CPL Theory
Aerodynamics (CADA)

CAE Oxford
Aviation Academy

CADA 2 – Stability

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2. Related Documents

Related Documents	Document Identification

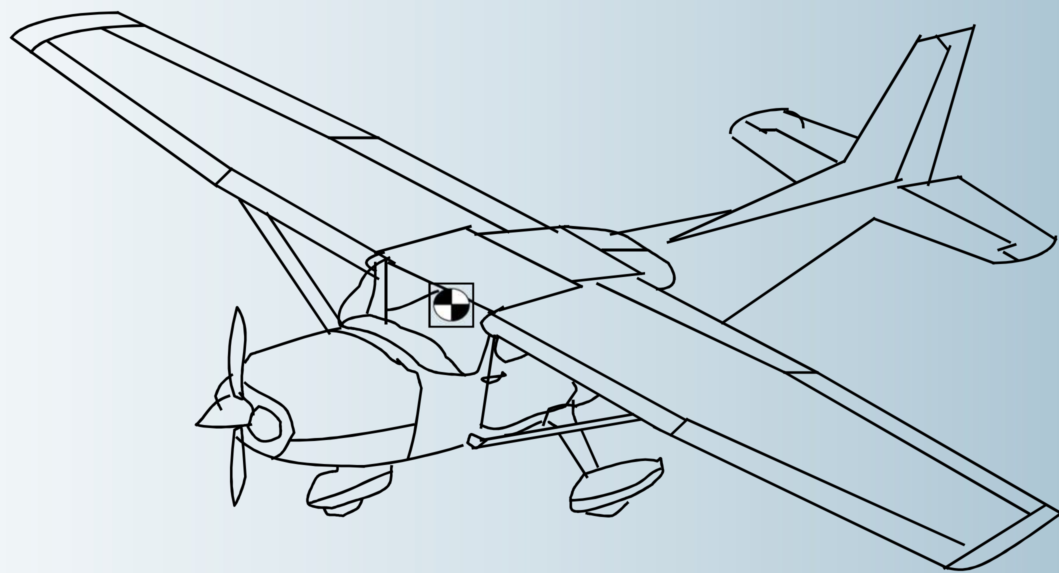
CADA 2 – Stability

Amendments made to this document since the previous version are listed below. All amendments to this document have been made in accordance with CAE OAAM's document management procedure.

Slide	Changes

AIRCRAFT AXES

Aircraft Axes



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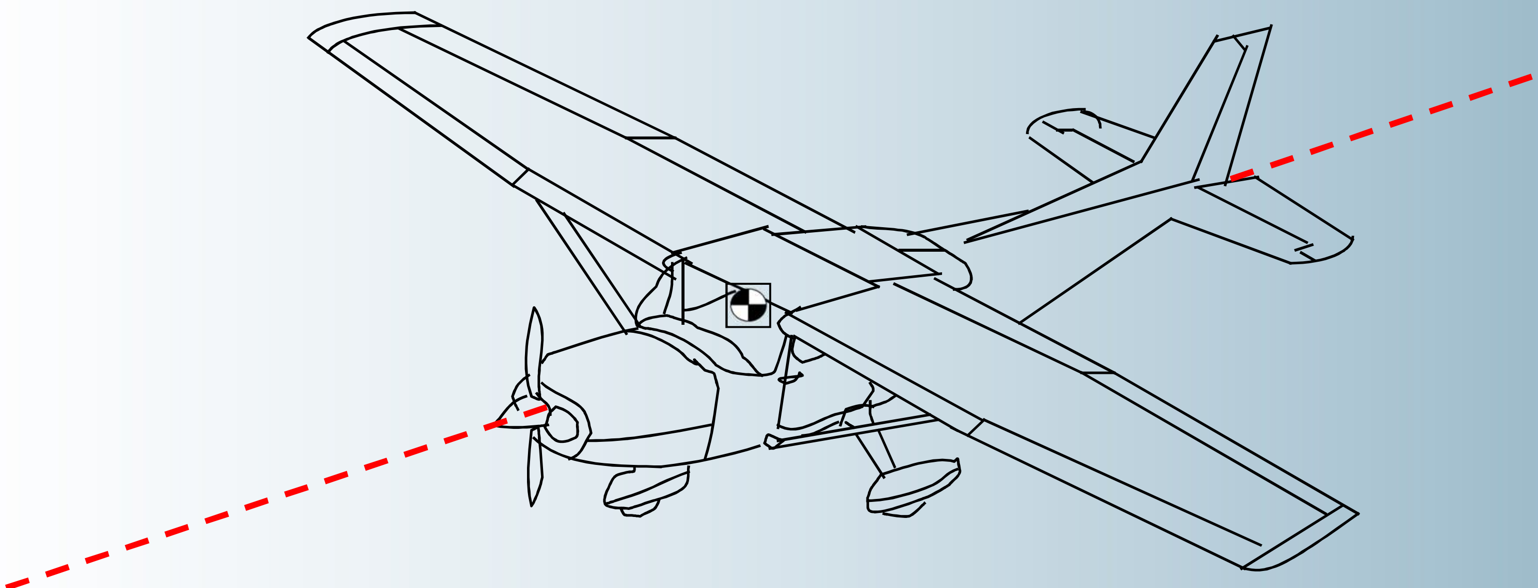

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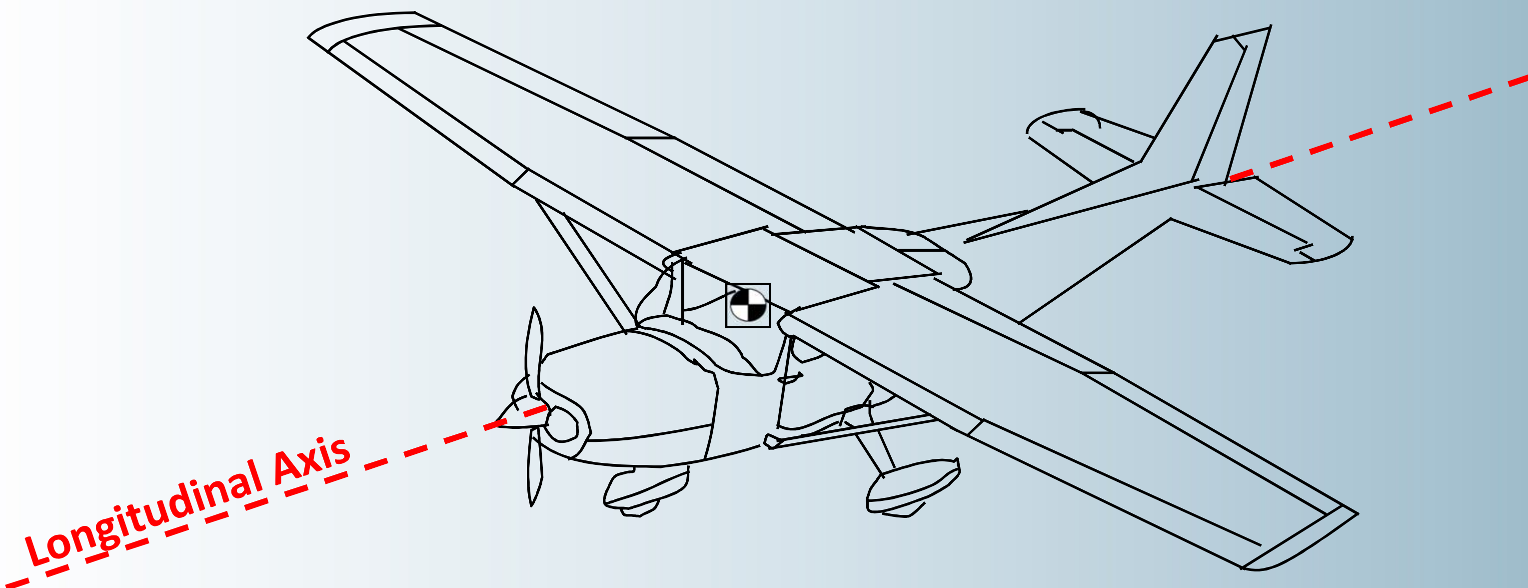

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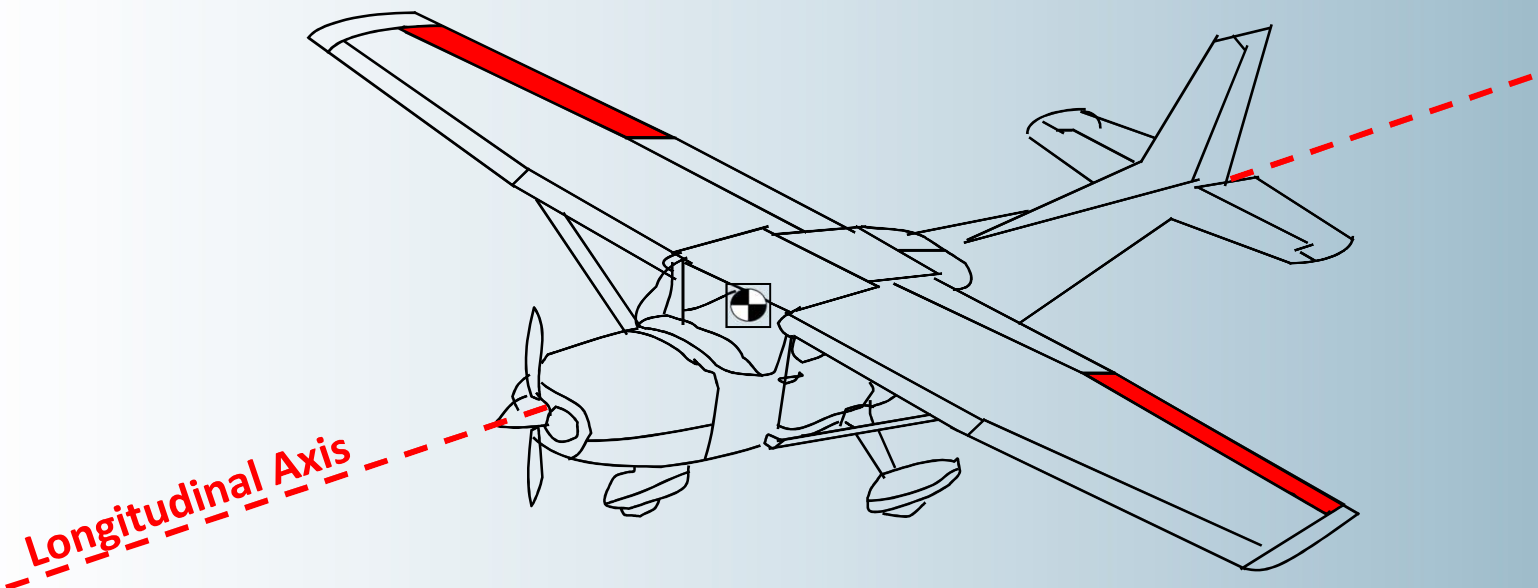

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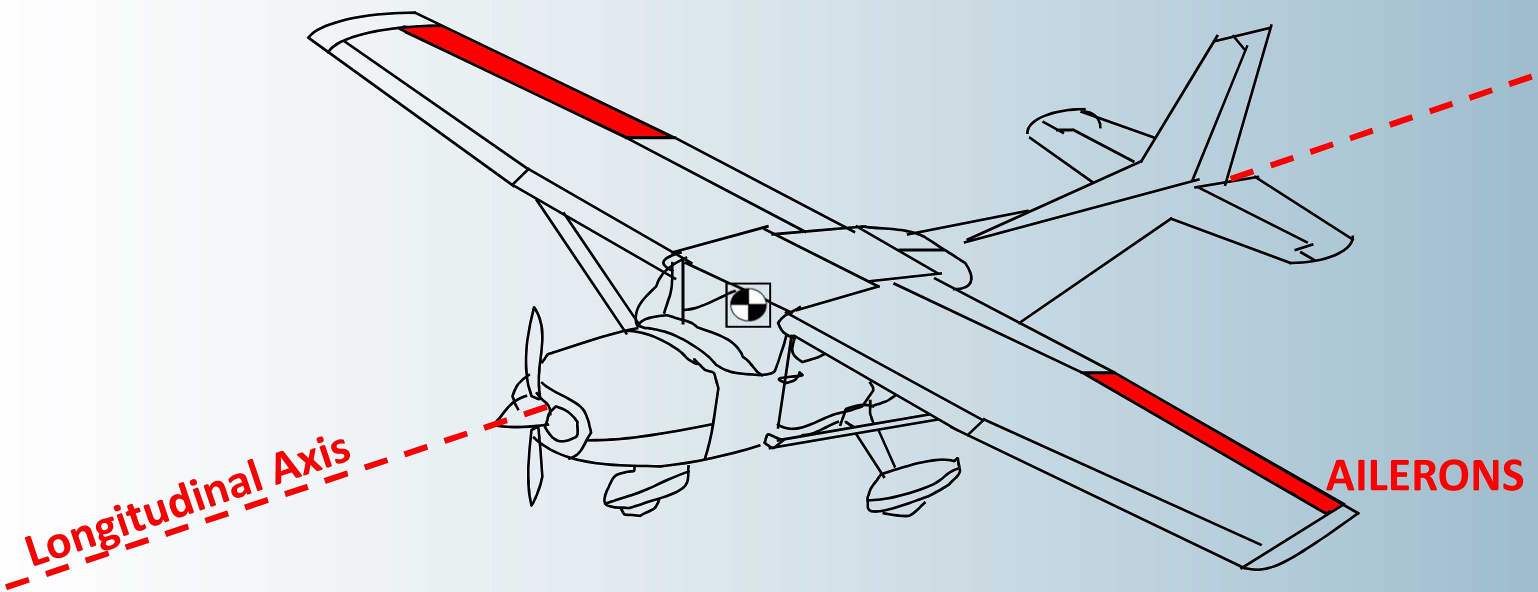

