MASS AND BALANCE IN AIRCRAFT

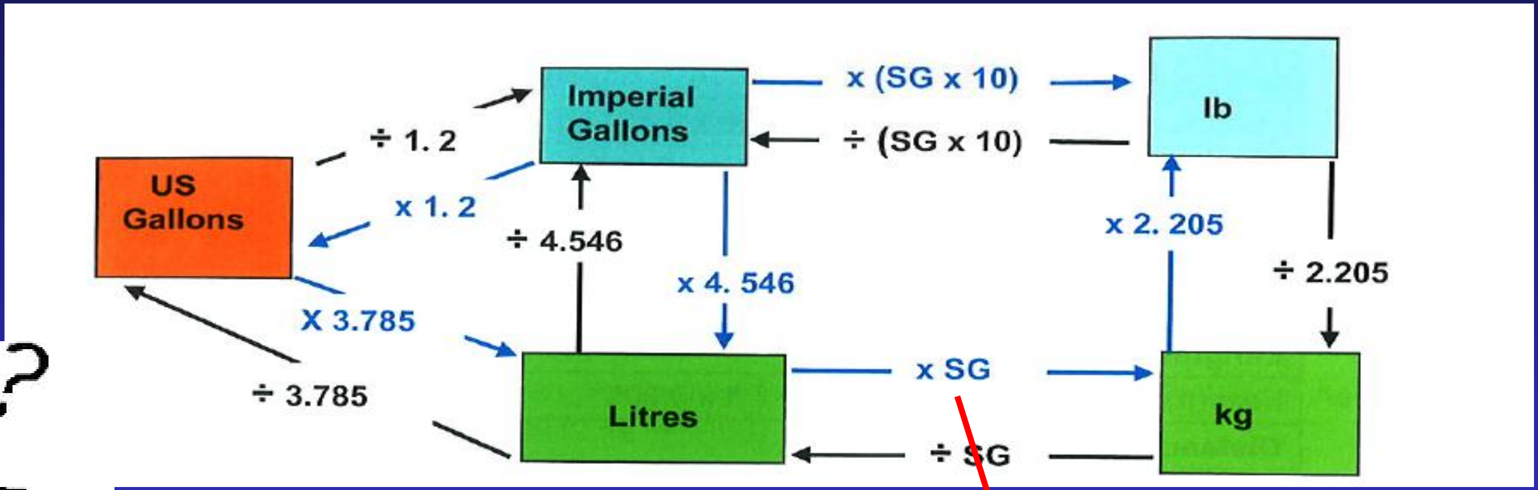
KADİR BUHARALI

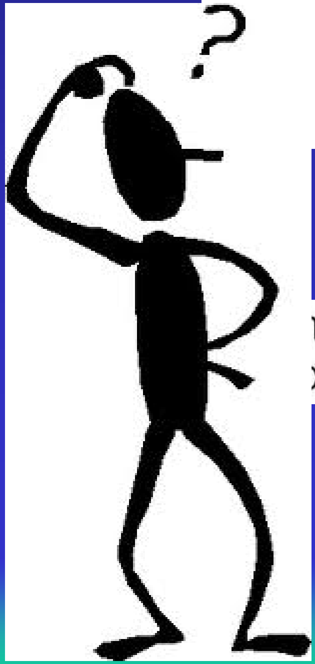
MASS AND BALANCE INTRODUCTION

- ✓ **Deals with the loading of aircraft**
- ✓ **Ensure that they are not overloaded or misloaded**

MASS AND BALANCE

- **VOLUMETRIC AND MASS CONVERSIONS**





e specific gravity of Jet A1 is greater than for AvGas, and will vary slightly with temperature.
r the mass and balance JAA exam, assume the SG of AvGas to be 0.72, and Jet A1 as 0.8.

MASS AND BALANCE THEORY

- DEFINITION:
- MASS: THE AMOUNT OF AN ITEM INSIDE A BODY
- CENTER OF GRAVITY (C.G): THE POINT THROUGH WHICH THE FORCE OF GRAVITY IS SAID TO ACT ON A MASS.
- BALANCE OF ARM (BA): THE DISTANCE FROM THE DATUM TO THE CENTRE OF GRAVITY OF A MASS
- MOMENT: THE PRODUCT OF THE MASS AND THE BALANCE ARM = MASS * ARM

MASS AND BALANCE THEORY

- DATUM OR REFERENCE DATUM:
- (RELATIVE TO AN AEROPLANE) IS THAT (VERTICAL) PLANE FROM WHICH THE CENTRES OF GRAVITY OF ALL MASSES ARE REFERENCED

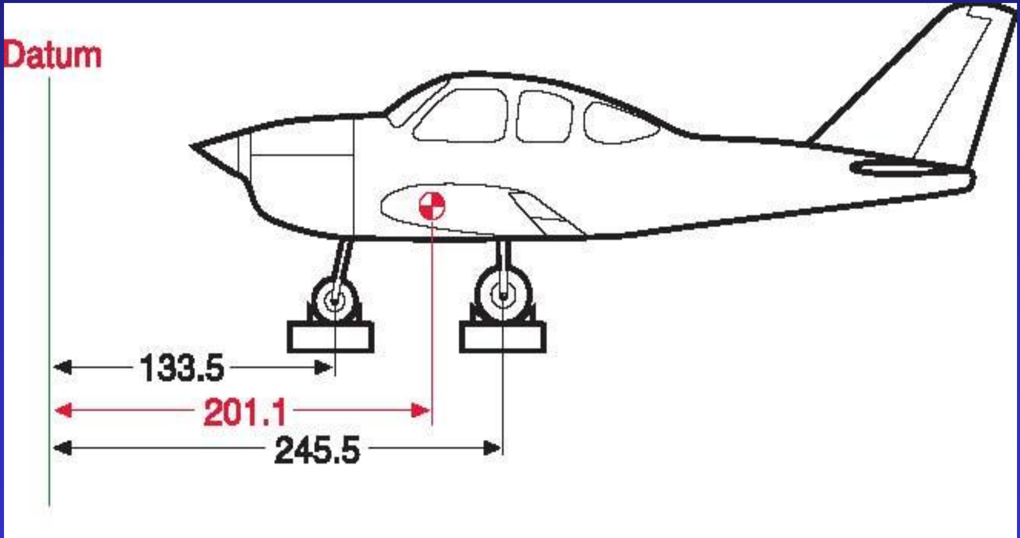


Figure 2-8. *Determining the CG of an airplane whose datum is ahead of the airplane.*

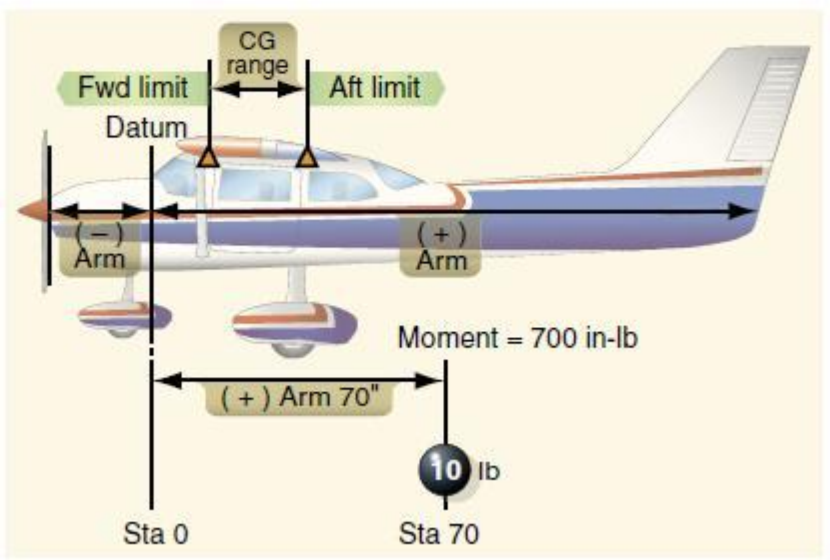


Figure 9-2. *Weight and balance.*

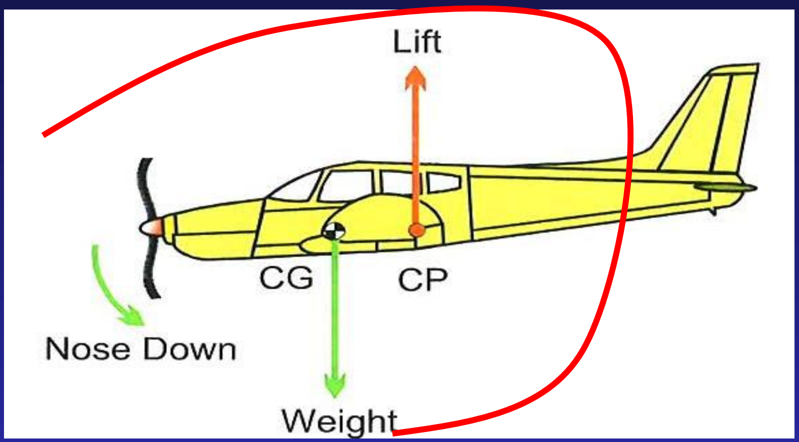
FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

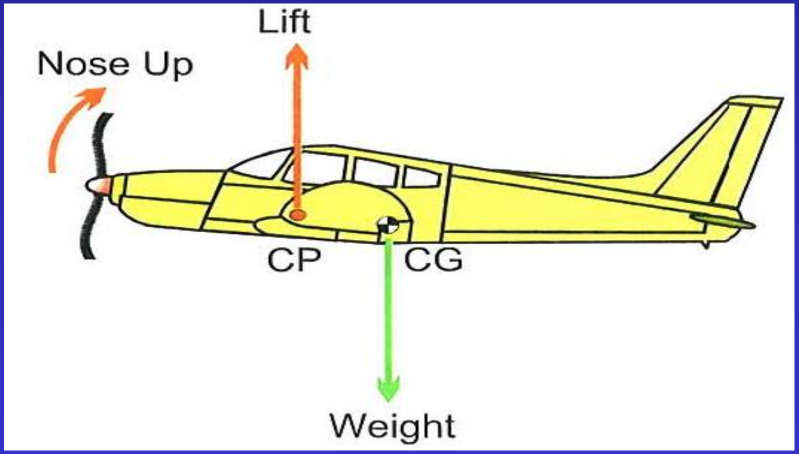
- THE EFFECT OF CG LOCATION VS. CP LOCATION:

✓ When the CG is forward of the CP, there is a natural tendency for the aircraft to want to pitch nose down.

✓ If the CP is forward of the CG, a nose up pitching moment is created. This increases AoA, causing the CP to move further forward and can lead to a stall.

✓ For natural longitudinal stability, the CG should be in front of the CP.





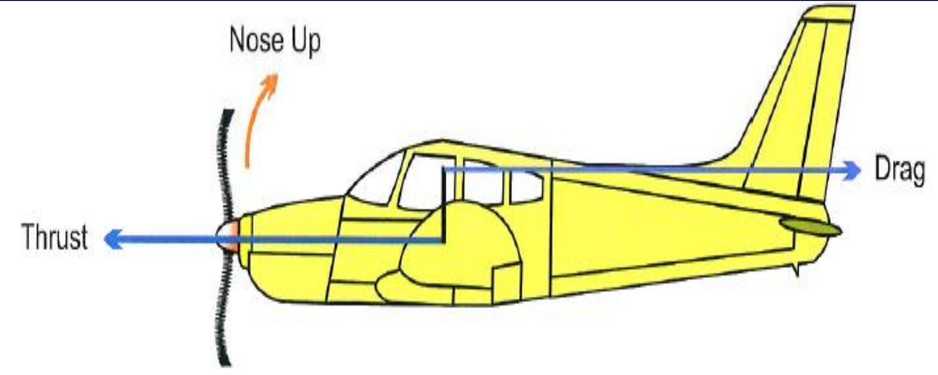
FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

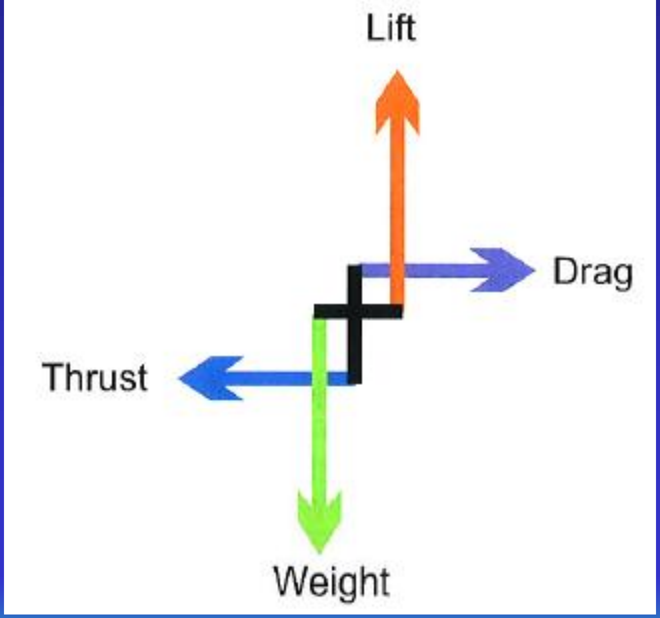
- THRUST AND DRAG:

✓ The forces are arranged so that lift acts behind weight and thrust acts below drag.

✓ Ideally, the pitching moments should cancel each other out, but in practice, a secondary method of balancing is used.

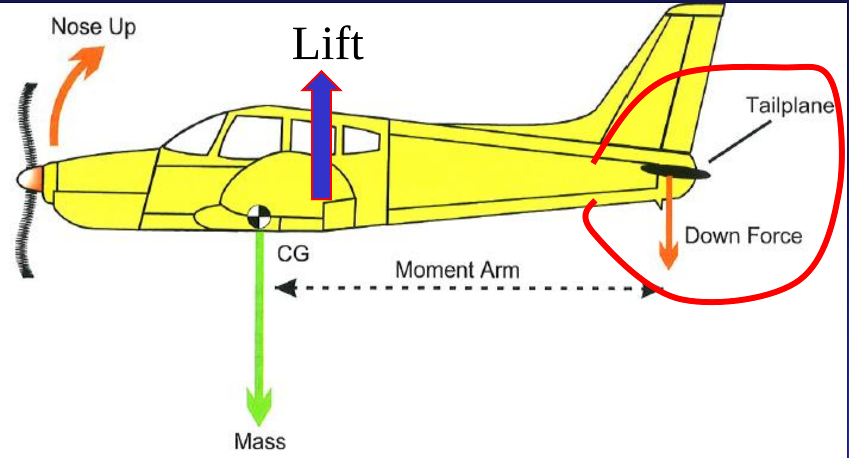
✓ It is normally done by the tailplane.

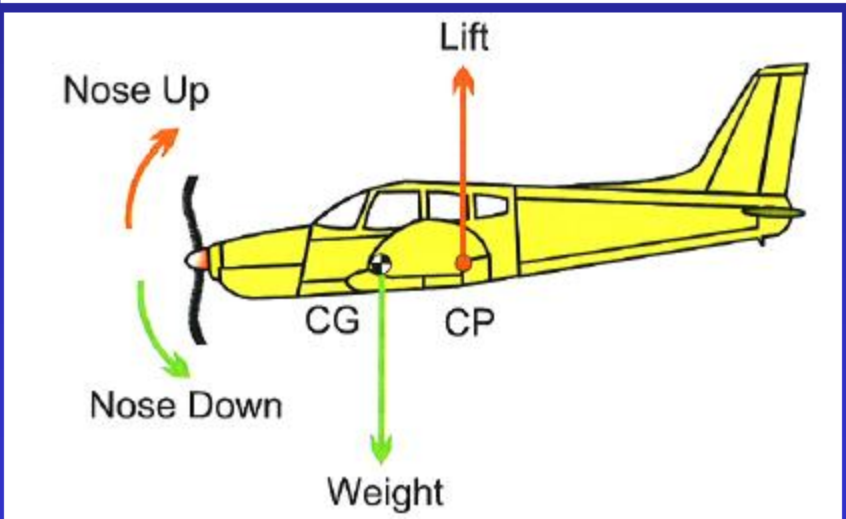




FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

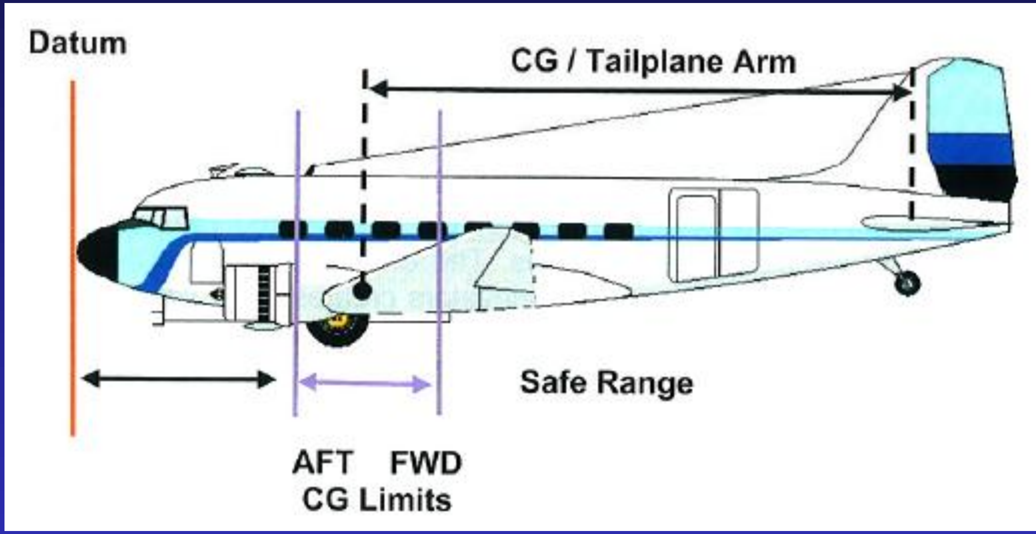
- TAILPLANE:
- It supplies the force necessary to balance any residual pitching moment.
- Long Momemt Arm requires smaller aerodynamic surface.
- It creates either a down force or up force. At slow speed the force is insufficient to balance.
- In these cases, the elevator is deflected to increase or reduce the forces. It creates drag, which is referred to as Trim Drag.





FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

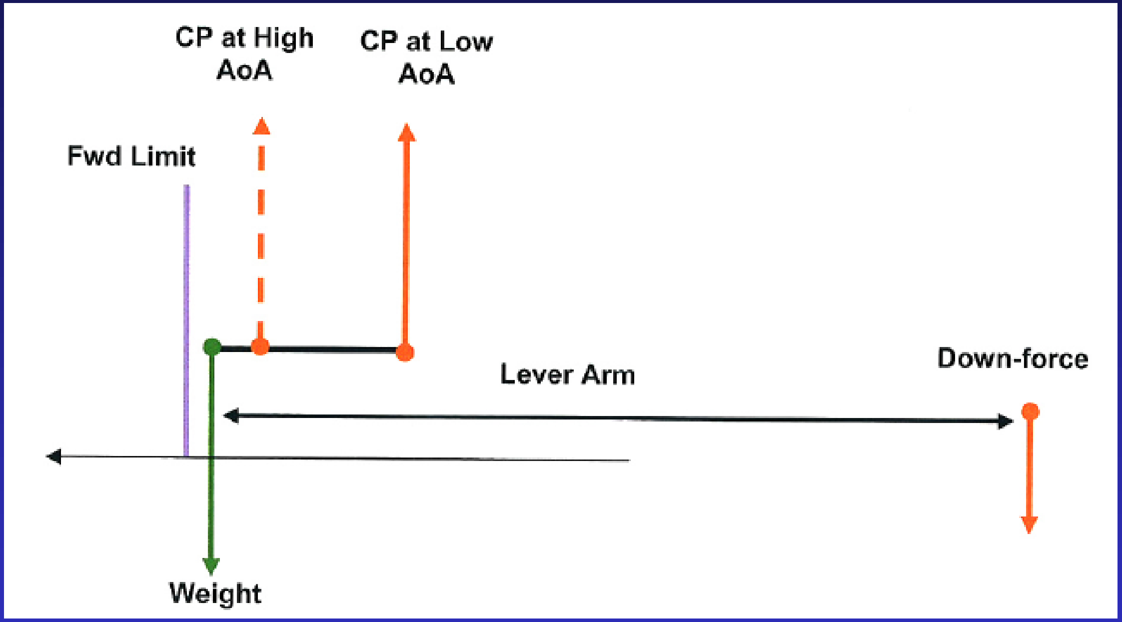
- CG CONSTRAINTS:



- To ensure that the aircraft is correctly controllable and stable, the manufacturer places front and rear constraint or limits for th location of CG, both on the ground and in flight.
- If the aircraft's CG falls on or within these lines, the CG is in limits.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

