Learn & Fly

Basics of Flight

Module #3

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3. Basics of Flight
3.1 Major components of an aircraft

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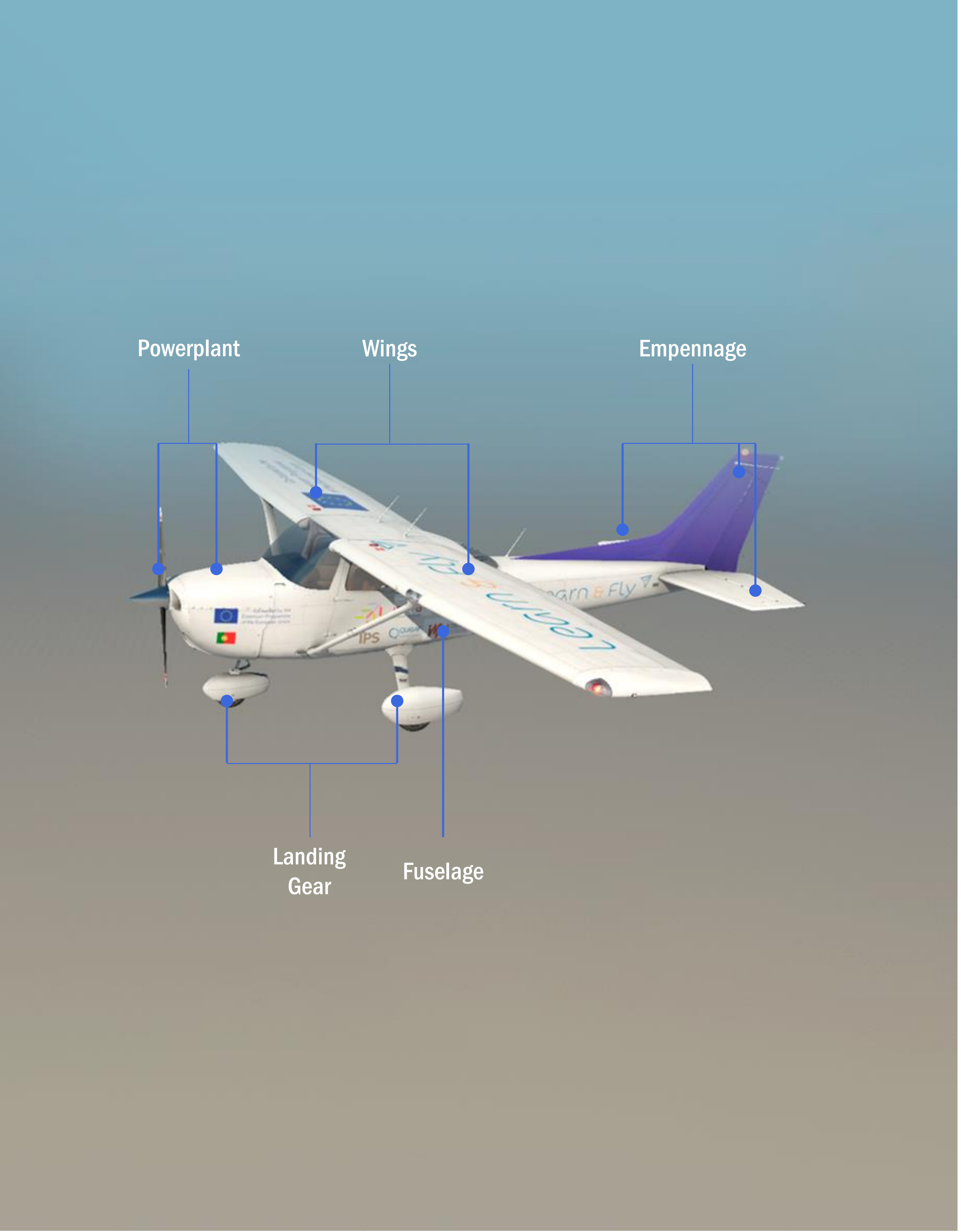


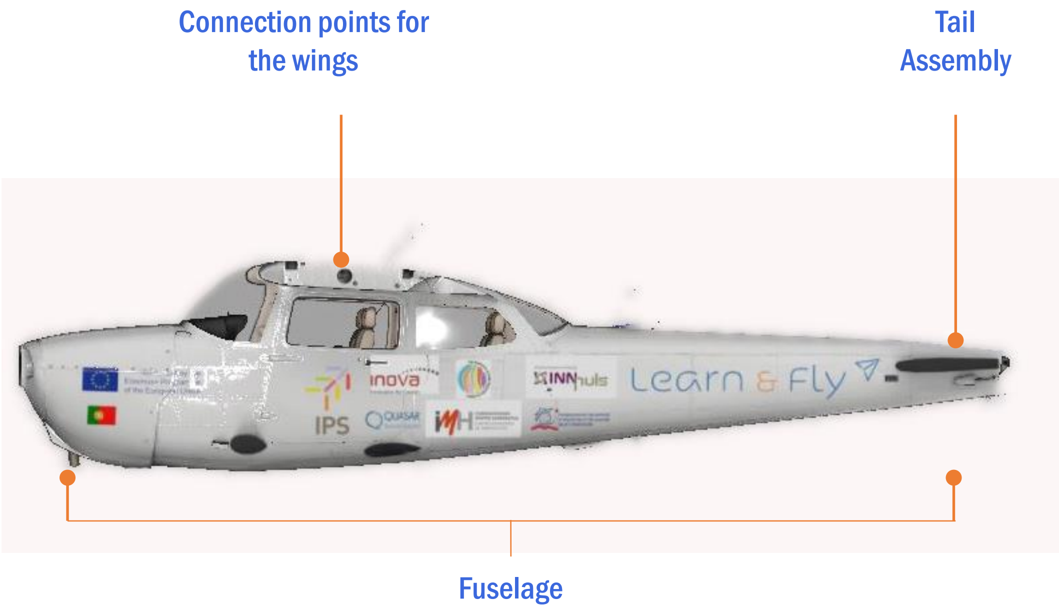
Fuselage
The fuselage is the central body of an airplane.

Wings
The wings are airfoils attached to each side of the fuselage.

Empennage
The empennage includes the entire tail group.

Landing Gear
The landing gear is the principal support of the airplane when on ground.

Powerplant
The powerplant includes both the engine and the propeller.



Fuselage

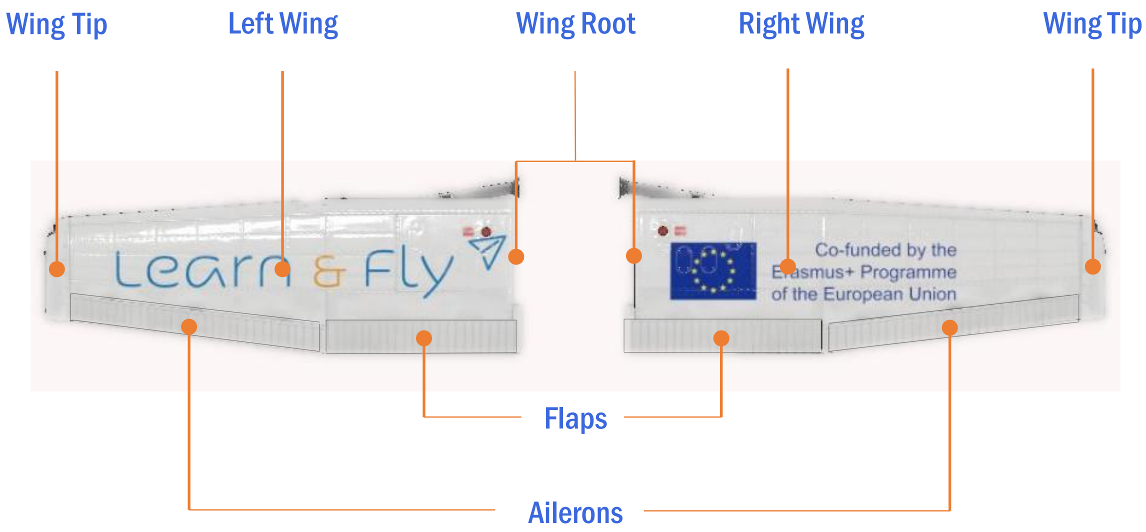
The fuselage is the central body of an airplane and is designed to accommodate the crew, passengers, and cargo.

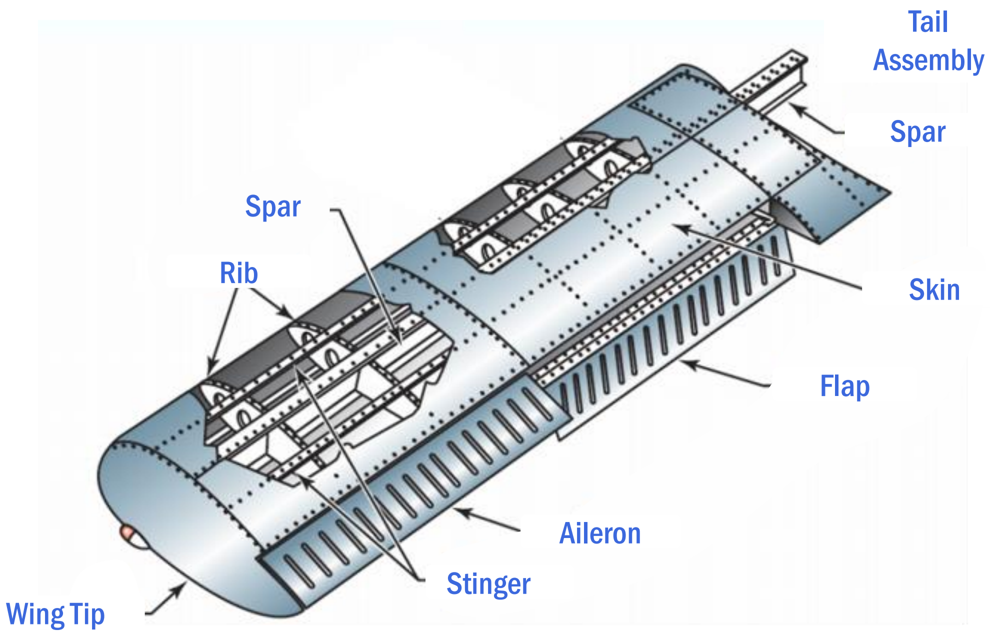
It also provides the structural connection for the wings and tail assembly.

