UNITS

The metric unit of distance is the metre (m).

The imperial units of distance are the inch (in) and the foot(ft)

1ft=12in.

From inches back to feet:

1in= 1/12ft

for example

9 in = 9/12= 0.75ft

Example 2

What is the length in METERES, of crate 6ft in 10 inches long?

Solution

First: convert from inches to ft—> 10in= 10/12= 0.833

Second= add 6ft to 0.833 (the conversion from inch to ft)—> (6+0.833)=6.833ft

Third= Lengths of crate= 6.833+0.305m= 2.08m

MASS

Mass is the quantity of matter body possesses. It remains same wherever the object is the universe.

The units of mass used in MASS AND BALANCE are the metric unit, the kilogram (KG) and imperial unit, the pound (lb)

KG=lb x 0.454

Lb=KG x 2.205

Weight

Weight is the force that a body with mass possesses when it is in a gravitation field. The weight of an object differs in different gravitational fields

g=9.81 m/s^2

Volume

We need to be aware of 3 measurements of volume: the litre(l), the Imperial gallon (Imp. Gall) and the US gallon (US Gall).

Litres (l)= Imp.Gall x 4.546l

Litres(l)= US Gall x 277.42 in^3

Imp.Gall= US Gall/1.2

Us Gall= L/3.785 (liters)

Specific Gravity

Specific gravity (SG) is the ratio of the density of a liquid, if a substance's relative density is less than 1,
it will be less dense than water.

To calculate the mass of a volume of a liquid use the equations:

KG= litres x SG

Pounds= Imp Gall x 10 x SG

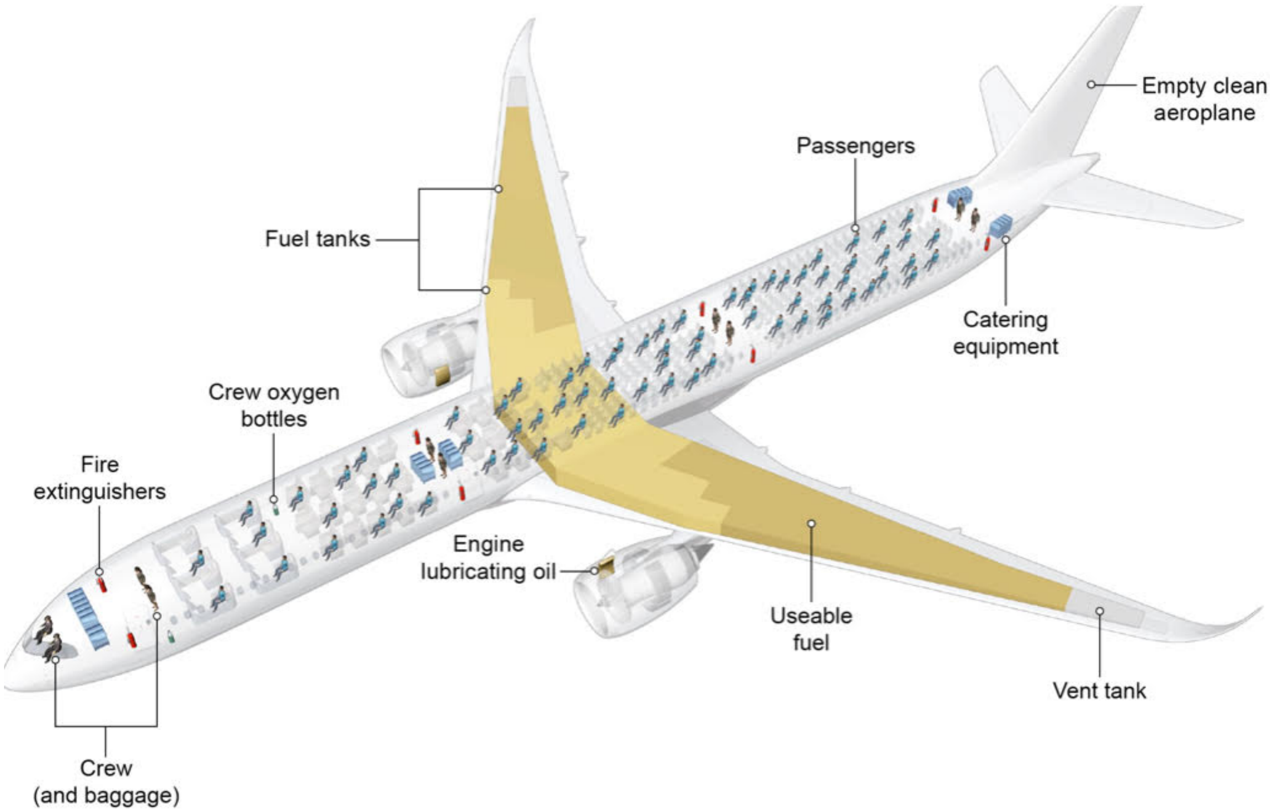
Aircraft Mass Definitions

Components of ALL-UP MASS

The mass of an aircraft is known as the ALL-UP MASS (AUM) or *__gross mass or sometimes total mass__*