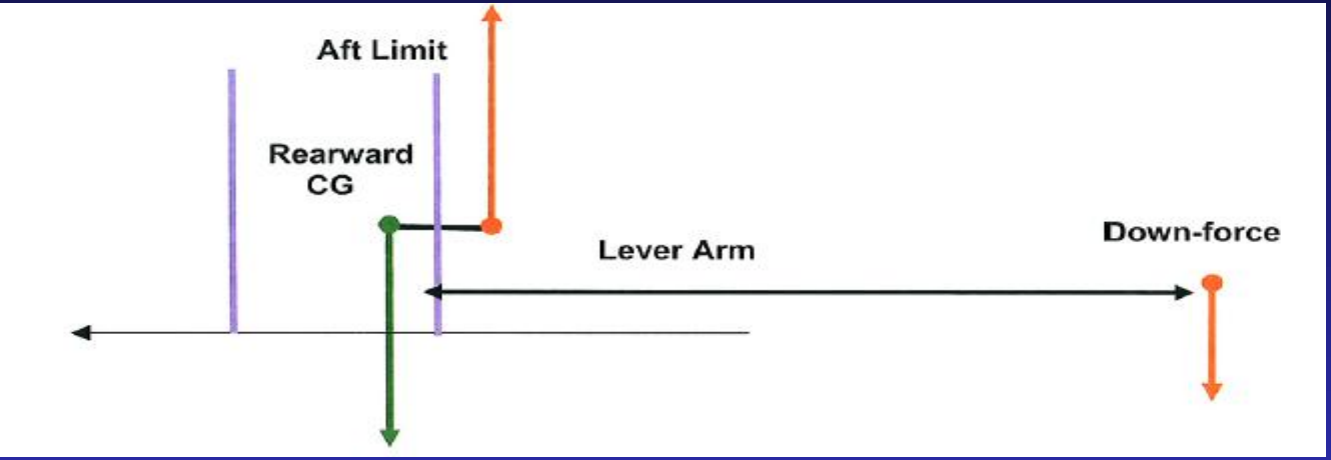
- FORWARD LIMIT:



- The forward limit is determined by the authority that the tailplane has to trim out the increased nose down pitching moment created by the location of the CG.
- This authority is determined by the range of the elevator, the airspeed of the aircraft, and the size of the tailplane and the lever arm.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

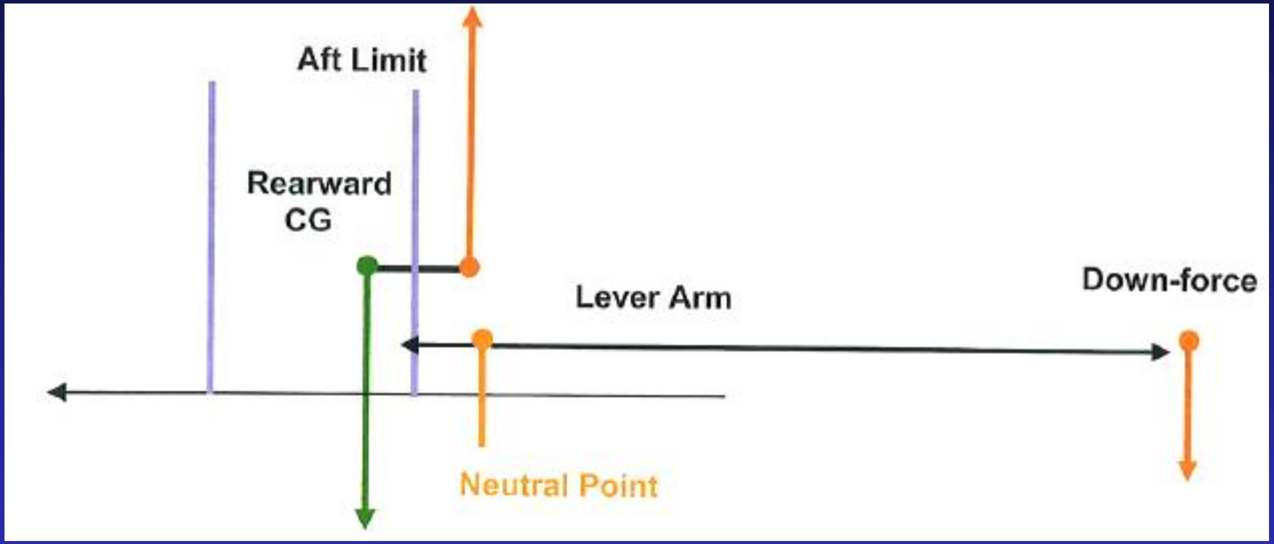
- AFT LIMIT:



- ✓ As the CG is located rearward, there is a reduction in the nose down pitching moment. This reduces down force requirement and large elevator deflections.
- ✓ It allows for extra control surface deflection to be used to alter pitch attitude of the aircraft. There is also a reduction in trim drag and stick fixed force making it easier for the pilot to move the controls.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

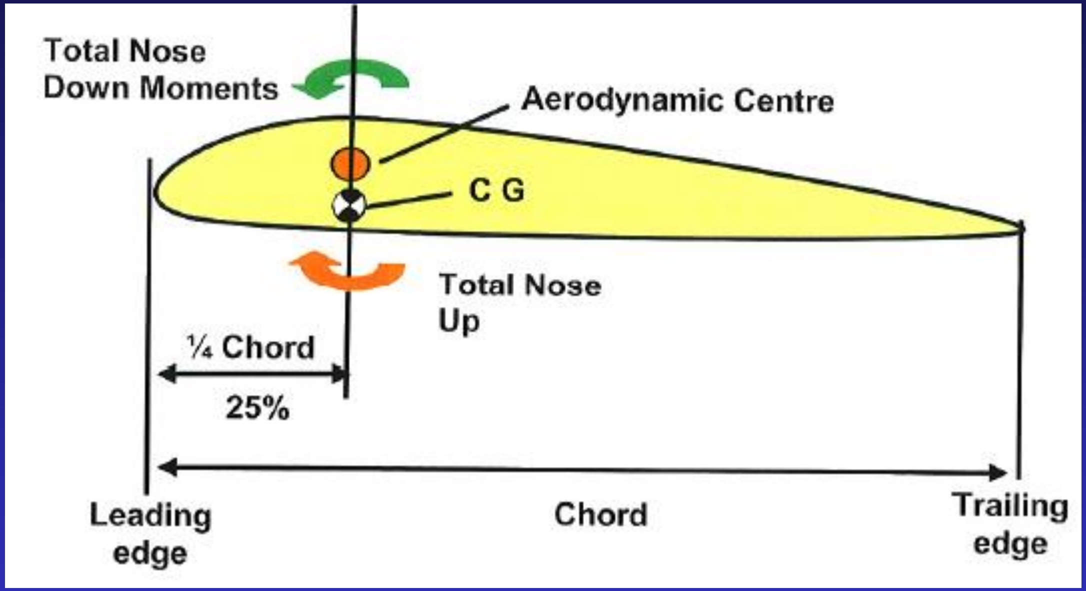
- NEUTRAL POINT:



- As the CG moves further aft, the controllability increases with the decrease in stability. The rear limit is set to maintain sufficient stability.
- The rear limit is set forward of the neutral point. The neutral point occurs on a point termed the aerodynamic center, which in subsonic aircraft is normally located at the ¼ chord point behind the leading edge.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

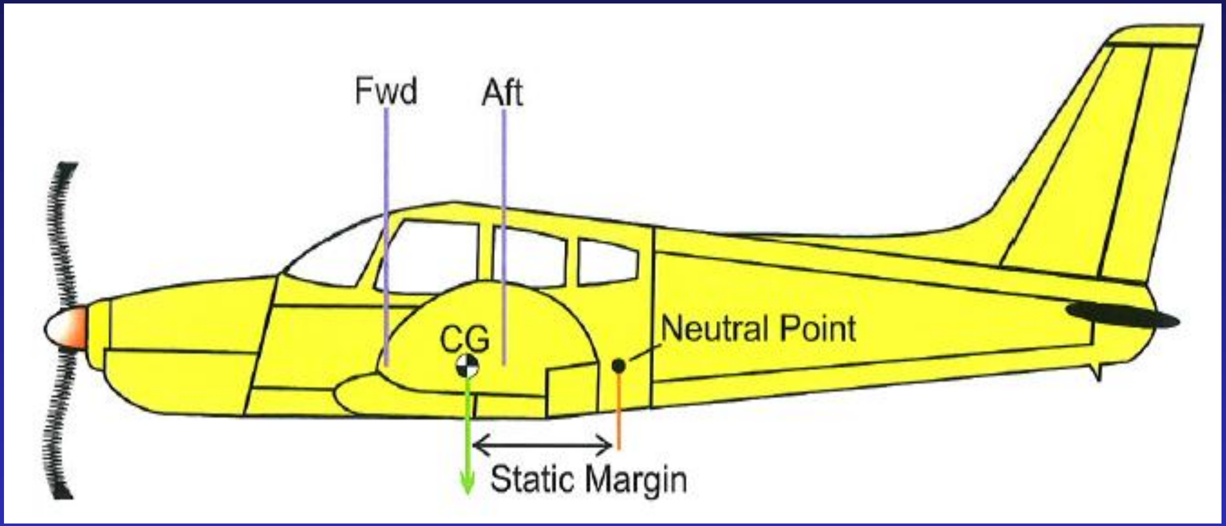
- AERODYNAMIC CENTER:



- For calculation, the AC is considered to be located at 25% chord. In reality, it moves between 23-27% of the chord for a subsonic aircraft.
- If the CG is located on the AC, there is no net pitching moment (increased controllability, neutral stability) – not desirable

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- AERODYNAMIC CENTER:



- Since it is not desirable in an air transport aircraft, The cg rear limit is set forward of this point.This gives the aircraft longitudinal static stability.
- The distance between the neutral point and the CG is termed the static margin or CG margin. Therefore, in real terms, the real limit is forward of the neutral point, and the CG is not allowed to get this far aft.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- FACTORS AFFECTING THE LONGITUDINAL CG POSITION IN FLIGHT:

✓ Fuel consumption

✓ Flap extension / retraction

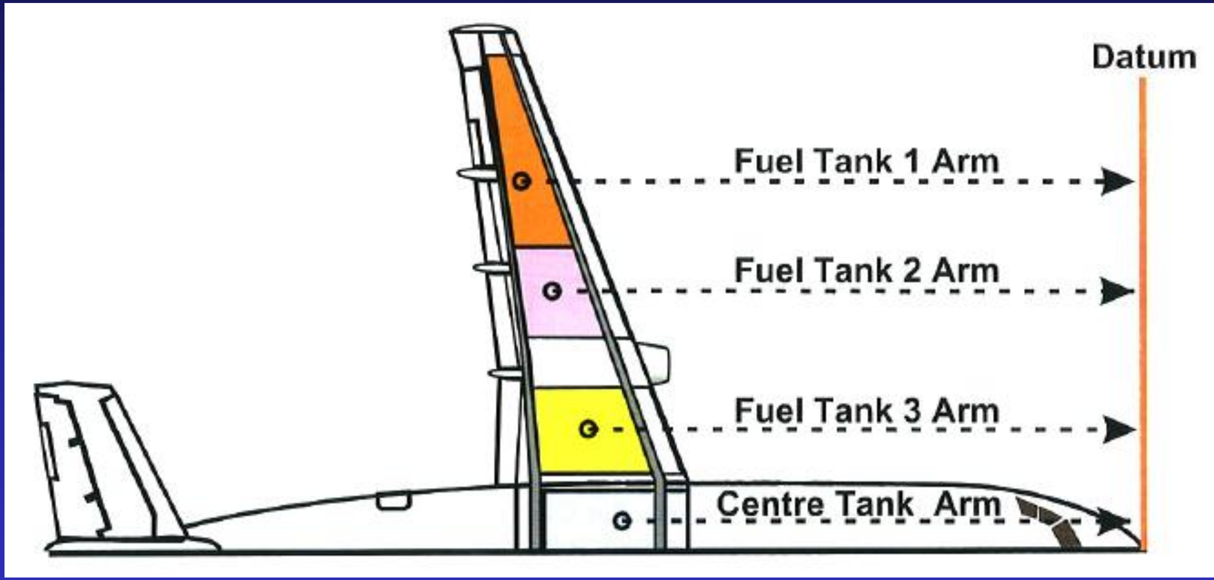
✓ Gear extension / retraction

✓ Cargo movement

✓ Passenger / crew movement

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

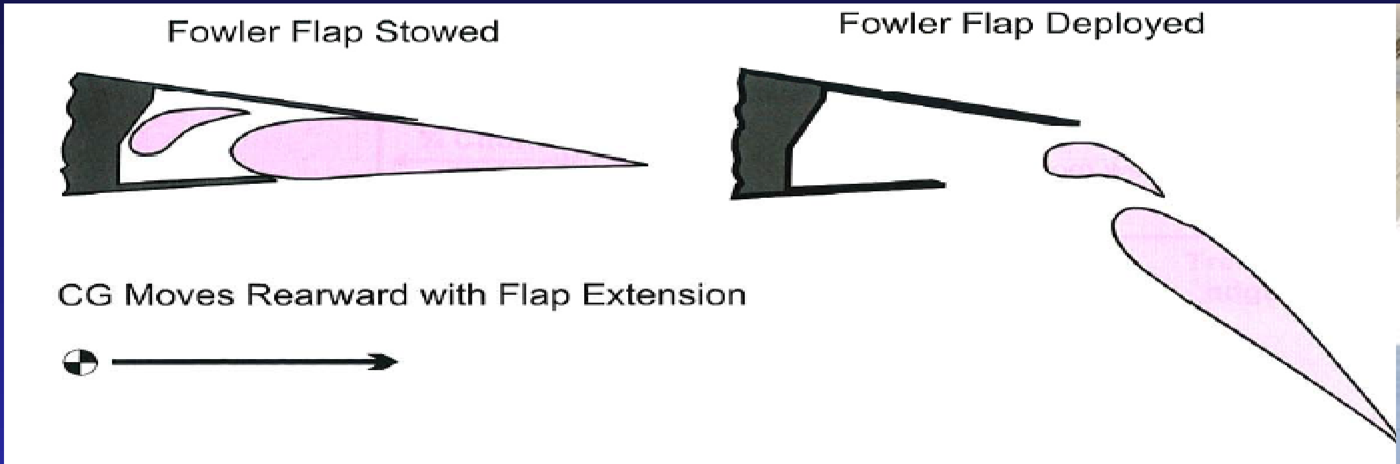
- FUEL CONSUMPTION:



- In flight, the mass of the aeroplane reduces through consumption of fuel.
- If the aircraft has fuel tanks with varying arms, as the trip fuel is burnt off, the CG position varies due to this consumption and the drop in aircraft mass.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- FOWLER FLAPS:



- Transport aircraft frequently use Fowler flaps as trailing edge flaps. These flaps translate rearward on extension, moving rearward as well as lowering the trailing edge.
- This results in the CG moving rearward with the flaps’ extension and forward with the flaps’ retraction.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- LANDING GEAR DESIGN:

- Most aircraft have main gears that retract laterally (no effect on the longitudinal CG). However, the raising of a forward retracting nose gear moves the CG forward and vice versa.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- CARGO:
- When an aircraft is loaded, The CG and mass must be within prescribed limits of the aeroplane. If the cargo should shift in flight, the aircraft can become either too stable or uncontrollable .
- Additionaly, cabin crew and passenger movements have an effect on the trim of the aeroplane .
- THREE CG POINTS THAT MUST BE CALCULATED:
- If the aircraft is not overloaded, The CG may fall on or between the CG limits. However, as the aircraft's CG location moves with the consumption of fuel, prior to any flight,
- the aircraft's calculated Take-Off Mass (TOM),
- Landing Mass (LM),
- Zero Fuel Mass (ZFM)
- and corresponding CG s must be compared to the limits.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT – CARGO LOADING

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- SUMMARY:
- As the CG moves toward the forward limit:

➢ Stability increases and controllability decreases.
➢ On take-off, the nose is heavy requiring more elevator deflection to rotate the aircraft.
➢ The climb is suppressed, as the nose wants to pitch down.
➢ Greater deflection of the elevators, which results in an increase in trim drag.
➢ Greater down force requires greater lift, which results in a higher stalling speed.
➢ The increase in trim drag requires more thrust to maintain a given airspeed.
➢ The increase in thrust results in more fuel being burned (shorter range)
➢ Strong longitudinal stability reduces the effectiveness of the elevator.

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- As the CG moves toward the aft limit:
- ➢ Stability decreases and controllability increases.
- ➢ On take-off, the nose is lighter, requiring less elevator deflection. The aircraft rotates more rapidly than expected.
- ➢ The down force required from the elevator reduces. (less drag)
- ➢ The reduction in drag, requires less thrust.
- ➢ Less thrust results in fuel flow reducing and range increase.
- ➢ The decreased down force, which results in a lower stalling speed.
- ➢ In the event of a landing climb (go around), the aircraft’s nose rotates more easiliy.

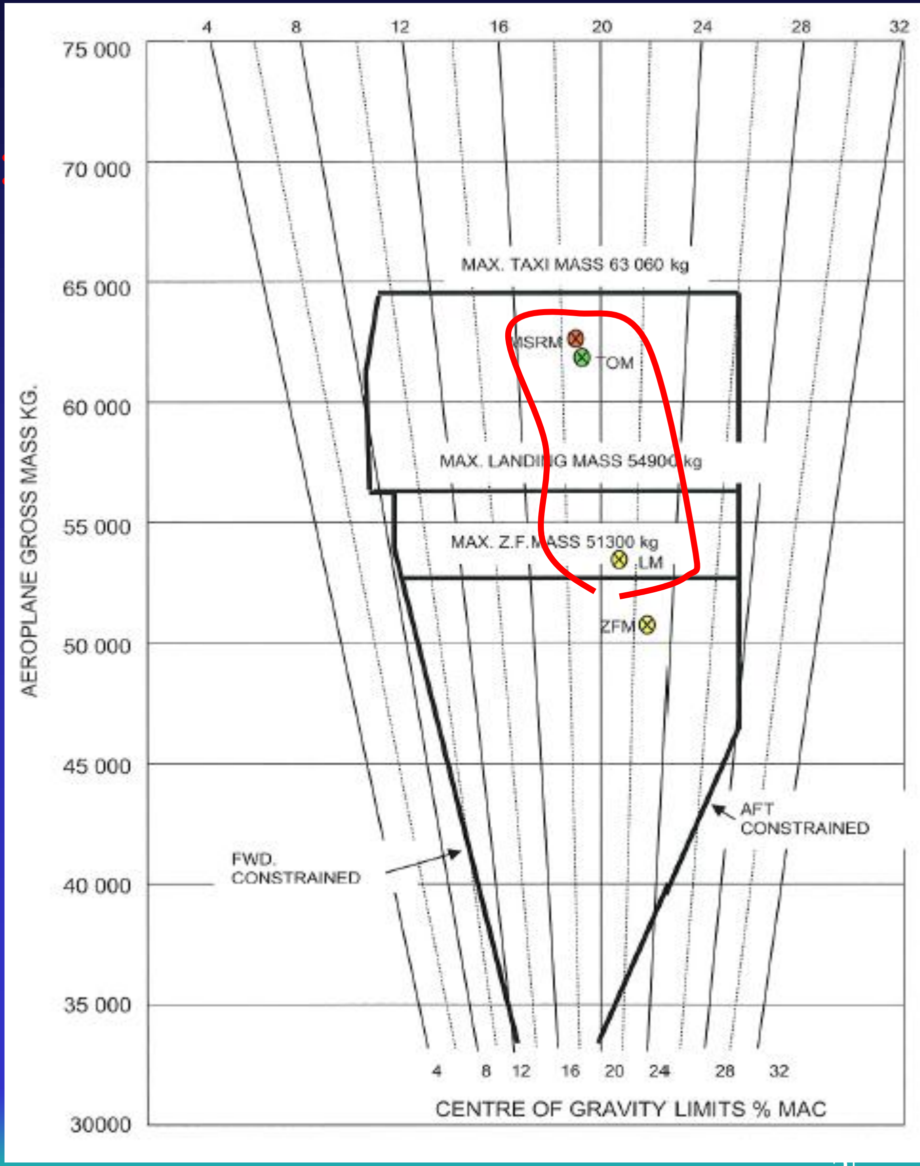
FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

MASS AND BALANCE

- An Aircraft Accident:
- March 21, 1980
- Piper PA-31-350 with a pilot, a pilot-in-command trainee and 8 passengers
- MTOM :7000lbs
- Actual TOM:7280 lbs!
- No baggages in the forward cargo compartment!
- Center of Gravity 3 in beyond the rear limit!(138 in instead of 135 in max.)

FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- Desirable CG Position in Flight:
  - A **slightly aft location** for the optimum CG position.
  - Sufficiently stable but more manoeuvrable.
  - Less drag
  - Less thrust
  - More efficient cruise



FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- EFFECT OF OVERLOADING:
- If Maximum Take-off Mass (MTOM) is exceeded, but the CG is located within the safe range, it results in:

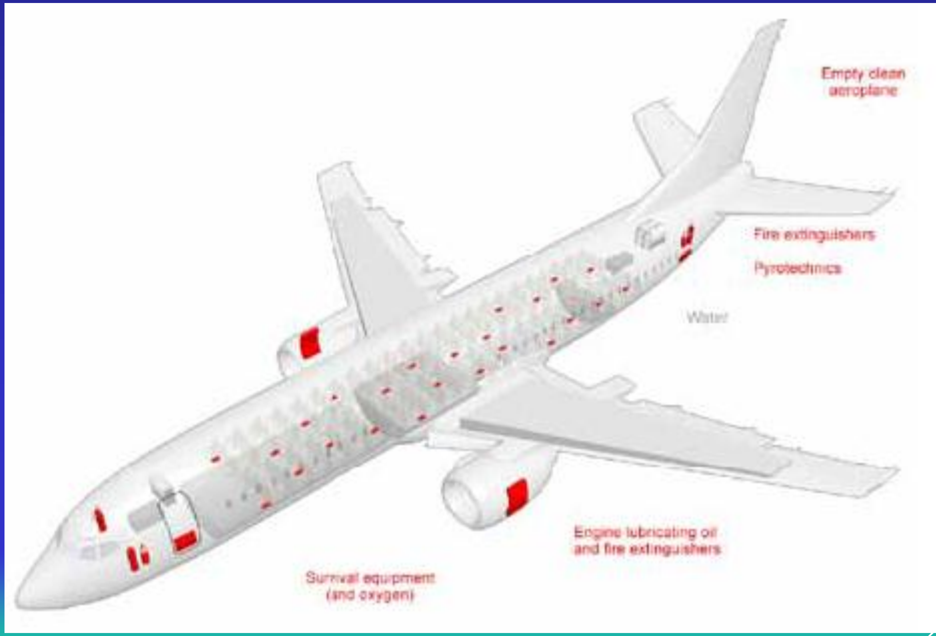
- ➢ A greater take-off run, because it requires a greater speed for required lift.
- ➢ Reduced climb performance
- ➢ A reduction in airspeed for a given power setting.
- ➢ **Higher stalling speed. If it is heavier than calculated, it is more likely to stall**.(no stall safety margin)

- ➢ Reduced excess power means reduced service ceiling.
- ➢ Increase in fuel consumption.
- ➢ A decrease in range.
- ➢ A higher landing speed due to stall risk. Longer landing run.
- ➢ Heavy braking, damaged tyres.
- ➢ A mass above the maximum structural landing mass will result in failure.

