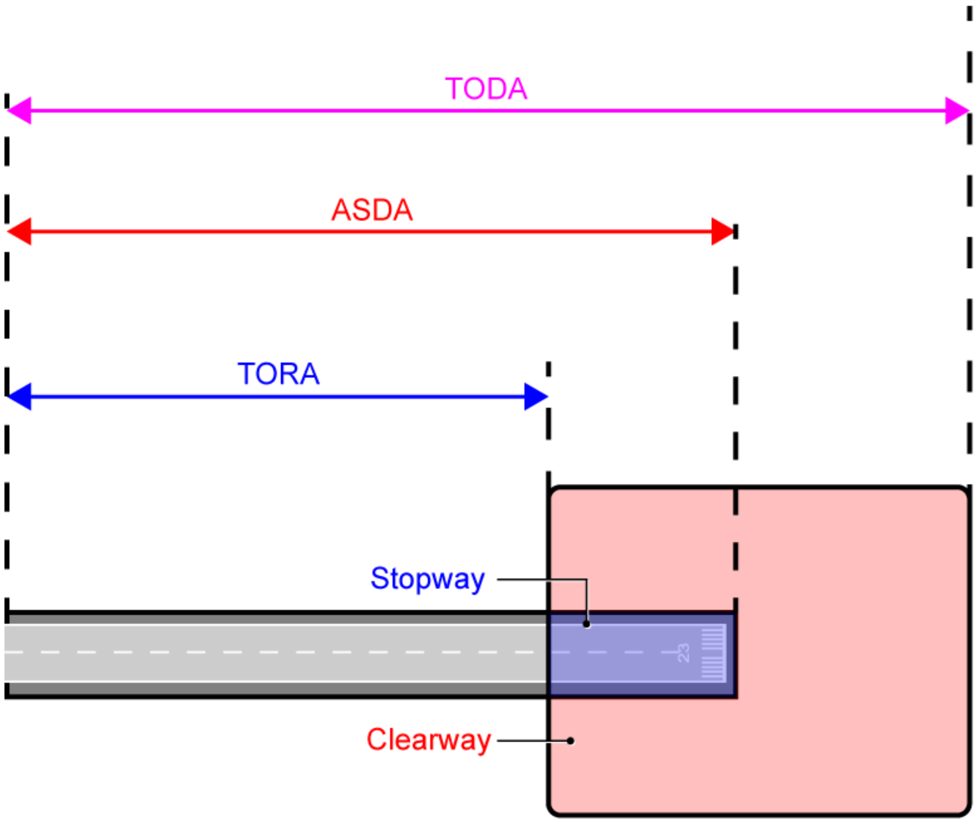
Performance - notes

Kap1: Definitions and Terms Used



The clearway used can't exceed 50% of the TORA.

Reference Zero – an imaginary horizontal plane passing through a point 35ft vertically beneath below the aeroplane at the end of **TODR**

Contaminated Runway: more than **25%** of RWY cowered with

- More than **3mm** of water, slush or snow (equivalent to more than 3 mm water)
- Compressed snow
- Ice

Kap2: Introduction to Performance

- **Absolutte Ceiling**: ROC =0
- **Service Ceiling**: ROC = **100ft/min** (prop), **500ft/min** (jet)
- **Aerodynamic Ceiling**: the altitude at which the speeds for low speed buffet and for high speed buffet are the same.

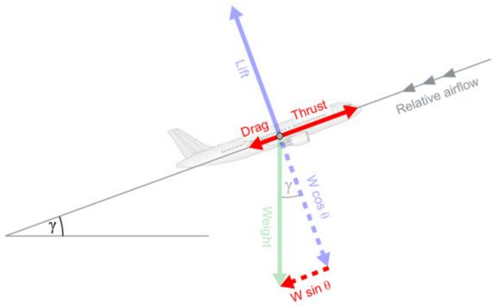
Performance - notes

Kap3: Performance Basics

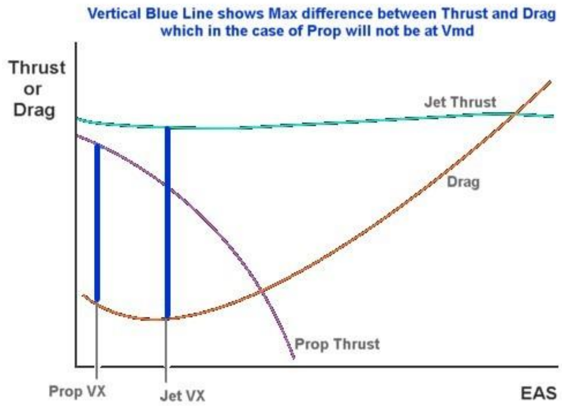
- TOD will increase by 20% for each 10% increase in mass
- TOD will increase by 20% for a tailwind component of 10% of the lift off speed