The AUM comprises 4 component masses:

- The Basic Empty Mass (BEM)
- The Variable Load
- The traffic Load
- The fuel



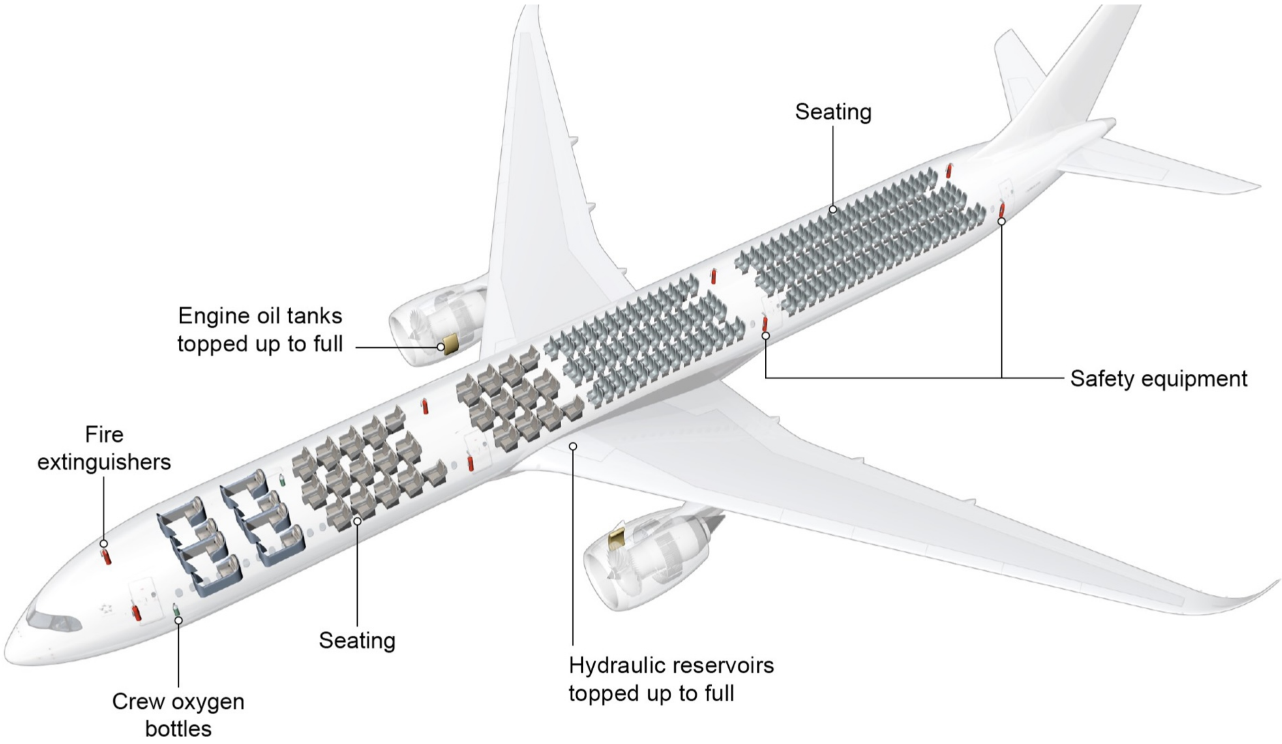
The Basic Empty Mass

Basic Empty Mass (BEM) is the mass of the empty aircraft including

- The empty, clean aircraft
- Any unusable fuel
- The full quantity of operating liquids (Engine oil and Hydraulic fluids)
- Safety equipment (Fire extinguishers etc.)
- Supplementary electronic equipment

The BEM is the aircraft mass before the crew, fuel, passengers, baggage cargo and necessary equipment to support them are added.

The BEM is assumed to remains constant, it's recorder in the aircraft's mass and balance schedule and depending on the operating company, may also be recorded in the aircraft's technical log and the Company Operation Manual.