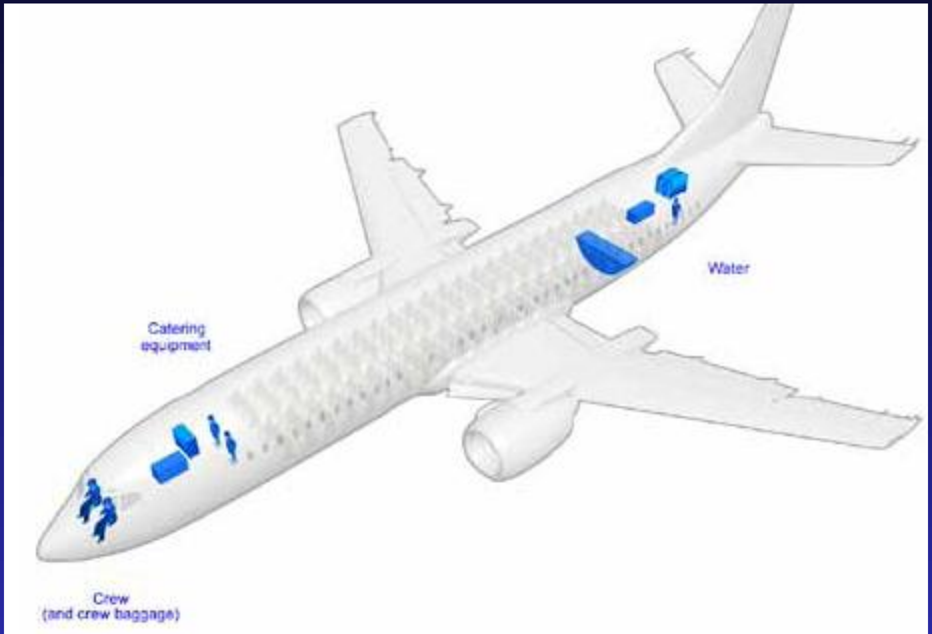
FACTORS AFFECTING MASS AND BALANCE IN AIRCRAFT

- **Basic Empty Mass - BEM (Basic Mass - BM) :**
- **is the mass of an aeroplane plus standard items such as:**

✓ **Unusable fuel and other unusable fluids**
✓ **Lubricating oil in the engine and auxiliary units**
✓ **Fire extinguishers**
✓ **Emergency oxygen equipment**

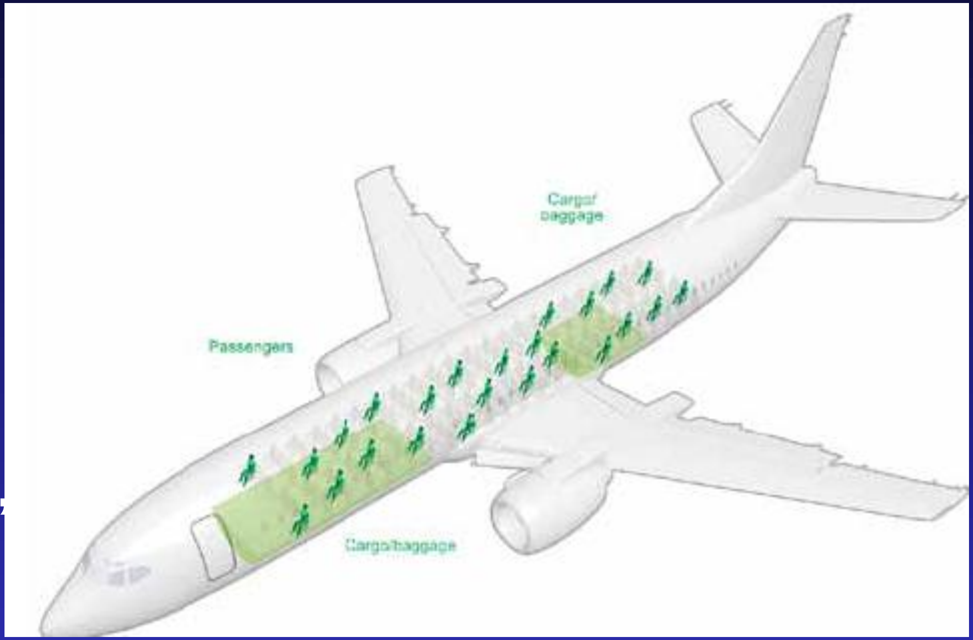


MASS DEFINITIONS AND LIMITATIONS



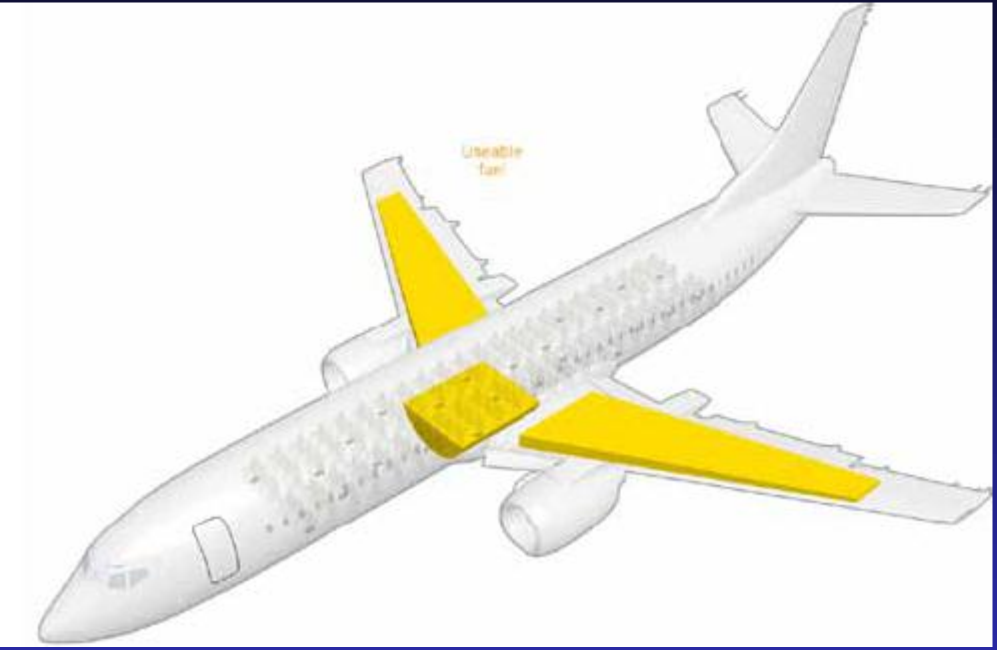
- **Variable Load**
- ✓ **Crew and crew baggage**
- ✓ **Catering and removable passenger service equipment**
- ✓ **Potable water and lavatory chemicals**
- ✓ **Food and beverages**
- ✓ **BEM + Variable Load = Dry Operating Mass**
-

MASS DEFINITIONS AND LIMITATIONS



- **Traffic Load**
  - **The total mass of passengers, baggage, and cargo, including any non-revenue load.**

- **Pay Load**
  - **This is defined as that part of the traffic load from which the revenue is earned.**



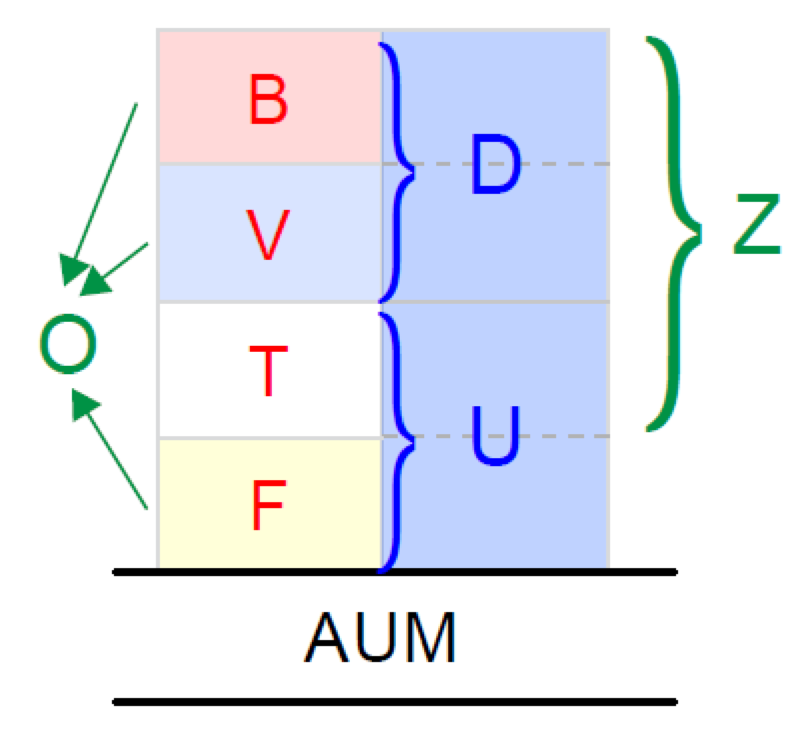
- Fuel Definitions:
  - ✓ Block Fuel (Bulk Fuel) or Ramp Fuel
  - ✓ Start, Run-up, and Taxi Fuel
  - ✓ Take-Off Fuel
  - ✓ Trip Fuel
  - ✓ Landing Fuel (reserve fuel)

- To summarise

Landing Fuel + Trip Fuel = Take-Off Fuel

Take-Off Fuel + Start Fuel = Ramp Fuel

MASS DEFINITIONS AND LIMITATIONS



➢Fuel Definitions

✓ Operating Mass (OM)

- is the DOM plus fuel but without traffic load.
- DOM + TOF = OM
  BEM + VL + TOF = OM

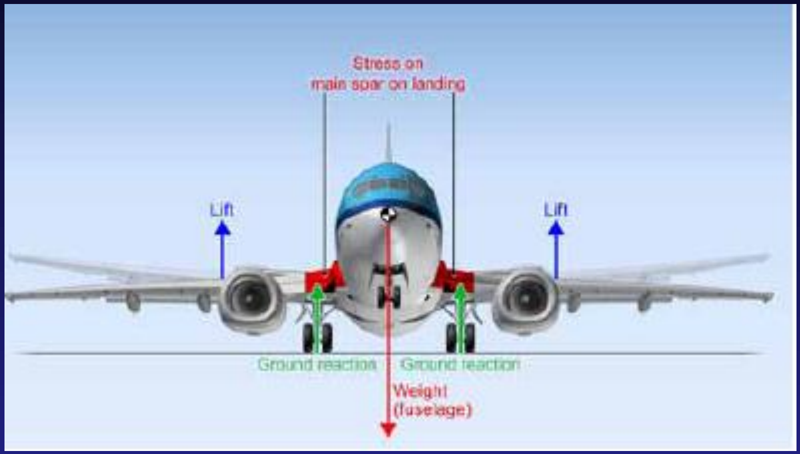
✓ Zero Fuel Mass (ZFM)

- is DOM plus traffic load but excluding fuel.
- DOM + Traffic Load = ZFM
  BEM + VL + Traffic Load = ZFM

MASS DEFINITIONS AND LIMITATIONS

- STRUCTURAL LIMITATIONS:
- Maximum Structural Taxi Mass (MSTM)
  - ✓ is the structural limitation on the mass of the aeroplane at the commencement of taxi.(Maksimum Taxi/Ramp Mass)
- Maximum Structural Take-Off Mass
  - ✓ The maximum permissible total aeroplane mass at the start of the take-off run.(Maximum Take-off Mass – MTOM)

MASS DEFINITIONS AND LIMITATIONS



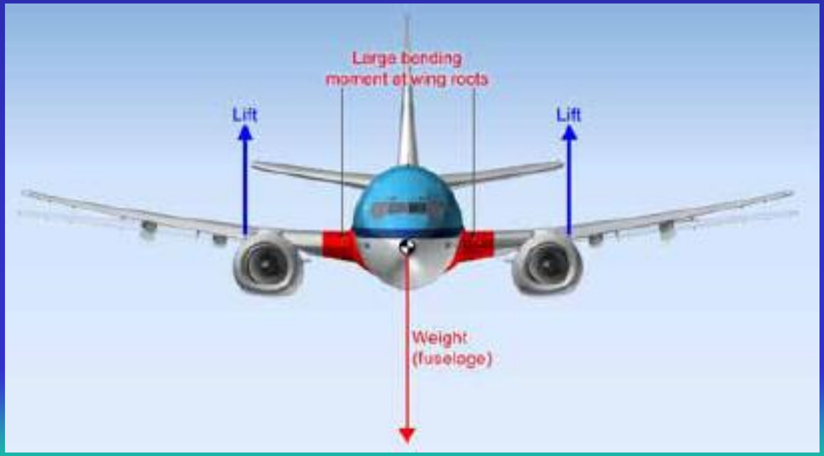
➢STRUCTURAL LIMITATIONS:

➢ Maximum Structural Landing Mass

✓ The maximum permissible total aeroplane mass on landing under normal circumstances.(Maximum Landing Mass – MLM)

➢ Maximum Zero Fuel Mass (MZFM)

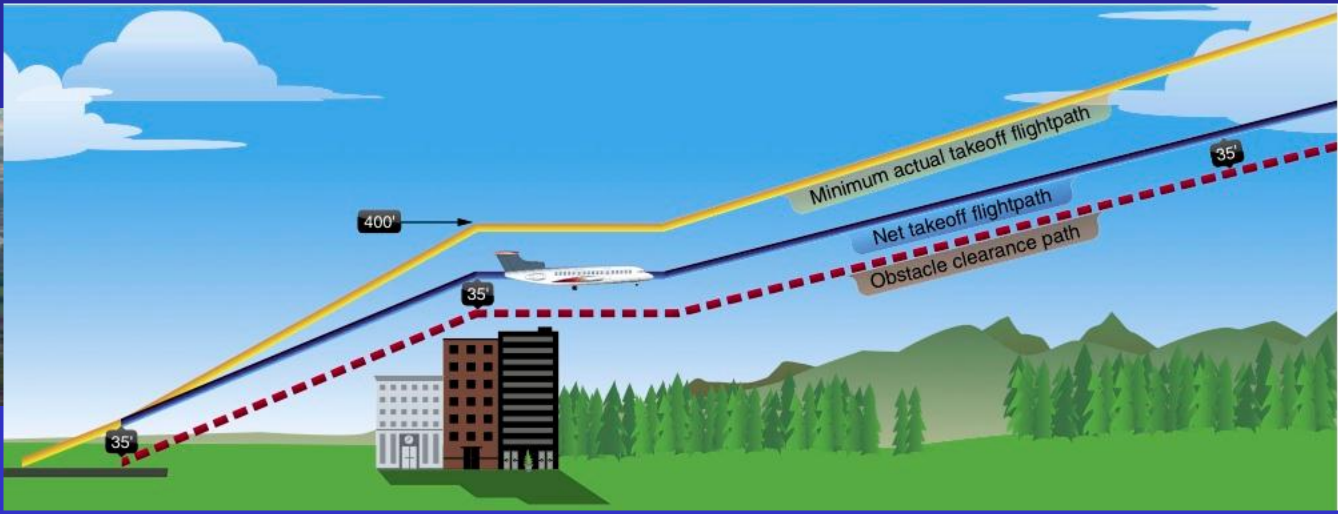
✓ The maximum permissible mass of an aeroplane with no usable fuel.



MASS DEFINITIONS AND LIMITATIONS

- **PERFORMANCE LIMITATIONS:**
- **The altitude of the airfield (density)**
- **The air temperature (density)**
- **The length of the runway**
- **The topography of the area**

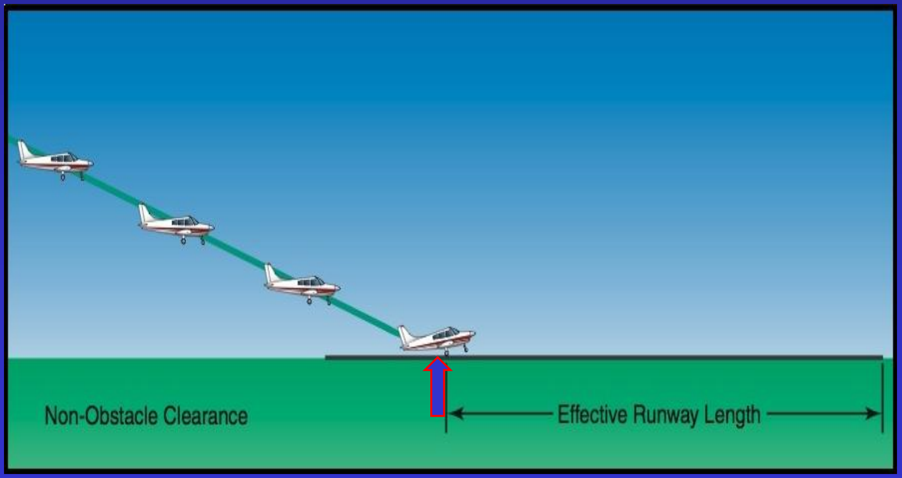
- Performance Limited Take-off Mass (PLTOM)
- ✓ is the take-off mass subject to departure airfield limitations.

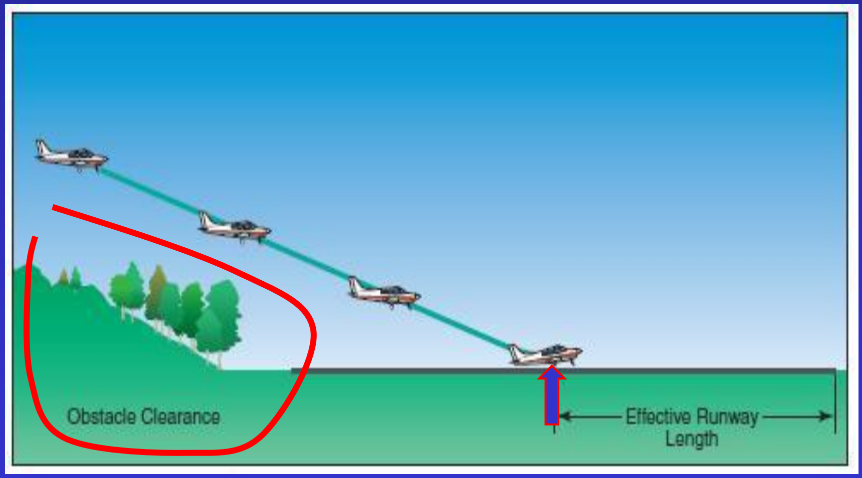


MASS DEFINITIONS AND LIMITATIONS

- **PERFORMANCE LIMITATIONS:**
- **The altitude of the airfield (density)**
- **The air temperature (density)**
- **The length of the runway**
- **The topography of the area**

- Performance Limited Landing Mass (PLLM)
- ✓ Is the mass subject to the destination airfield limitations.





MASS DEFINITIONS AND LIMITATIONS

- **REGULATED LIMITATIONS:**

- Regulated Take-off Mass (RTOM)
- ✓ Is the lowest of Performance Limited and Structurtal Limited Take-Off Mass.(Maximum Allowable Take-Off Mass (MATOM)
- ✓ Regulated Landing Mass (RLM)
- ✓ Is the lowest of Performance Limited and Structural Limited Landing Mass. (Maximum Allowable Landing Mass)(MALM)

MASS DEFINITIONS AND LIMITATIONS
CALCULATING THE MAXIMUM TAKE-OFF MASS

- The maximum mass at which an aeroplane can take-off is the most restrictive(lowest) of the three limitations below:

1. The regulated take-off mass RTOM, which is the more restrictive (lower) of the performance limited take-off mass and the maximum structural take-off mass.
2. The regulated landing mass RLM (which is the more restrictive of the performance limited landing mass and the the maximum structural landing mass) plus the trip fuel.
3. The Maximum Zero Fuel Mass MZFM plus the fuel at take-off.

MASS DEFINITIONS AND LIMITATIONS
CALCULATING THE MAXIMUM TAKE-OFF MASS

Example

Given the following calculate the maximum take-off mass.

