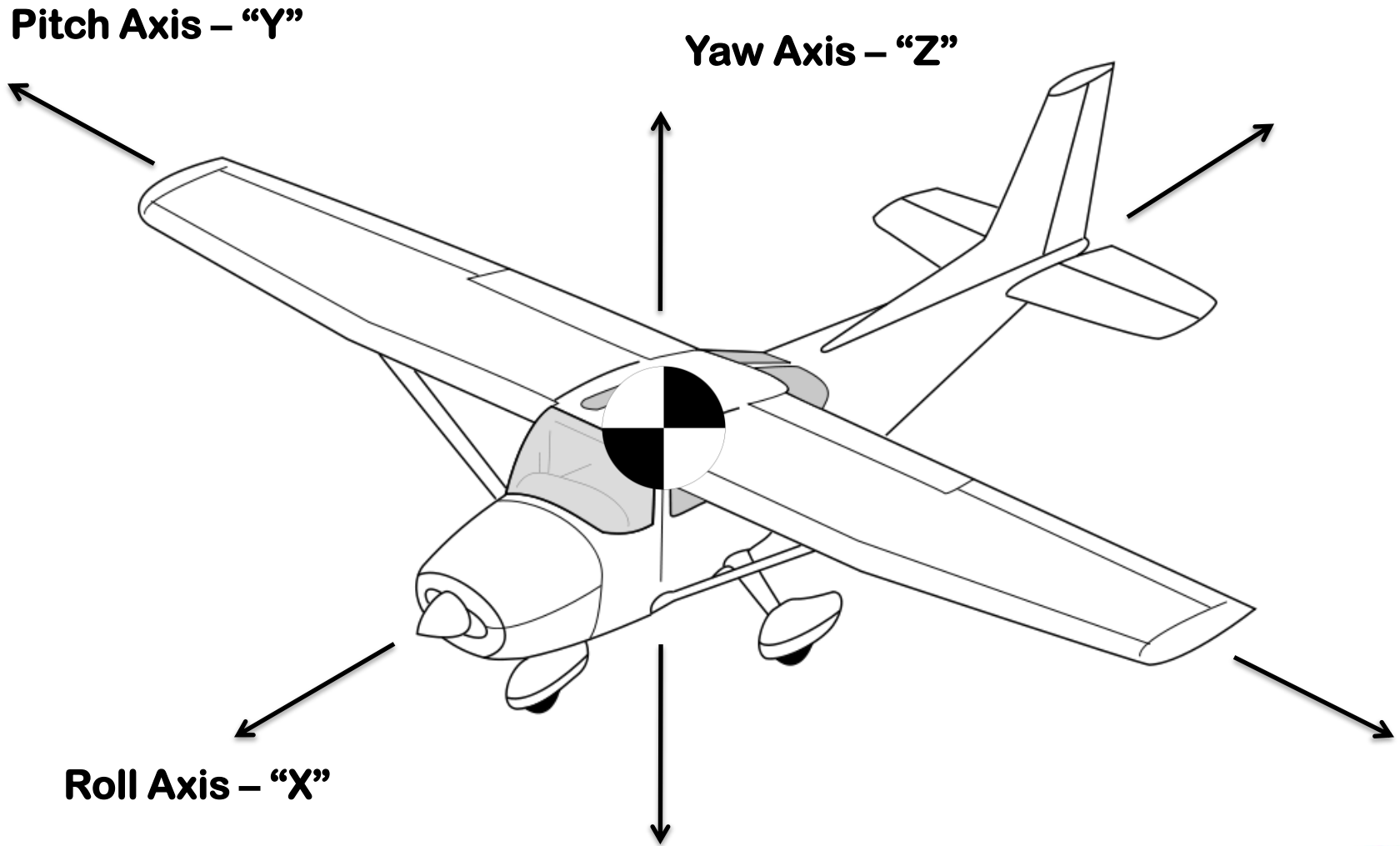
Aircraft Dynamic Stability (Pitch Axis)

“Stability over time”