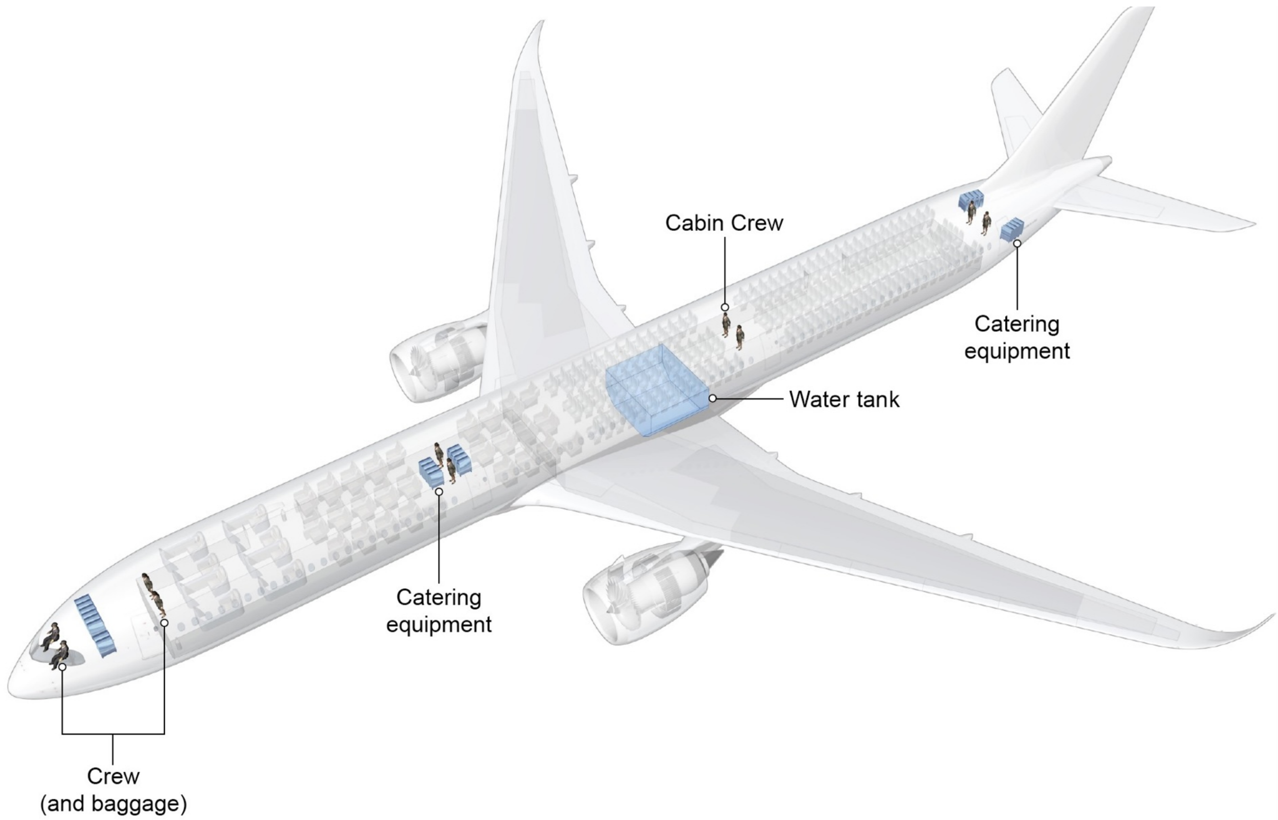


The Variable Load

Before the aircraft can fly, which requires fuel and earn revenue from transporting passengers, baggage and cargo.

This is the Variable Load which includes:

- The crew and their baggage
- The catering and other removable passenger service equipment
- Food and beverages
- Potable water
- Lavatory chemicals, and any other special operational equipment