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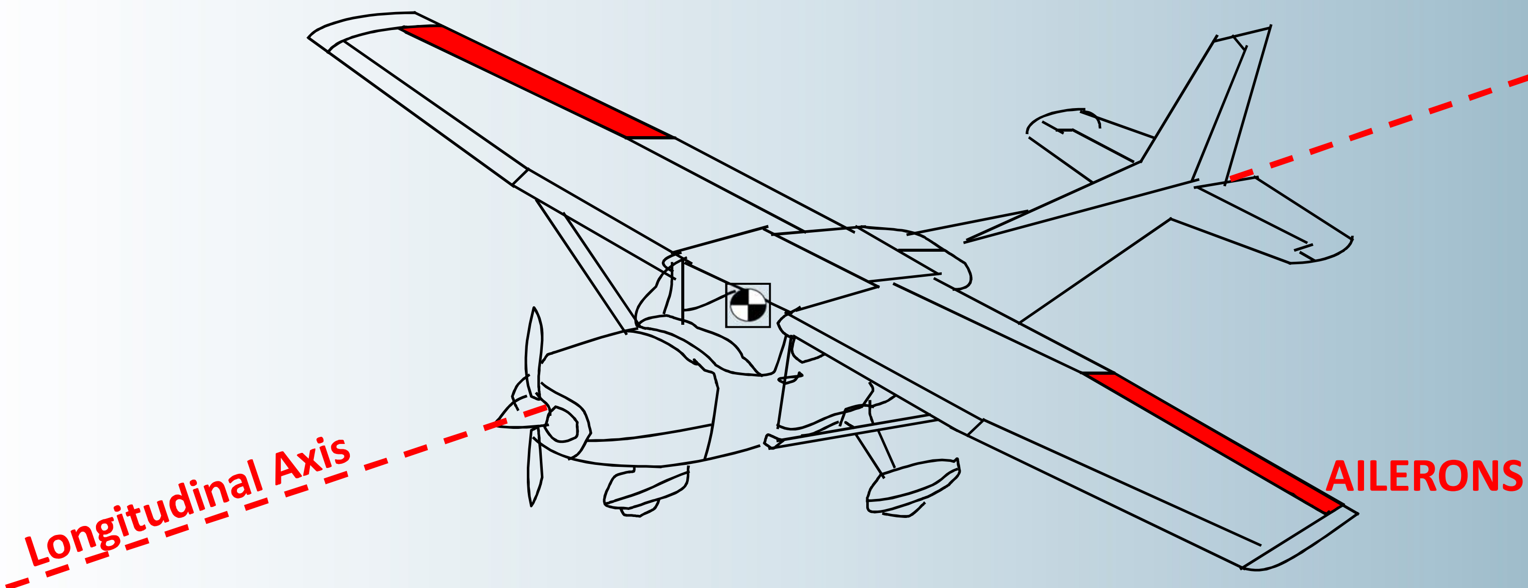
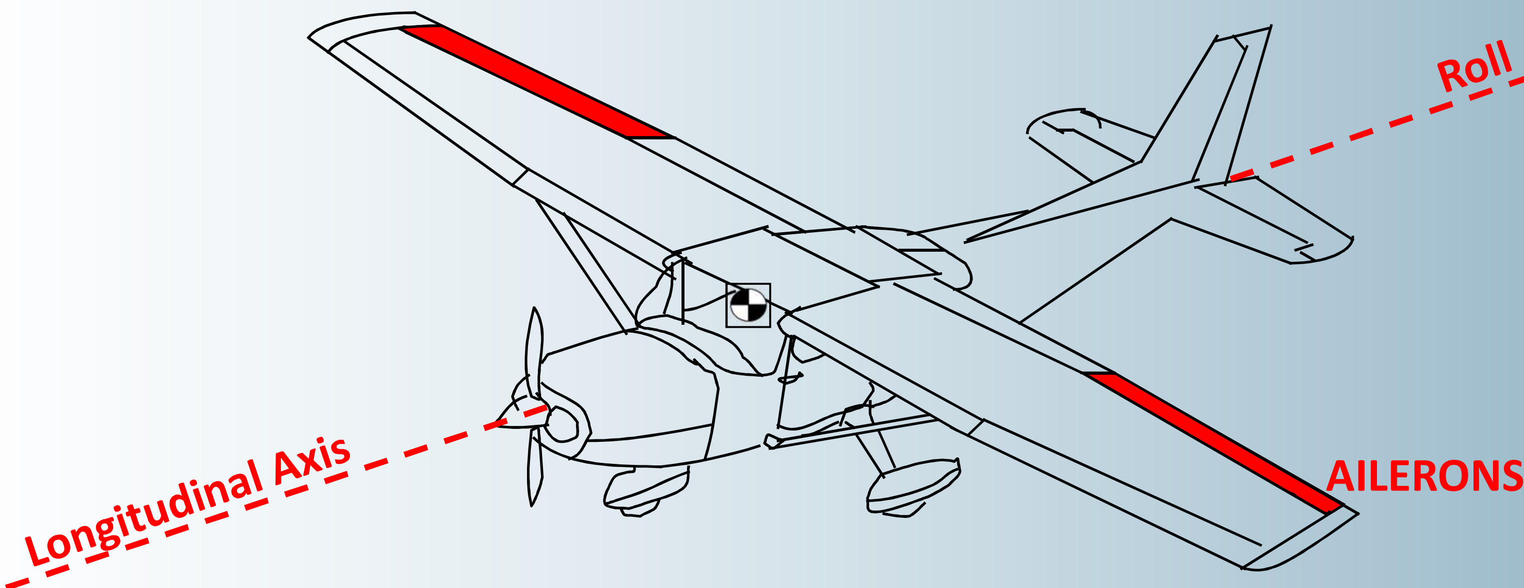


Ailerons – Operated through the Control Column and work in the natural sense.

Aircraft Axes



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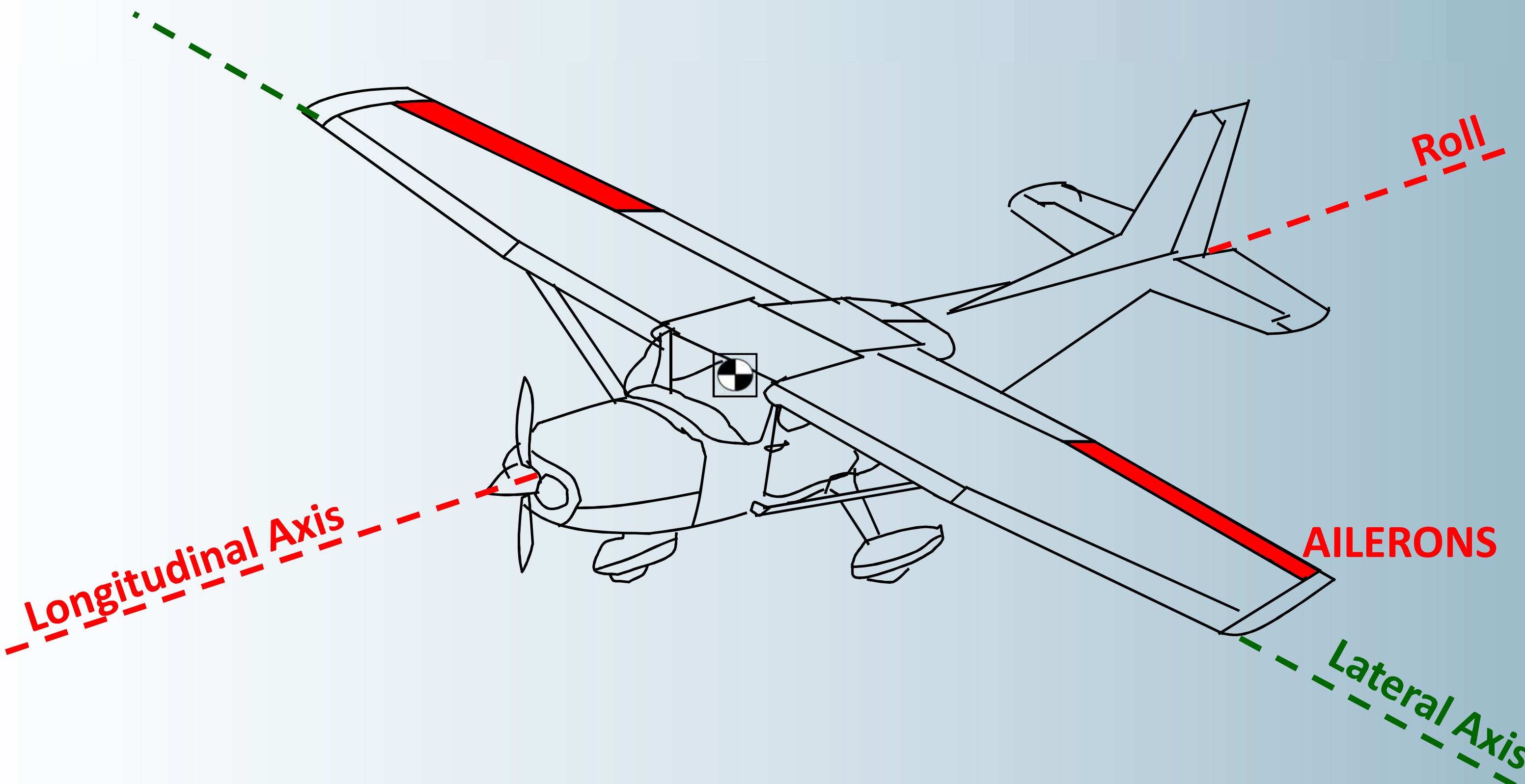

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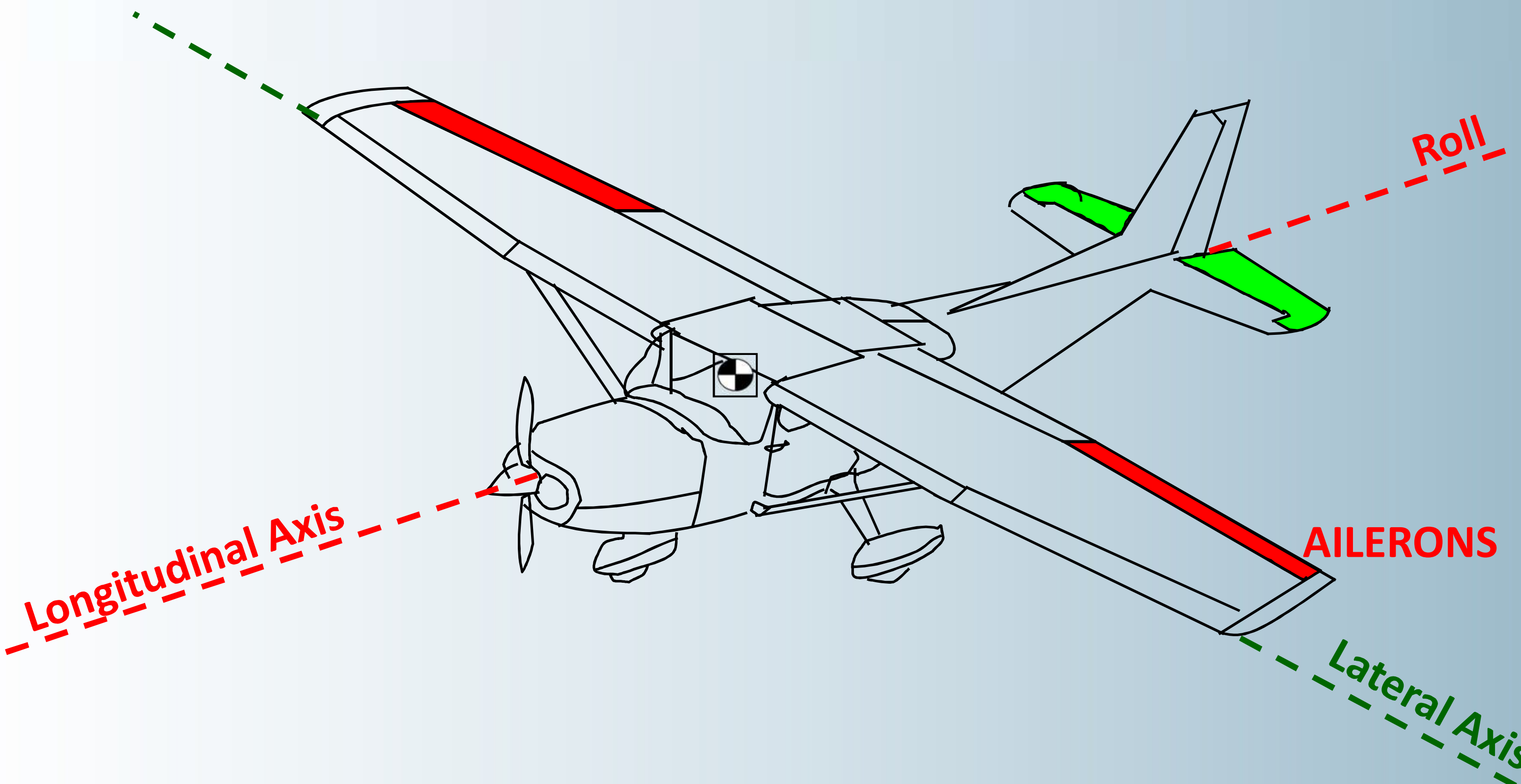