Wings

The wings are airfoils attached to each side of the fuselage and are the main lifting surfaces that support the airplane in flight.

Attached to the rear, or trailing edges, of the wings are two types of control surfaces referred to as ailerons and flaps.





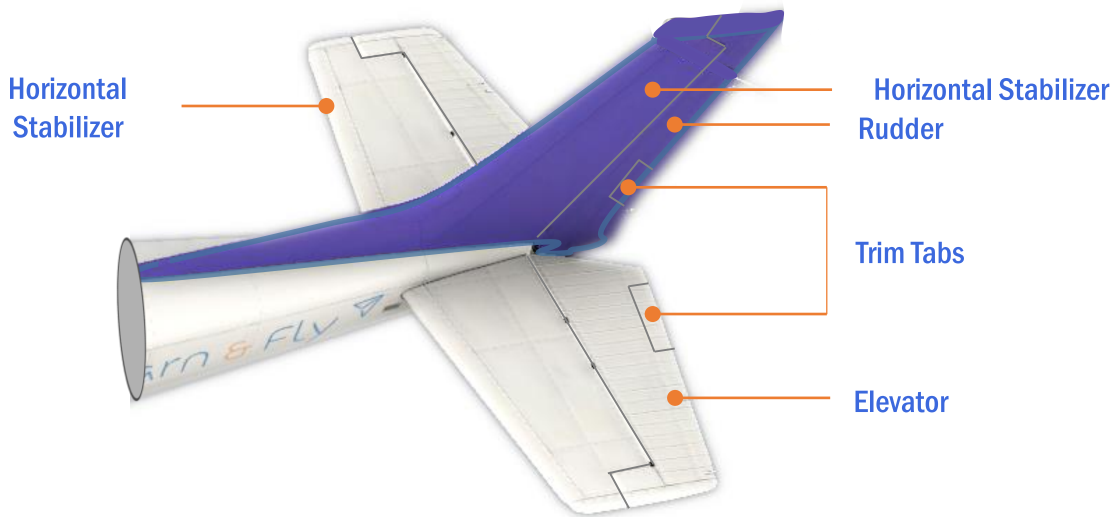
Wings

The principal structural parts of the wing are spars, ribs and stringers.

Empennage

The empennage includes the entire tail group and consists of fixed surfaces, such as the vertical stabilizer and the horizontal stabilizer.

The movable surfaces include the rudder, the elevator, and one or more trim tabs.

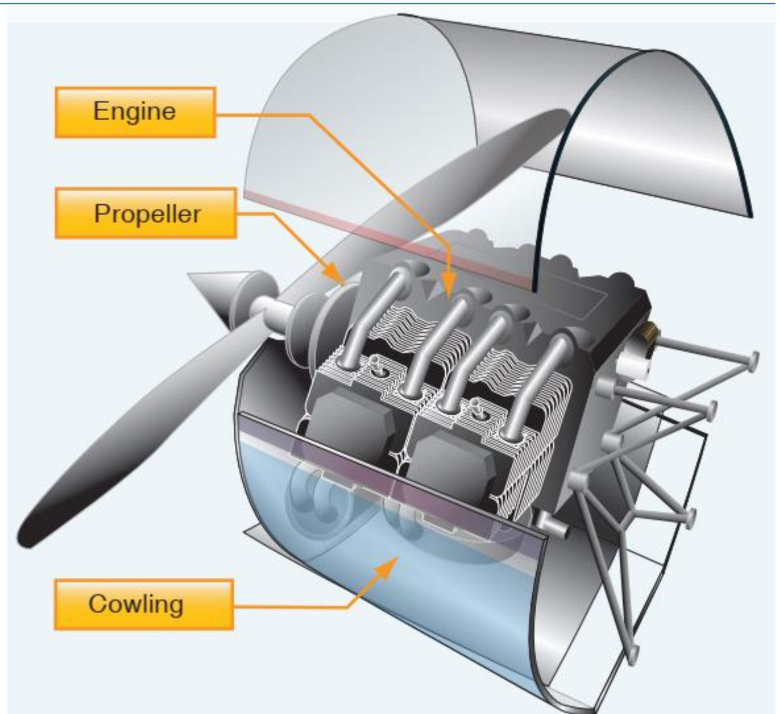


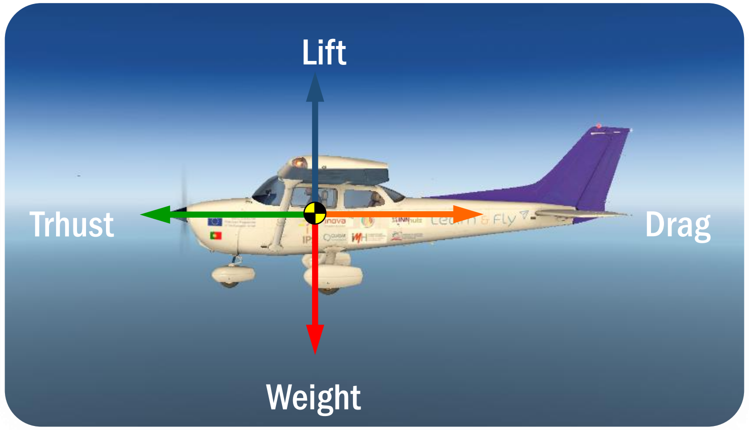
Landing Gear

The landing gear is the principal support of the airplane when parked, taxiing, taking off, or landing.
The most common type of landing gear consist of wheels, but airplanes can also be equipped with floats for water operations or skis for landing on snow.

Powerplant

The powerplant usually includes both the engine and the propeller. The primary function of the engine is to provide the power to turn the propeller. It also generates electrical power, provides a vacuum source for some flight instruments.
The engine is covered by a cowling, or a nacelle, which are both types of covered housing.





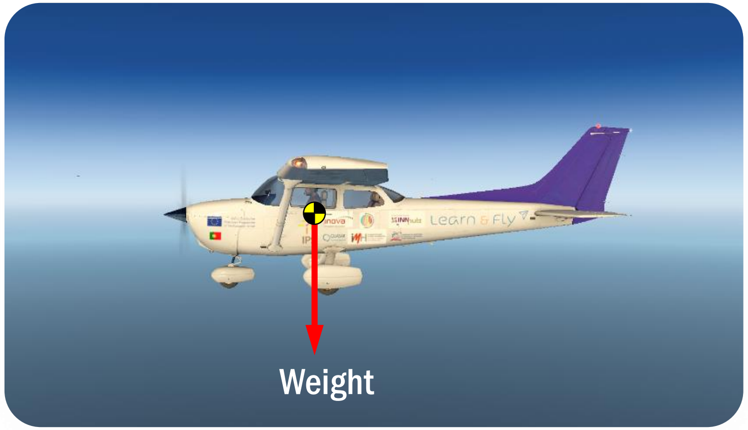
Four Forces

L – Lift
W – Weight
T – Thrust
D – Drag

In cruise speed the forces applied must obey the equations:

Lift = Weight

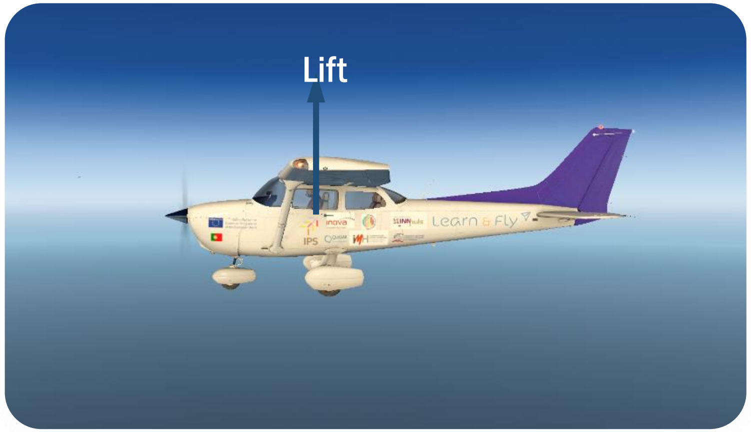
Thrust = Drag



Weight

Weight is the force that pulls the aircraft toward the earth. Weight is the force of gravity acting downward upon everything that goes into the aircraft, such as the aircraft itself, crew, fuel, and cargo.
The weight may be defined as the mass times the acceleration of gravity.

$$W = m\,g$$



Lift

Lift is the force that directly opposes the weight of an airplane and holds the airplane in the air. Lift is generated by every part of the airplane, but most of the lift on a normal aircraft is generated by the wings.