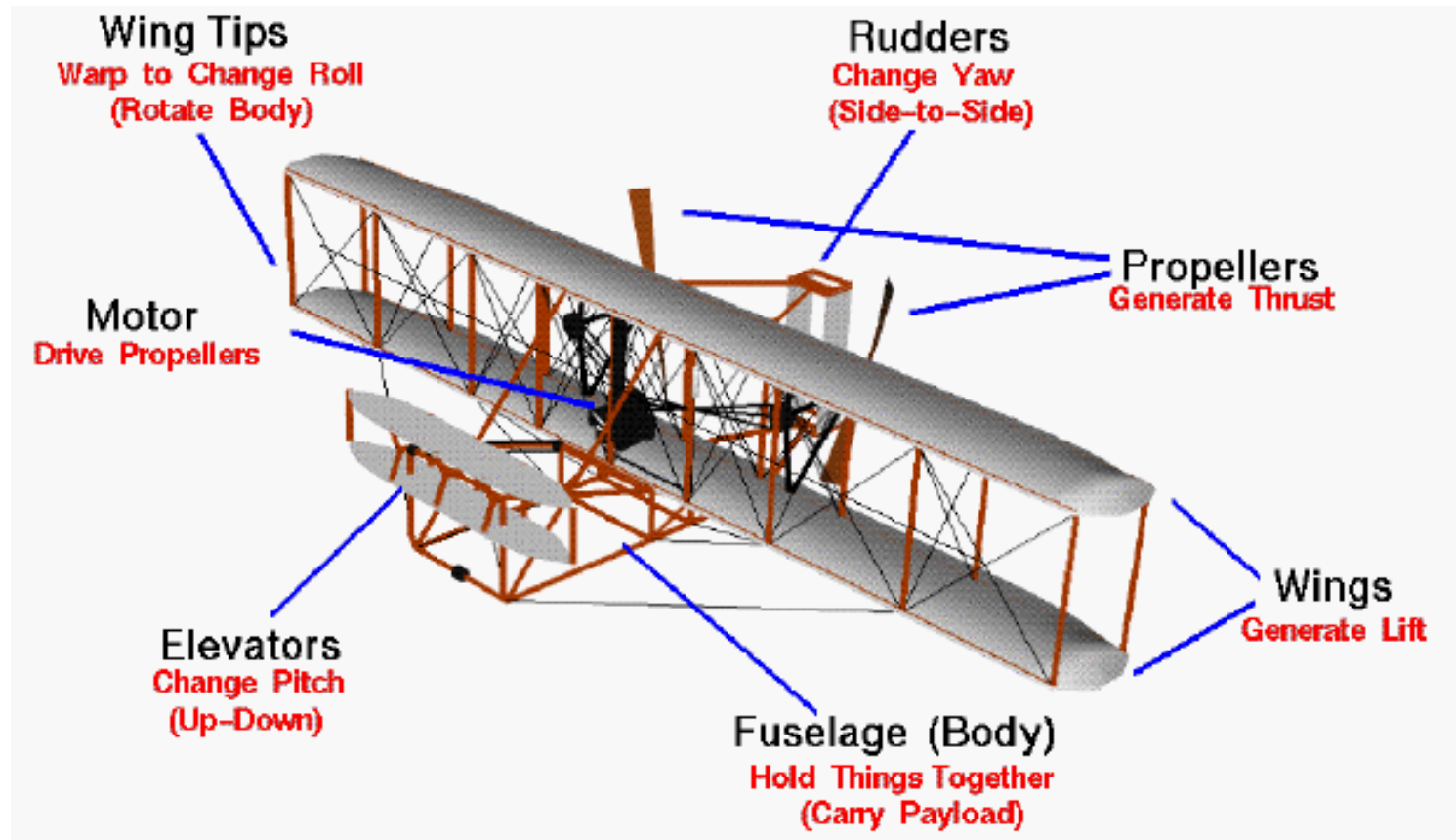
Which airplane do you want to fly?

What about the other axes (Roll and Yaw)?