Maximum Structural Take-off Mass 78 000 kg

Maximum Structural Landing Mass 71 500 kg

Maximum Zero Fuel Mass 63 000 kg

Maximum Performance Limited Take-off Mass 85 000 kg

Maximum Performance Limited Landing Mass 67 000 kg

Fuel at take-off 13 800 kg

Trip fuel 5200 kg

RTOM	RLM	MZFM
	+ trip fuel	+ take-off fuel
78 000 kg	67 000 kg	63 000 kg
	+ 5 200 kg	+ 13 800 kg
78 000 kg	72 200 kg	76 800 kg

MTOM

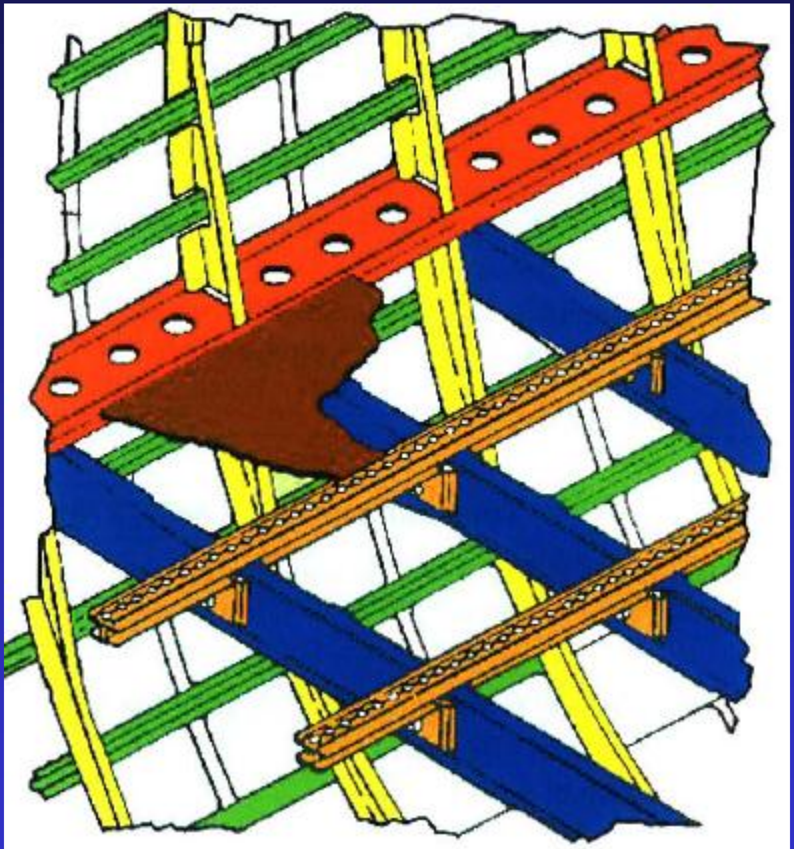
The maximum take-off mass is therefore the lowest of the above masses, 72 200kg.

AIRCRAFT FLOOR LOADING
CARGO HANDLING

- Cargo Compartments:
- Compartments in the lower deck accomodate baggage and cargo.
- All compartments have a maximum floor loading (kg/m^2) and maximum running load value (kg/m).
- Containerised Cargo
- Palletised Cargo
- Bulk Cargo

AIRCRAFT FLOOR LOADING

- FLOOR LOADING:
- Lightweight panels are supported on crossbeams (blue).
- These are attached to the longerons(red) and the frames (yellow).
- In the passenger cabin, seat rails (dark yellow) carry the passengers.
- Limitations are;
  - Running Loads
  - Static Loads



AIRCRAFT FLOOR LOADING

- EXAMPLE FOR CARGO COMPARTMENT LIMITATIONS:

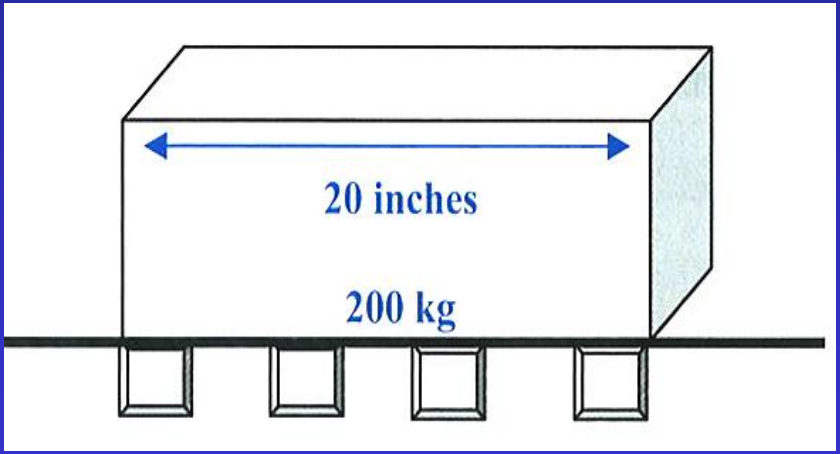
The hold has an overall length of 280 inches and is located between balance arms 220 to 500 in. The hold is sub-divided into three separate sections: from 220 to 280 in, from 280 to 340 in, and from 340 to 500 in.

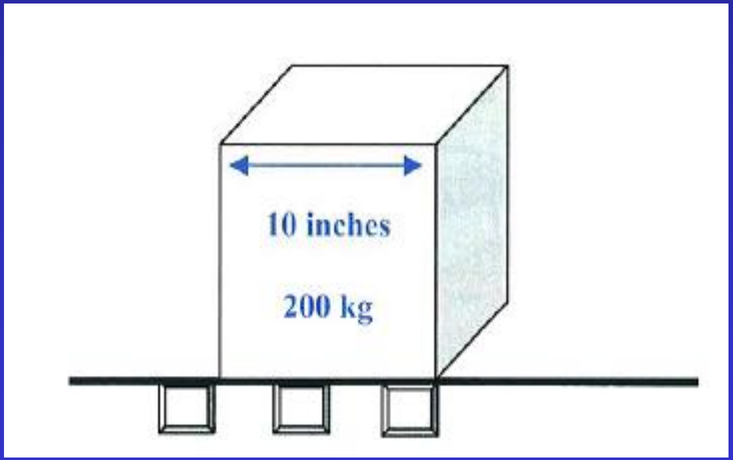
FORWARD CARGO COMPARTMENT

BA – IN 220	280	340	500
MAXIMUM COMPARTMENT RUNNING LOAD IN KG PER INCH	10.5	8.9	15.12
MAXIMUM DISTRIBUTION LOAD INTENSITY KG PER SQUARE FOOT	60		
MAXIMUM COMPARTMENT LOAD KG	630	534	2419.2
MAXIMUM TOTAL LOAD KG	3583.2		
HOLD CENTROID B.A.- IN	374		

AIRCRAFT FLOOR LOADING

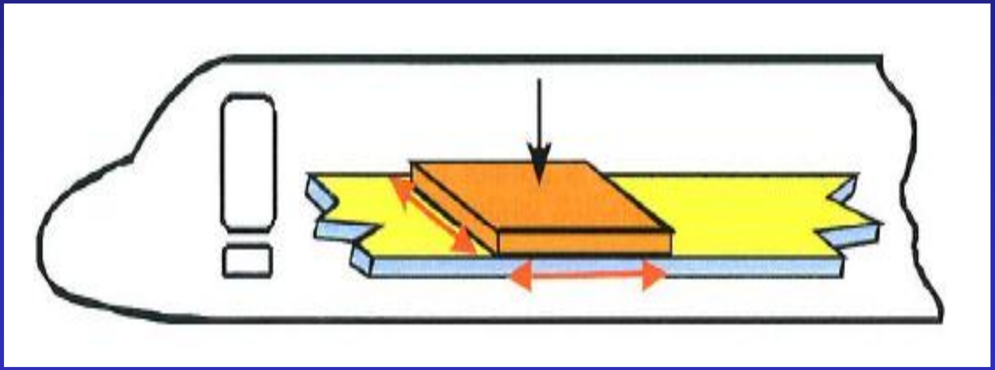
- PRINCIPLE OF RUNNING LOAD:
- If a container 10 in wide, 20 in long, weighing 200 kg is placed in the fwd compartment (max. Running load is 10,5 kg/in), the running load is: 200/20 = 10 kg/in
- If the container is rotated through 90 degree, the container's running load increases to 200/10 = 20 kg/in which is over the limit.





AIRCRAFT FLOOR LOADING

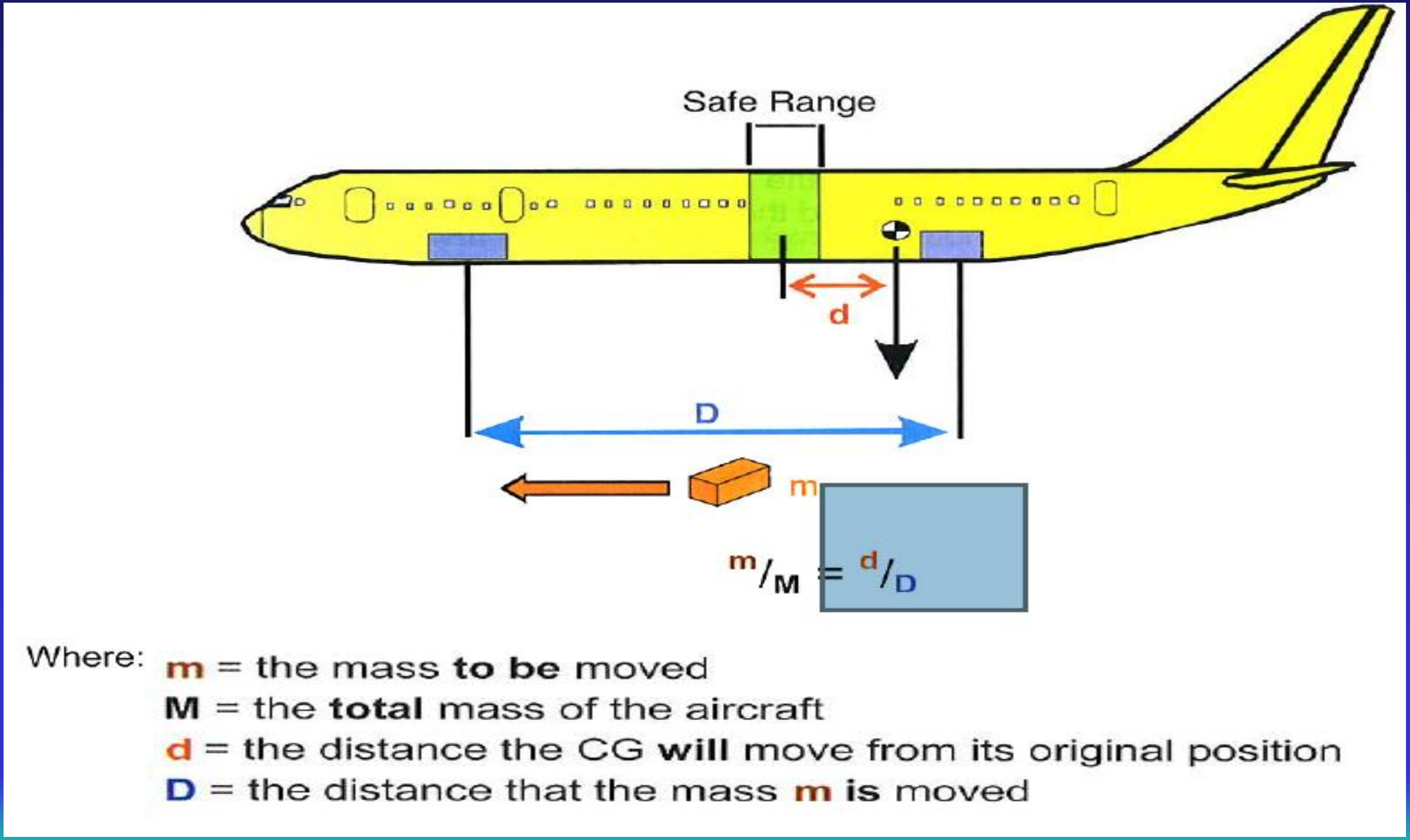
- LOAD SPREADERS:
- Used to increase the surface area over which a mass can act.



LOAD SHIFTING, LOAD ADDITION, AND LOAD SUBSTRACTION

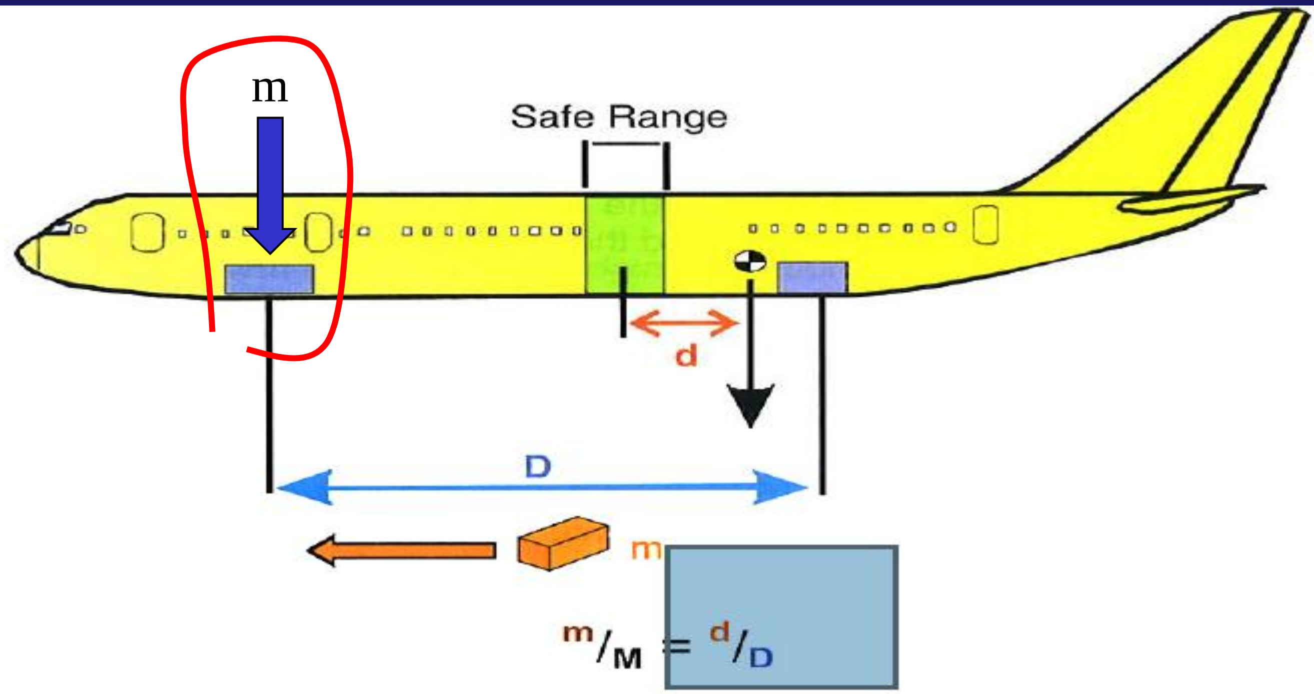
- LOAD SHIFTING:

✓The act of transferring a mass from one location to another within an aircraft has a double effect on the total moment.



LOAD SHIFTING, LOAD ADDITION, AND LOAD SUBSTRACTION

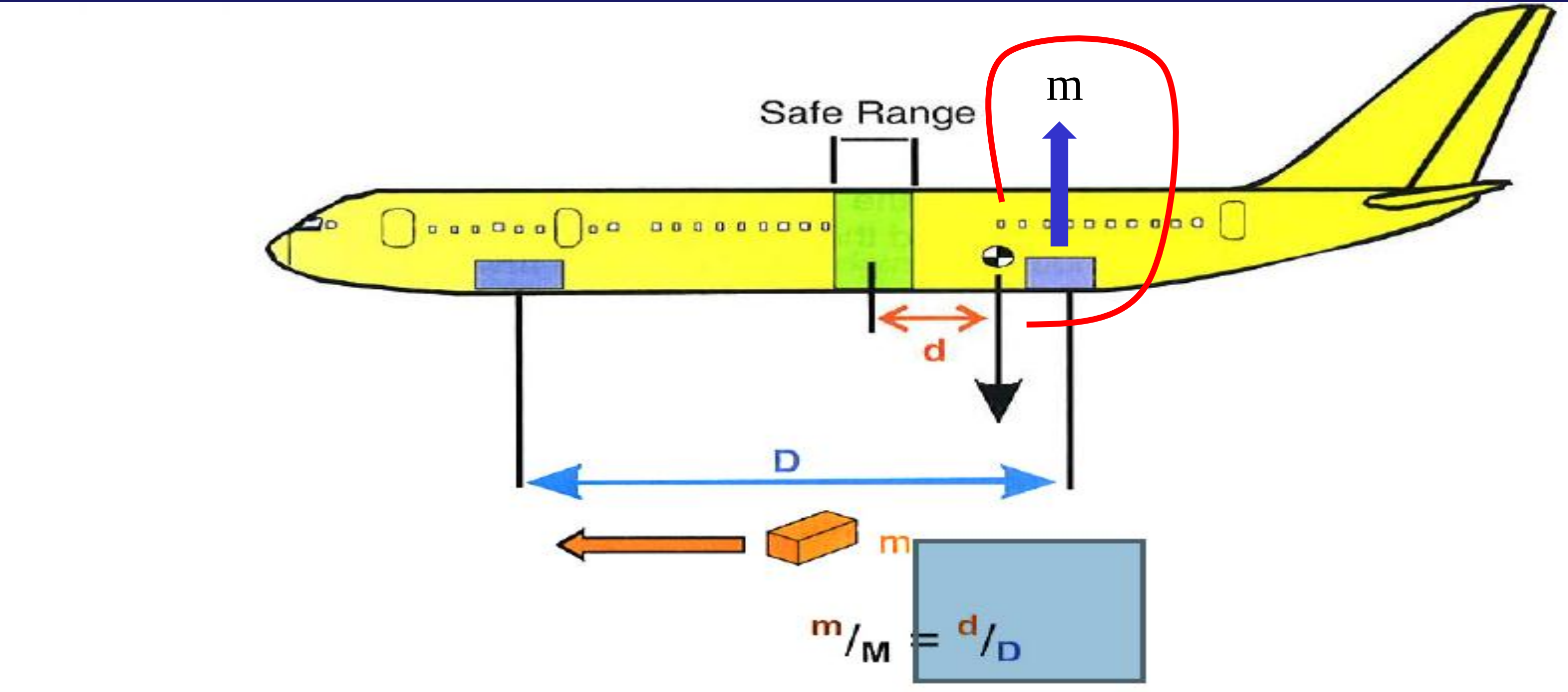
- LOAD ADDITION:



Where: **m** = the mass **to be** moved
M = the **total** mass of the aircraft
d = the distance the CG **will** move from its original position
D = the distance that the mass **m is** moved

LOAD SHIFTING, LOAD ADDITION, AND LOAD SUBSTRACTION

- LOAD SUBTRACTION:



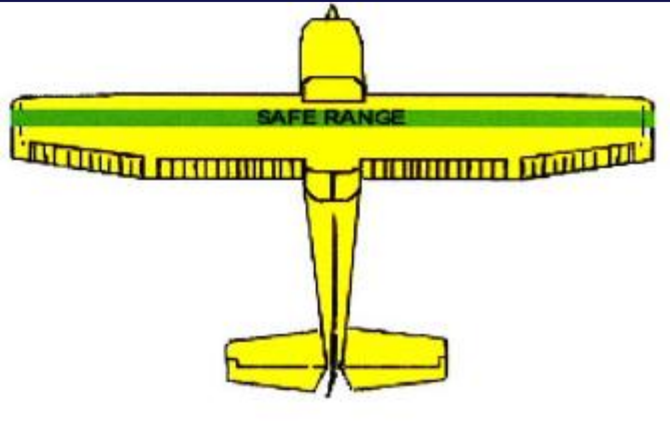
$$m/M = d/D$$

Where:

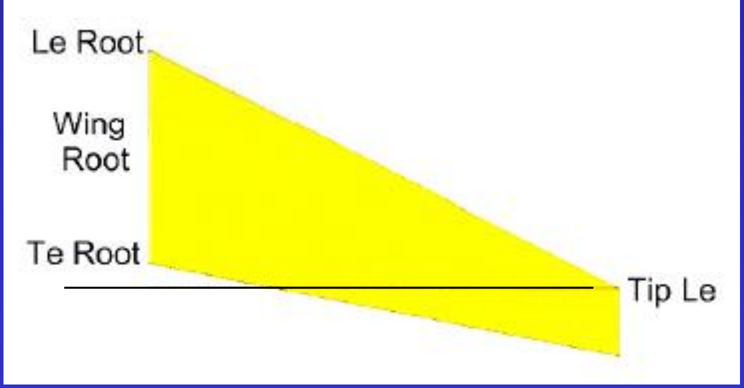
m = the mass **to be** moved
M = the **total** mass of the aircraft
d = the distance the CG **will** move from its original position
D = the distance that the mass **m is** moved

MEAN AERODYNAMIC CHORD

✓**Light aircraft** predominantly use straight wings that are either tapered or semi-tapered. These wings are mounted at right angles to the fuselage. (90 degree).This means that the CG safe range runs across the span of the wings.



✓**Modern transport aircraft**, due to their higher speeds and efficiencies, use swept-back wings. Here, the leading edge (Le) of the wing at the tip is behind the junction of the leading edge at the wing root and in some designs (as shown below) behind the wing root trailing edge (Te).