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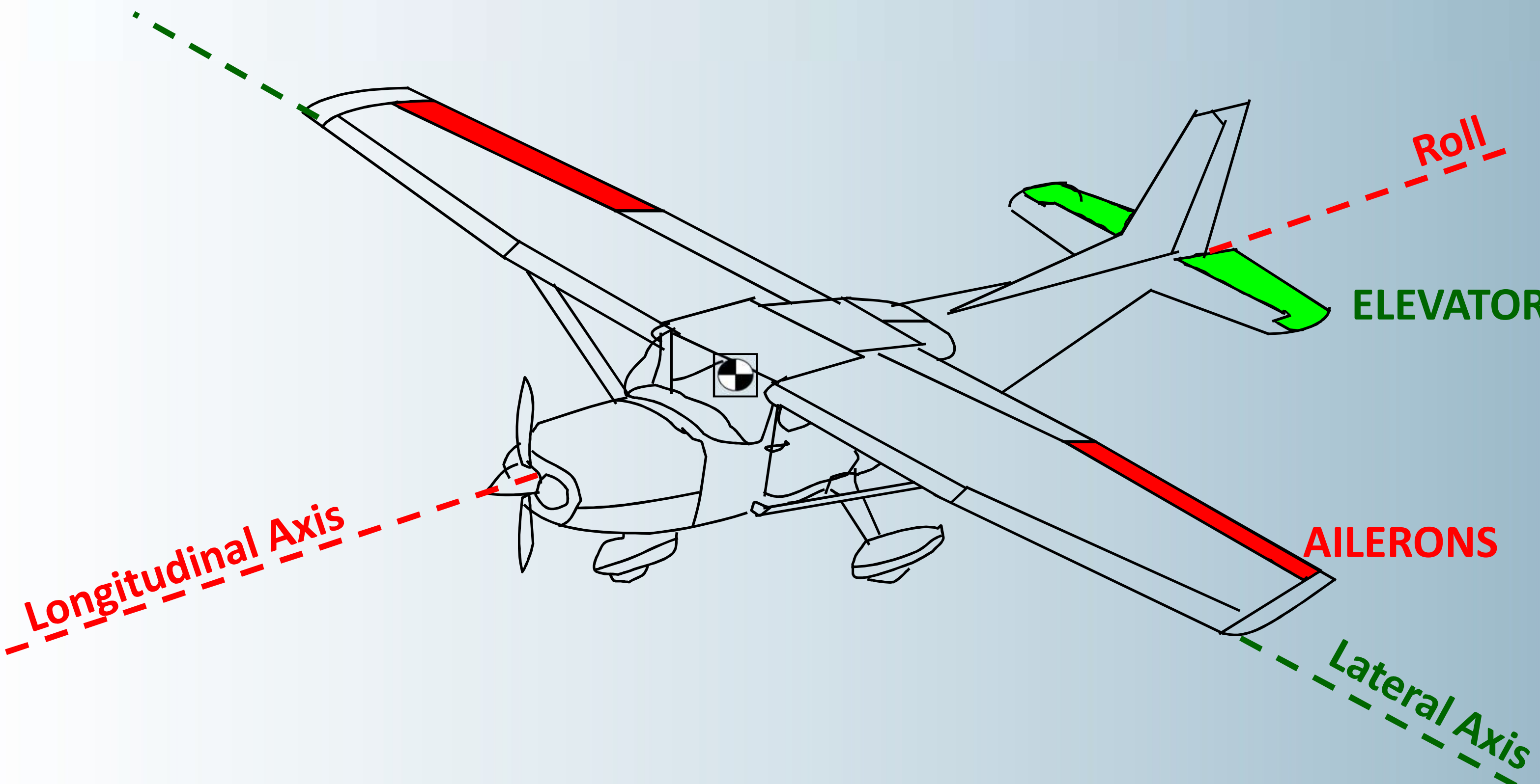

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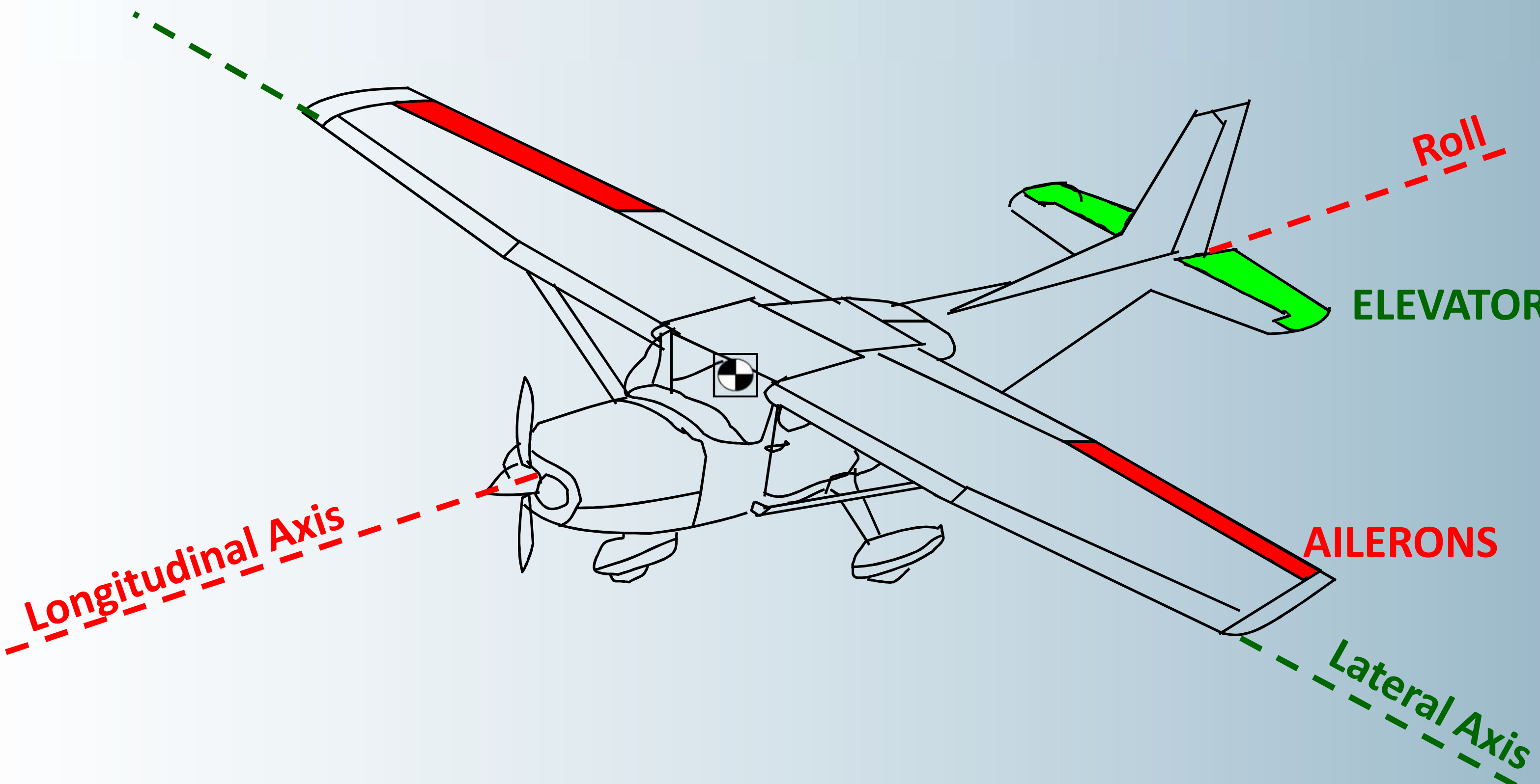

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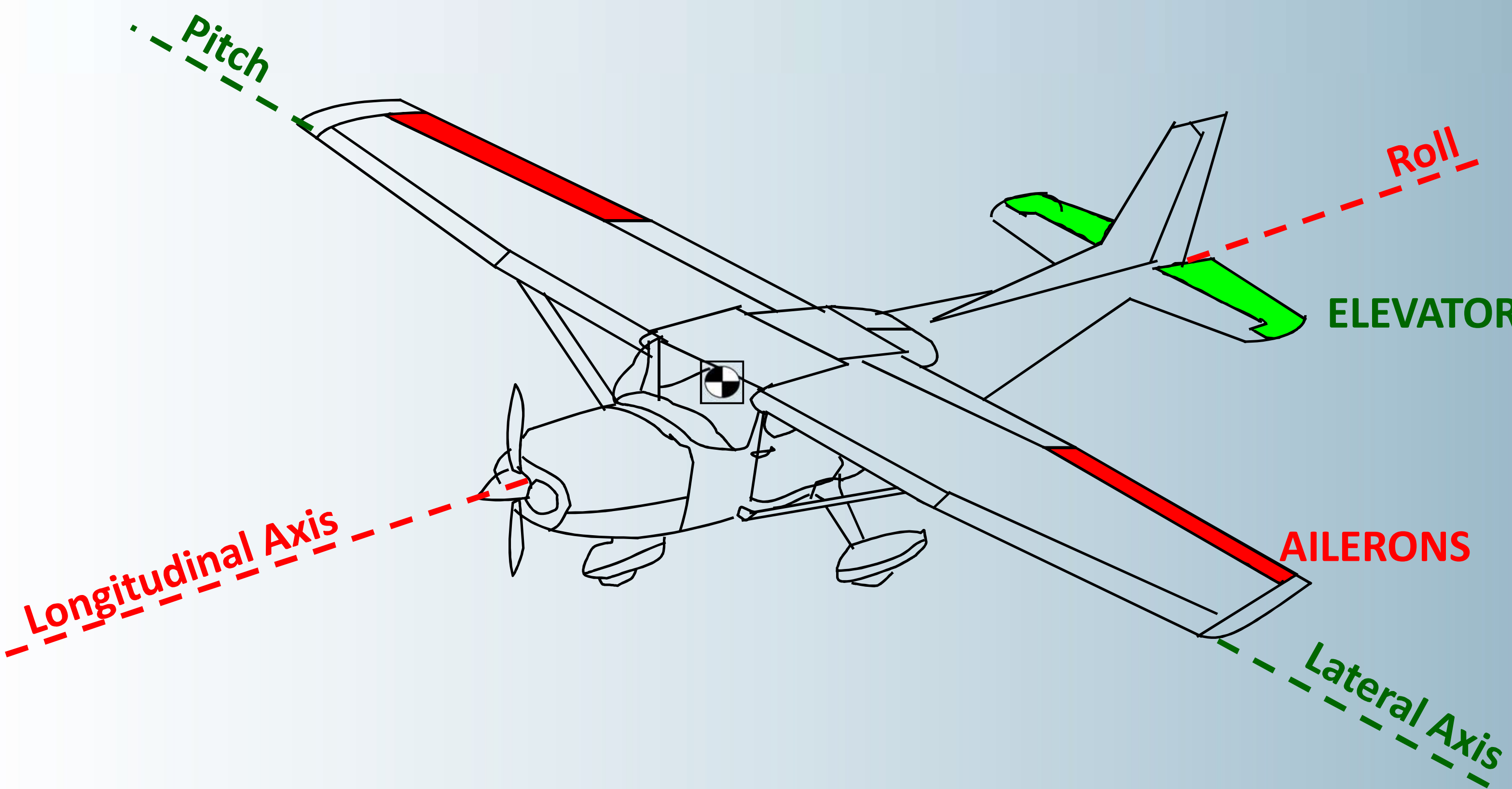

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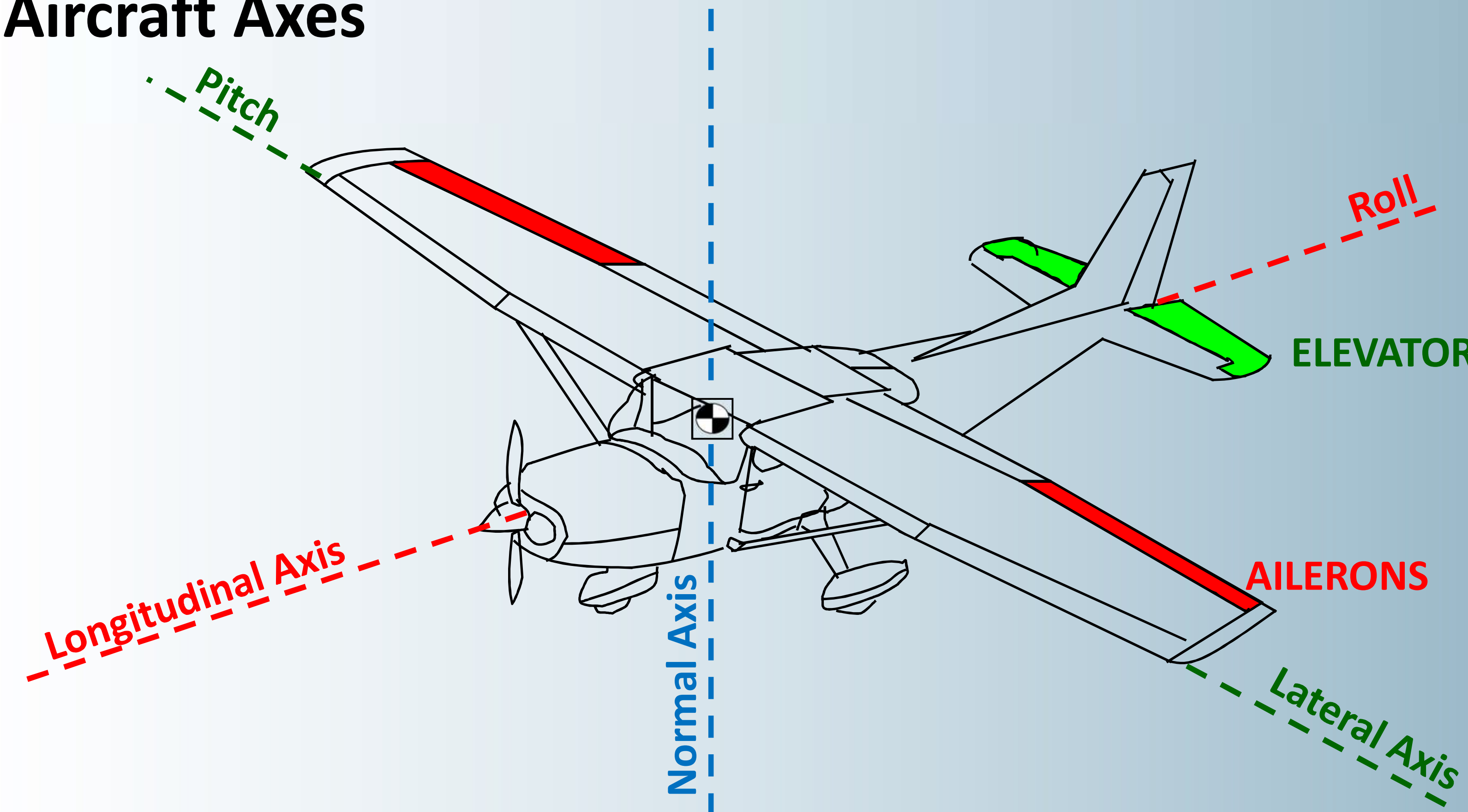