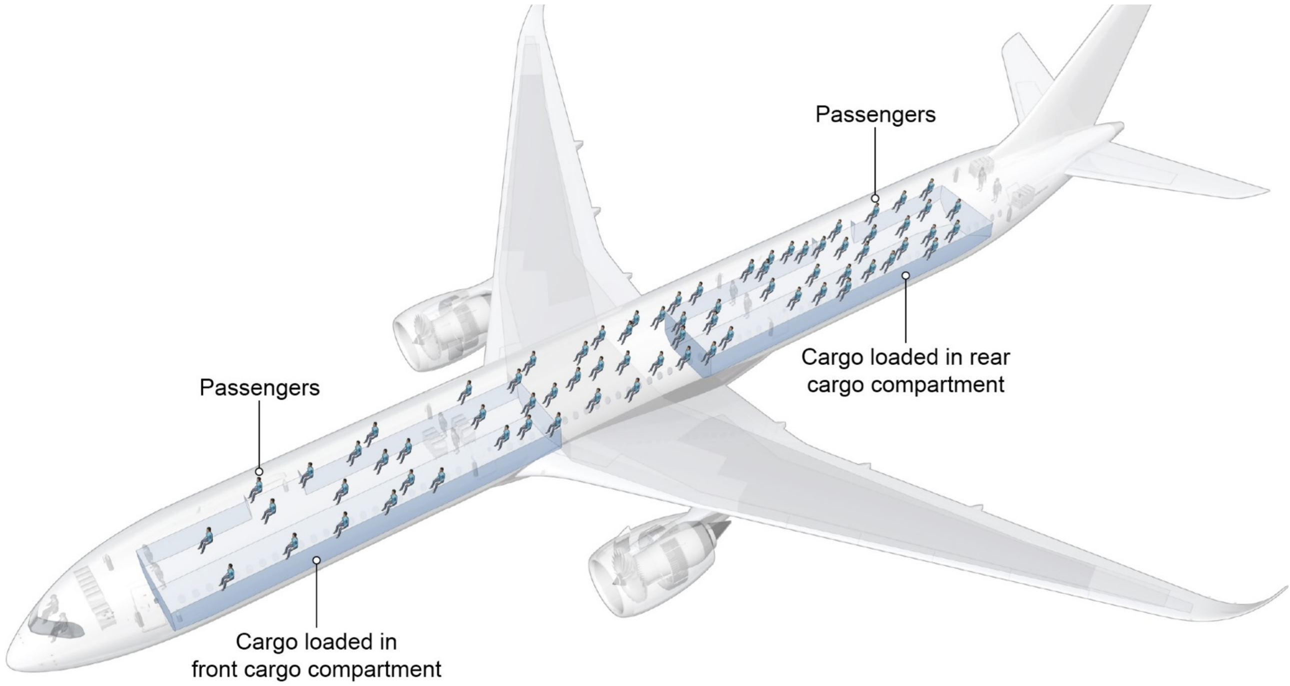
The traffic Load

The Traffic Load is the combined mass of passengers and their baggage, plus cargo, plus any Non-revenue load.

Non-revenue load= is the load which is being transported to support the company's own operations. (E.X Crew members and their baggage on position flights.)

Payload= Means the load which is paid to be carried

TRAFFIC LOAD= PAYLOAD + NON-REVENUE LOAD



The Fuel

Fuel comprises the usable fuel in the tanks. The usable fuel, as measured when the aircraft is on the ramp, before engine start, is known ***RAMP FUEL or BLOCK FUEL.***

Engine starting and then taxiing to the T.O. position consumes fuel.

The usable fuel on board at the start T.O run will be less than the ramp fuel and is known ***Take-Off fuel***

- **Ramp Fuel = Taxi Fuel + Take-off Fuel**
- **Take-off Fuel= Ramp Fuel – Taxi Fuel**
- **Landing Fuel = Take-off Fuel – Trip Fuel**

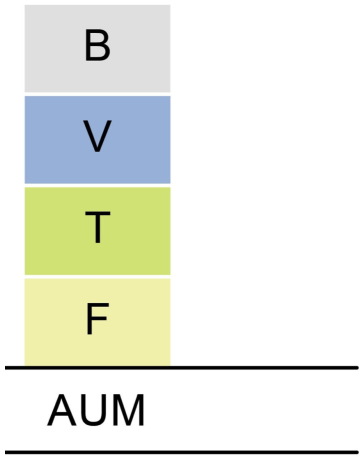
Remembering the 4 Components of AUM

The actual value of the AUM depends on the phase of flight. At the end of the flight, with almost all the usable fuel gone, the AUM will be considerably less than at the beginning of the flight.

4 components of AUM as a block system.

Basic Empty Mass, **V**ariable load, **T**raffic load and **F**uel are each represented by a block

Memorise = **B**ig Vans **T**ravel **F**ast.

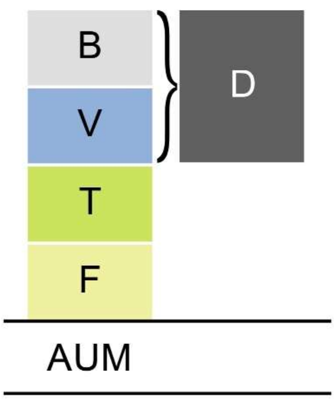


The dry operating Mass and Useful Load

The Dry Operating Mass (DOM) is the BEM plus the Variable Load.

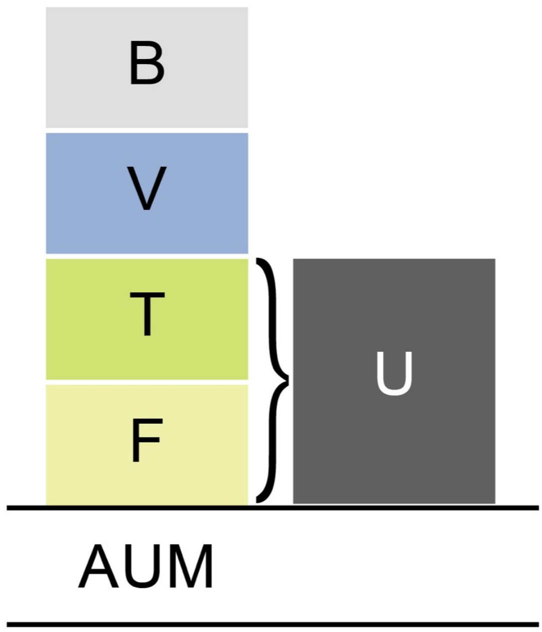
DOM= BEM + Variable Load

Tot mass of the aircraft after it has been configured and outfitted for a specific type of operation such as carrying passengers or carrying cargo.