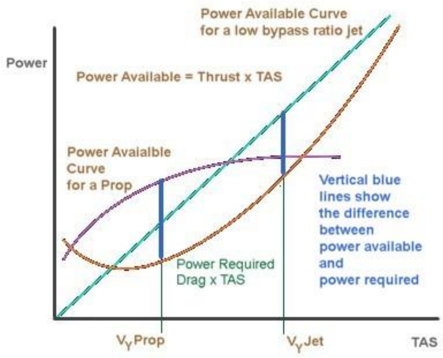
Unaccelerated Climb

- **W cos(y) = Lift**
- **Thrust = Drag + W sin(y)**

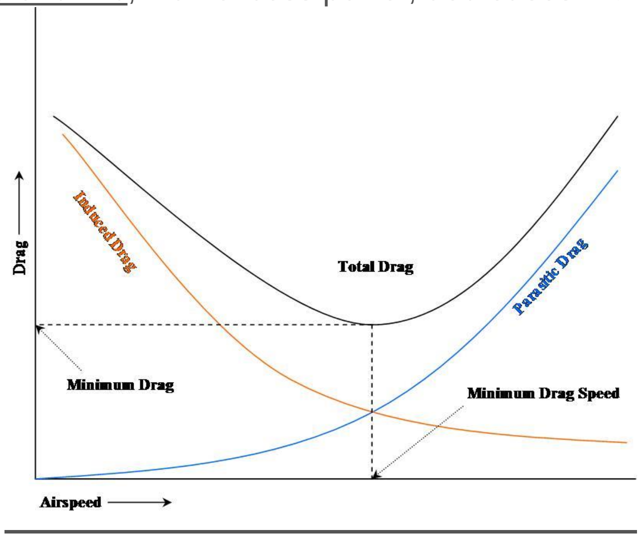


Excess thrust = Thrust – Drag





Vx – speed best <u>climb angle</u>, max excess thrust, max value of the vector; W x sin(Y), increases with altitude
VY – speed best <u>rate of climb</u>, max excess power, decreases with altitude