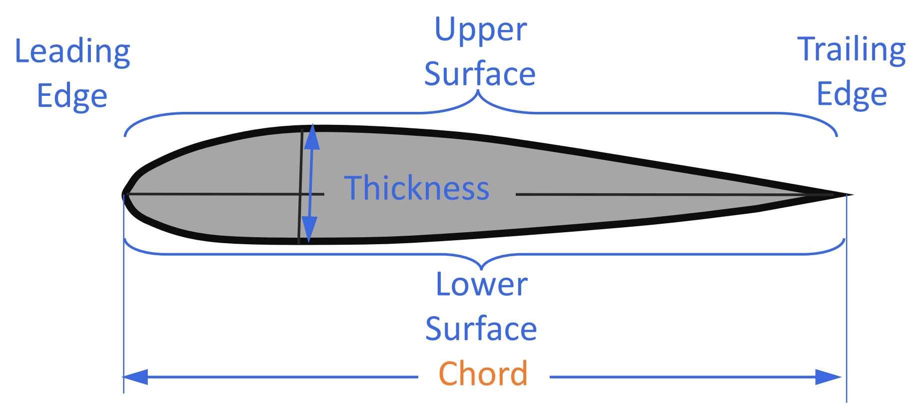
Airfol

An airfoil is a surface designed to obtain lift from the air through which it moves.

The chord, the thickness and the shape (upper surface and lower surface) of the airfoil is fundamental for generate lift.

Usually the upper surface has a more pronounced curvature (camber) than the lower surface.

It is this difference in the curvature surfaces that generate lift when a fluid (air) turned the airfoil.



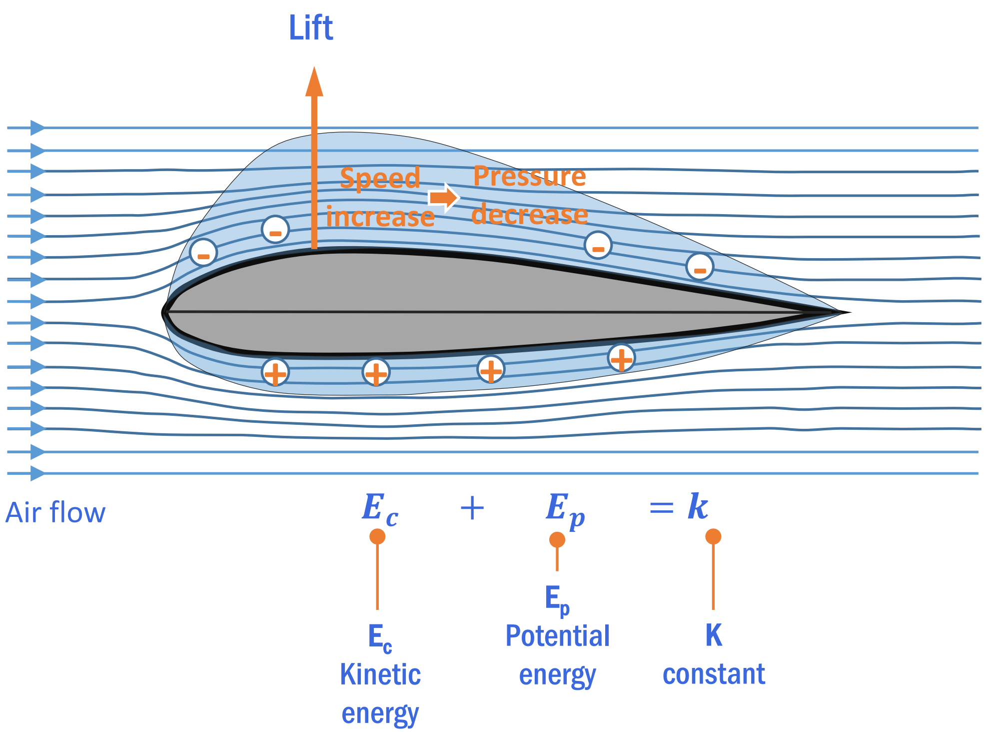
Bernoulli's principle

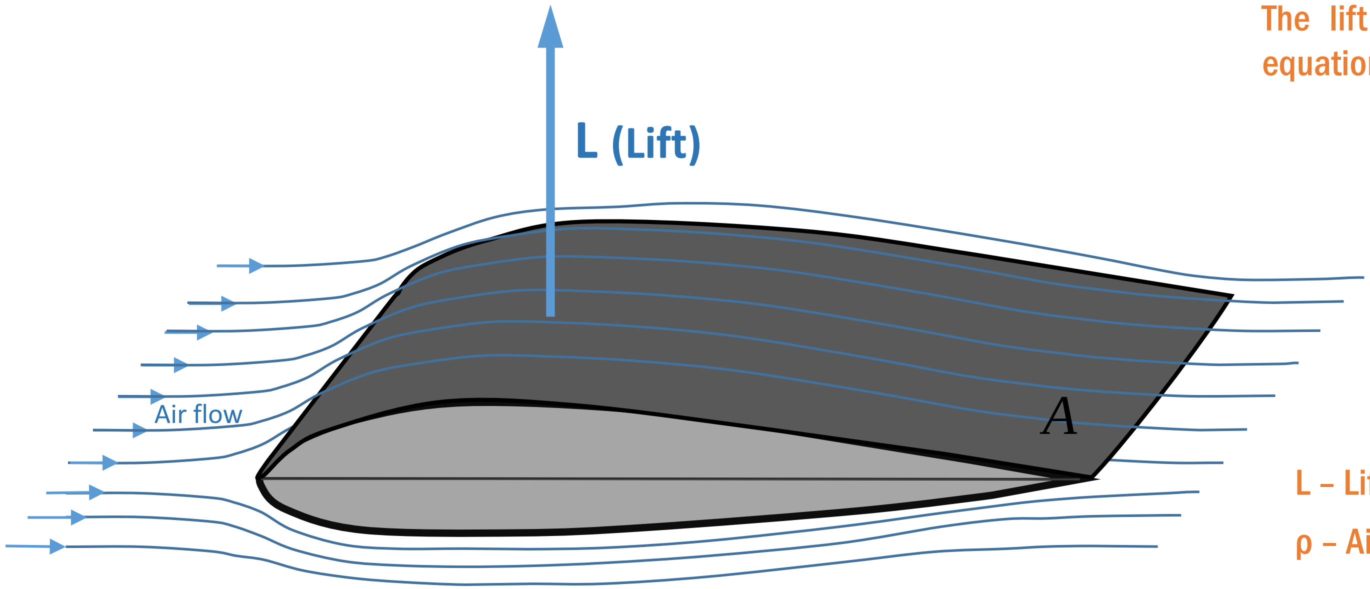
Bernoulli's principle can be derived from the principle of conservation of energy.

This states that, in a steady flow, the sum of all forms of energy in a fluid along a streamline is the same at all points on that streamline.

Due to the curvature of the upper surface of the airfoil the air speed increases (kinetic energy) and the pressure (potential energy) has to decrease.

A lower pressure is created at the upper surface. The difference of pressures between the upper surface and the lower surface are related with the lift force.





Lift Equation

The lift force L of an airfoil can be achieved by the equation:

$$L = \frac{1}{2}\rho\, v^2 A\, c_L$$

Air density

Wing area

Airspeed

Lift coefficient

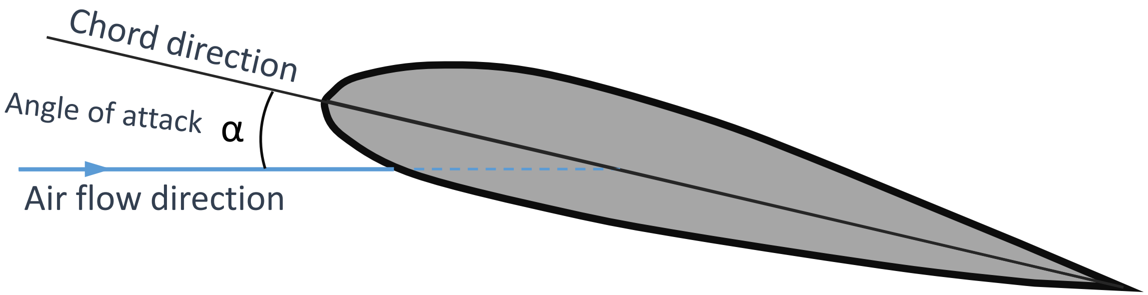
L – Lift force (N - Newton)

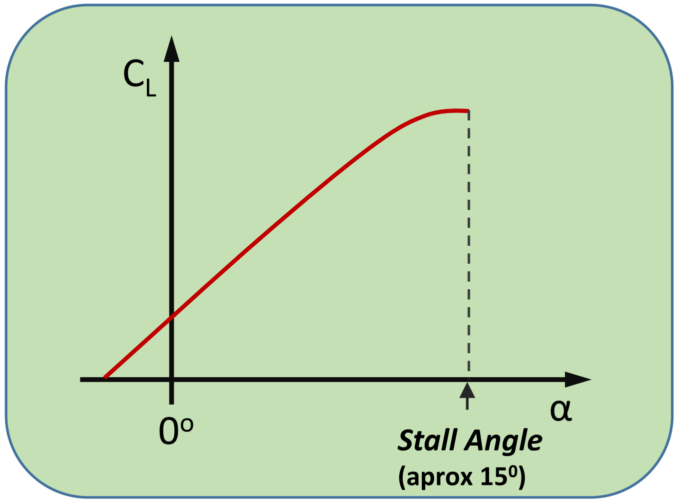
ρ – Air density (1.225 kg/m^3 at 15oC and 1013hPa)

v – velocity or airspeed (m/s)

A – Wing area surface (m^2)

CL – Lift coefficient (dimensionless)





Lift Coefficient C_L

The lift coefficient C_L is obtained experimentally. It depends on the airfoil shape and the angle of attack α.

The angle of attack α (also known as AoA) is the angle between airfoil chord and the air flow direction.