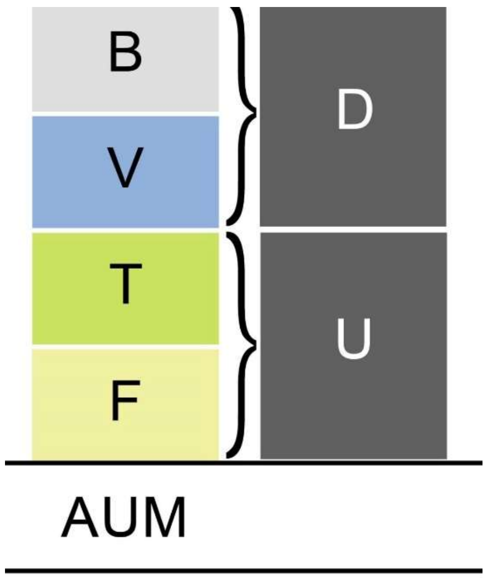


The Useful Load is the total mass of the passengers, including any non-revenue load and useable fuel.

Is the total load that can be carried after the aircraft has been fitted out for a specific purpose.



The phrase now becomes= **B**ig Vans **T**ravel **F**ast **D**own **U**nder



Operating Mass and Zero Fuel Mass

Operating Mass (OM)

The Operating Mass (OM) is the Dry Operating Mass (DOM) plus fuel but without the TRAFFIC Load. The OM includes take-off fuel but no taxi FUEL.

OM= TOM – Traffic load

Zero Fuel Mass (ZFM)

ZFM= DOM+traffic load

The ZFM is the DOM plus the traffic load. As its name implies, it's also the AUM, minus the FUEL, hence the term *"ZERO FUEL MASS"*

Structural Limitations on Mass

- **MAXIMUM RAMP/TAXI (MRM)**= This is the maximum permissible total mass of the aircraft when it begins to taxi (limited by stress on the oleo shock)

- **MAXIMUM STRUCTURAL TAKE-OFF MASS(MSTOM)=** The MSTOM is the absolute maximum permissible aircraft mass at the start of the Take-off run. This limit is set by the aircraft manufacture and is given in the AFM

- **IN-FLIGHT MASS=** This is the mass of the aircraft in flight at any specified time

- **MAXIMUM ZERO FUEL MASS (MZFM)=** The maximum permissible mass of an aircraft with NO USUABLE FUEL

- **MAXIMUM STRUCTURAL LANDING MASS (MSLM)=** This is the maximum permissible aircraft mass on landing in normal circumstances

Performance Limitations on MASS

Performance mass limits are imposed to ensure that the aircraft is light enough to complete the take-off and landing with the distance available

The Performance depends with the conditions of the day.

- **Performance Limited Take-Off Mass (PLTOM)**: This's the maximum take-off mass allowable to comply with departure performance limitations (RNW and minimum climb gradients)

- **Performance Limited Landing Mass (PLLM)**: This is the maximum landing mass allowable to comply with landing runway limitation (RNW available and minimum climb gradients in case of go-around)

ALLOWED TAKE-OFF Mass

FUEL BURN

Assuming that the traffic load remains on-board for the entire flight, then the aircraft's mass will only reduce as a result of fuel burned.

The aircraft has its heaviest fuel load, before push-back and engine start.

Block Fuel (Ramp fuel)

The **block fuel** is the total fuel required for the flight and is thus the fuel on board the aircraft when it's standing on the ramp before APU or engine start

- TAXI FUEL
- TRIP FUEL
- CONTINGENCY FUEL
- RESERVE FUEL
- ADDIOTANAL FUEL
- EXTRA FUEL

3.1.2 The Components of Block Fuel

Taxi Fuel

Taxi fuel is the fuel used before take-off. It takes account of the fuel used by the APU before start, the fuel used during engine start, and the fuel used to taxi to the take-off position.

Trip Fuel

The *trip fuel* is the fuel expected (planned) to be burned between take-off and destination aerodromes.

Contingency Fuel

The *Contingency Fuel* allows for small changes in fuel burn caused by unexpected routing, cruise levels and changes in forecast wind.