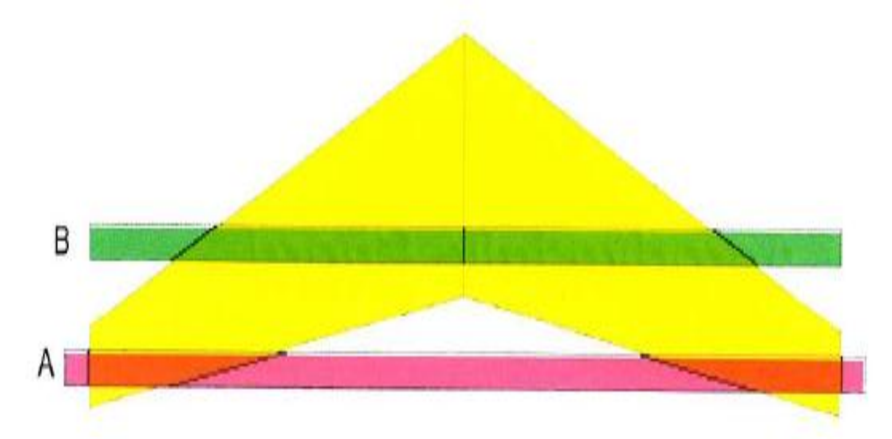


MEAN AERODYNAMIC CHORD

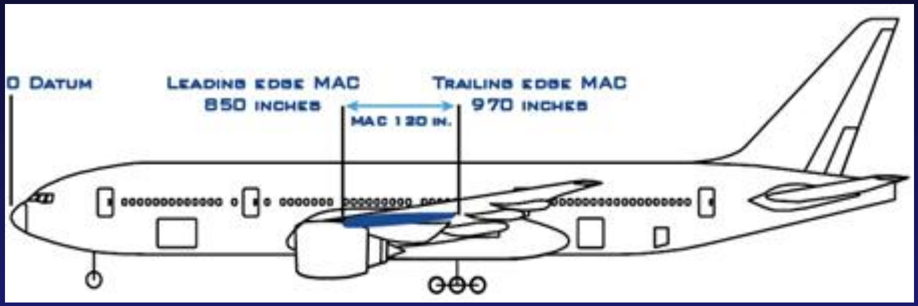
✓The safe range on a straight wing can easily be visualised as a band running from one wing tip to the other and be seen to fall within the lifting area. For a swept-back wing, if the safe range band were to pass through the wing tips (as per band A in the diagram above), the CG would be behind the Centre of Pressure.

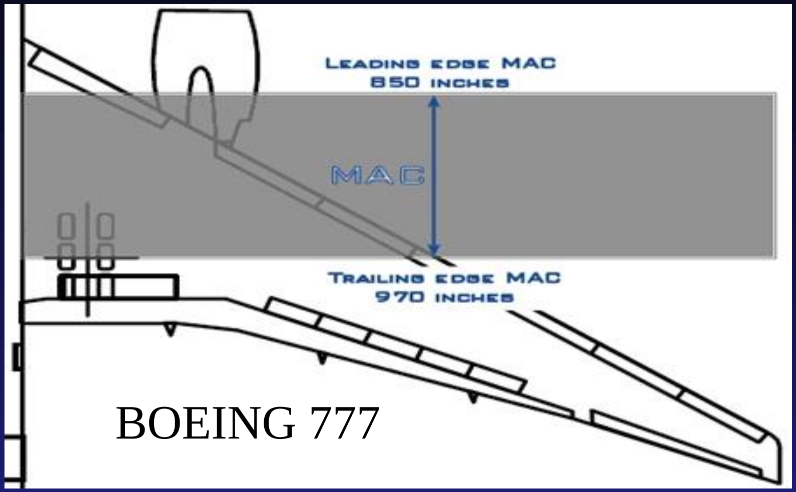
✓To ensure that the CG safe range is ahead of the CG, the safe range is located forward on the wing and is shown below as band B.

✓To rationalise this, a system called the Mean Aerodynamic Chord (MAC) is used.



MEAN AERODYNAMIC CHORD

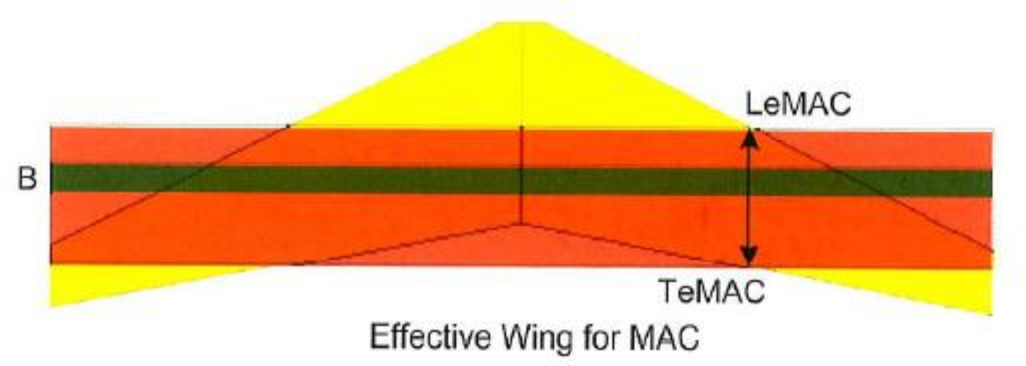




- MEAN AERODYNAMIC CHORD:

✓The mean aerodynamic chord of a wing, is the chord of a rectangular wing, with the same span, and having similar pitching moment characteristics.

✓The MAC is the primary reference for longitudinal stability considerations.



✓For mass and balance purposes, the aircraft can be considered to have a straight wing of this chord . It is considered that the lift generated by the wings comes from this chord. **The length of the chord is referred to as MAC.**

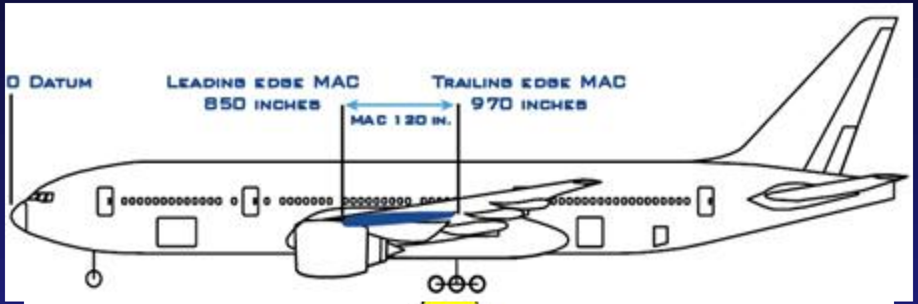
MEAN AERODYNAMIC CHORD

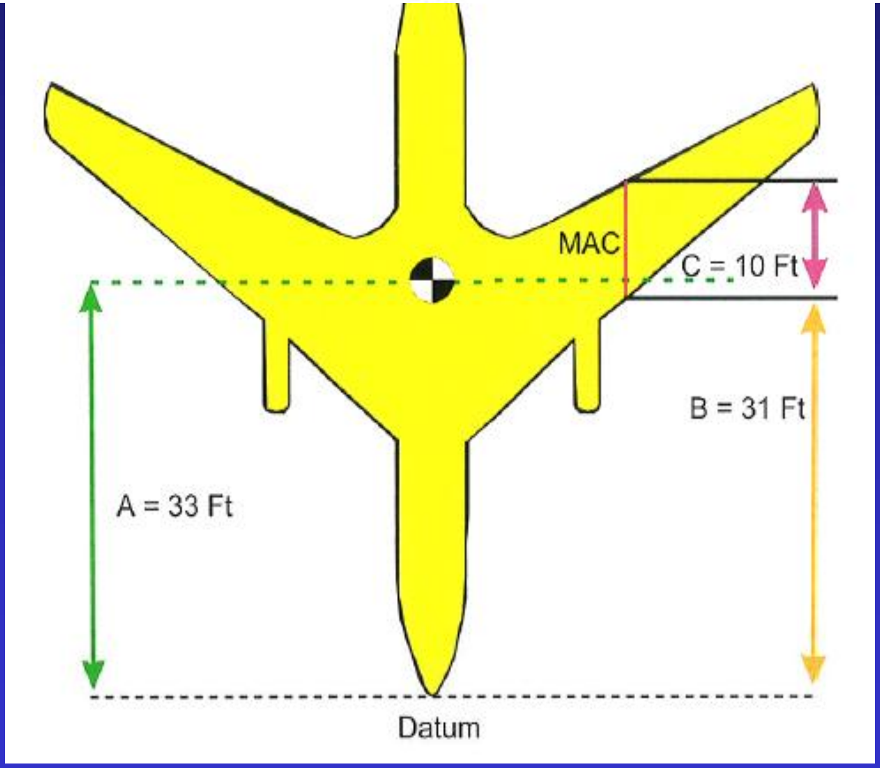
- ✓For mathematical computation, whatever the actual length of the chord, it is discussed in the terms of percentage. LeMAC is always 0% MAC, and TeMAC is 100% MAC whatever the distance.
- ✓This allows the fwd and aft CG limits to be given as percentages of MAC.
- ✓For example, to find the linear distance that 20% of Mac represents, divide the chord length of MAC by 100 and multiply it by 20.

- ✓15 ft/100 = 0.15 ft
- ✓0.15 ft * 20 = 3 ft

MEAN AERODYNAMIC CHORD

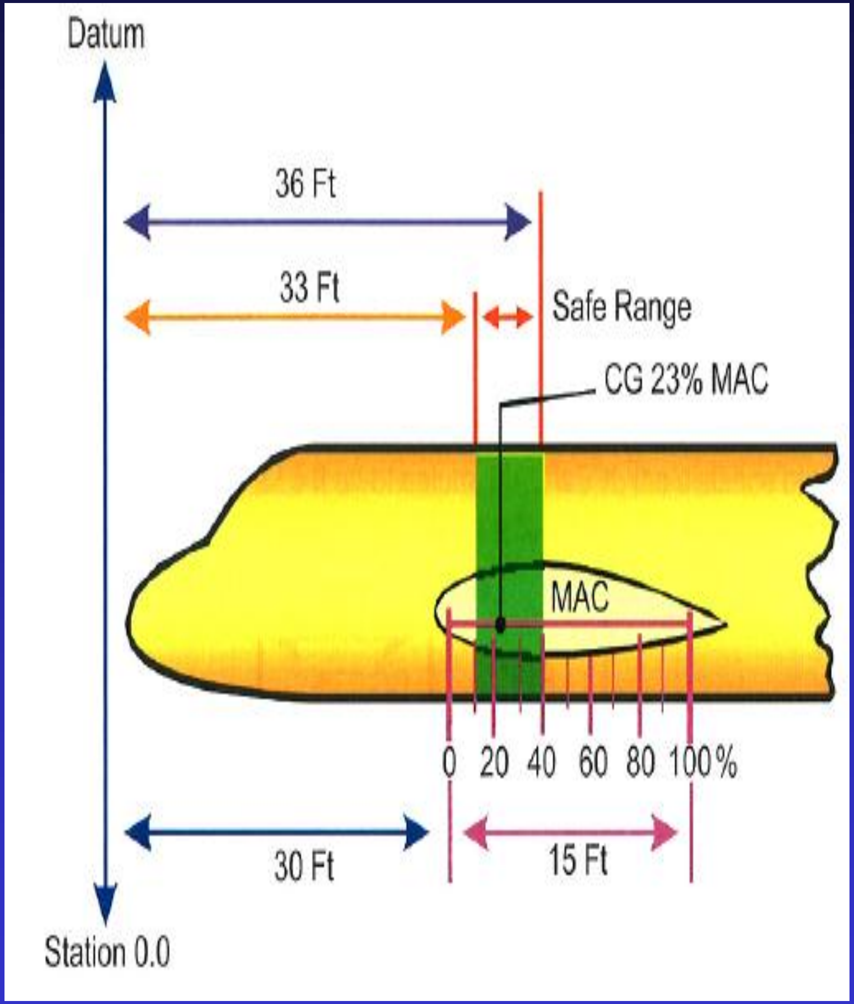
✓As all components are given in relation to the aircraft's datum, the leading edge of MAC has to be given as a linear distance from the datum. The CG can be given as a linear distance from the datum that requires converting to a percentage of MAC.





MEAN AERODYNAMIC CHORD

- CG LIMITS AS PERCENTAGES:
- In the diagram below, the fore and aft CG limits can be seen and would normally be given as a percentage of MAC, in the case 10% and 40%.
- Example: Express the CG as a lineer distance from the datum.
- a) 33 ft c)34 ft
- b) 33.5 ft d)34.5 ft
- Solution:
- 15 ft*0.23 = 3.45 ft
- 30 ft + 3.45 ft = 33.45 ft ≈ 33.5 ft



JAR – OPS 1 REQUIREMENTS

➢**MASS VALUES FOR CREWS:**

➢**Operators are required to account for the mass of their crew members and baggage as part of determining the dry operating mass. The operator can use:**

- ✓ **The actual mass of the crewmembers and their baggage**
- ✓ **The standard mass of 85 kg for flight crew and 75 kg for cabin crew (regardless of gender or build)**
- ✓ **Any other standard mass acceptable to the Aviation Authority**
- ✓**The operator must correct the DOM and its CG position if the crew has additional baggage.**

JAR – OPS 1 REQUIREMENTS

TABLE 1 — PASSENGER MASS VALUES FOR UP TO 20 OR MORE SEATS

	Table 1		
Passenger Seats	20 and more		30 and more
	Male	Female	All adult
All flights except holiday charters	88 kg	70 kg	84 kg
Holiday charters	83 kg	69 kg	76 kg
Children	35 kg	35 kg	35 kg

Where the total number of passenger seats in an aeroplane is between 20 and 29, the operator is to use the gender-based masses for 20 and more, as per table 1, for determination of the passenger load. If the aircraft has 30 or more seats, the operator is to use the all adult masses.

All flights except holiday charters	Schedule service, etc.
Holiday charters	Part of holiday package travel
All adult	Adult mass regardless of gender

JAR – OPS 1 REQUIREMENTS

TABLE 2 — PASSENGER MASS VALUES FOR UP TO 19 SEATS

Table 2			
Passenger seats	**1 – 5**	**6 – 9**	**10 – 19**
Male	104 kg	96 kg	92 kg
Female	86 kg	78 kg	74 kg
Children	35 kg	35 kg	35 kg

For aircraft with 19 passenger seats or less, table 2 applies (see above). The smaller the seating capacity, the greater the standard adult passenger's mass becomes. Within these masses is an allowance for hand baggage. On flights (table 2 only) where no hand baggage is carried in the cabin or where the hand baggage is accounted for separately, 6 kg may be deducted from the adult mass. Articles such as small cameras, overcoats, umbrellas, and small handbags are not considered hand baggage.

LOADING MANIFESTS, SEP 1

Item	Mass	Arm (in)	Moment ÷ 100
1. Basic Empty Condition			
2. Front Seat Occupants		79	
3. Third and Fourth Seat PAX		117	
4. Baggage Zone 'A'		108	
5. Fifth And Sixth Seat PAX		152	
6. Baggage Zone 'B'		150	
7. Baggage Zone 'C'		180	
Sub-total = Zero Fuel Mass			
8. Fuel Loading			
Sub-total = Ramp Mass			
9. Subtract Fuel for Start, Taxi and Run Up (see Note)			
Sub-total = Take-off Mass			
10. Trip Fuel			
Sub-total = Landing Mass			

NOTE: Fuel for start taxi and run up is normally 13 lb at an average entry of 10 in the column headed **Moment (÷ 100)**

LOADING MANIFESTS, SEP 1

- EXAMPLE FOR SEP1:
- Pilot of 140 lb
- 200 lb of cargo in Zone A
- Passengers with a total mass of 120 lb in seats 5&6
- 100 lb in baggage Zone C
- Fuel load of 50 US gal, of which 40 US gal will be burnt as trip fuel 1 US gal = 6 lb
- 50 US gal * 6 = 300 lb
- Moment * 100
- If the ZFM, TOM, and LM masses and CG positions are in limits (Check SEP 1 data) the A/C is safe to fly.

Column 1	2	3	4
ITEM	**MASS** (lb)	**ARM (in)**	**MOMENT X 100**
1. Basic Empty Condition	**2415**	**77.7**	**1876.46**
2. Front Seat Occupants	140	79	110.6
3. Third & Fourth Seat Pax	0	117	0
4. Baggage Zone A	200	108	216
5. Fifth & Sixth Seat Pax	120	152	182.4
6. Baggage Zone B	0	150	0
7. Baggage Zone C	100	180	180
Sub–Total = ZERO FUEL MASS	**2975**	**86.2**	**2565.46**
8. FUEL Loading	300	75	225
Sub–Total = RAMP MASS	**3275**	**85.2**	**2790.46**
9. Subtract Fuel for Start, Taxi, and Run Up (see Note)	-13	SEE NOTE ON SEP1 PAGE 3	-10
Sub–Total = TAKE-OFF MASS	**3262**	**85.2**	**2780.46**
10. TRIP FUEL	- 240		-180
Sub–Total = LANDING MASS	**3022**	**86.4**	**2610.46**

MEDIUM RANGE JET TRANSPORT (MRJT)

FUSELAGE PLUGS (BOEING 737)

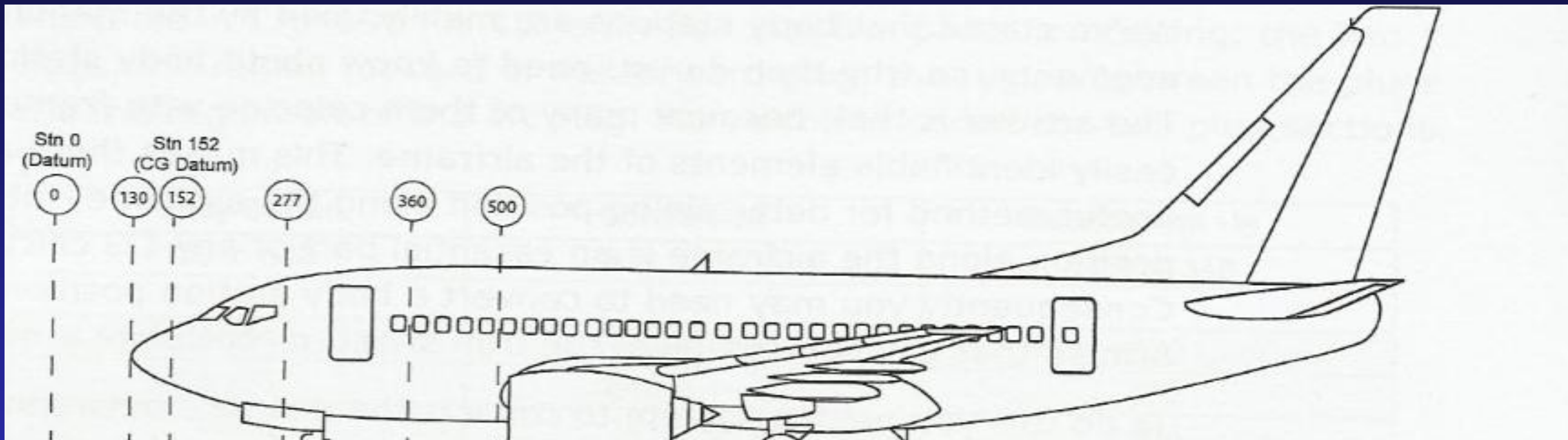
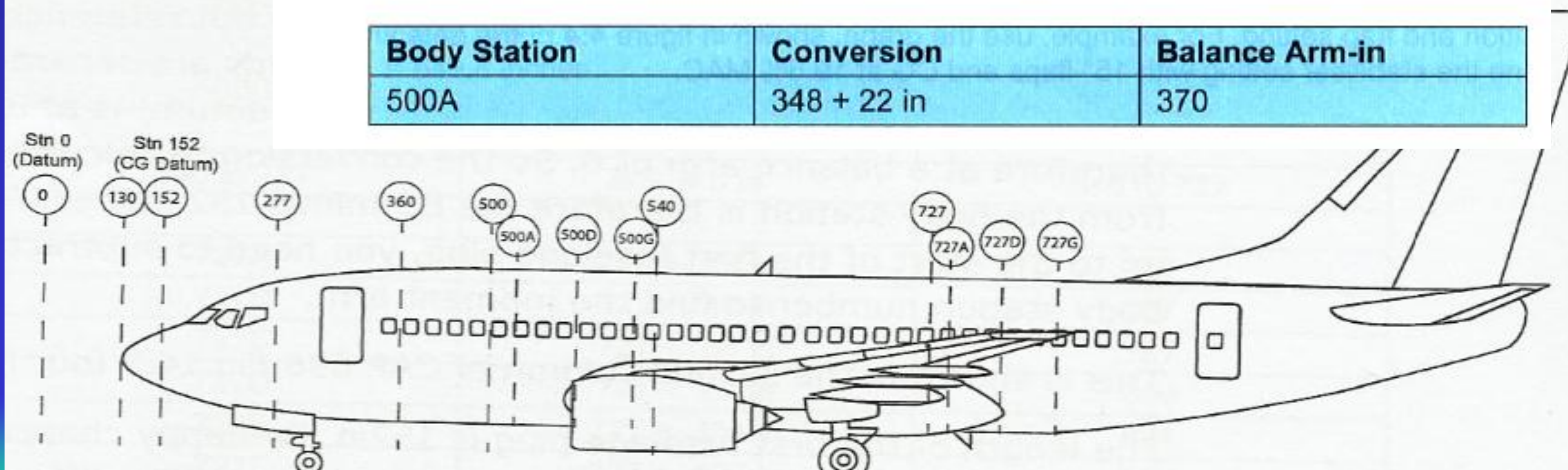


TABLE TO CONVERT BODY STATIONS TO BALANCE ARM (FIGURE 4.2)

Body Station	Conversion	Balance Arm-in
500A	348 + 22 in	370



MEDIUM RANGE JET TRANSPORT (MRJT)

- PASSENGERS (PAX) AND PERSONNEL:

5 Passenger and Personnel Data

5.1 Maximum Passenger Load 141

Maximum Passenger Load	141
First Class	15
Club/Business	18
Economy	108

5.2 Passenger Distribution

Figure 4.7 shows the balance arms (in inches) for the distribution of passengers. If the pax load is low, zones B, C and D are the preferred seating areas.