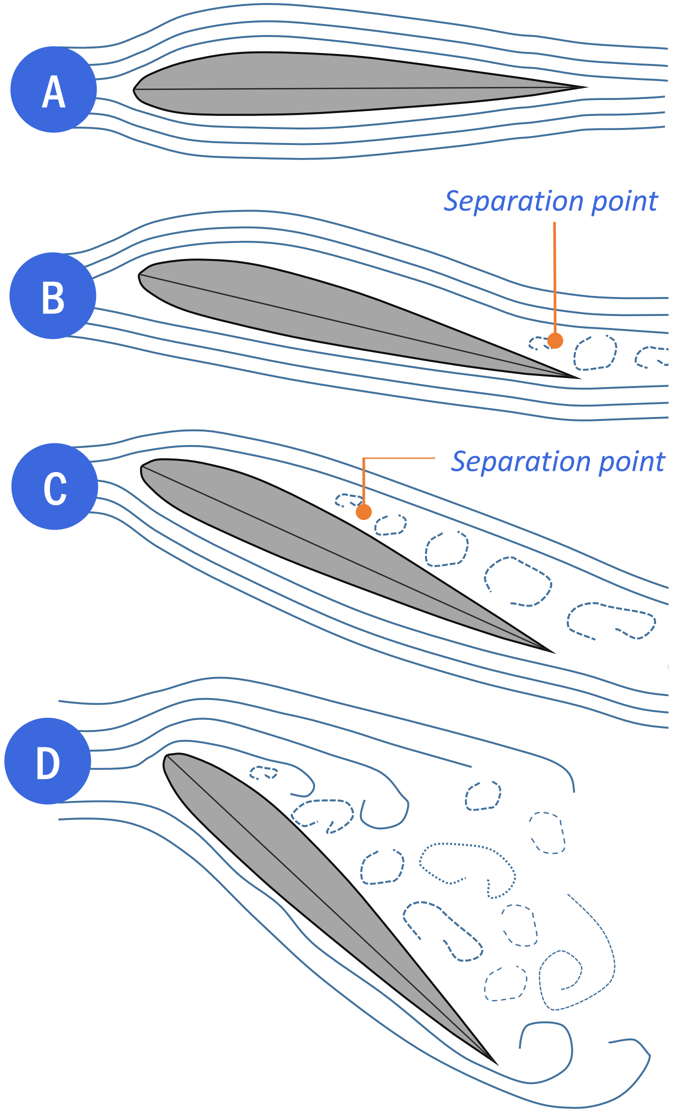
Angle of attack

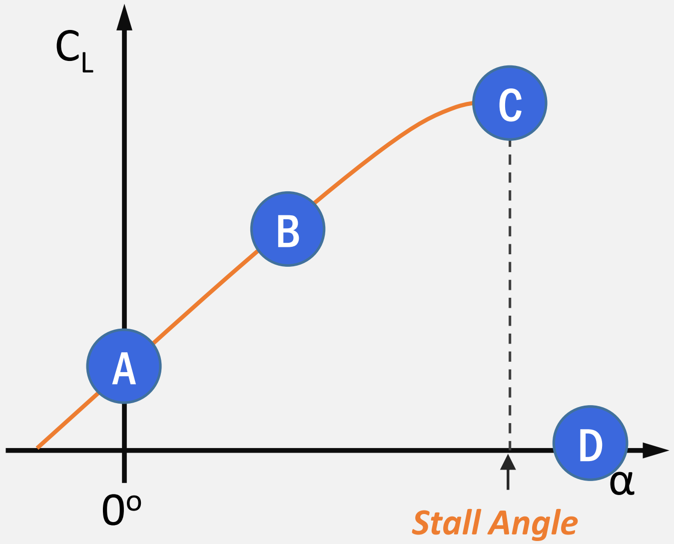
No angle of attack
No separation flow
Lift generated

Medium angle of attack
Separation flow
Lift increased

Maxim angle of attack
Separation flow increased
Maximum Lift

Angle of attack above maximum
No laminar flow
No Lift





Drag force

Drag is the aerodynamic force that opposes an aircraft's motion through the air. Drag is generated by every part of the airplane.

Drag acts in a direction that is opposite to the motion of the aircraft.

The drag equation is similar to the lift equation and given by:

$$D = \frac{1}{2}\rho\, v^2 A\, c_D$$

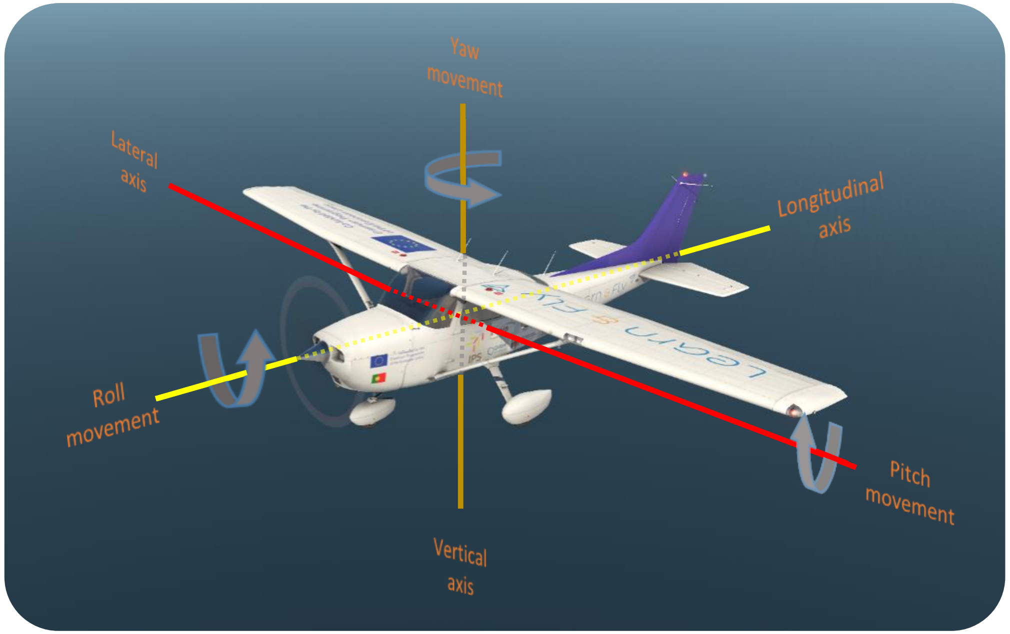
Air density (ρ), *Airspeed* (v), *Reference area* (A), *Drag coefficient* (c_D)

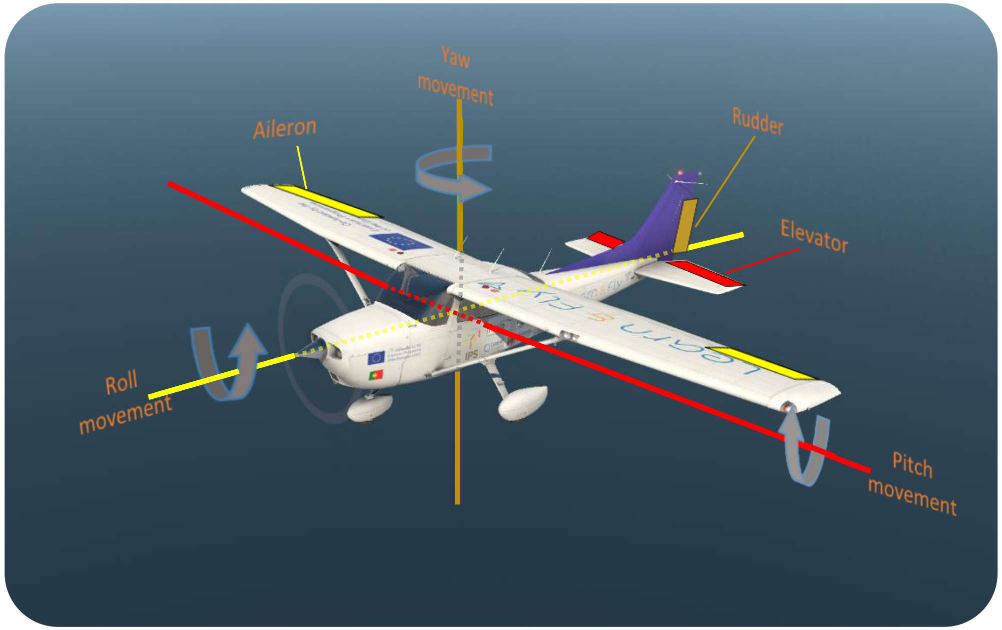
Thrust force

Thrust is the force which moves an aircraft through the air.

Thrust is used to overcome the drag of an airplane.

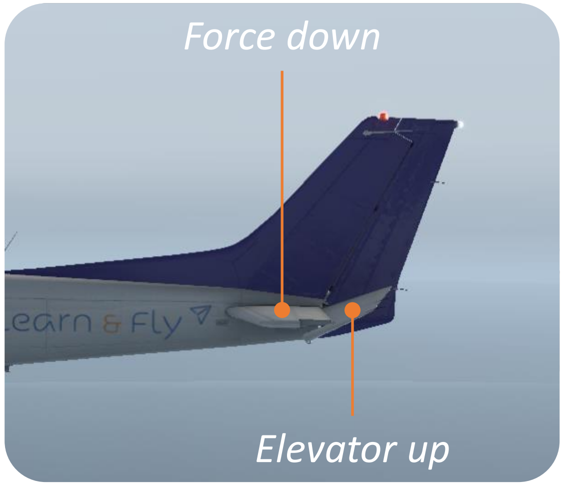
Thrust is generated by the engines of the aircraft through some kind of propulsion system.