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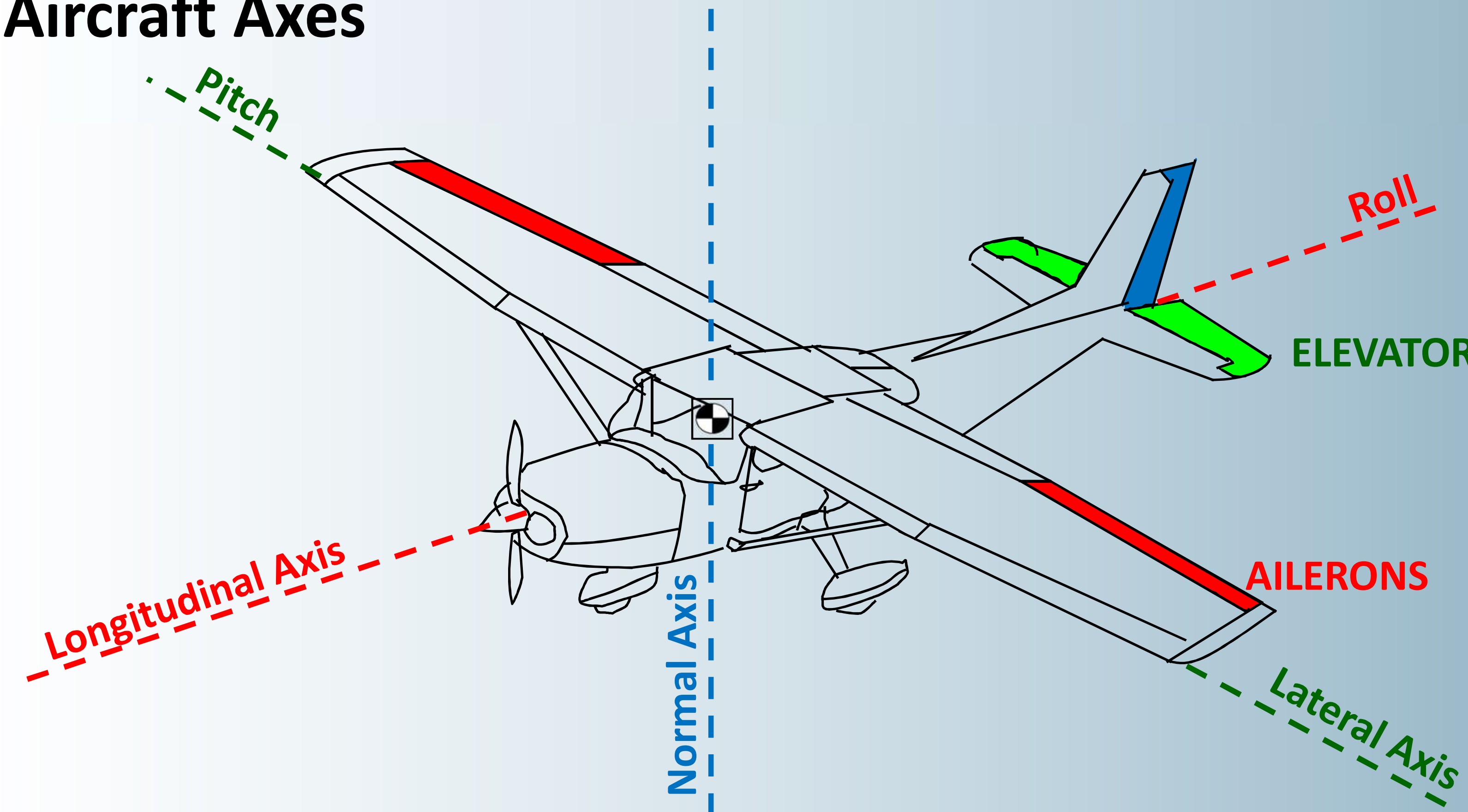

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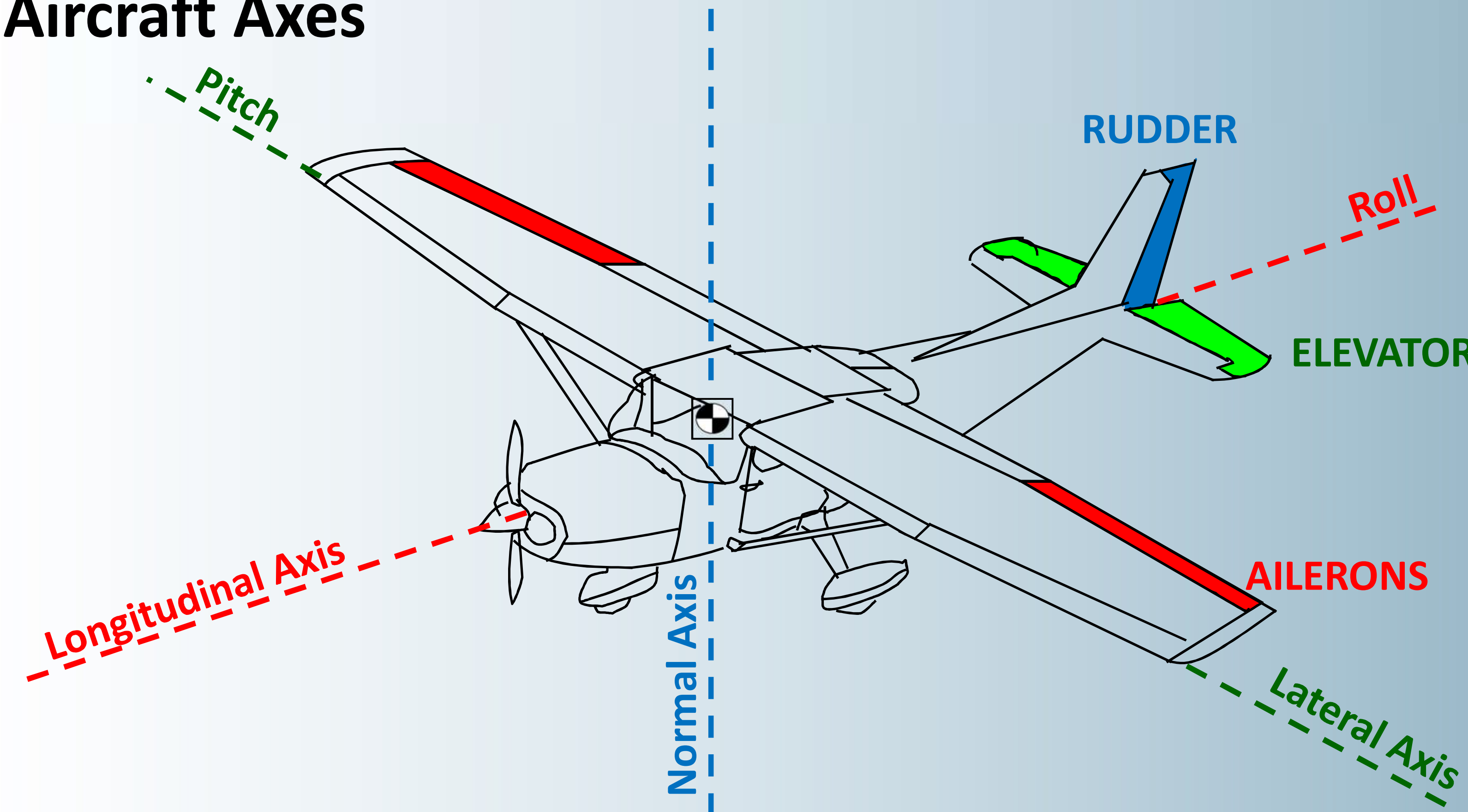

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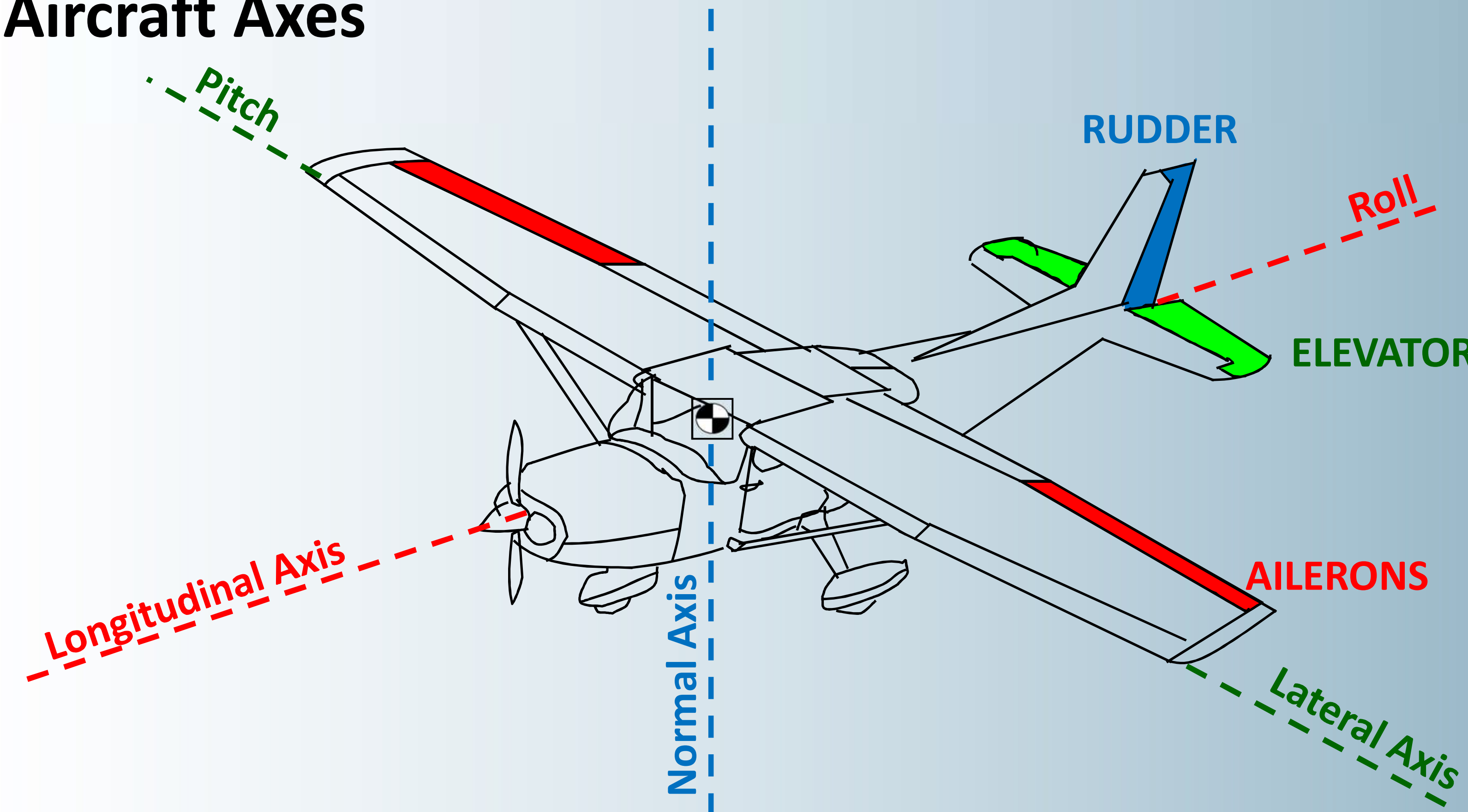

Ailerons – Operated through the Control Column and work in the natural sense.

Elevator – Operated through the Control Column and work in the natural sense.

Rudder – Operated through the Rudder Pedals and work in the natural sense.