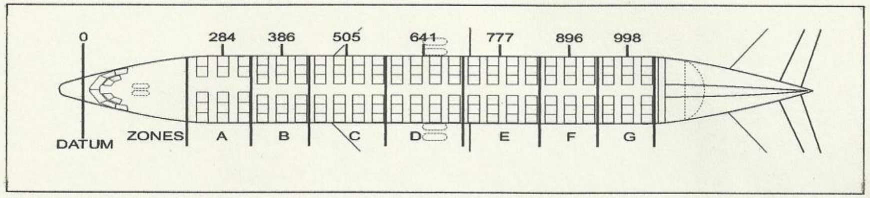


Figure 4.7 Balance Arms (in)

ZONE	NO. PAX	B.A.
A	15	284
B	18	386
C	24	505
D	24	641
E	24	777
F	18	896
G	18	998

Figure 4.8 Table of Passenger Zones, Number of Passengers and Balance Arms

5.3 Passenger Mass

Unless otherwise stated, passenger mass is assumed to be 84 kg (this includes a 6 kg allowance for hand baggage).

5.4 Passenger Baggage

Unless otherwise stated, a baggage allowance of 13 kg may be made per passenger.

5.5 Personnel

Standard Crewing

	No.	BA	Standard Mass (kg) each
Flight Deck	2	78.0	90
Cabin Staff Forward	2	162.0	90
Cabin Staff Aft	1	1,107.0	90

MEDIUM RANGE JET TRANSPORT (MRJT)

Figure 4.10 Loading Manifest – MRJT 1

Max Permissible Aeroplane Mass Values:

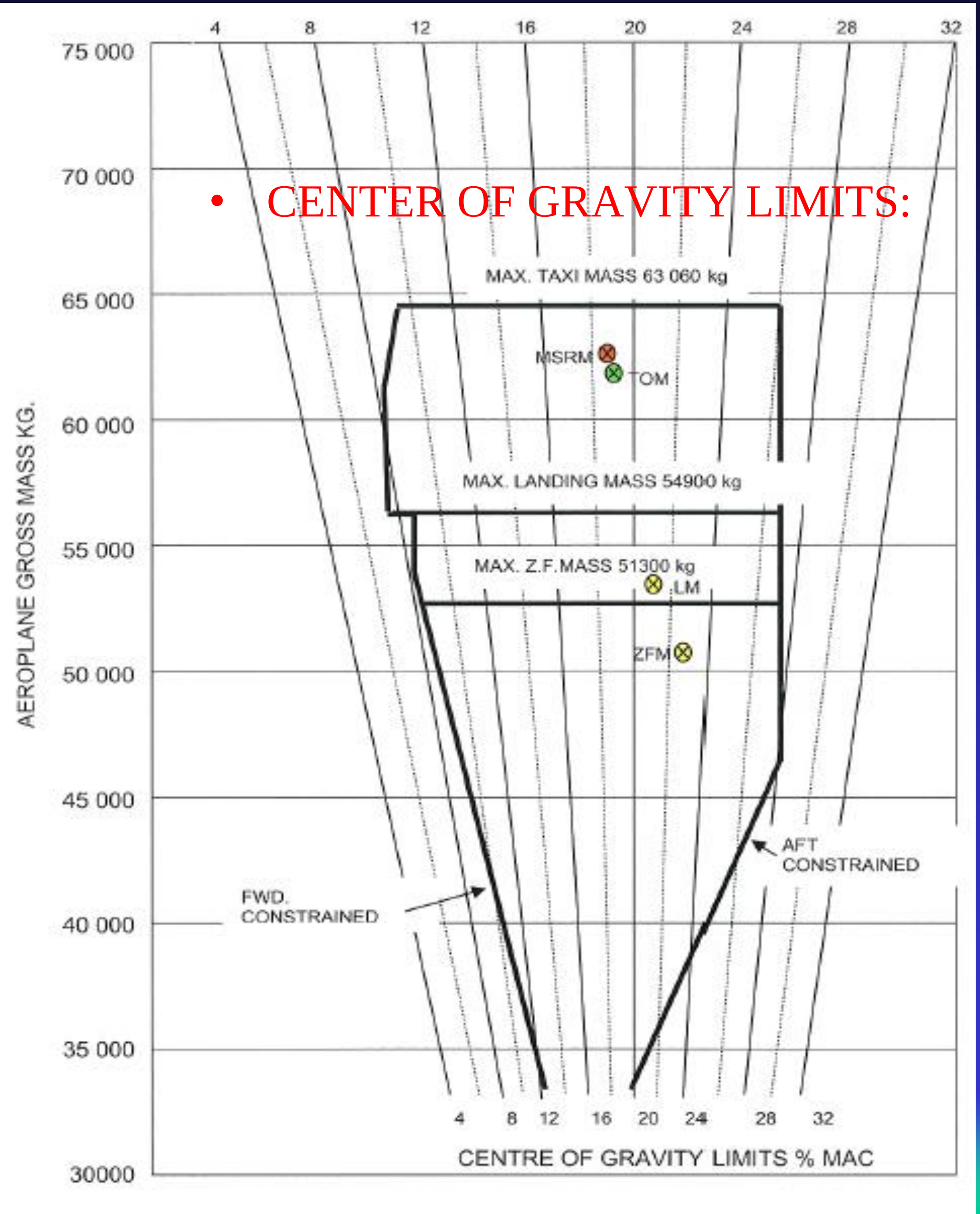
TAXI MASS - 63 060 kg ZERO FUEL MASS - 51 300 kg

TAKE-OFF MASS - 62 800 kg LANDING MASS - 54 900 kg

ITEM	MASS (kg)	BA IN	MOMENT kg in/1000	CG %MAC
1. DOM	34 500	649.00	22 390.5	
2. PAX Zone A	840.00	284.00	238.60	-
3. PAX Zone B	1512	386.00	583.60	-
4. PAX Zone C	2016	505.00	1018.1	-
5. PAX Zone D	2016	641.00	1292.3	-
6. PAX Zone E	2016	777.00	1566.4	-
7. PAX Zone F	1512	896.00	1354.8	-
8. PAX Zone G	1092	998.00	1089.8	-
9. CARGO HOLD 1	650.00	367.9	239.10	-
10. CARGO HOLD 4	2120	884.5	1875.1	-
11. ADDITIONAL ITEMS	NIL	N/A	NIL	-
ZERO FUEL MASS	48 274	655.60	**31 648.3**	**22.30**
12. FUEL TANKS 1 & 2	9084	650.70	5911	-
13. CENTRE TANK	4916	600.40	2951.6	-
TAXI MASS	62 274	650.50	**40 510.9**	**18.50**
LESS TAXI FUEL	-260.00	600.40	-156.10	-
TAKE-OFF MASS	62 014	650.70	**40 354.8**	18.70
LESS FLIGHT FUEL	4844 4656 Total 9500	650.7 600.4	-3152 -2795.5	-
EST. LANDING MASS	52 514	655.20	**34 407.3**	22.53

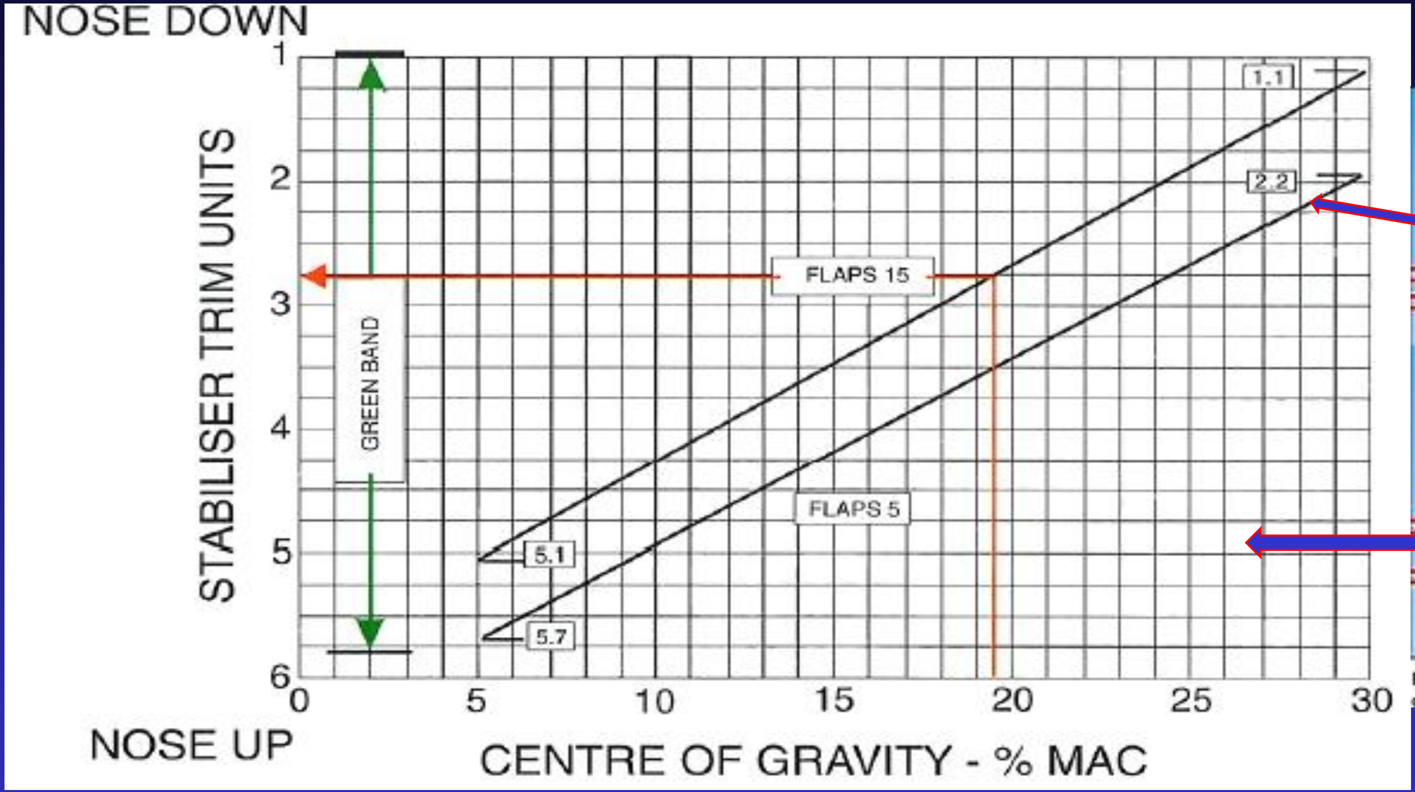
MEDIUM RANGE JET TRANSPORT (BOEING 737)

- CENTER OF GRAVITY LIMITS:



MEDIUM RANGE JET TRANSPORT (MRJT)

- TAKE-OFF HORIZONTAL STABILISER TRIM SETTING:



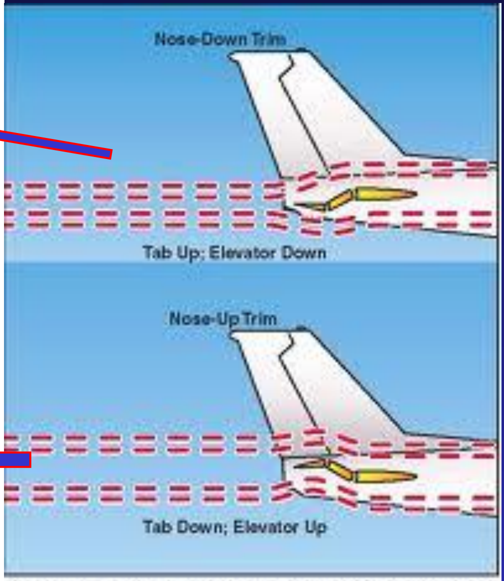
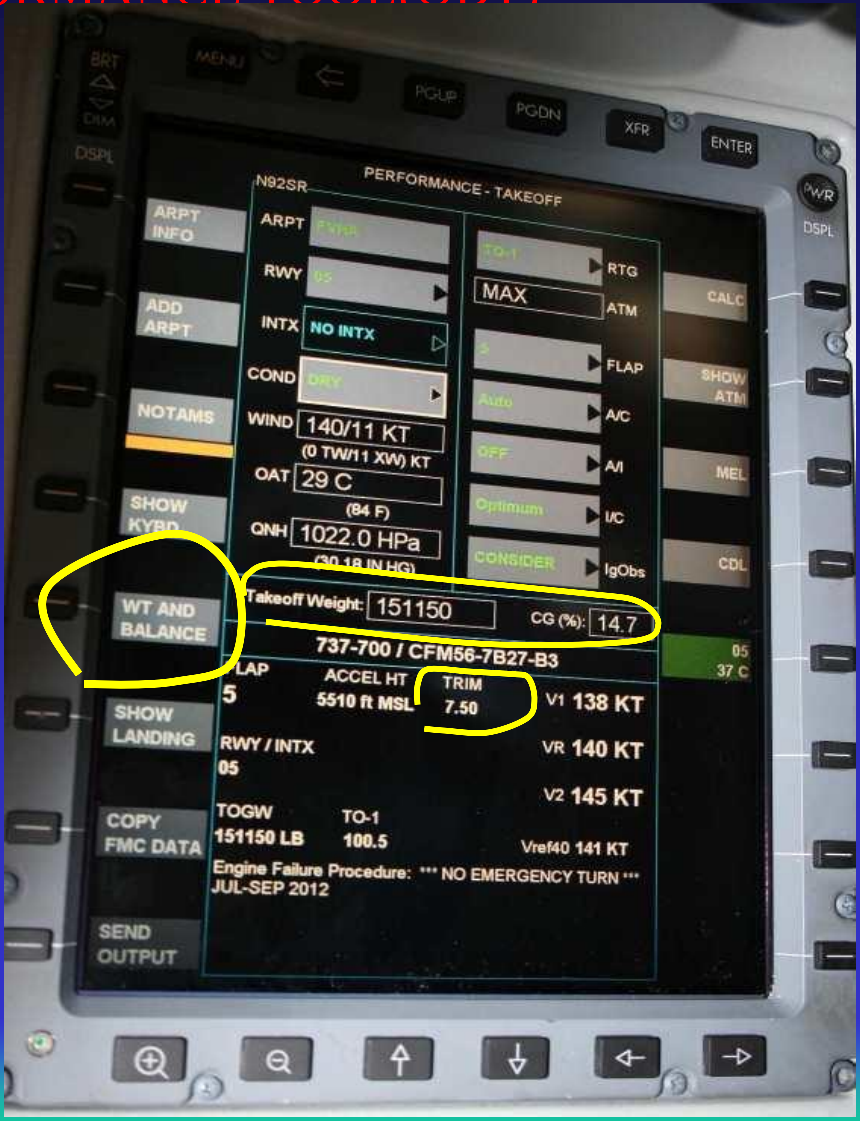


Figure 4-16. The movement of the elevator is opposite to the direction of movement of the elevator trim tab.

-

MEDIUM RANGE JET TRANSPORT (MRJT)

- TAKE-OFF HORIZONTAL STABILISER TRIM SETTING CALCULATION:
- ON BOARD PERFORMANCE TOOL(OBT)



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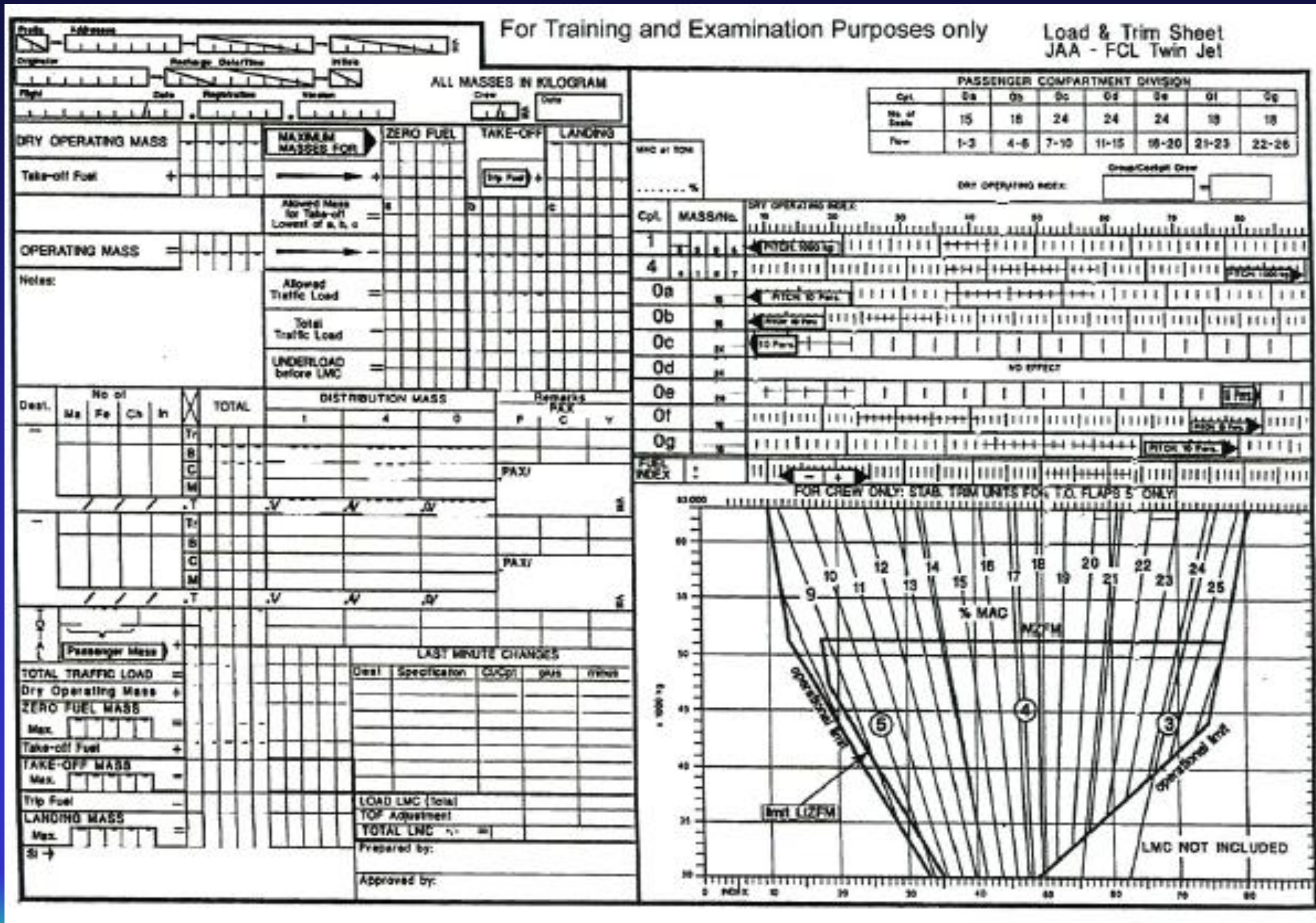
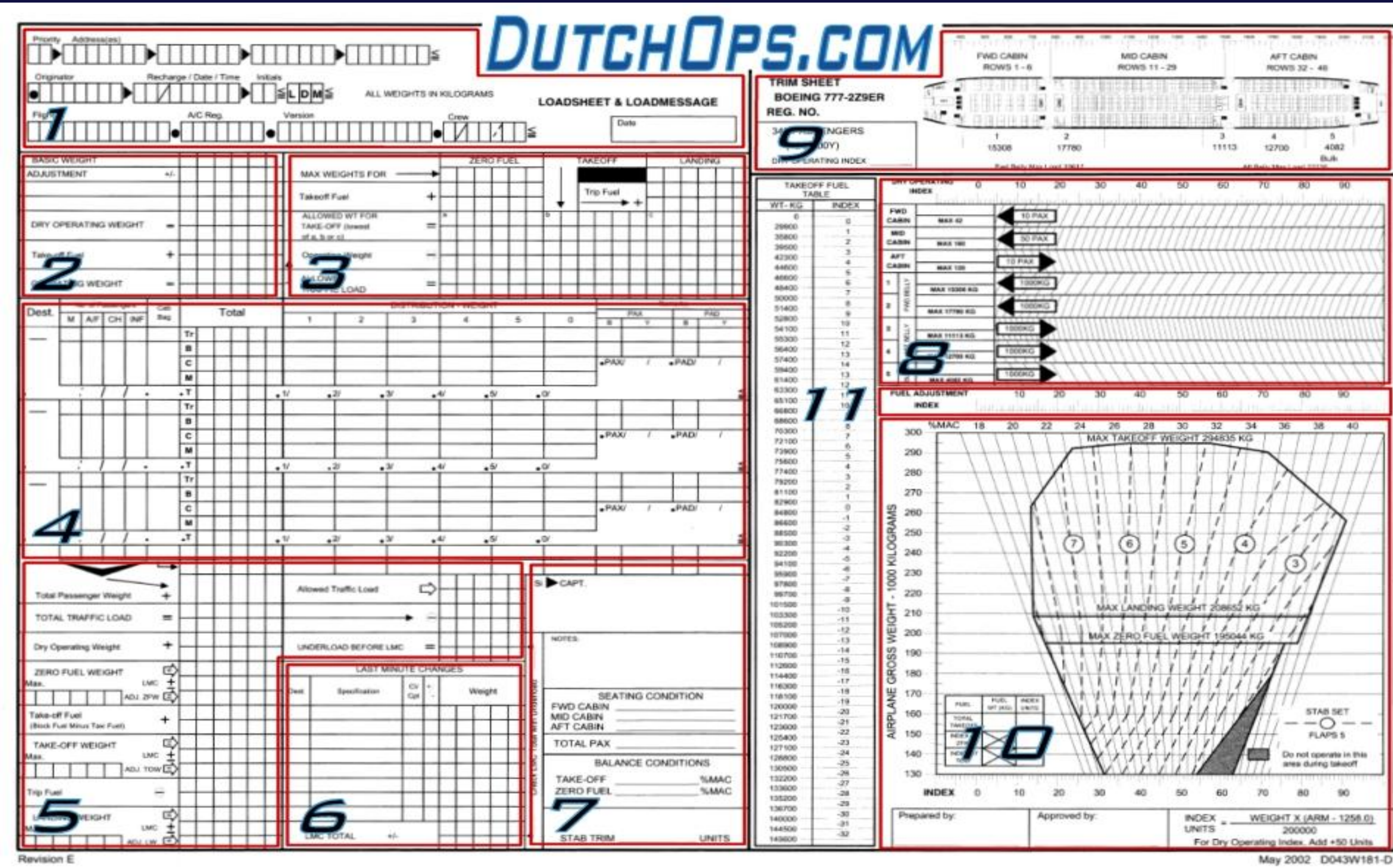
MEDIUM RANGE JET TRANSPORT (MRJT)