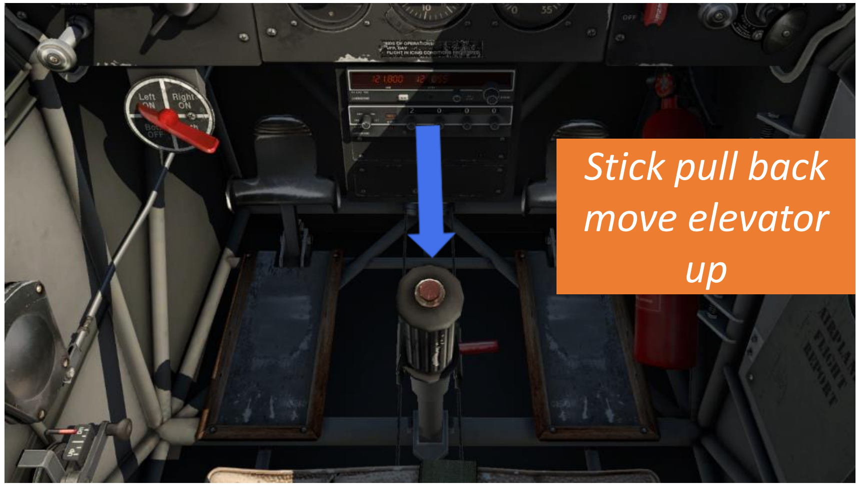




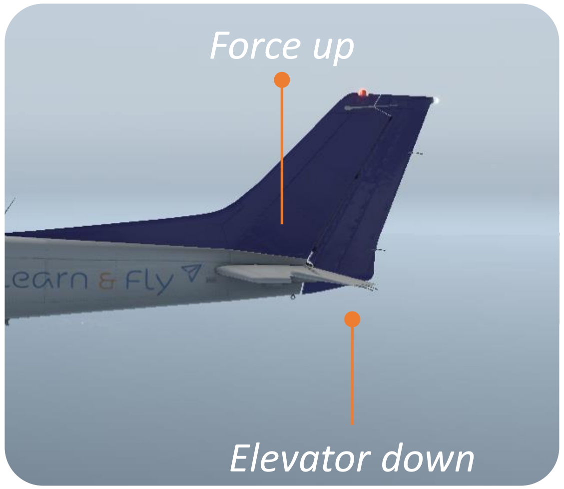
Axis	Movement
Lateral	**Pitch**
Longitudinal	Roll
Vertical	**Yaw**

Movement	Surface Control
Pitch	Elevator
Roll	**Aileron**
Yaw	Rudder





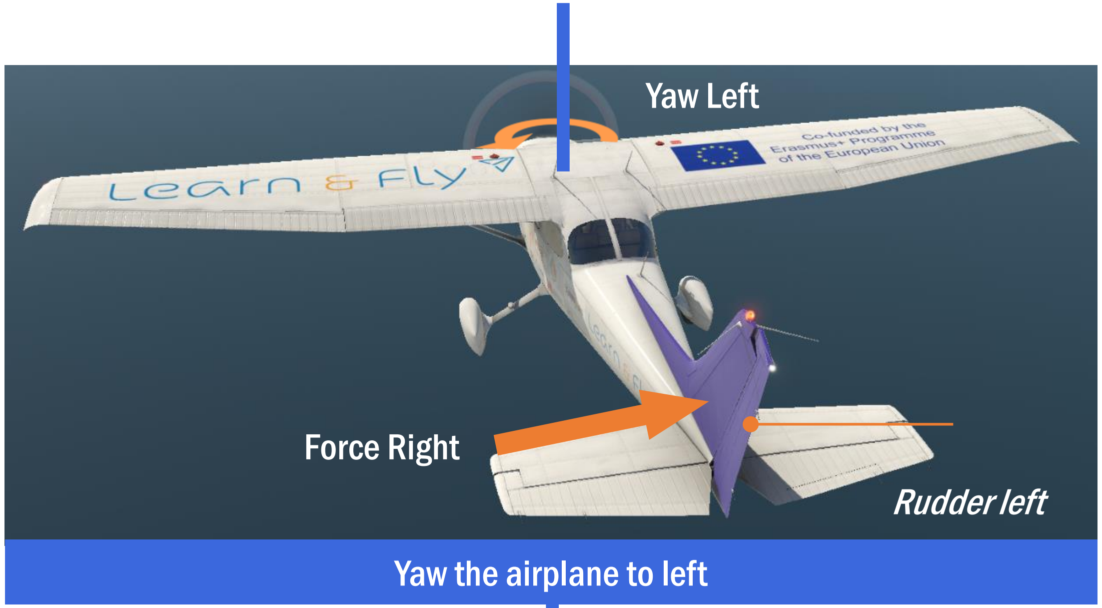
Aircraft climb up



Aircraft climb down

Rolling the airplane to right bank

Rolling the airplane to left bank


Yaw Left
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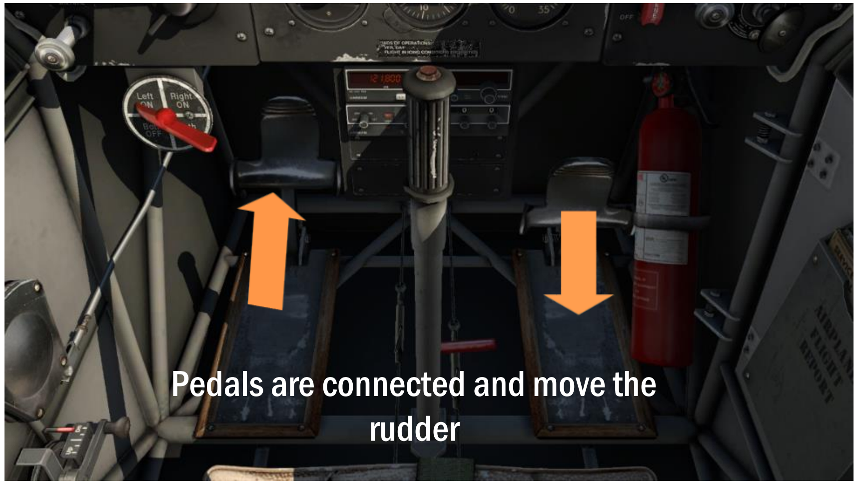
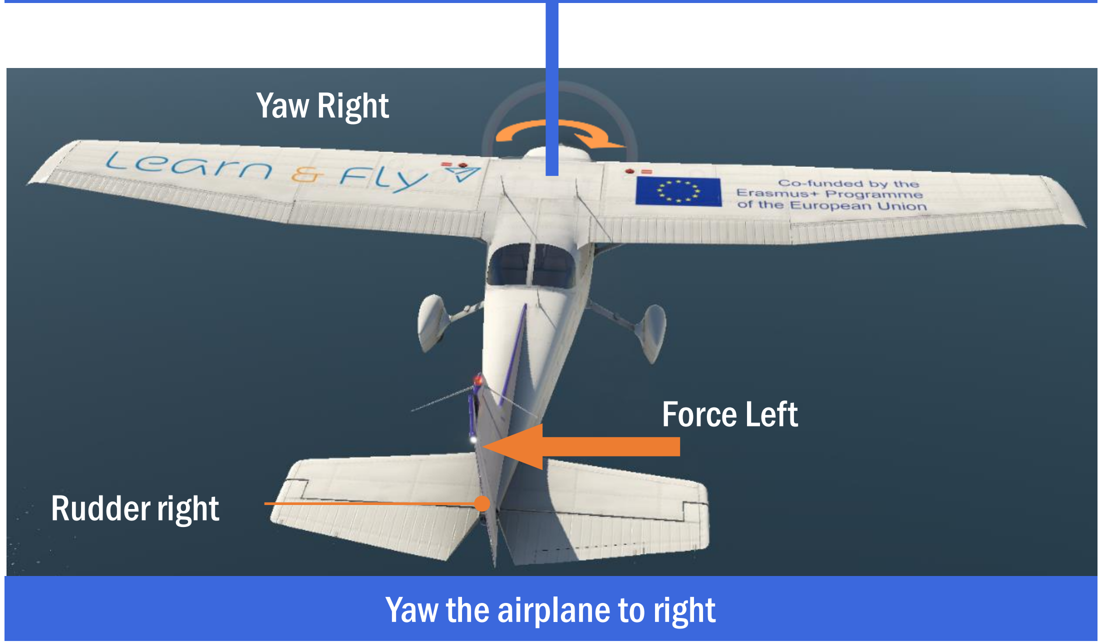
Force Right
Rudder left
Yaw the airplane to left