Reserve Fuel

The reserve fuel comprises 2 elements:

- The Alternate Fuel is the amount of fuel required from the missed approach point at the destination aerodrome until landing at the alternate aerodrome.
- The Final Reserve Fuel is the remaining fuel which must be on board at the planned landing at the planned destination. It allows for a further period of holding at 1500 ft above the alternate destination. The periods are 30 minutes for turbine engined aircraft and 45 minutes for piston aircraft.

Additional Fuel

The Additional Fuel is an additional allowance of fuel to comply with specific requirements e.g. extended twin operations (ETOPS) requires additional fuel.

Extra Fuel

The *Extra Fuel* is a further fuel allowance added at the discretion of the aircraft commander.

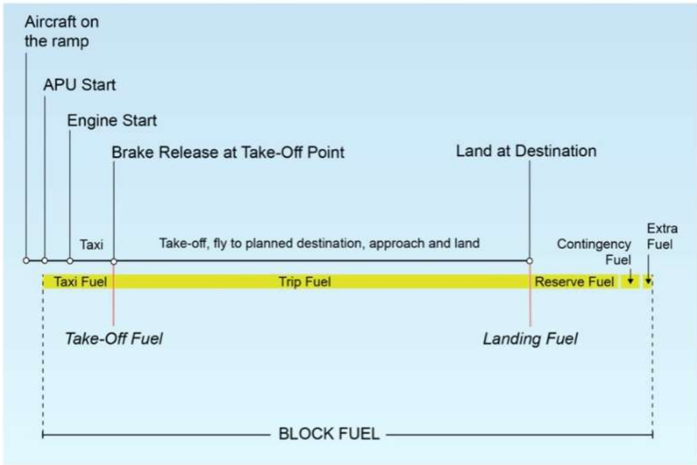


Figure 3.1 Schematic diagram of fuels for a non-ETOPS flight which arrived exactly as planned at destination having had no need to use the Extra or Contingency fuels

Maximum Traffic and Fuel Load

Determining the Maximum Traffic Load

Step1→ Calculate the MTOM→ (RLM+TRIP FUEL)

Step 2→Calculate the maximum traffic load by subtracting the DOM and take-off fuel

Max Traffic Load= MTOM-DOM-TAKE-OFF Fuel

Determining the Maximum Fuel Load

Determining the maximum traffic load

STEP 1 –> CALCULATE THE MTOM (RLM+TRIP FUEL)

STEP 2 –> CALCULATE THE MAXIMUM FUEL LOAD, BY SUBTRACTING THE DOM AND TRAFFIC LOAD.

MAX FUEL LOAD= MTOM-DOM-TRAFFIC LOAD

ADJUSTING THE CG POSITION

SHIFTING THE TRAFFIC LOAD

The CG position can be moved by shifting the existing load to a new position

- **If the load is shifted aft, the CG position moves aft**
- **If the load is shifted forwards, the CG position moves forwards**

You can then calculate the new CG position by dividing the new moment by the aircraft's mass

DISTANCE TO **CG= TOTAL MOMENT/TOTAL MASS**

RATIO METHOD

The second much quicker method is to use the ratios of masses and balances arms.

- M or m represented the mass
- D or d represents a distance.

The lower case letters represent the smaller values.

The upper case letters represent the larger values

As the mass being shifted (m) is proportional to the distance the CG moves (d) and the mass and distances are proportional to each other.. $m/M = d/D$ or $M/m = D/d$

ADDING OR REMOVING LOAD

Load is added or removed after the CG has been calculated, usually for operational reasons.

THE CG will move FORWARD if the load is:

- **ADDED FORWARD OF THE ORIGINAL CG**
- **REMOVED AFT OF THE ORIGINAL CG.**

THE CG will move AFT if the load is:

- **REMOVED FORWARD OF THE ORIGINAL CG**
- **ADDED AFT OF THE ORIGINAL CG**

DATUM, MOMENTS AND DETERMING THE CG

MOMENTS

A moment is the tendency of a force to rotate an object around an axis.

The size of a moment depends on the size of the force and the distance at which it's acting from axis of rotation

MOMENT= FORCE X DISTANCE

For the aircraft NOT TO PITCH UP OR DOWN means that the moment is ZERO (0).

This means that the moments which tend to pitch the nose down, must be exactly equal and opposite to the moments that tend to pitch the nose up.