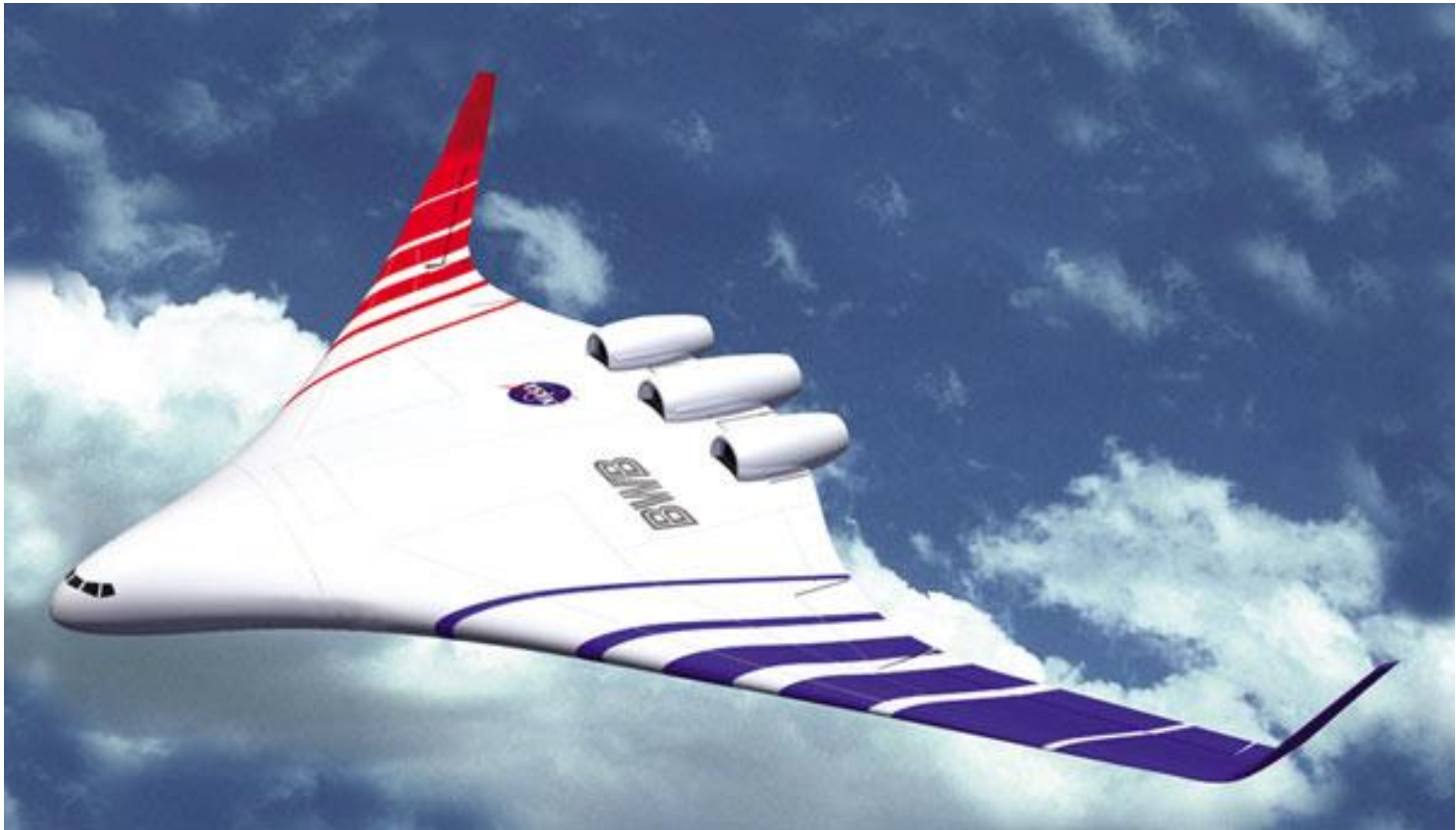
Aircraft Stability

What about this design?