Pedals are connected and move the rudder


Yaw Right
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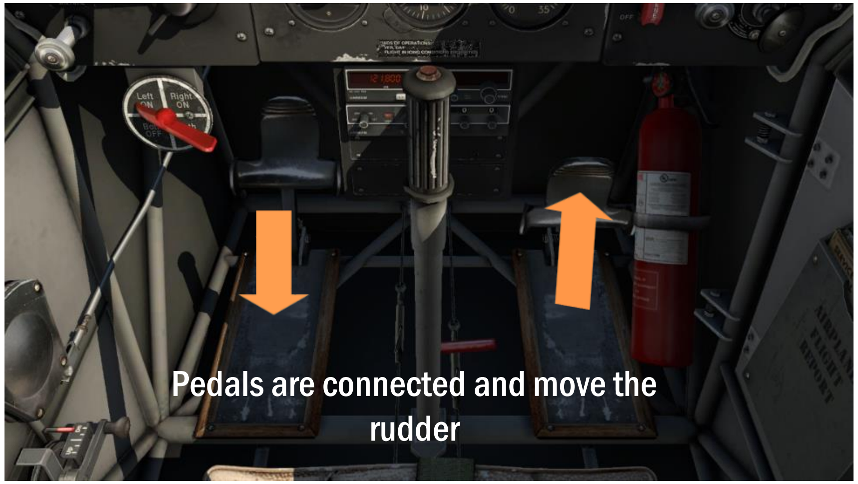
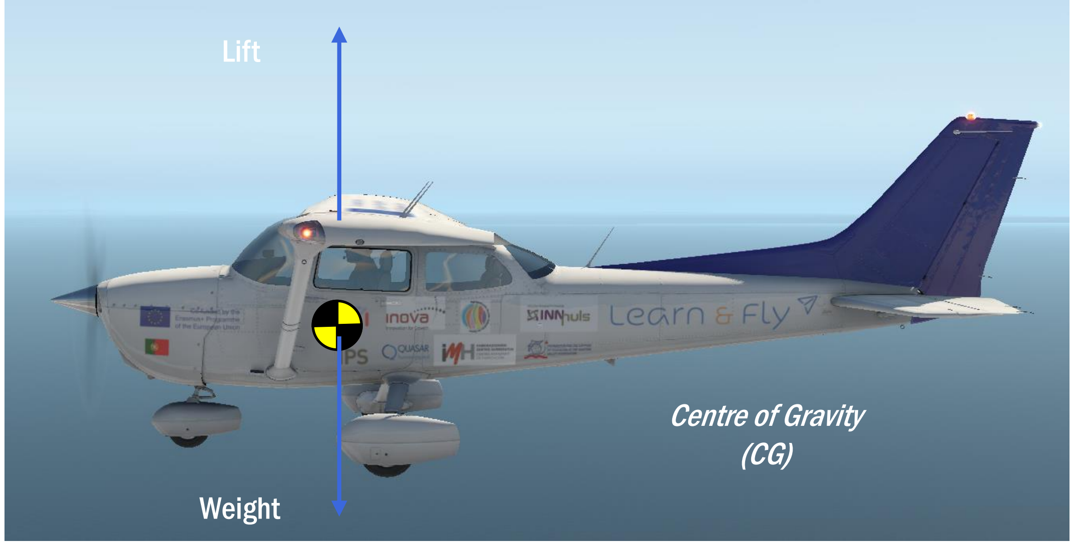
Force Left
Rudder right
Yaw the airplane to right


Pedals are connected and move the rudder



Centre of Gravity (CG)

The Centre of Gravity (CG) of an aircraft is the point over which the aircraft would balance.

The CG is the point where the resulting force of the weight is applied.

The CG affects the stability of the aircraft. To ensure the aircraft is safe to fly, the CG must be under certain limits

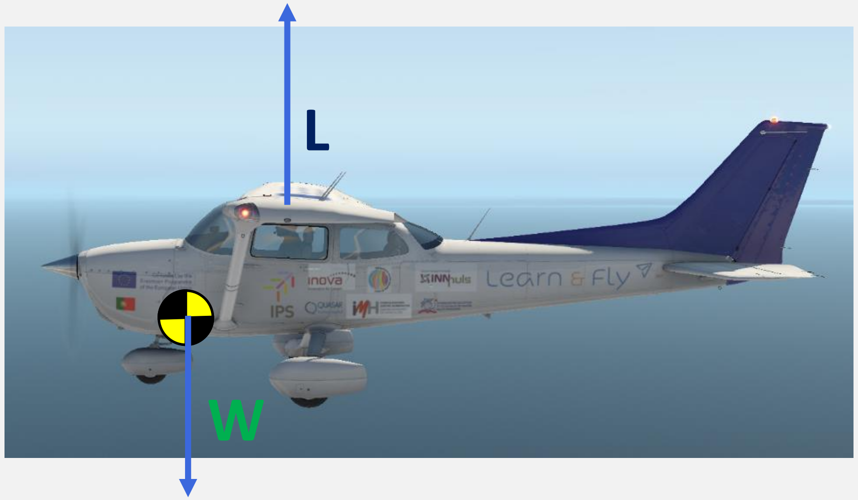
Centre of Gravity (CG) out of limits

If the Centre of Gravity (CG) of an aircraft is completely out of limits, situations such as the shown in the picture on left can occur.

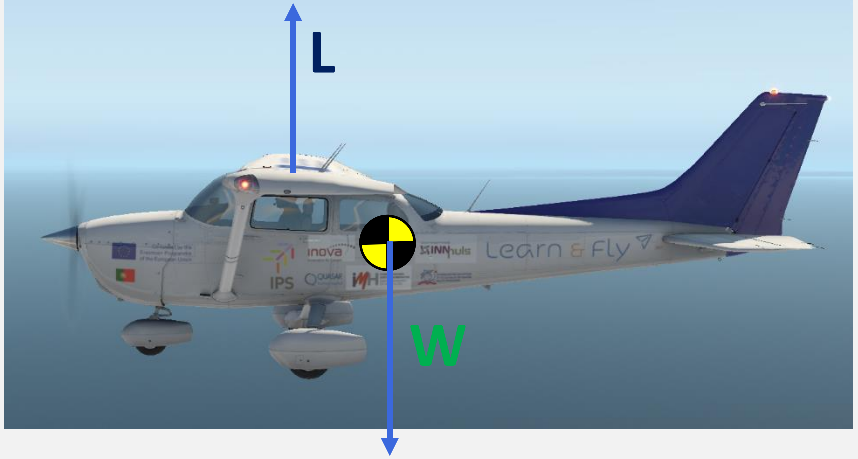
To ensure the aircraft is safe to fly, the CG must fall within specified limits, established by the aircraft manufacturer.

Before flight, the pilots must ensure that the CG is within limits.

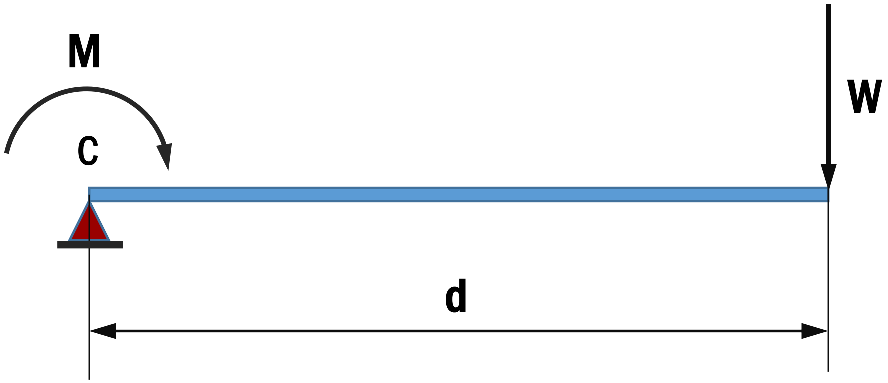
If the Centre of Gravity of an aircraft is out of limits



If the CG lies too far forward, the aircraft tends to nose down.



If the CG is far behind, aircraft tends to nose up.



Moment of a force relative to a point

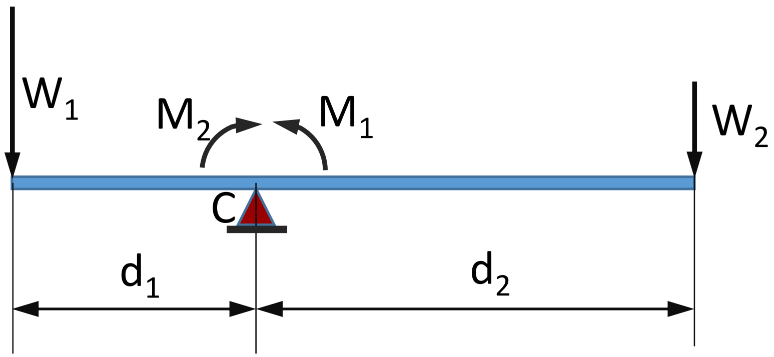
The **moment of a force** relative to a point C can be defined by the equation (note that the direction of the force must be perpendicular to the bar).

$$M = W \times d$$

The **moment M** measures the tendency to rotate the bar around point C.

The distance d is called the **arm** of the force.

As you can see, the bigger the arm the greater the moment.



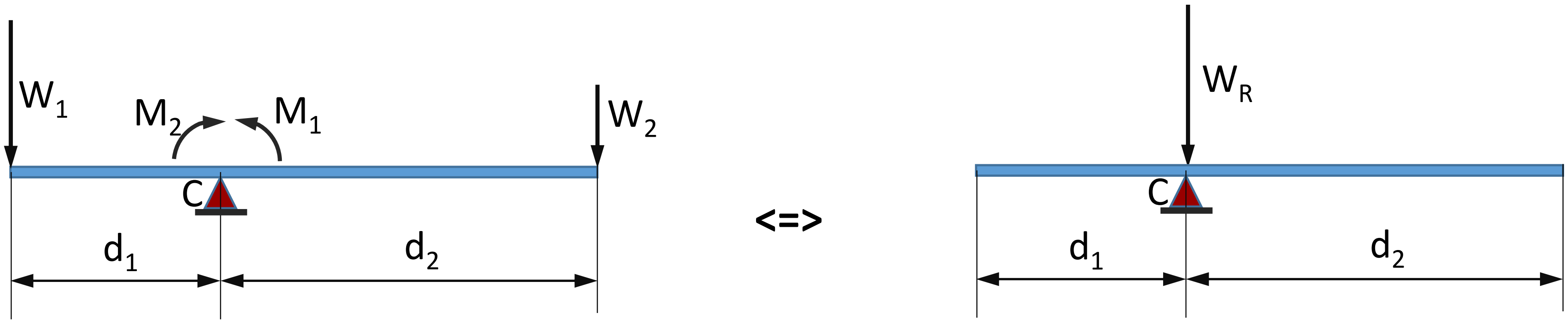
Balance Condition

In order to the bar be in balance it is necessary that M_1=M_2 or:

$$W_1 d_1 = W_2 d_2$$

So, the total moment M_T at point C must be null.