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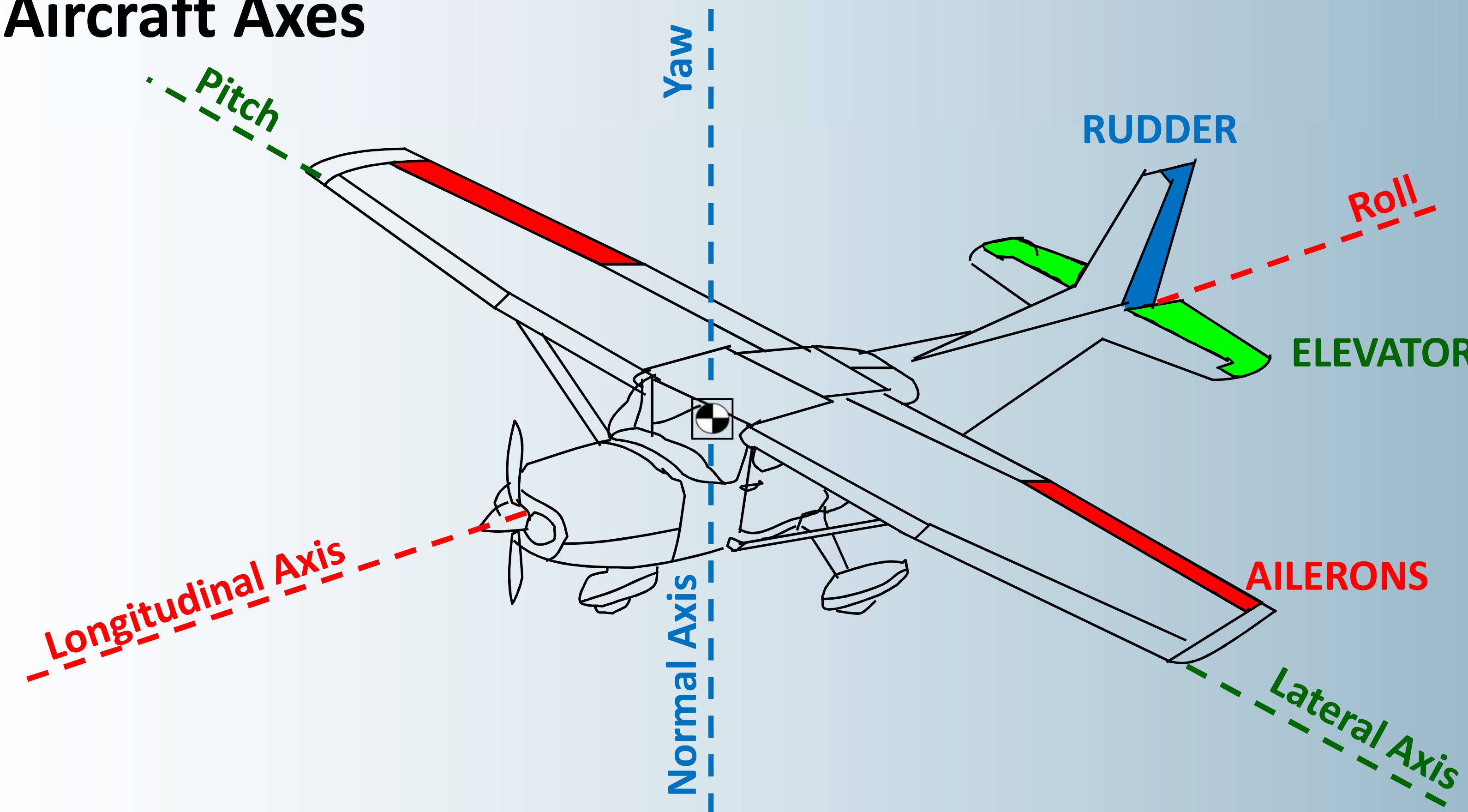

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STABILITY

Stability

- Part of learning to fly the aircraft straight and level is learning the stability characteristics of that aircraft

- What is stability?

"The reaction of any body when its equilibrium is disturbed"

- There are two types of stability we need to be aware of:

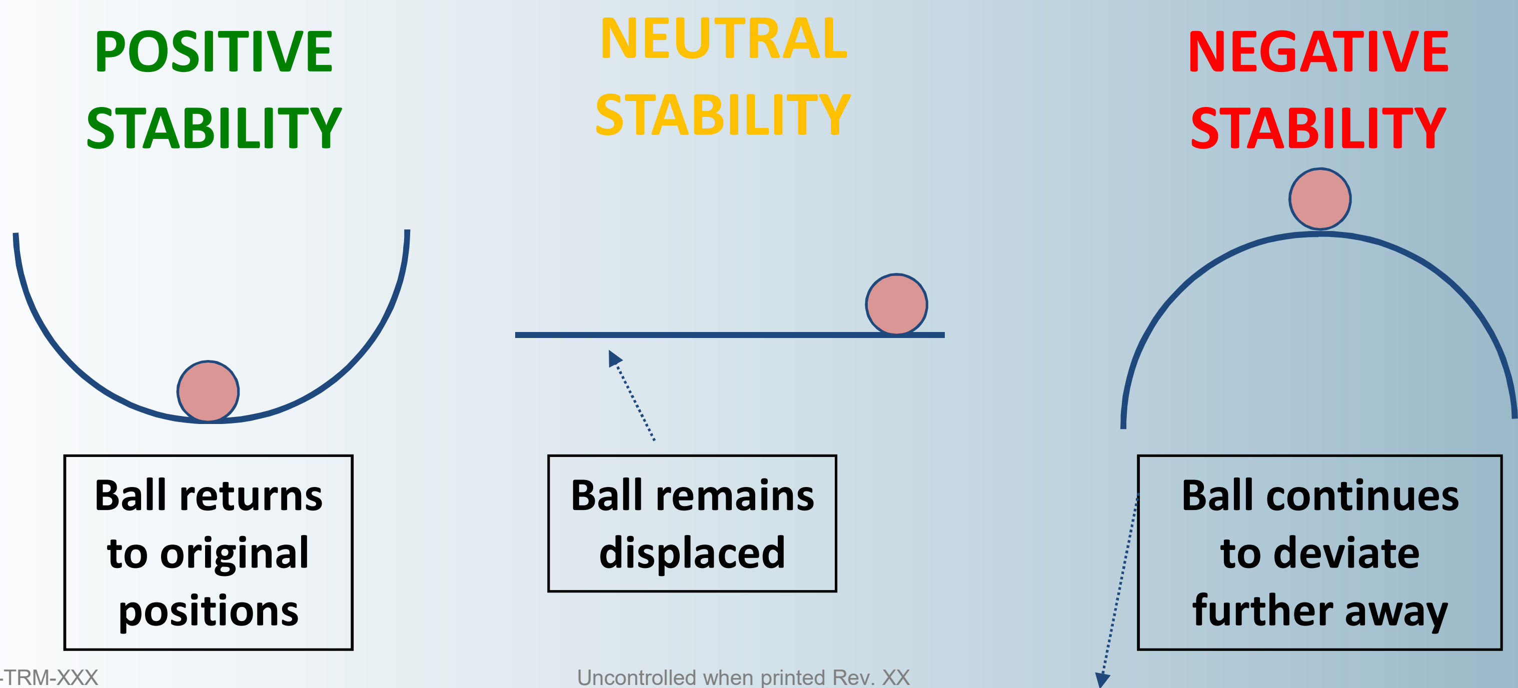
1. Static

2. Dynamic

Static Stability

Static Stability

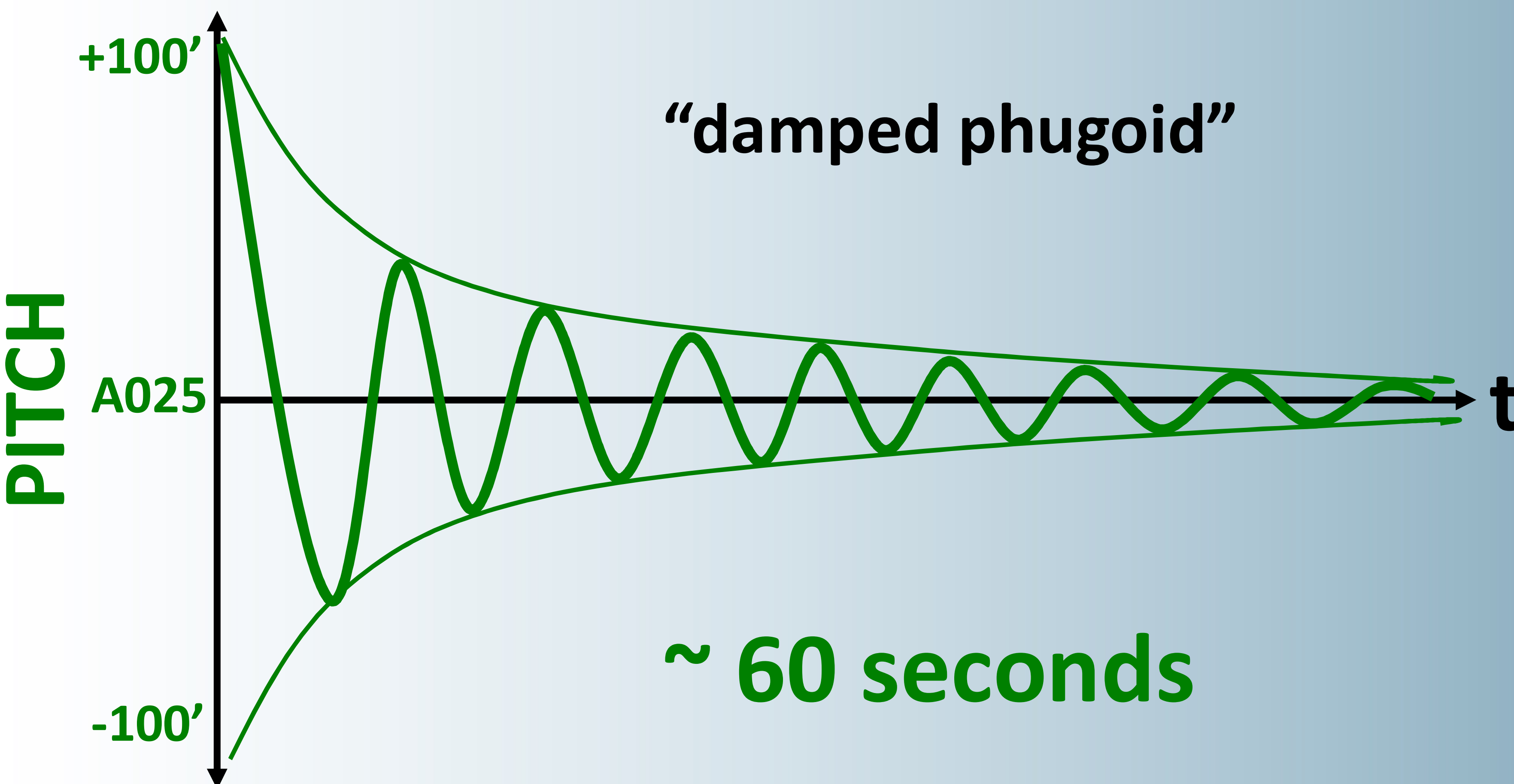
- The **initial response/tendency** of an aircraft when disturbed from a given AoA, slip or bank
- Describes the natural tendency of an aircraft to return to its original attitude following a disturbance (e.g. Turbulence)
- Occurs about all three axis



Dynamic Stability

Dynamic Stability

- The aircraft response **over time** after the disturbance



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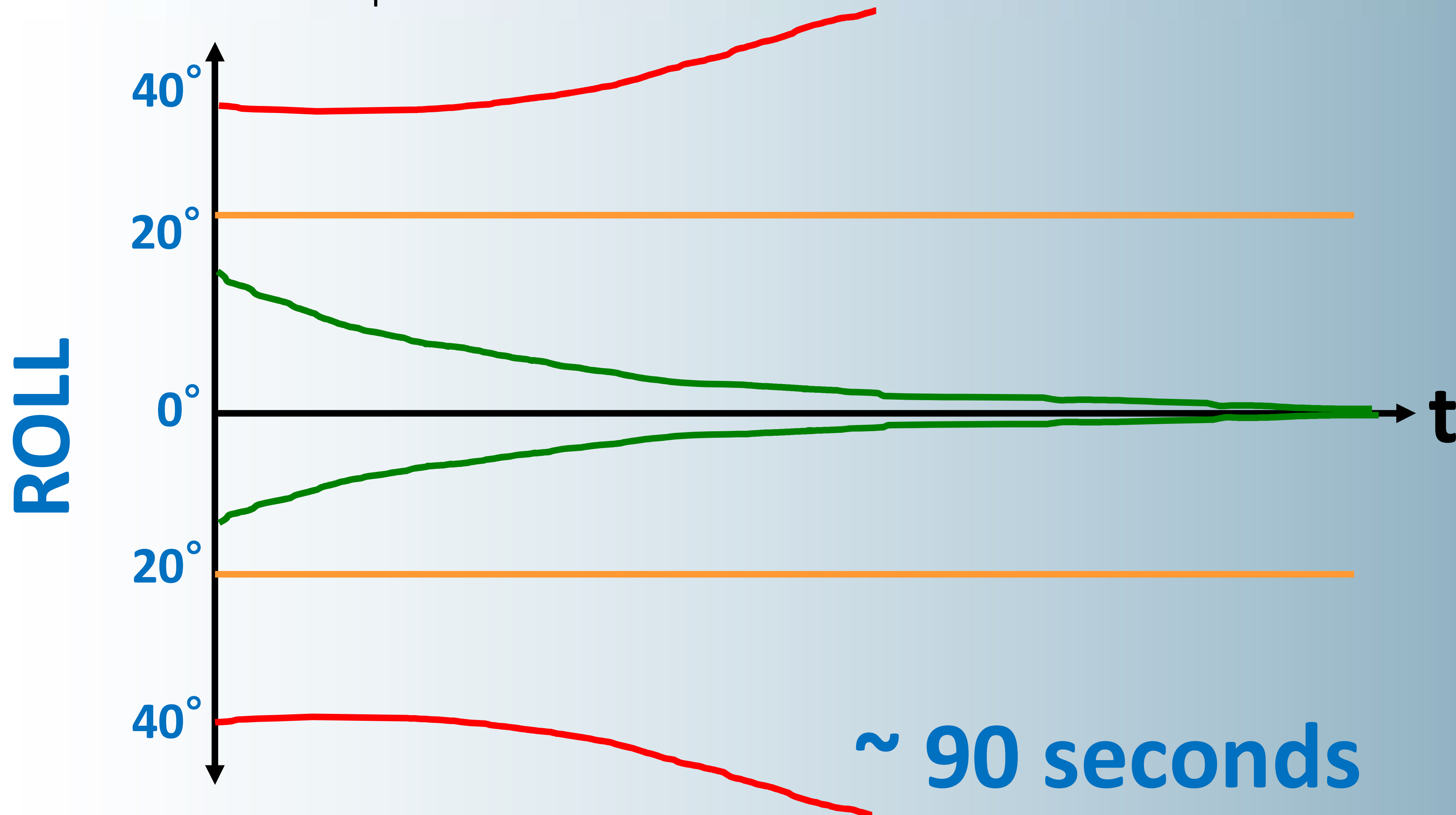