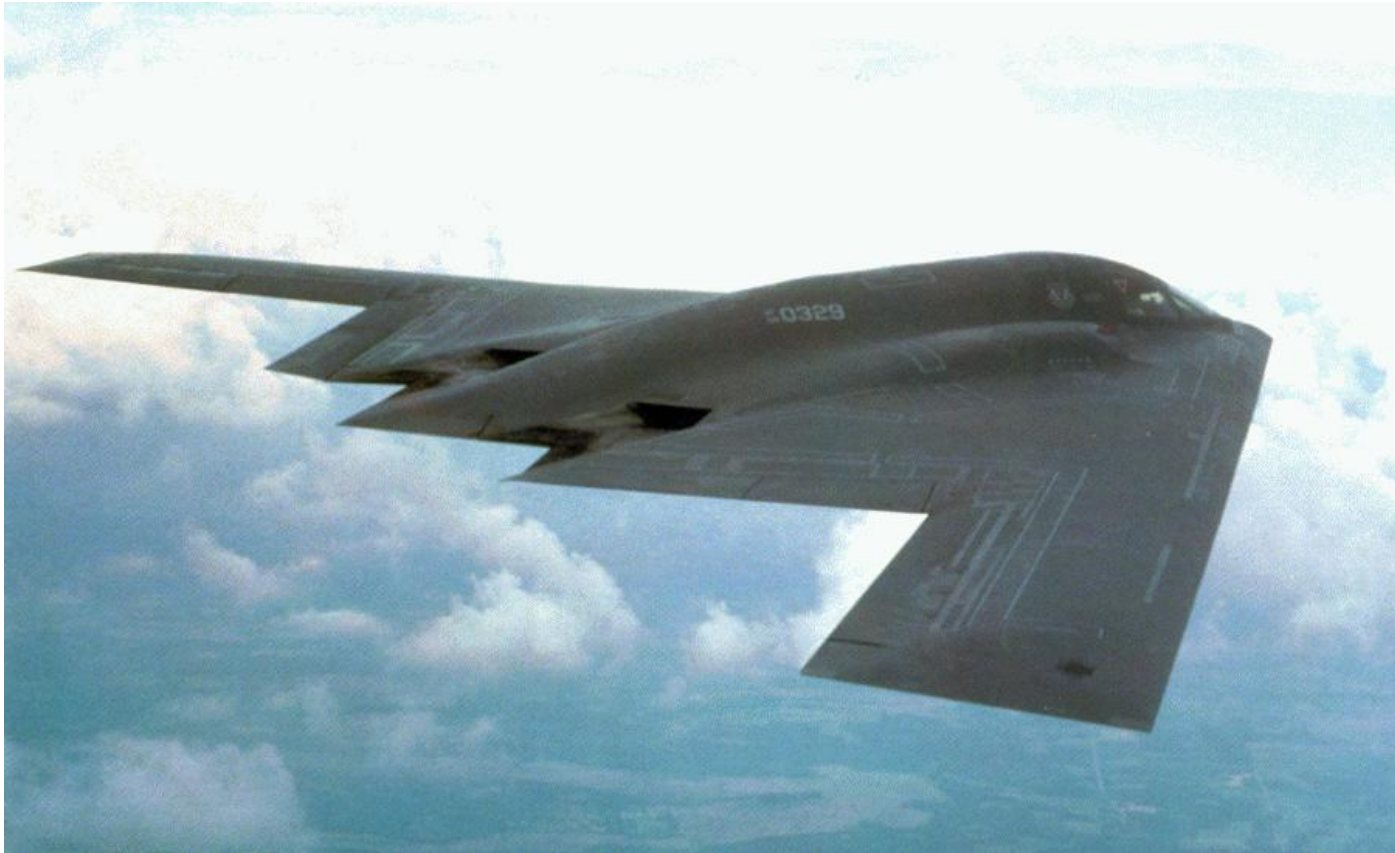
Aircraft Stability

And this one?



Aircraft Stability

And this one?



Aircraft Stability

And this one?



Aircraft Stability



Again, the physics is exactly the same!

Aircraft Designs



Aircraft Designs



Aircraft Designs



Aircraft Designs



Aircraft Designs



Aircraft Designs



Let's Review

- 1. The four forces of flight?**
- 2. Three different types of static stability?**
- 3. Three axes of an aircraft?**
- 4. Motion about the axis of an aircraft?**
- 5. Control surfaces for each axis?**

The Physics of Flight

Other things we didn't talk about today:

- Performance**

(how high, how far, how fast, how much...)

- Advanced Stability and Control**

(fly-by-wire, fly-by-light, wing warping...)

- Structures**

(materials, strength, durability, stealth...)

- Thermodynamics and Propulsion**

(how powerful, how efficient, hypersonics, new fuels...)

- Aircraft subsystems**

(ECS, communications, navigation, sensors, mission...)

Questions?