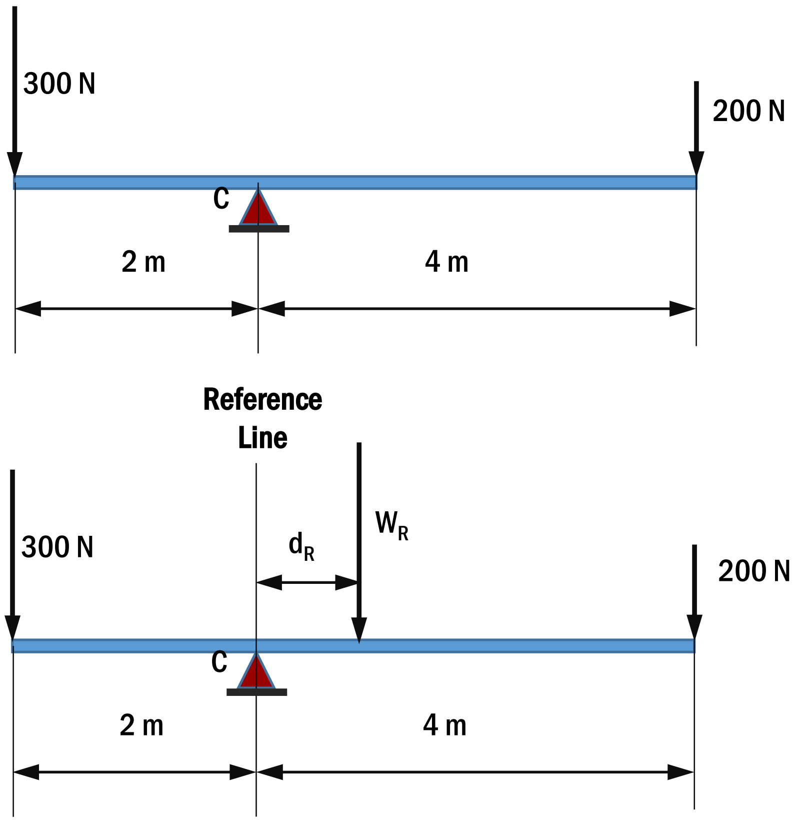
$$M_T = M_1 + M_2 = 0$$



Balance Condition

The resultant force W_R is given by $W_R = W_1 + W_2$

So, the resultant moment M_R at point C must be null to have balance $M_T = M_1 + M_2 = 0$



1. Check if the bar is in balance.
2. If not, calculate the position of the resultant force

(note that 1 Kgf = 9.81 N = 2.205 lbf)

Answers:

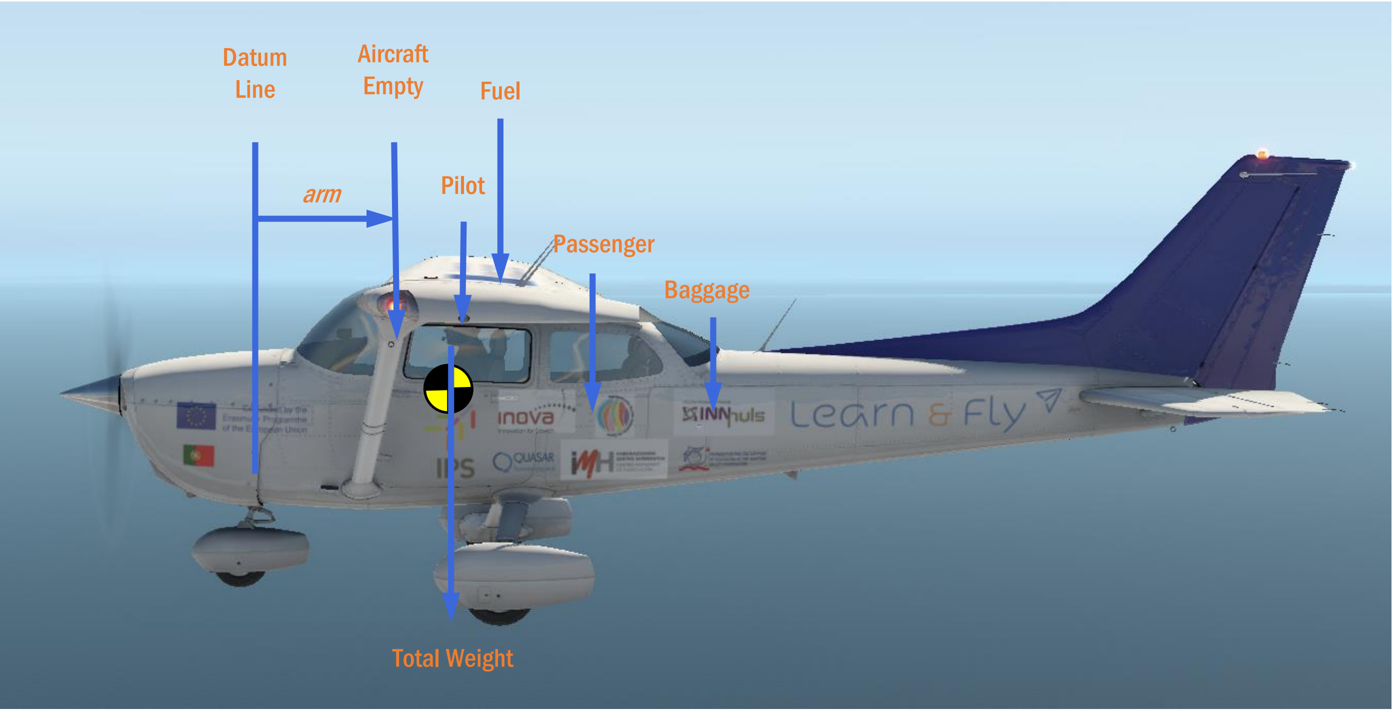
1. As the resultant moment is not null the bar is not in balance.

$$300 \times 2 \neq 200 \times 4 \; [Nm]$$

2. The position of resultant force (*CG*) can be given by:

$$\begin{cases} W_R = 300 + 200 \\ W_R \times d_R = -300 \times 2 + 200 \times 4 \end{cases}$$

$$d_R = \frac{-300 \times 2 + 200 \times 4}{500} = 0.4 \, m$$



Datum Line

There are several forces to considered for the calculation of the CG.

The Datum Line is a reference line to establish the arms of the several forces required to determine the CG.

For example in the Cessna as shown in the picture the Datum Line rest over firewall engine. On others aircrafts is usually the Datum Line match the leg nose landing gear.

As in the example before the CG can be achieved in the same way.

To avoid calculating the moment of each force you can use the final formula according to:

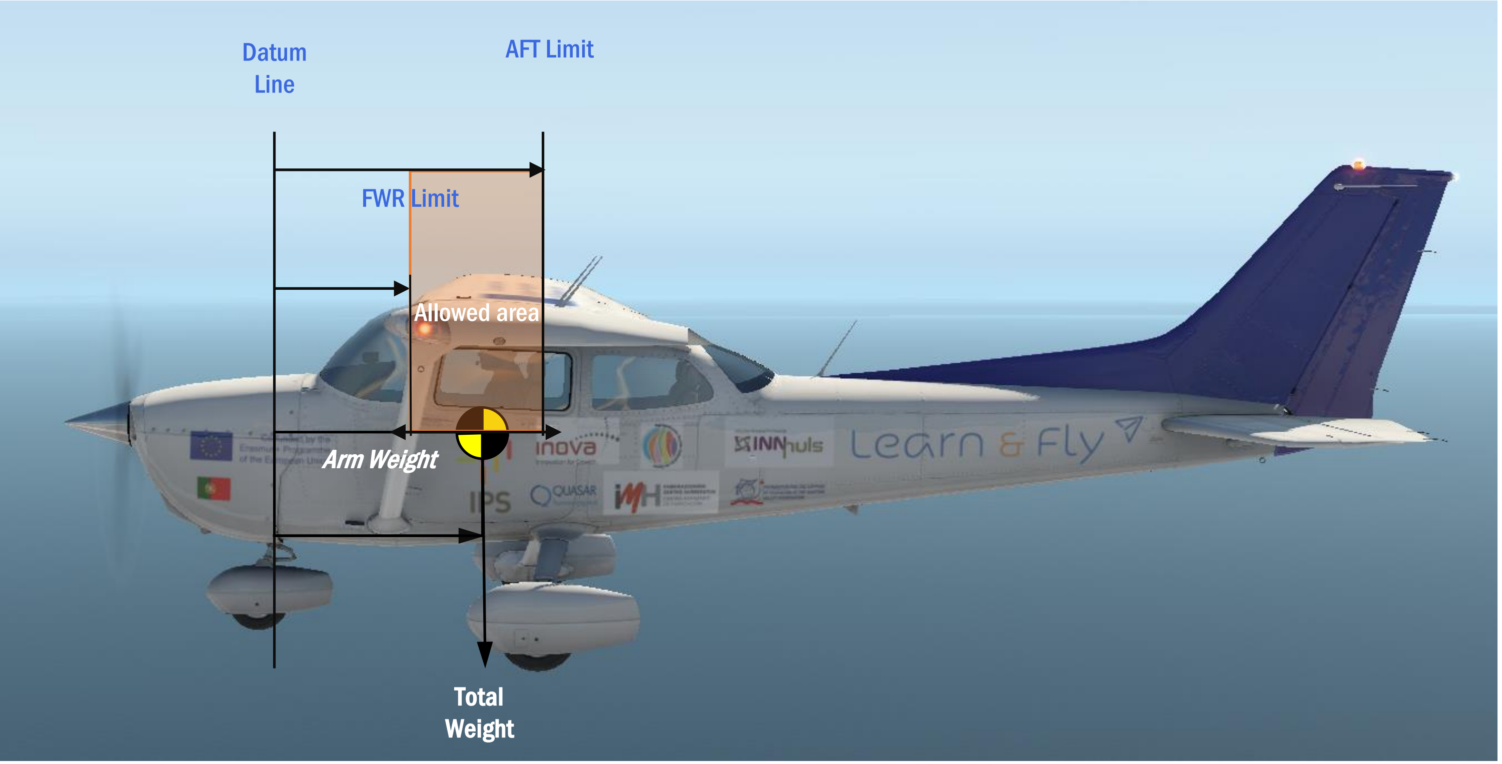
$$CG = \frac{\sum \text{Weight} \times d}{\sum \text{Weight}} = \frac{W_1 d_1 + W_2 d_2 + W_3 d_3 + \cdots + W_n d_n}{W_1 + W_2 + W_3 + \cdots + W_n}$$

in which:

the Weight are the individual weights of each component (n components)

d is the distance of each weight to the datum line (arm in the slide before)

As the weight is multiplying and dividing in the same fraction, you can use any units for weight. The CG becomes in the units of d, relative to the datum line.