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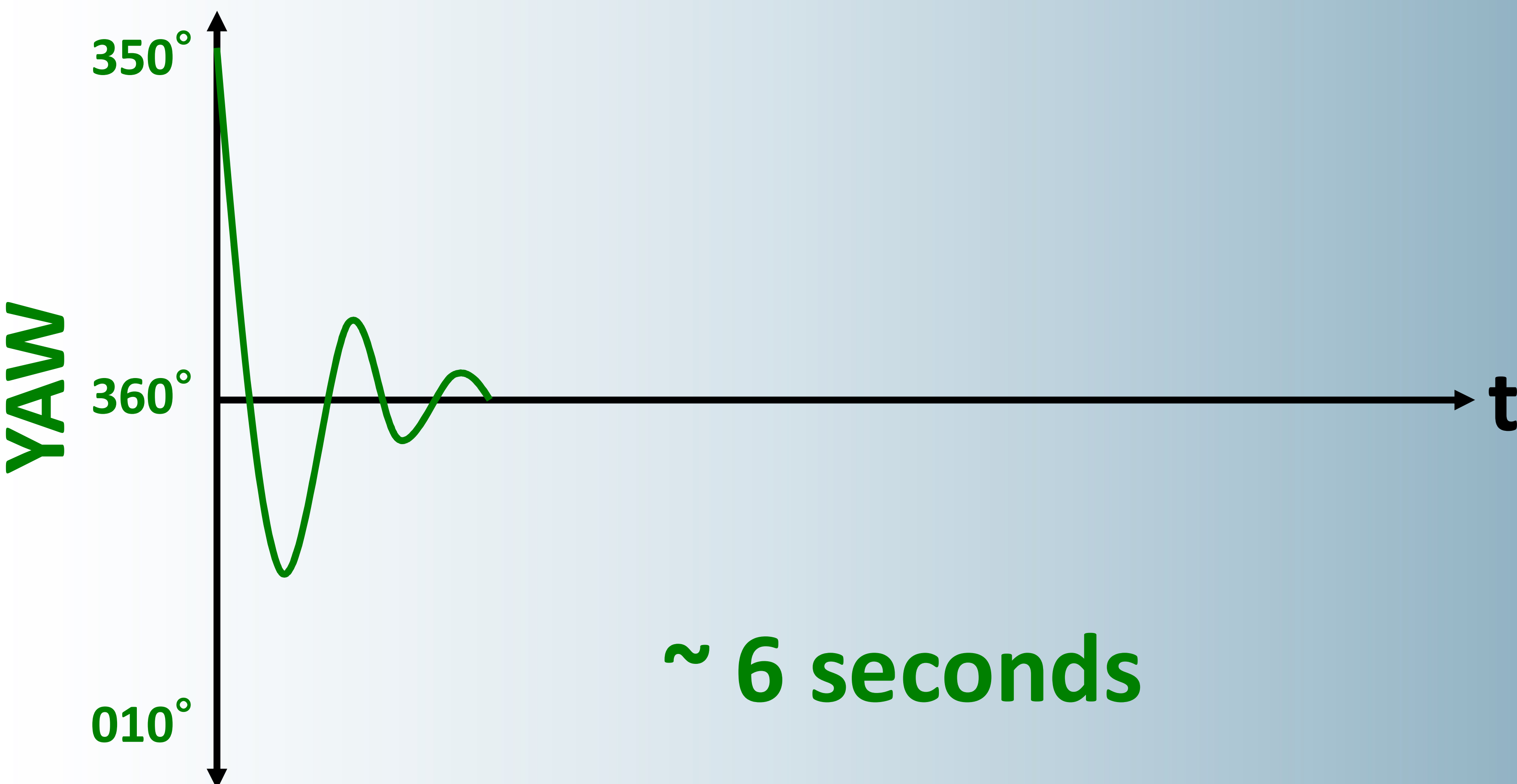

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LONGITUDINAL STABILITY

Longitudinal Stability

- An aircraft has Longitudinal Stability around the Lateral Axis
- In other words, it is “pitch” stability
- A longitudinally stable aircraft tends to maintain a trimmed condition of flight
- Several factors may contribute to Longitudinal Stability, including:

1. CoG Position

2. Tailplane Area

3. Longitudinal Dihedral

Longitudinal Stability – CoG Position

- The distance between the CoG and the tailplane CoP will affect Longitudinal Stability
- The further forward the CoG, the greater the length of the moment arm between the CoG and tailplane CoP and therefore the greater the righting moment
- The further aft the CoG, the smaller the length of the moment arm and therefore the smaller the righting moment
- Remember:

1. With a CoG forward of the forward limit – TOO STABLE

2. With a CoG aft of the aft limit - UNSTABLE

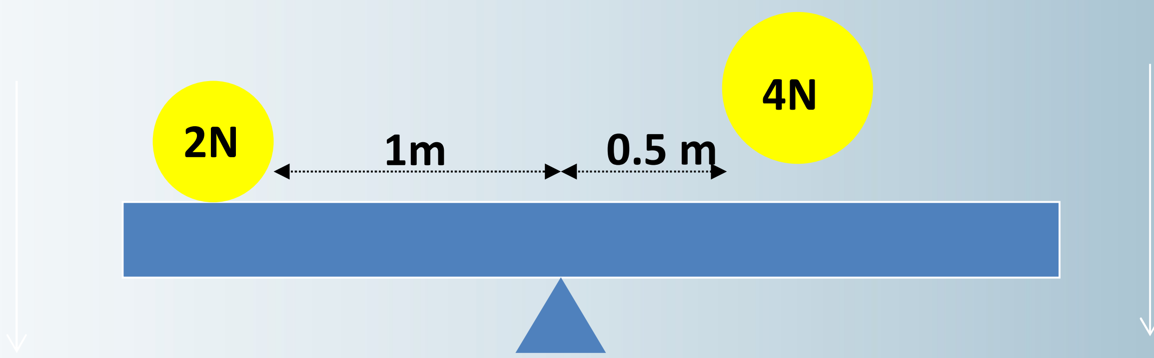
Moment

<u>Moment = Force x Arm</u>

The tendency to cause a rotation about a point or axis

To counteract this we require an opposing force to restore the object back to straight and level

Moment =
2N x 1m
= 2 N.m



Moment =
4N x 0.5m
= 2 N.m

Longitudinal Stability – Tailplane Area

- The area of the tailplane will also affect Longitudinal Stability

$$L = C_L \, ½ \, \rho \, v^2 \, S$$

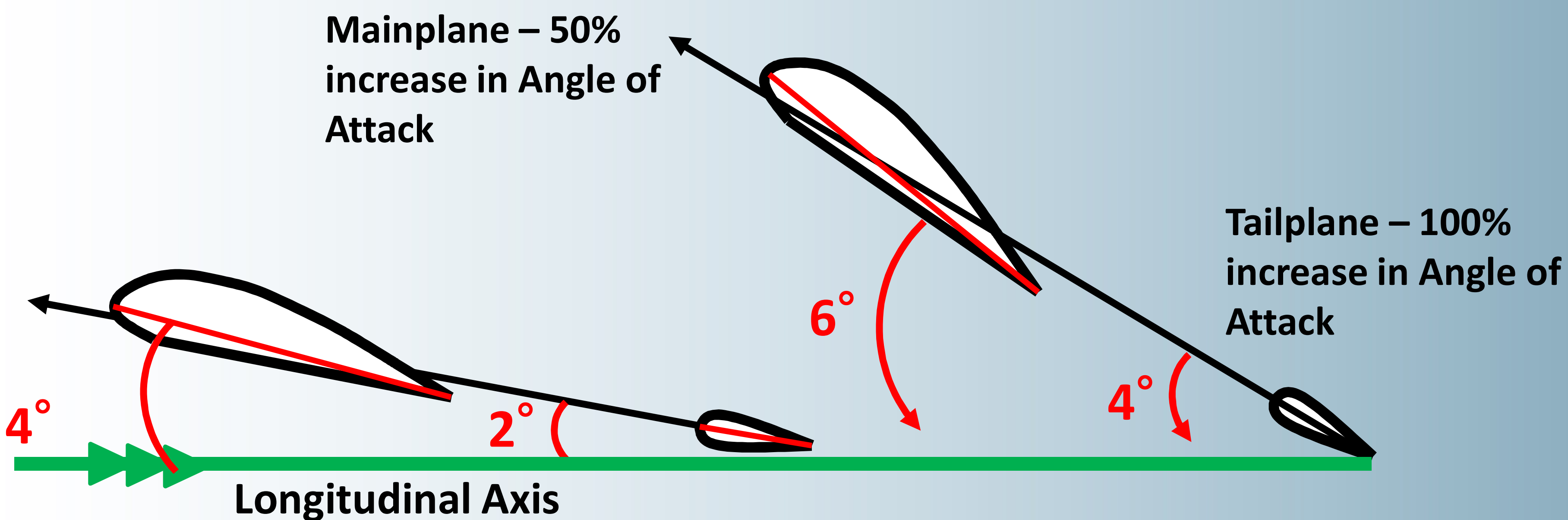
- The surface area of an aerofoil directly affects the amount of lift force generated

- Therefore, the larger the surface area of the tailplane, the greater the longitudinal stability

Longitudinal Stability – Longitudinal Dihedral

- Angle of Incidence refers to the angle between the chord line and the longitudinal axis

- In other words, the angle at which the wing is fixed to the airframe

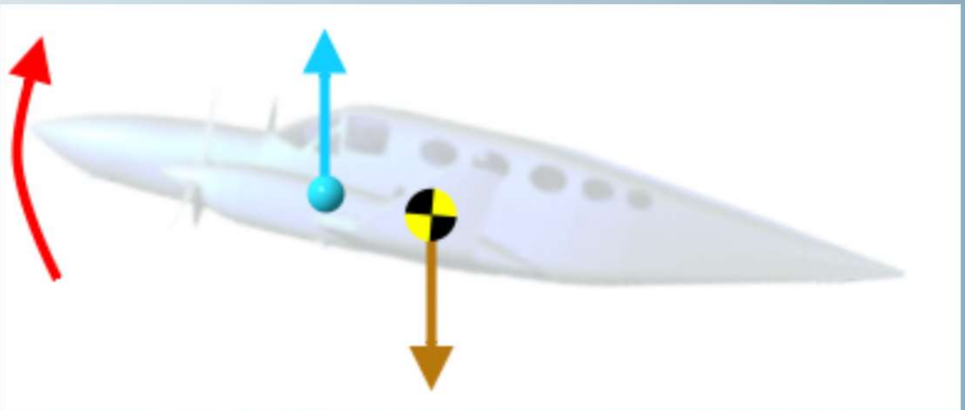


- The tailplane is presented at a smaller angle of incidence so that a greater % increase in lift will be produced when a disturbance occurs, producing a righting moment

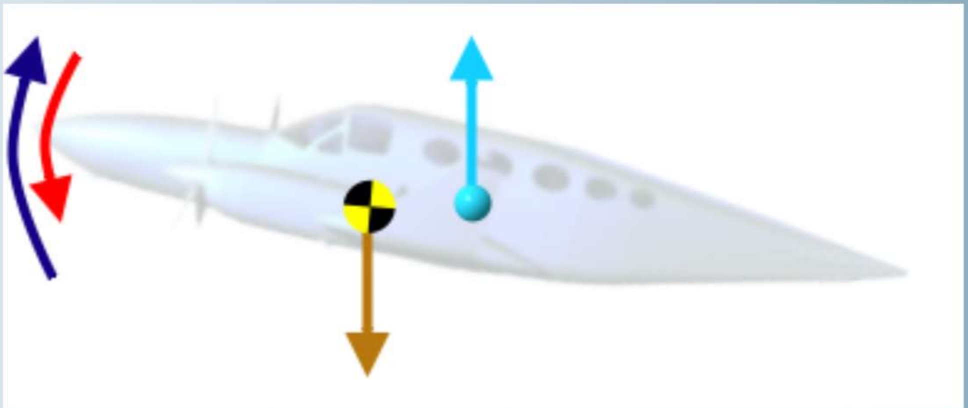
Longitudinal Stability – Centre of Pressure

- The position of the Centre of Pressure on a wing influences its stability

- If the CoP is forward of the CoG, a disturbance in pitch that increases the AoA would lead to an unstable condition as the nose-up moment would continue to pitch the nose higher and higher (negative static & dynamic)



- However, if the CoP is aft of the CoG, a disturbance in pitch that increases the AoA would naturally be restored by the nose-down moment (positive static & dynamic)