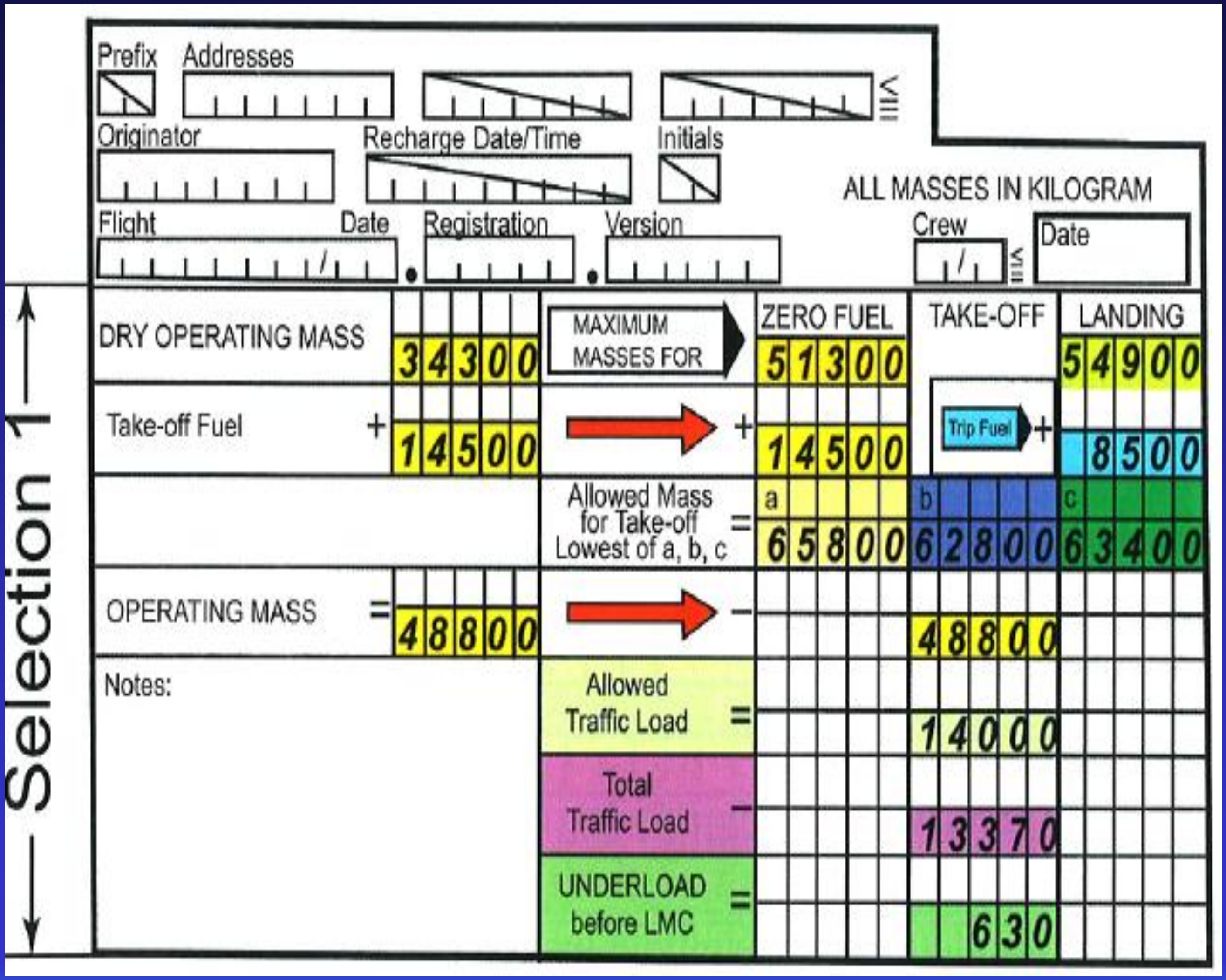
- LOAD AND TRIM SHEET:
- 

MEDIUM RANGE JET TRANSPORT (MRJT)

- LOAD AND TRIM SHEET FOR BOEING 777:



MEDIUM RANGE JET TRANSPORT (MRJT)



MEDIUM RANGE JET TRANSPORT (MRJT)

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Section 3

TOTAL	130	2450
	Passenger Mass +	10920
TOTAL TRAFFIC LOAD	=	13370
Dry Operating Mass		34300
ZERO FUEL MASS Max. 51300	=	47670
Take-off Fuel	+	14500
TAKE-OFF MASS Max. 62800	=	62170
Trip Fuel	−	8500
LANDING MASS Max. 54900	=	53670

SI →

LAST MINUTE CHANGES

Dest	Specification	Cl/Cpt	plus	minus

LOAD LMC (Total)		
TOF Adjustment		
TOTAL LMC +/- =		

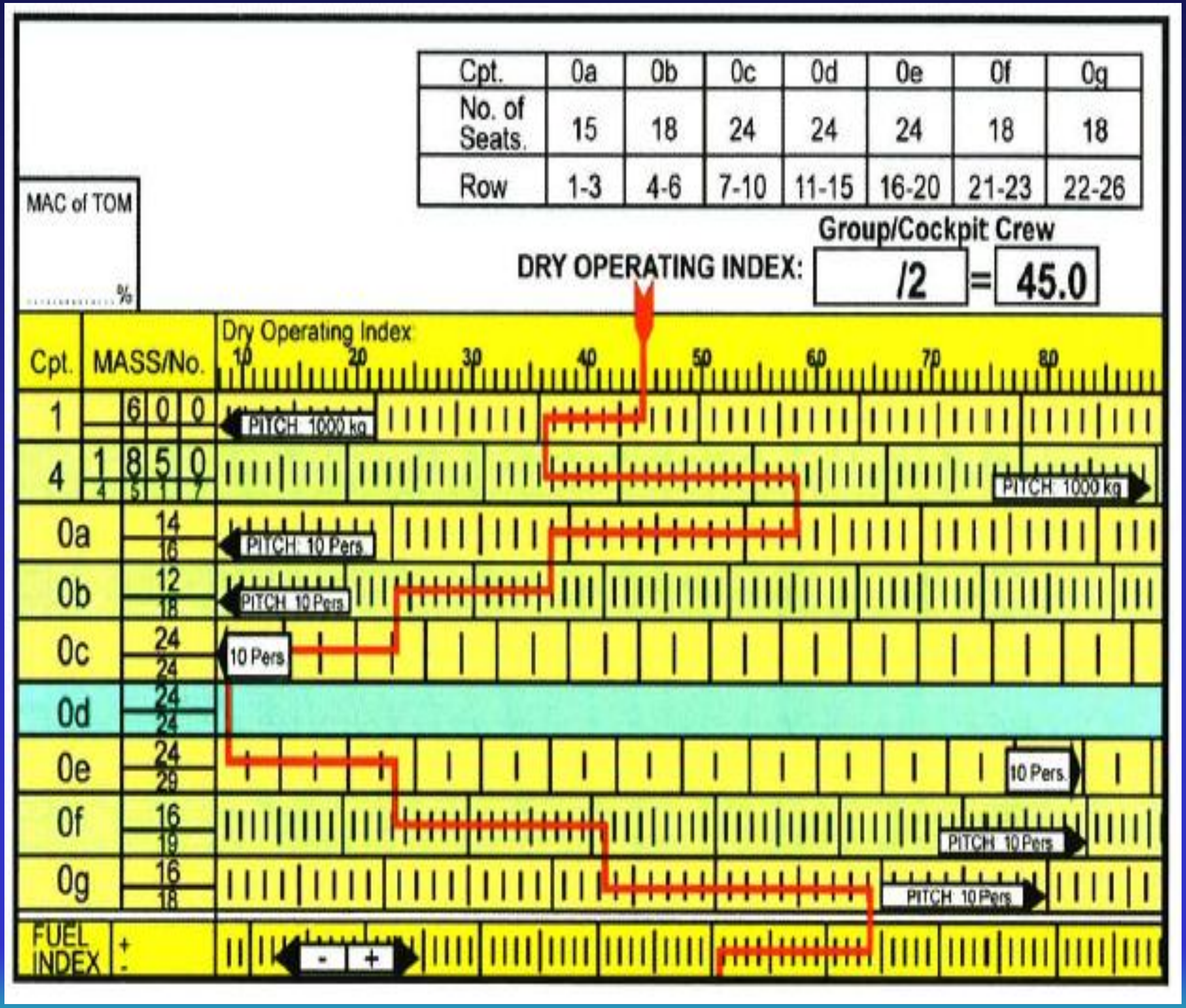
Prepared by:

Approved by:

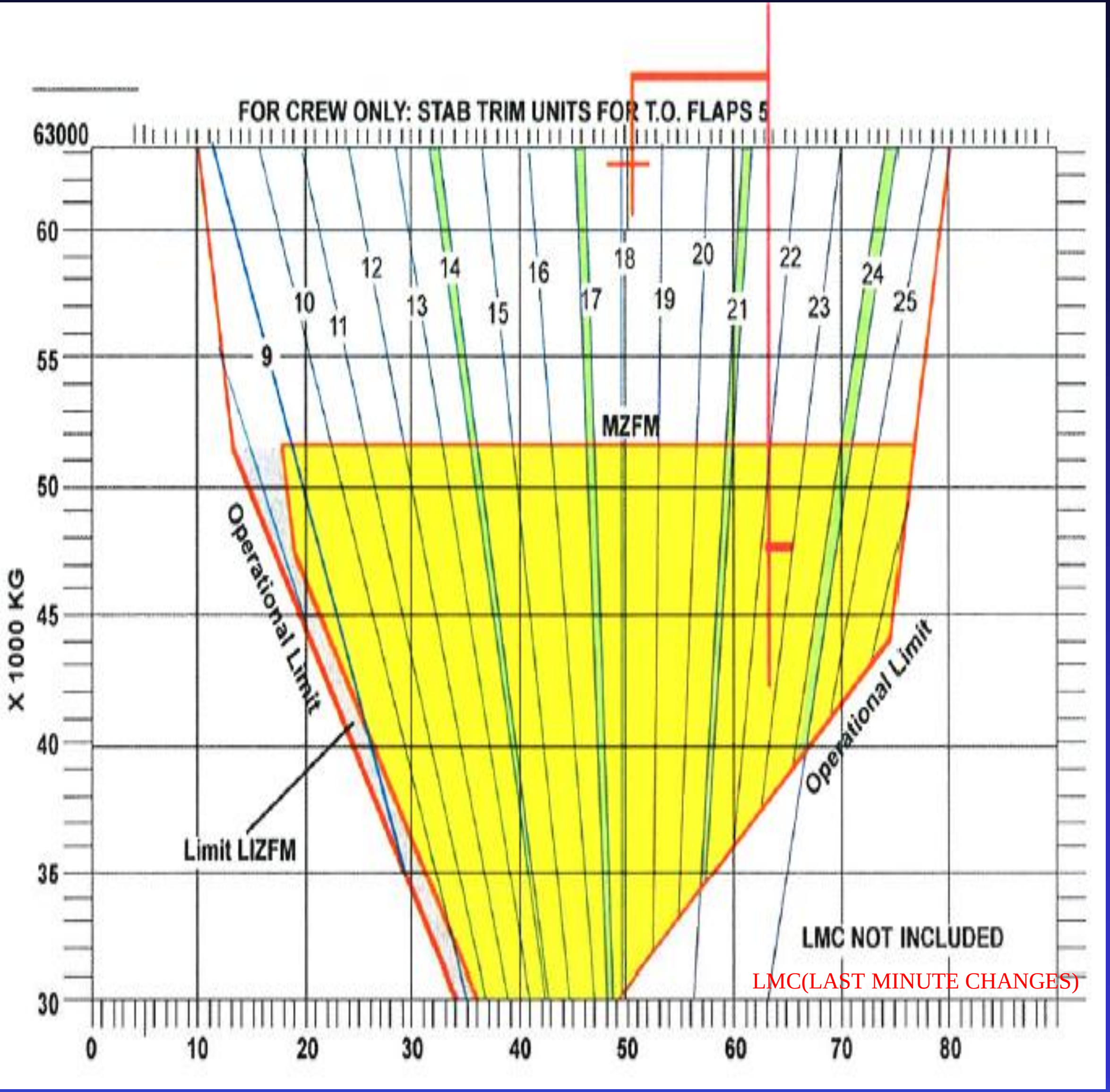
Part A

MEDIUM RANGE JET TRANSPORT (MRJT)

- Trim Sheet (Top section)
-



MEDIUM RANGE JET TRANSPORT (MRJT)



MEDIUM RANGE JET TRANSPORT (MRJT)

	Fuel Mass (kg)	Index Units		Fuel Mass (kg)	Index Units
	500	-1.0		9,330	-0.3
	750	-1.5		9,580	-0.9
	1,000	-1.9		9,830	-1.5
	1,250	-2.3		10,080	-2.1
	1,500	-2.6		10,330	-2.7
	1,750	-3.0		10,580	-3.3
	2,000	-3.3		10,830	-3.9
	2,500	-3.7		11,080	-4.5
	3,000	-4.3		11,330	-5.1
	3,500	-4.7		11,580	-5.7
	4,000	-5.1		11,830	-6.3
	4,500	-5.4		12,080	-6.9
	5,000	-5.7		12,330	-7.5
	5,500	-5.9		12,580	-8.1
	6,000	-6.0		12,830	-8.7
	6,500	-6.1		13,080	-9.3
	7,000	-5.9		13,330	-9.9
	7,500	-5.0		13,580	-10.5
	7,670	-4.6		13,830	-11.1
	7,830	-4.1		14,080	-11.7
	8,000	-3.7		14,330	-12.3
	8,170	-3.2		14,580	-12.9
	8,330	-2.6		14,830	-13.5
	8,500	-2.1		15,080	-14.1
	8,630	-1.6		15,330	-14.8
	8,750	-1.1		15,580	-15.4
	8,880	-0.6		15,830	-16.3
	9,000	-0.1		16,080	-17.1
tanks 1 and 2 full	9,080	+0.3	centre tank full	16,140	-17.3

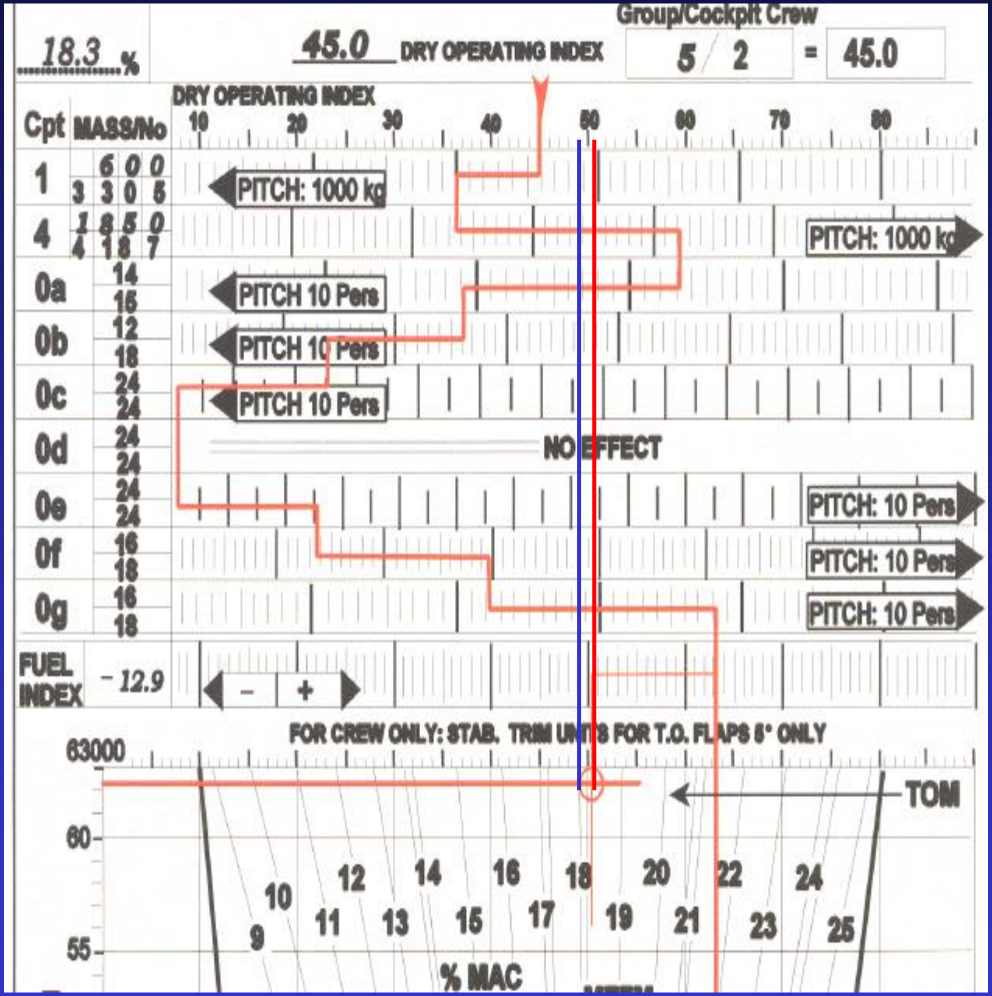
* Usable fuel quantities in lines = 20 kg (included in the tables).

Interpolation not necessary!