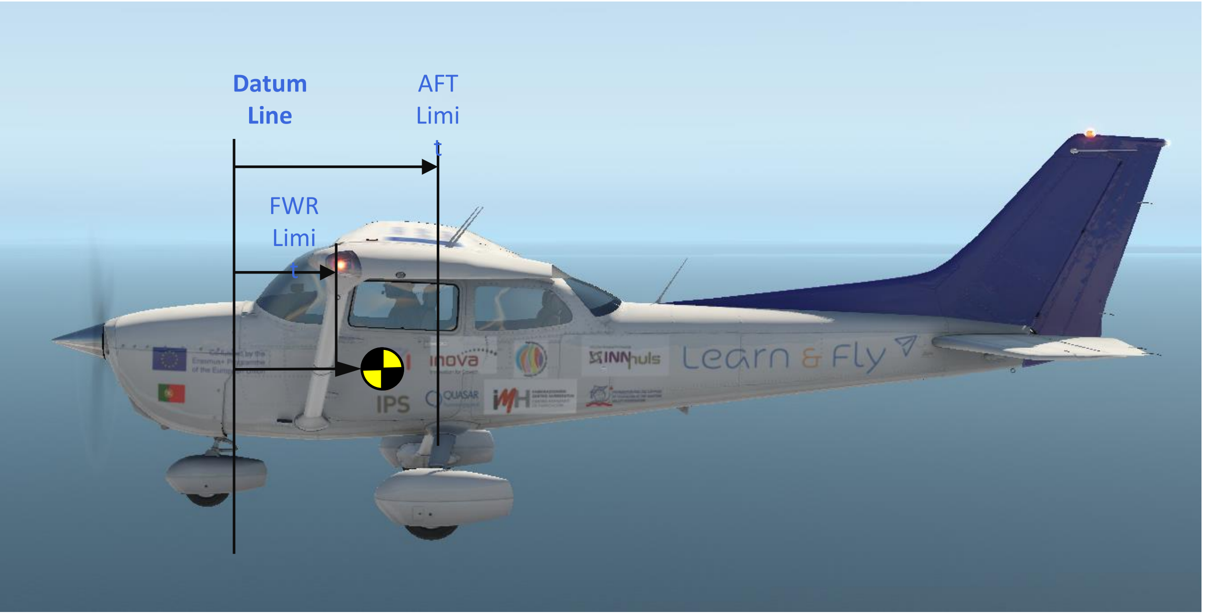


Limits of the Centre of Gravity

The CG must always remain between the FWR (Forward) and AFT (Afterward) limits in order to operate the aircraft safely.

The position of the CG must be calculated and verified if are inside limits.

Example of Calculation the CG



Item	Weight N		Arm m		Moment Nm
Empty Weight	8250	X	0.99	=	8167.5
Pilot	750	X	0.95	=	712.5
Passenger	900	X	1.88	=	1692.0
Baggage	300	X	2.46	=	738.0
Fuel	950	X	1.18	=	1121.0
TOTAL	**11150**				**12431.0**

$$CG = \frac{12431.0}{11150} = \mathbf{1.11\ m}$$

For this aircarft:

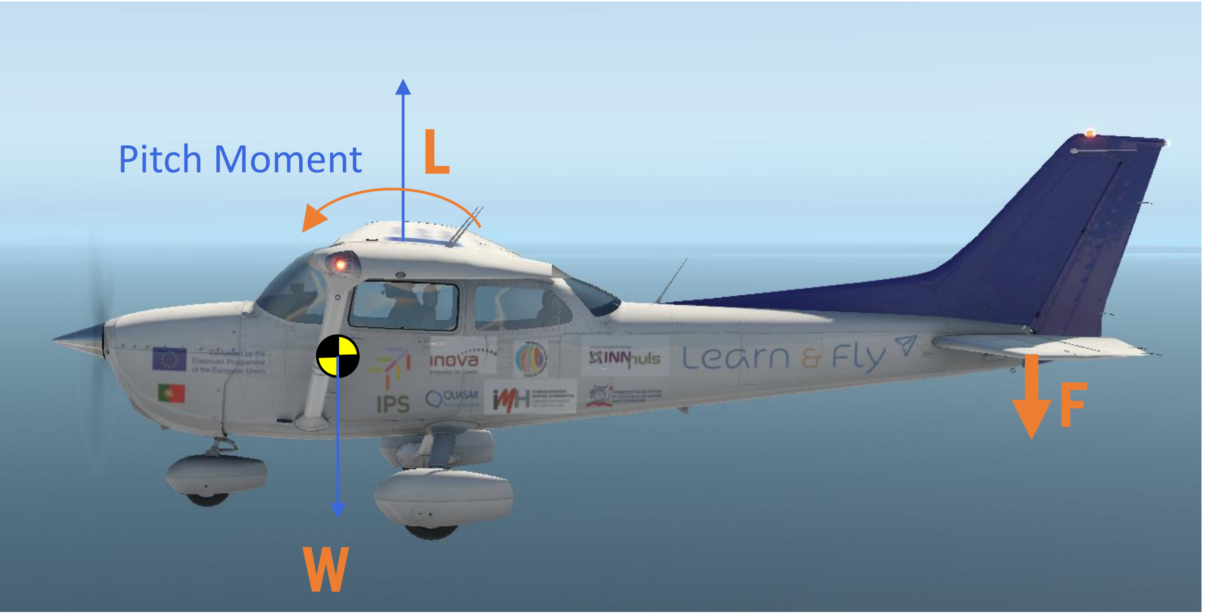
FWR Limit = 0.89 m

AFT Limit = 1.20 m

FWR < CG < AFT

0.89 m < 1.11 m < 1.20 m

*The CG is inside limits, **so will be safe to fly***



Stability of flight

In order to exist positive stability in flight the CG must be located ahead of the lift application.

As Lift (L) and Weight (W) are not in the same action line, a moment tends to put the nose aircraft down (Pitch Moment).

To counteract the Pitch Moment, the horizontal stabilizer is designed to create a vertical down force (F) in order to create a moment contrary to the Pitch Moment.

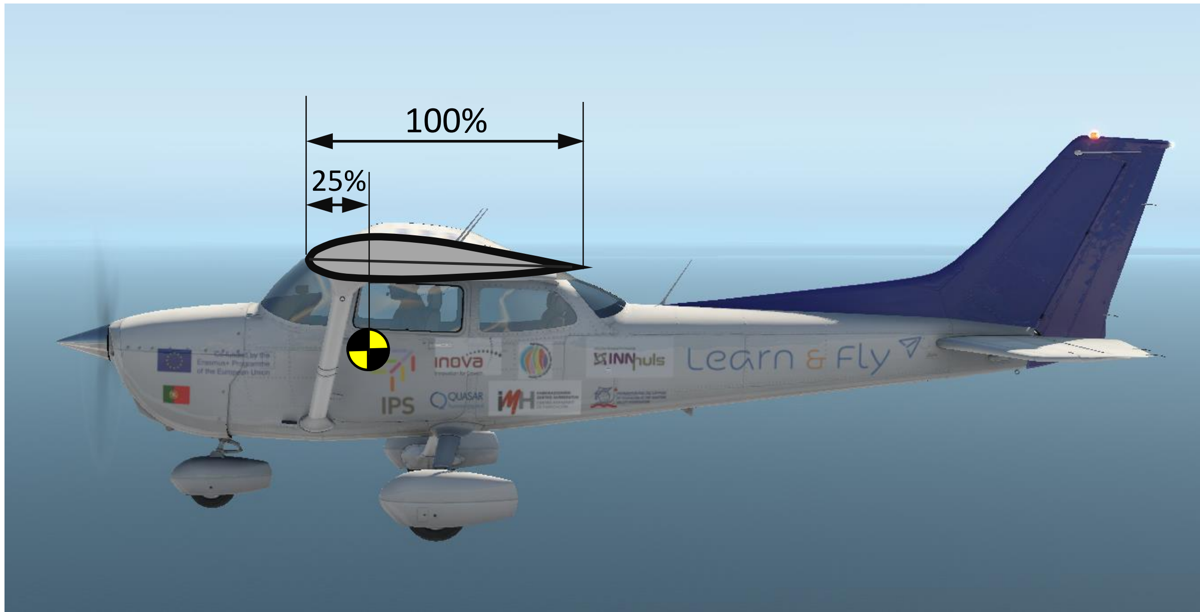
So the Lift force must be calculated by:

$$L = W + F$$

Longitudinal location of CG

The longitudinal location of the CG should found at 25% of the chord wing.

The magnitude of the FWR limit is normally 10% of the wing chord and the AFT is 30%.



See you on the

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