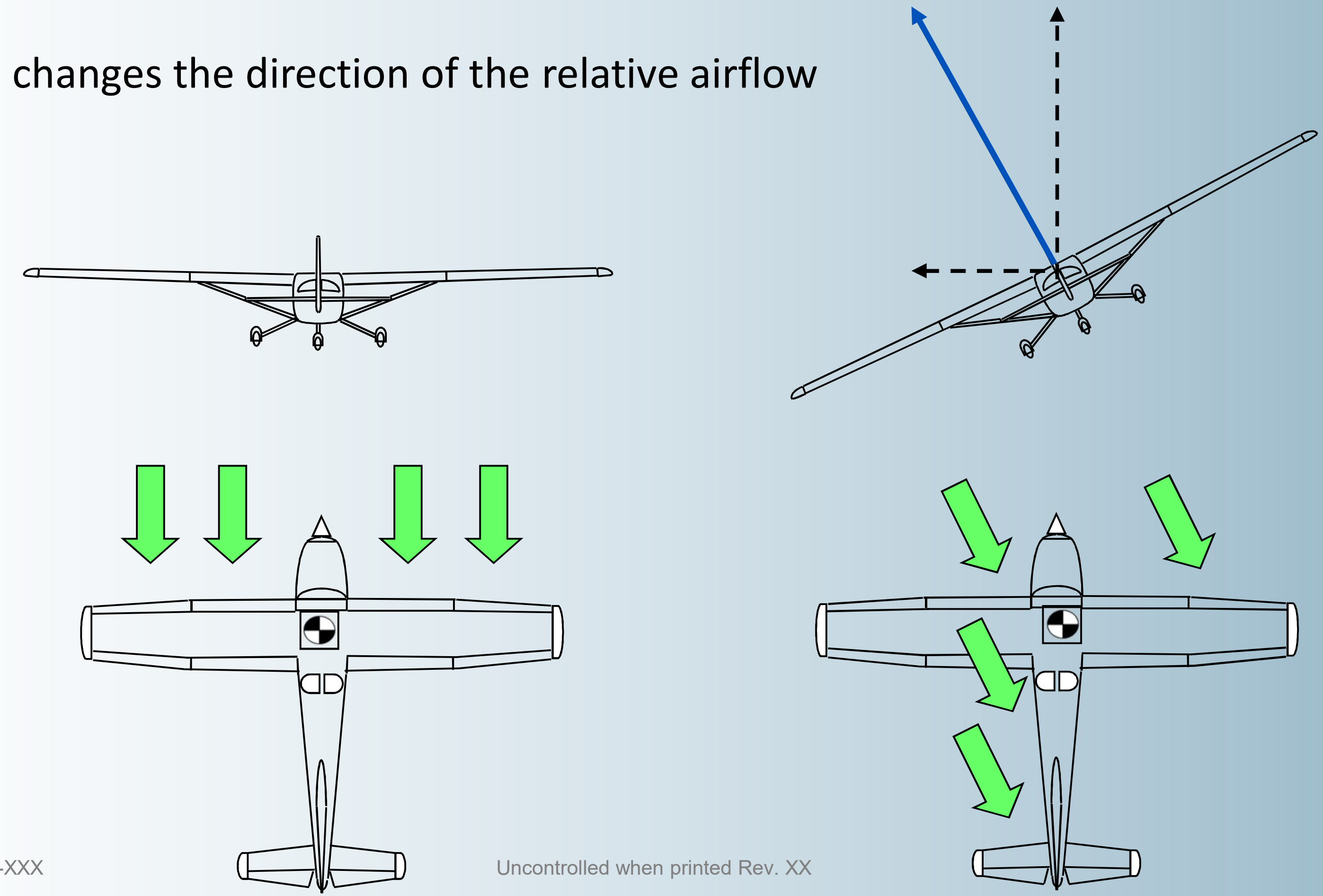
Longitudinal Stability – Thrust

- If thrust is increased, the nose will tend to pitch up (negative static & dynamic)
- If thrust is decrease, the nose will tend to pitch down (negative static & dynamic)

LATERAL STABILITY

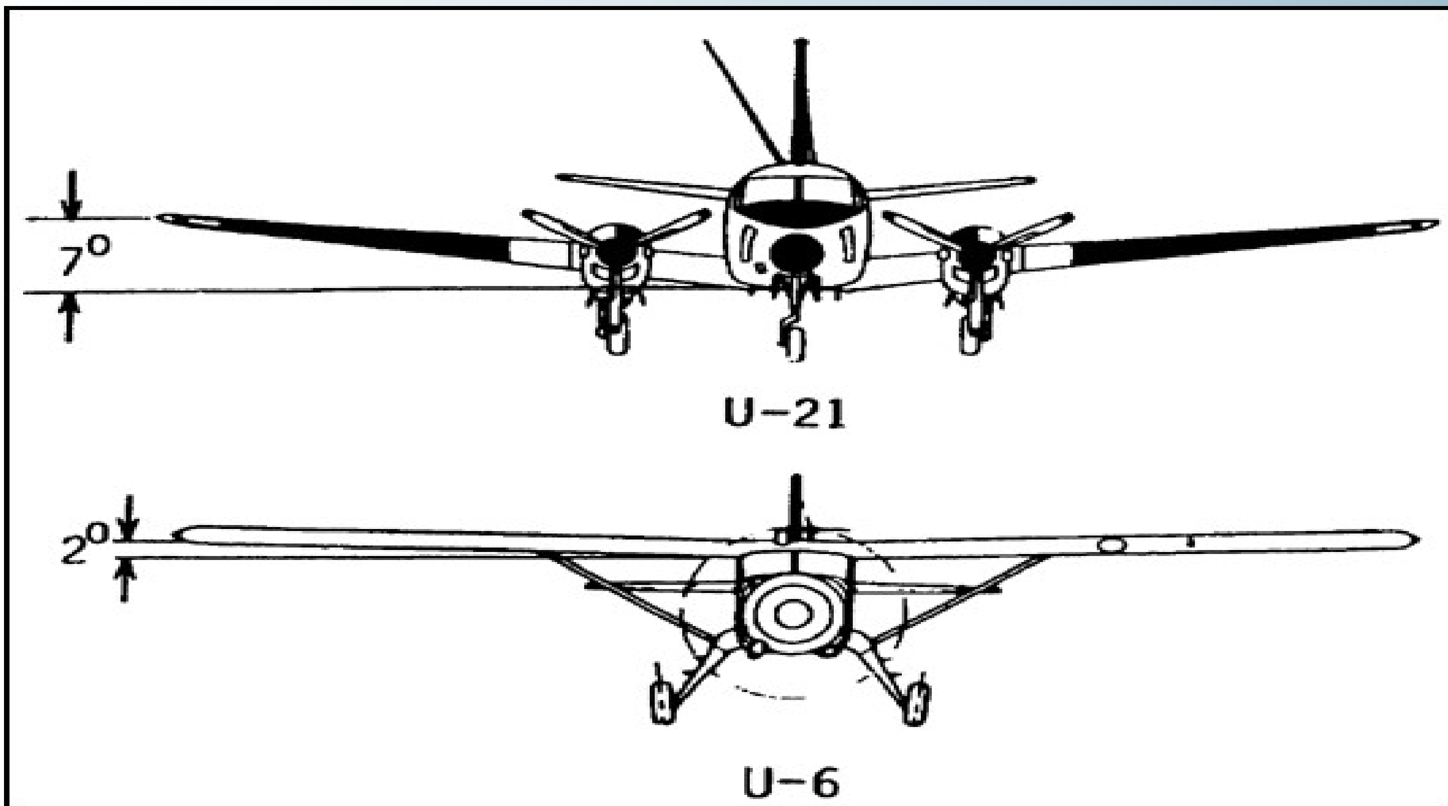
Lateral Stability

- An aircraft has Lateral Stability around the Longitudinal Axis – “roll” stability
- When an aircraft rolls, it will tend to sideslip into the turn initially
- This changes the direction of the relative airflow



Lateral Stability – Wing Dihedral

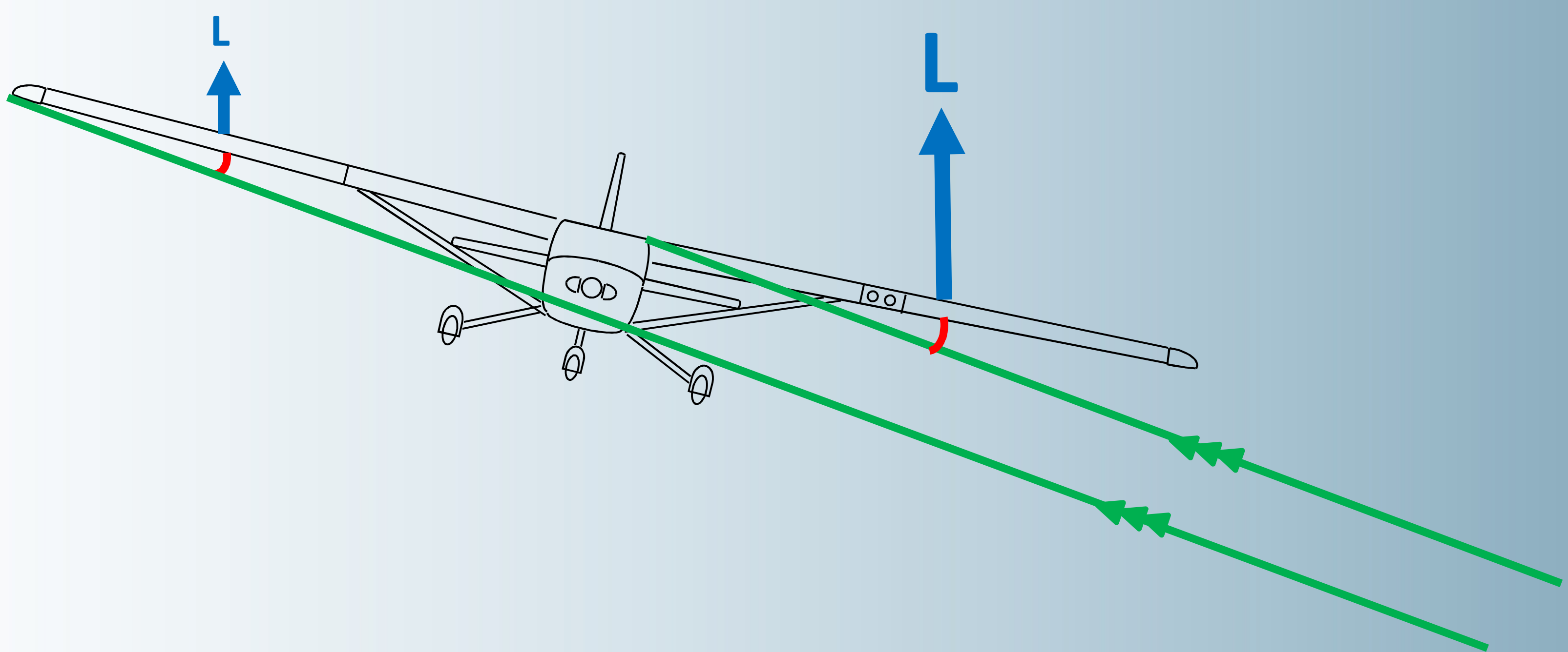
- Wing Dihedral improves Lateral Stability



- Instead of running parallel to the ground, the wings are angled slightly upwards

Lateral Stability – Wing Dihedral

- This means that during a sideslip, the lower wing presents at a greater angle of attack to the relative airflow



- Therefore, the lift on the lower wing will be greater and will work to level the wings

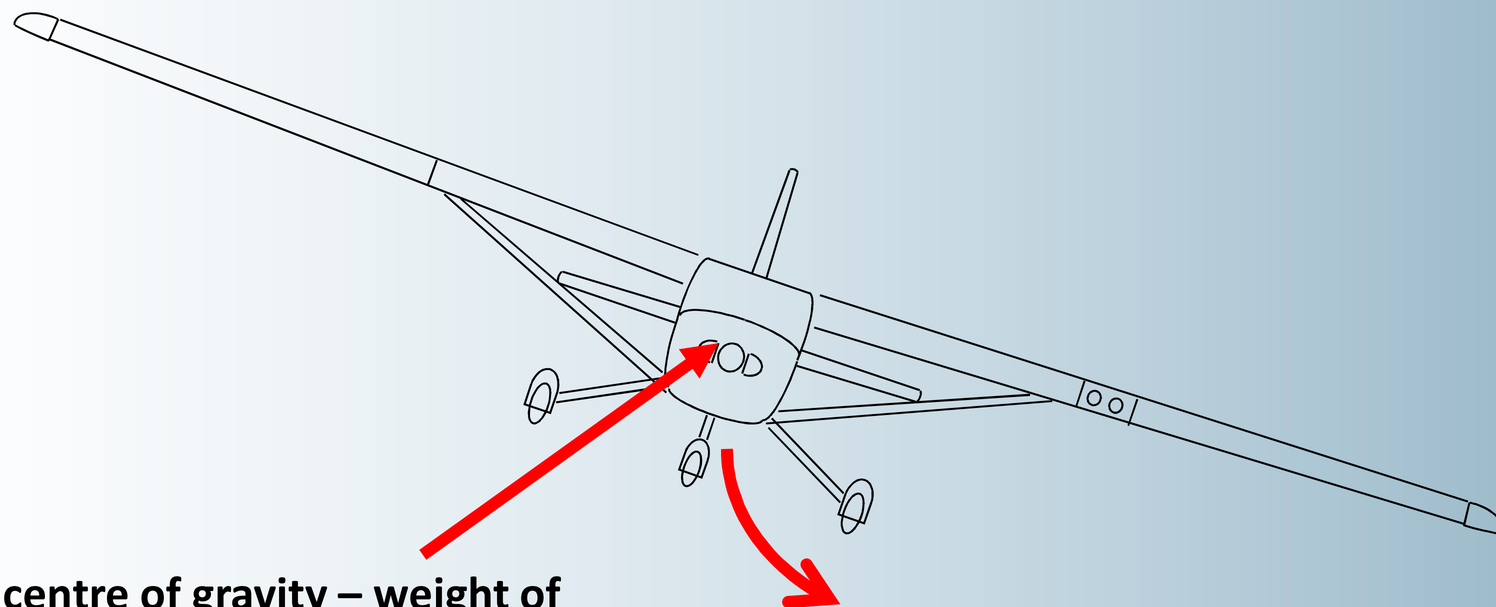
Lateral Stability – Wing Anhedral

- Wing Anhedral or Negative Dihedral decreases Lateral Stability

- It has a destabilising effect but increases manoeuvrability

Lateral Stability – Pendulum Effect

- When a high-wing aircraft is rolled, its low centre of gravity will also work to roll the wings level