DATUM

The DATUM is key to our ability to calculate moments. It's difined

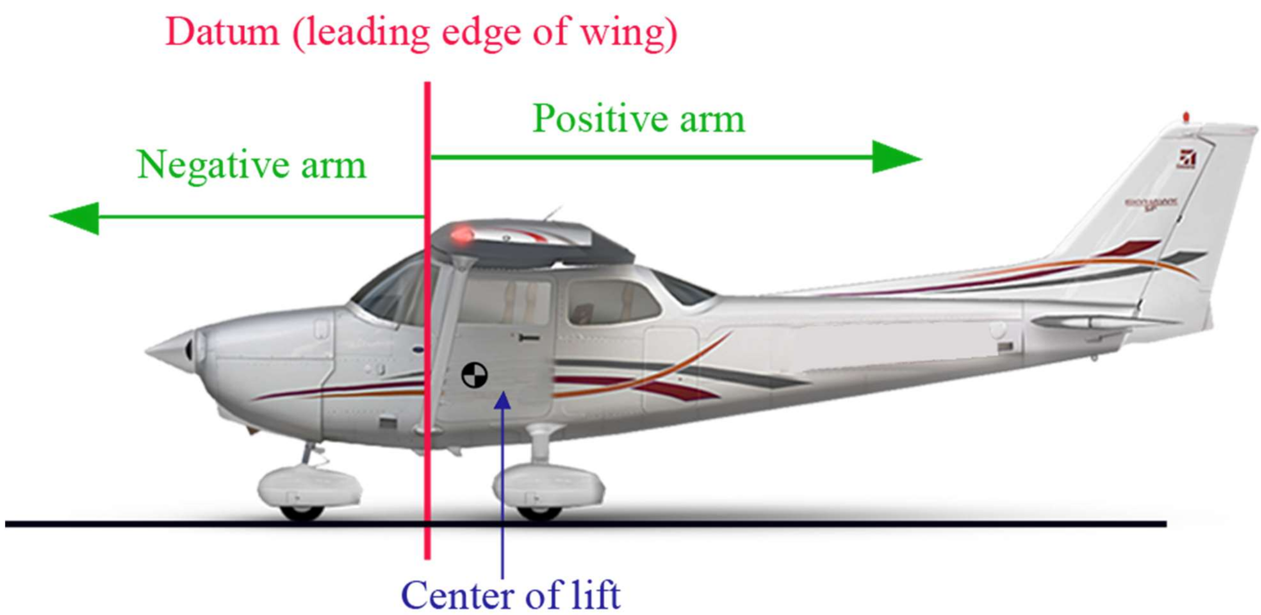
The DATUM is the point in the horizontal plane from which all masses are referenced.

BALANCE ARM

A BALANCE ARM (BA) is the DISTANCE from the DATUM to the CG of the mass.

So the DISTANCE is the BALANCE ARM (BA)

MOMENT= MASS X BALANCE ARM



MOMENT CONVENTIONS

Moment can act CLOCKWISE or ANTI-CLOCKWISE around a datum.

CLOCKWISE MOMENTS are POSITIVE and ANTI-CLOCKWISE MOMENTS are NEGATIVE.

A mass which is LEFT of the DATUM has a NEGATIVE BALANCE ARM (BA) and a mass to the RIGHT of a DATUM has a POSTIVE BA

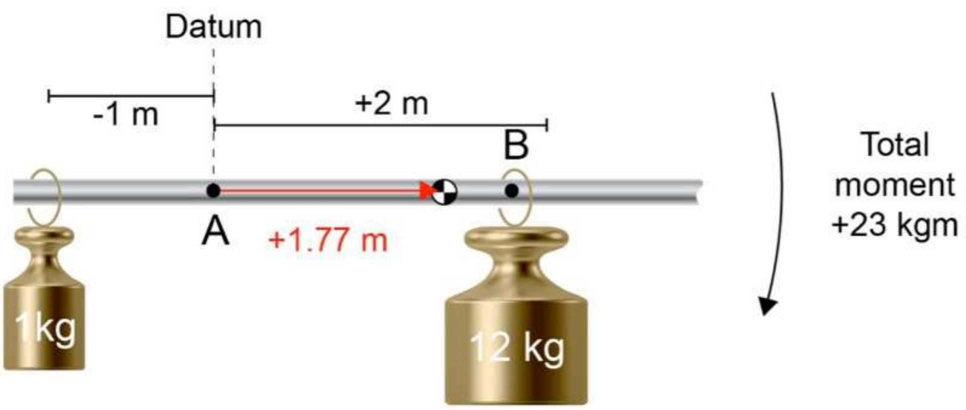
CENTRE OF GRAVITY POSITION

DEFINITION

The centre of gravity is the point through which the force of gravity is said to act.

The centre of gravity is the average position of all points through which gravitational force acts on a mass.