* Fuels in pipelines between tanks and engines

MEDIUM RANGE JET TRANSPORT (MRJT)

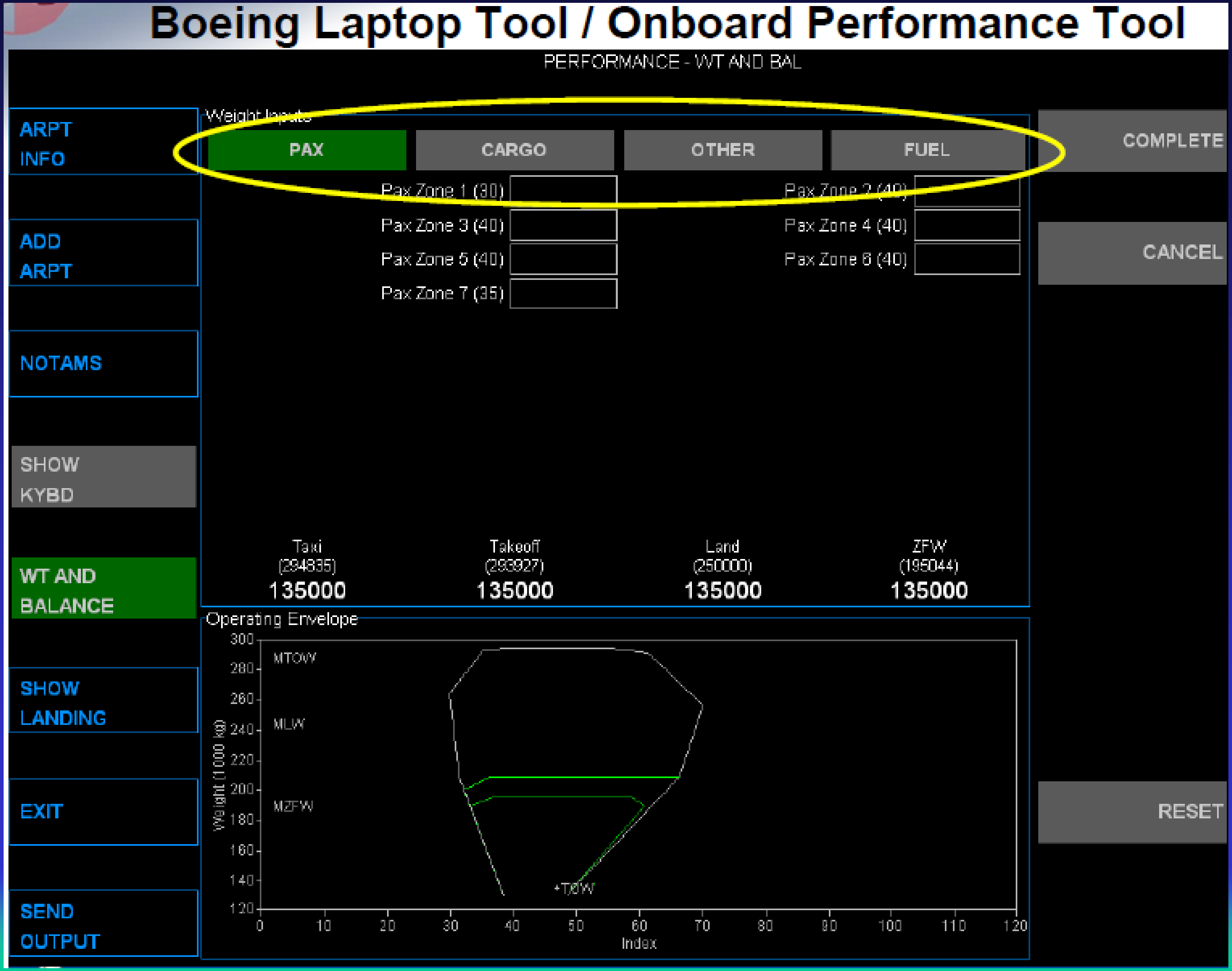
- EXAMPLE - ADJUSTING THE CG LOCATION:
- Use the worked example to relocate the CG from its current position to a new location of 18% MAC. After drawing the two vertical lines, it would be necessary to:



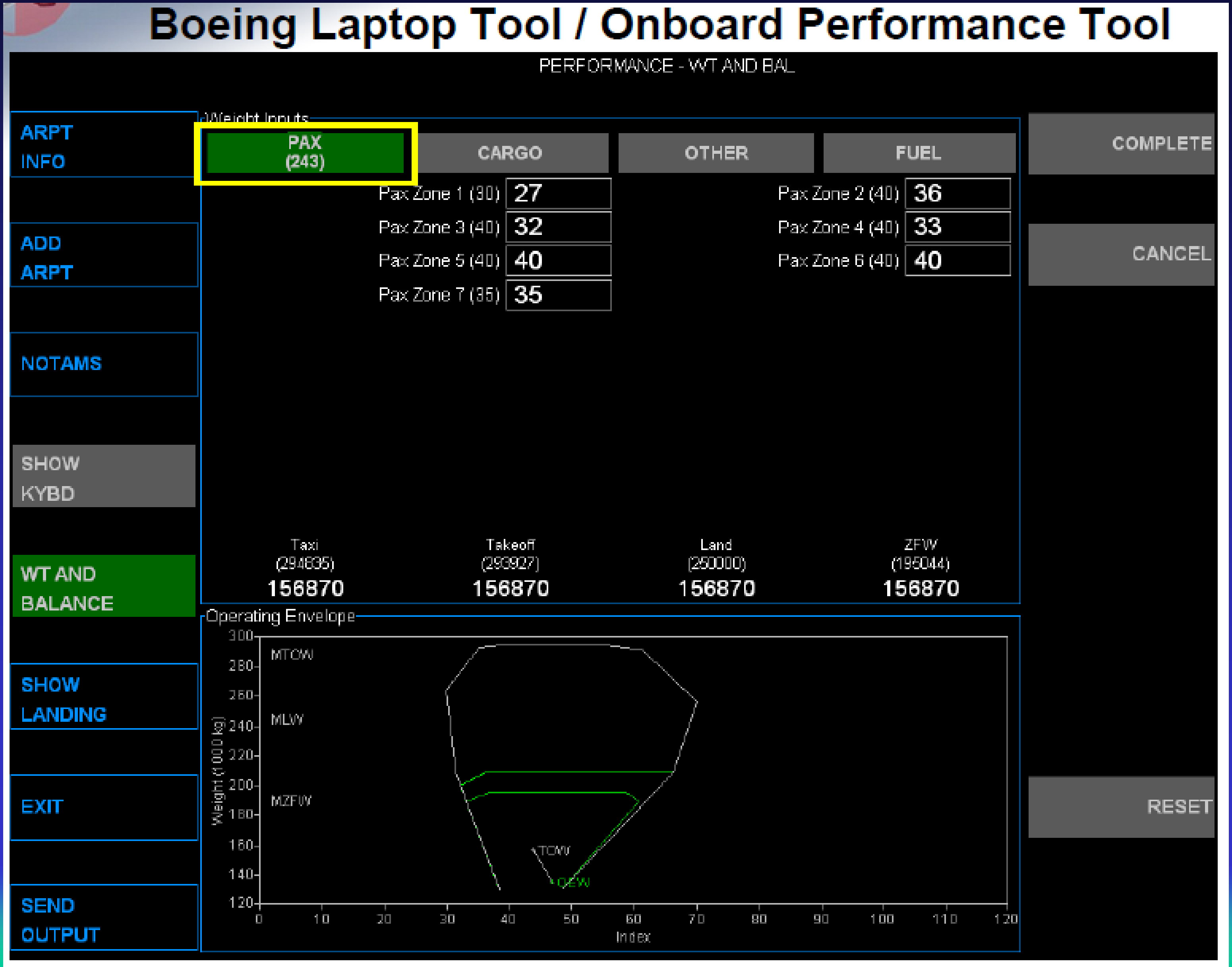
- ➢ Add 100kg to the fwd hold, or
- ➢ Remove 100kg from the aft hold, or
- ➢ Add 1 Pax to Cpt Oa, or
- ➢ Alterations in Cpt Od have no effect
- ➢ Remove 1 Pax from Cpt Oe, or

Any single alteration from the above list causes the CG to relocate to 18% MAC.

COMPUTERIZED WEIGHT AND BALANCE SYSTEM FOR BOEING 777



COMPUTERIZED WEIGHT AND BALANCE SYSTEM FOR BOEING 777



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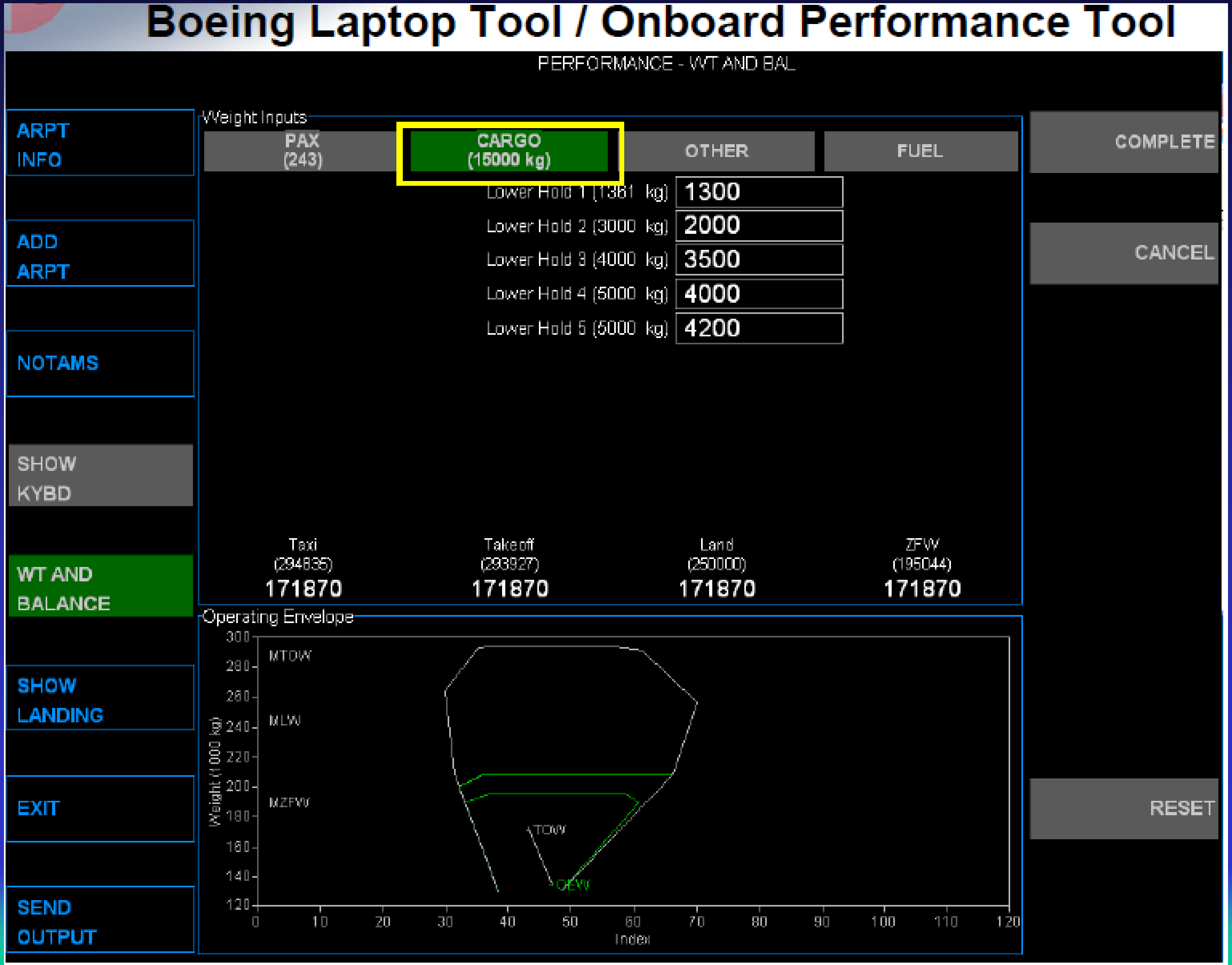

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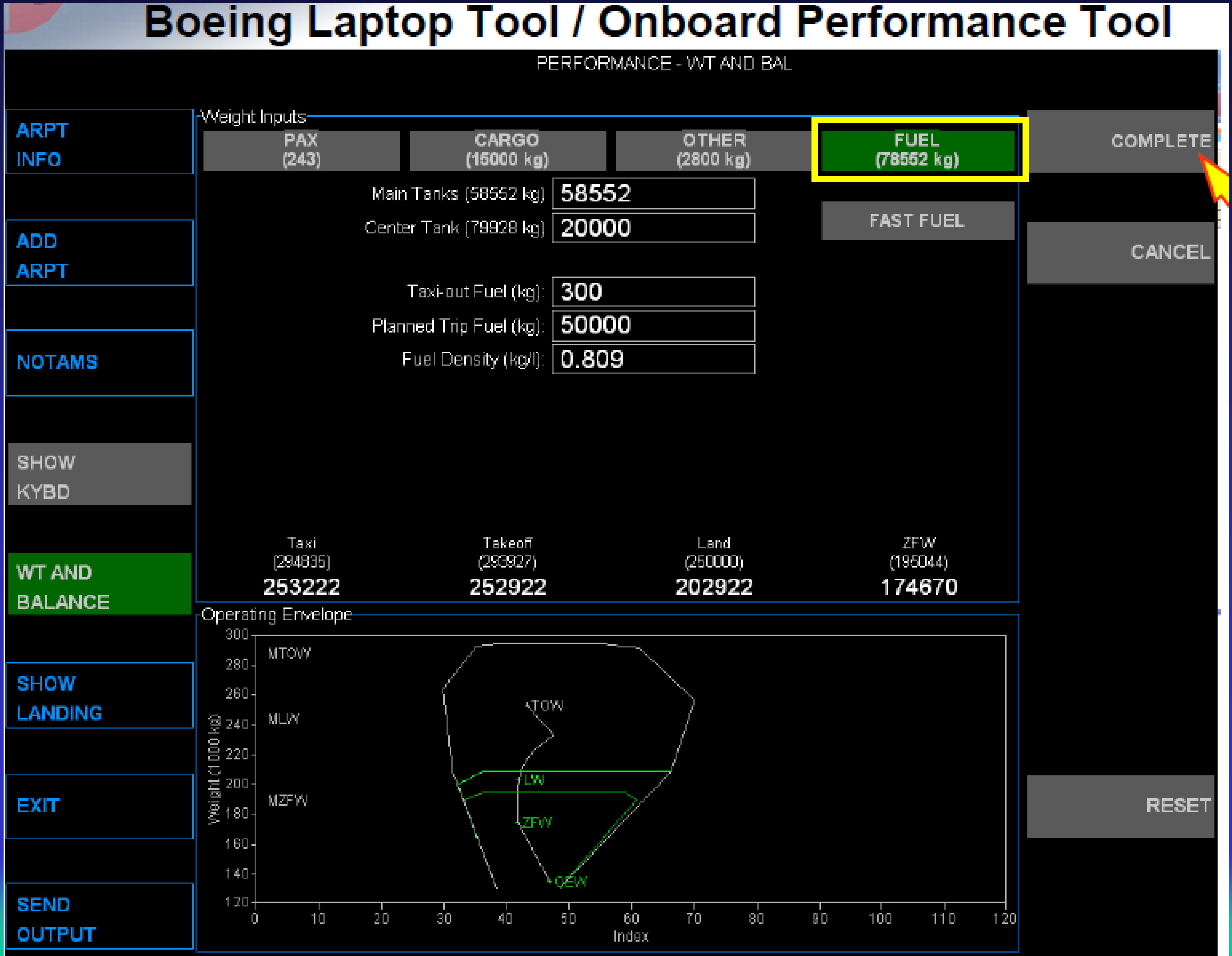
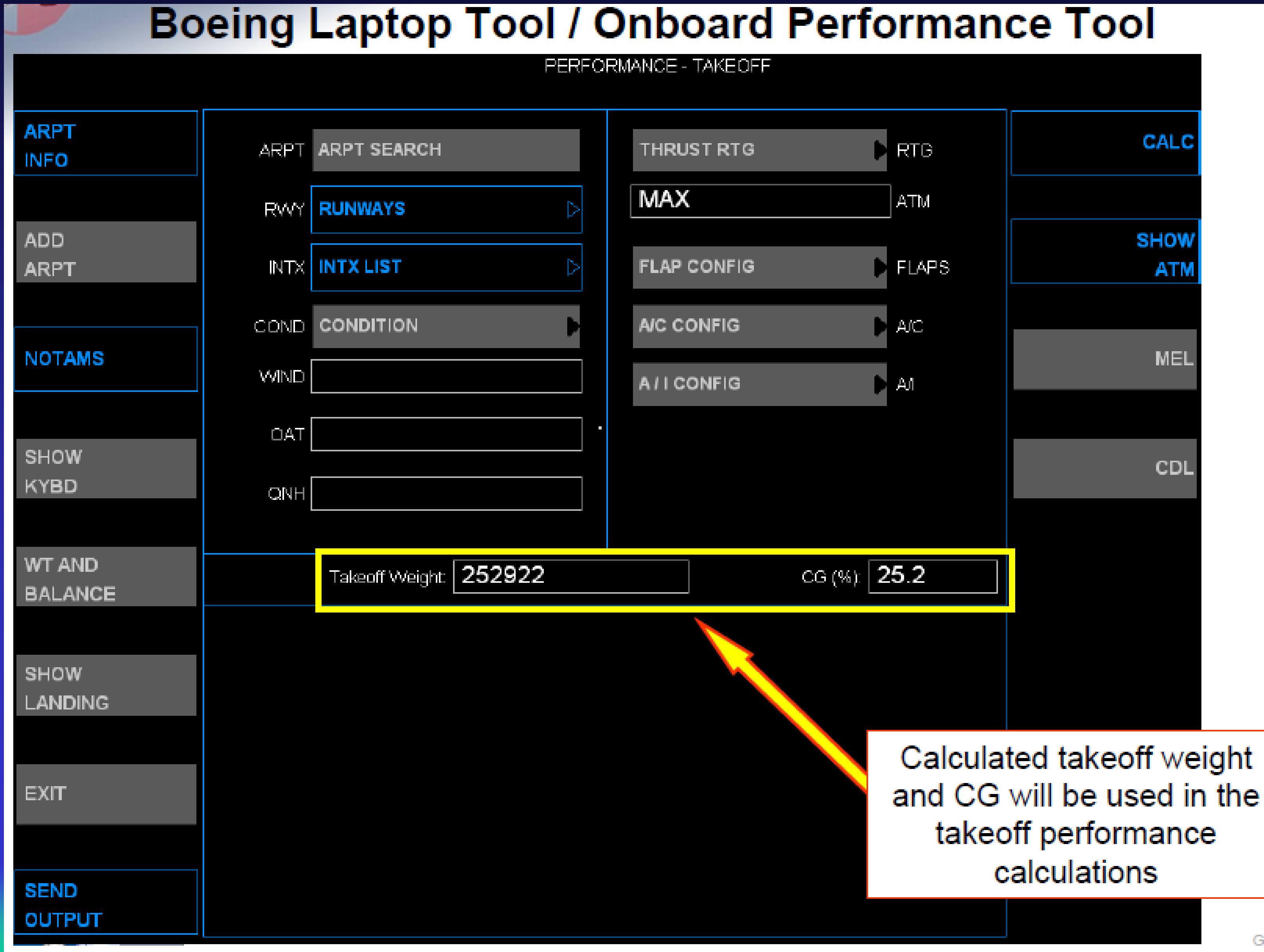
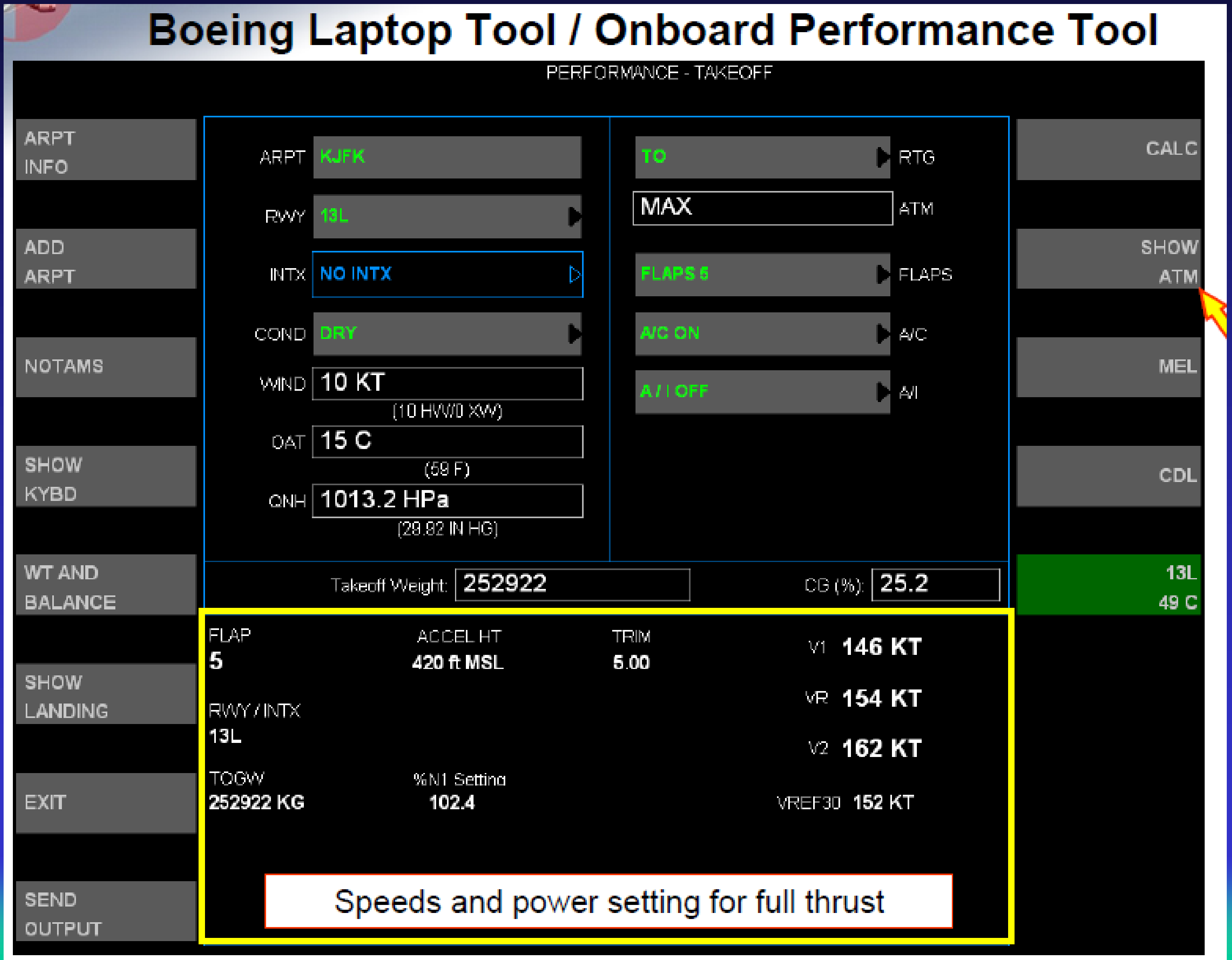


COMPUTERIZED WEIGHT AND BALANCE SYSTEM FOR BOEING 777



COMPUTERIZED WEIGHT AND BALANCE SYSTEM FOR BOEING 777



REFERENCE

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- www.padpilot.co.uk
- www.captainpilot.com