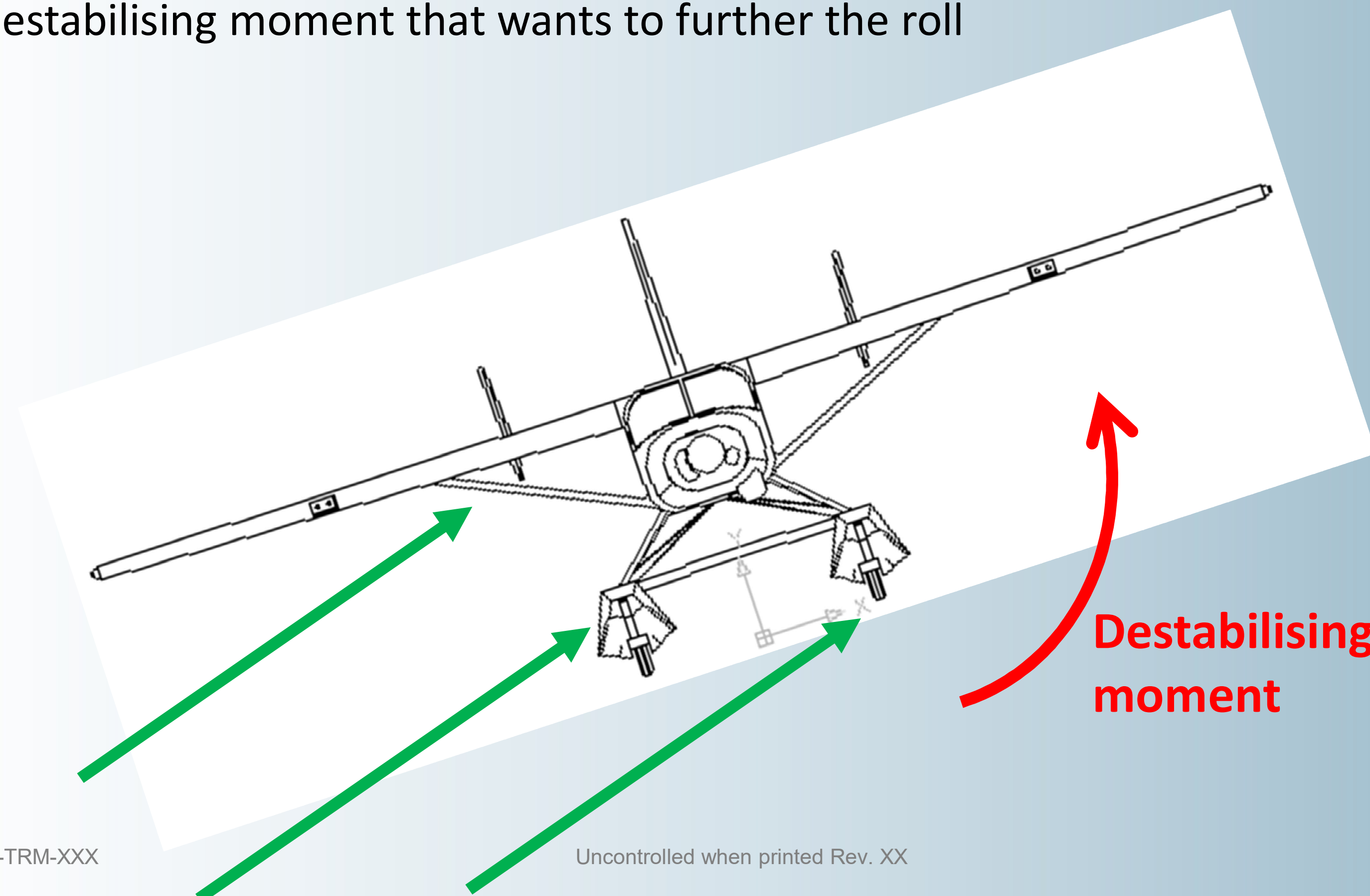


Low centre of gravity – weight of the aircraft due to gravity wants to return to aircraft to wings level

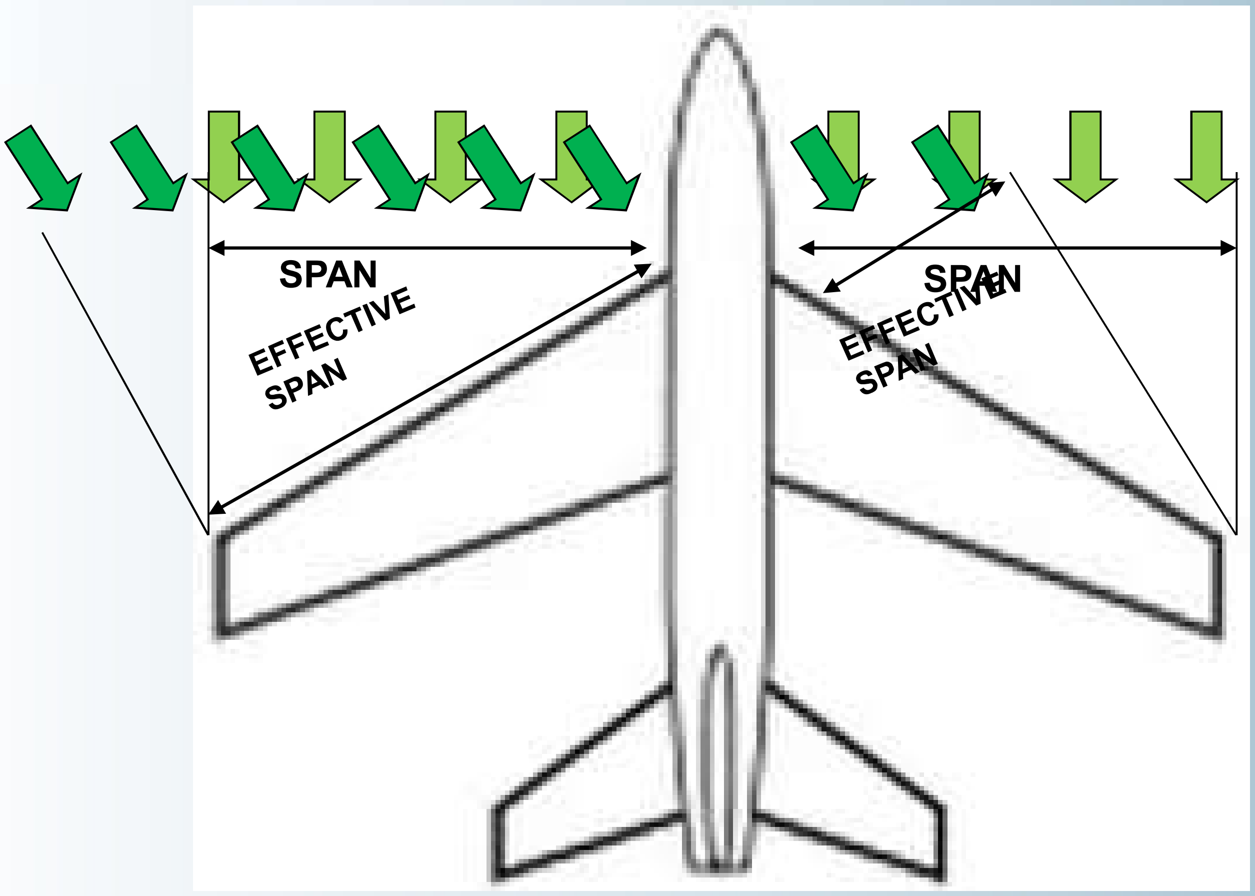
Lateral Stability – Floats & Other Keel Surfaces

- If an aircraft is fitted with floats or other keel surfaces such as wheel fairings, lateral stability may be decreased

- The relative airflow striking the keel surfaces in a sideslip during roll causes a destabilising moment that wants to further the roll



Lateral Stability – Swept Back Wings



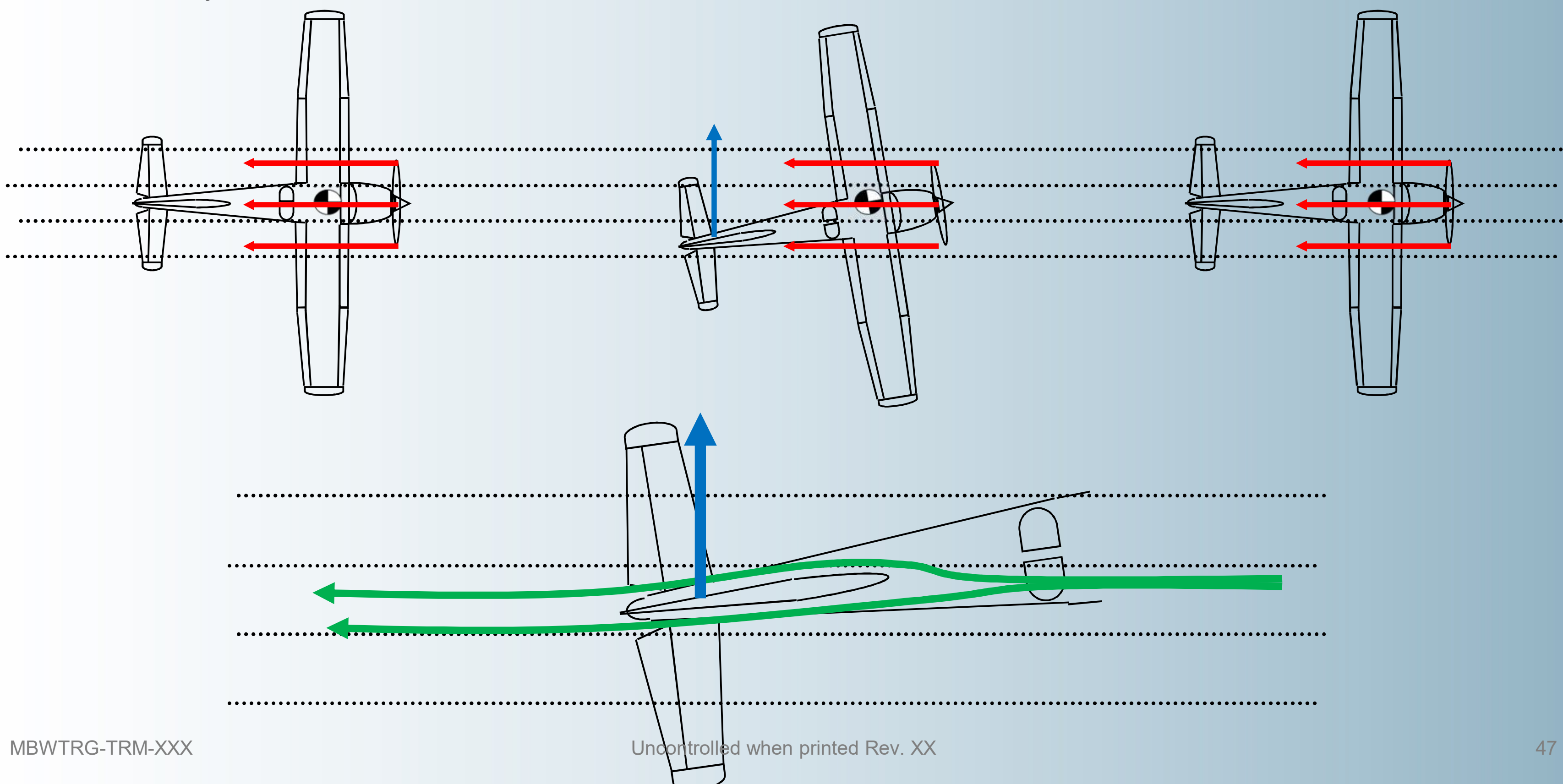
- During a sideslip in a roll, the lower wing will present more of its span to the relative airflow than the upper wing, therefore generating more lift to right the aircraft

DIRECTIONAL STABILITY

Directional Stability

- An aircraft has Directional Stability around the Normal Axis – "yaw" stability

- Large keel surfaces aft of the CoG provide the restoring force so once again, the greater the arm between the CoG and the vertical stabiliser, the greater the stability



SPIRAL INSTABILITY

Spiral Instability

- In light training aircraft, **Directional Stability** is the strongest
- When directional stability is stronger than lateral stability, an effect known as **spiral instability** may occur
- As the aircraft rolls, it will sideslip, changing the direction of the relative airflow
- At this point, two things will occur:

  1. **The lateral stability will attempt to roll the wings level**
  2. **The directional stability will try to yaw the aircraft to line it up with the new relative airflow**

- Directional stability is greater so the aircraft will yaw

Spiral Instability

- As the aircraft yaws, the outboard wing travels faster and therefore generates more lift, producing further roll

- The bank angle will continue to increase and eventually the aircraft will be established in a **spiral dive**

- **Symptoms:**
  - High AoB
  - Low nose attitude, high rate of descent
  - High and increasing airspeed.

- **Recovery:**
  - Reduce power to idle.
  - Gently roll wings level with aileron
  - Raise nose to the glide attitude