DISTANCE TO CG = TOTAL MOMENT/ TOTAL MASS



Object	mass	x distance to CG =	moment
1 kg mass	1 kg	-1 m	-1 kgm
12 kg mass	12 kg	+2 m	+24 kgm
Total	13 kg		+23 kgm

$$\text{Distance to CG (from datum A)} = \frac{\text{Total Moment}}{\text{Total Mass}} = \frac{+\,23\ \text{kgm}}{13\ \text{kg}}$$

$$= +1.77\text{m}$$

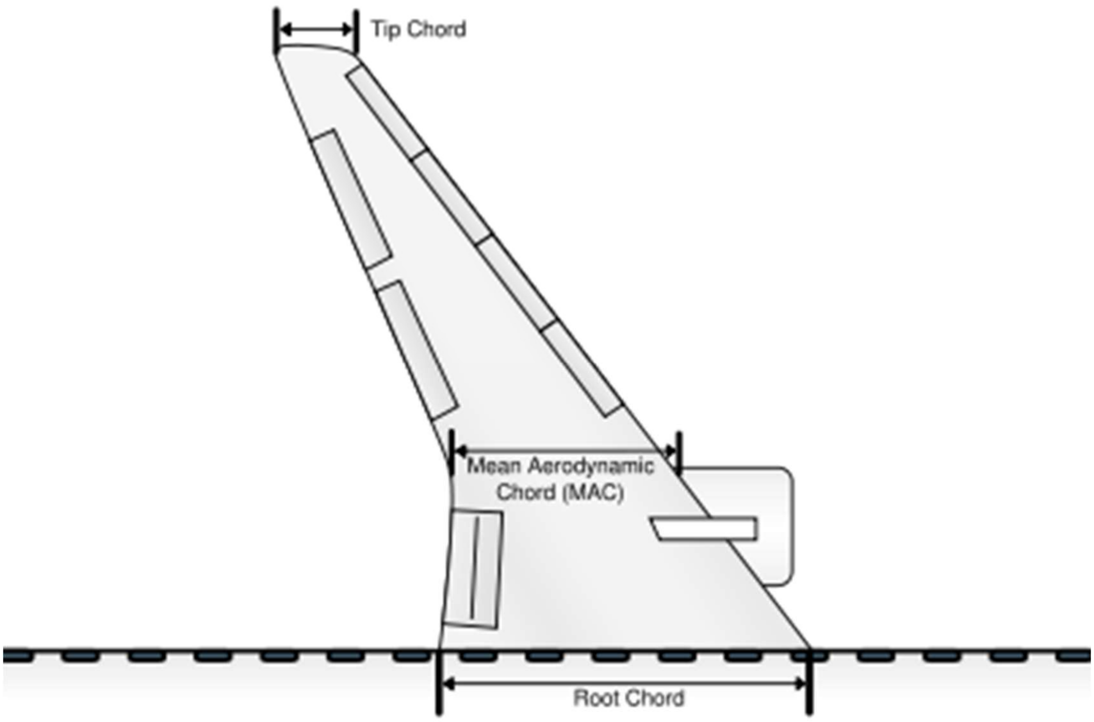
MEAN AERODYNAMIC CHORD

The CG position affects the aircraft's aerodynamic performance, CG position to the origin of the aerodynamic forces, the centre of pressure (CP).

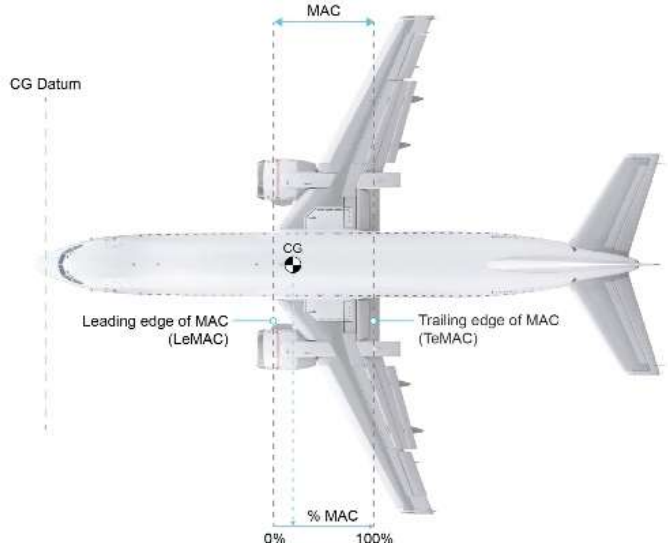
The CP sits somewhere along the chord of the wing. Modern commercial aircraft don't have straight wings with a constant chord, so we need some means of describing the average chord

The simple method would be take chord distance half way down the wing span, there is requirement to establish the MAC (MEAN AERODYNAMIC CHORD)

The MAC is distance from the LEADING EDGE OF MAC and TRAILING EDGE OF MAC



MAC remains constant and fixed distance from the aircraft's CG datum.



For a cambered wing, the CP is about ¼ of the distance between the leading and trailing edges.

$$\%MAC = \frac{\text{LeMAC TO CG}}{\text{MAC}} \times 100$$