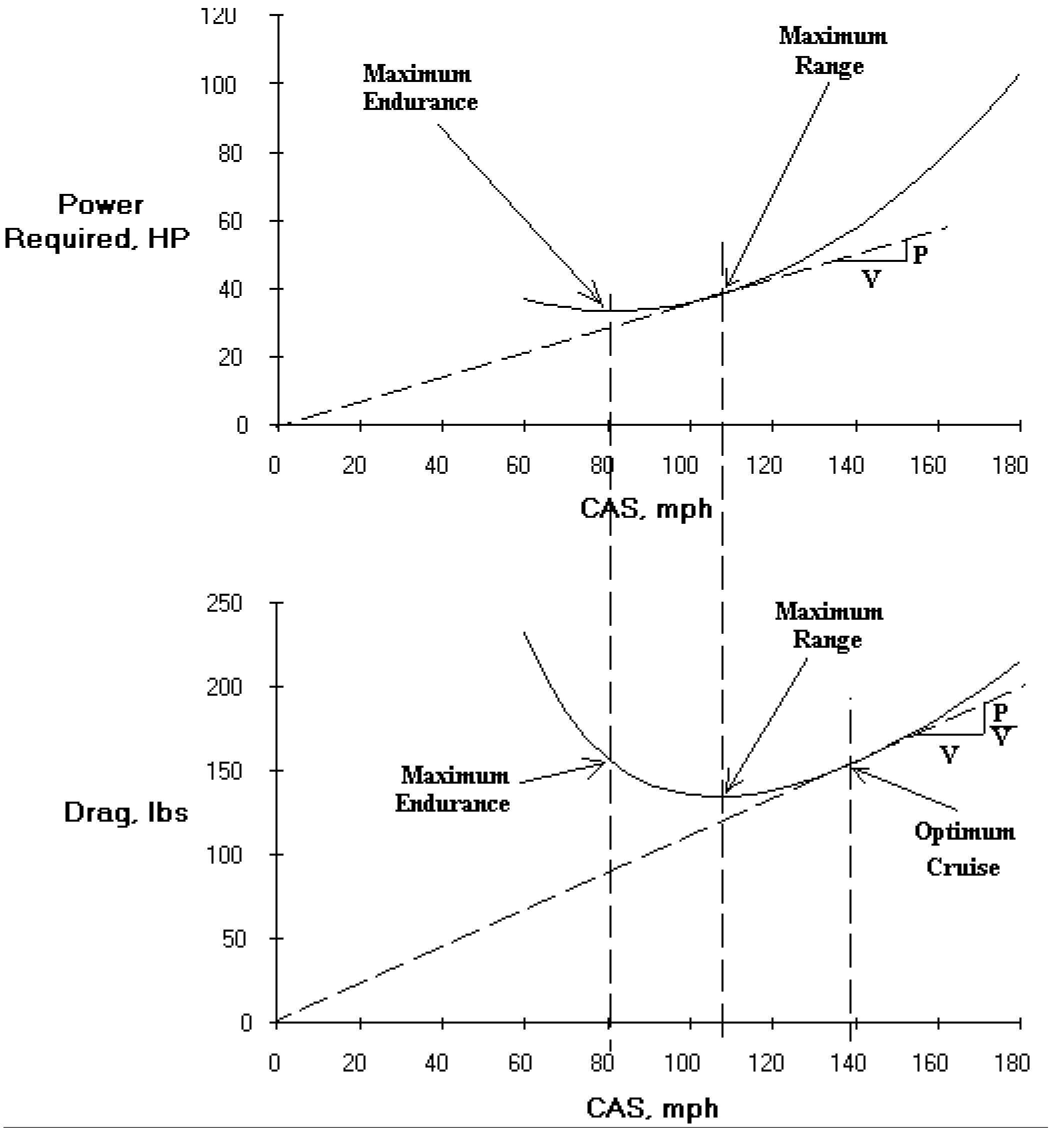
Performance - notes

Jet

- Max Endurance = V_{MD}
  - (bottom of drag/speed curve)
- Max Range = 1.32 x V_{MD}
  - (tangent from origin to drag/speed curve)

Propeller

- Max Endurance = V_{MP}
  - (bottom of power curve)
- Max Range = V_{MD}
  - (bottom of drag curve)
  - (tangent to power curve)

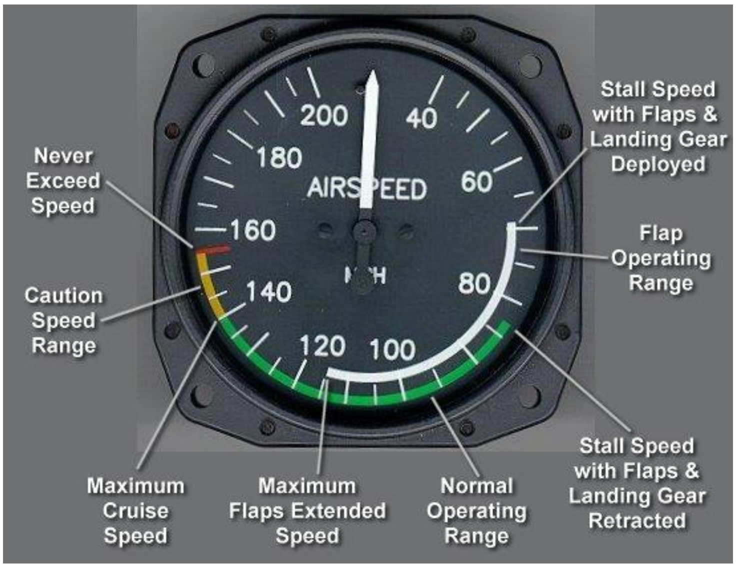


Specific Fuel Consumption (S.F.C.) expressed in **kg fuel/NM**. When S.F.C. Is lowest, the range is maximum.

Performance - notes

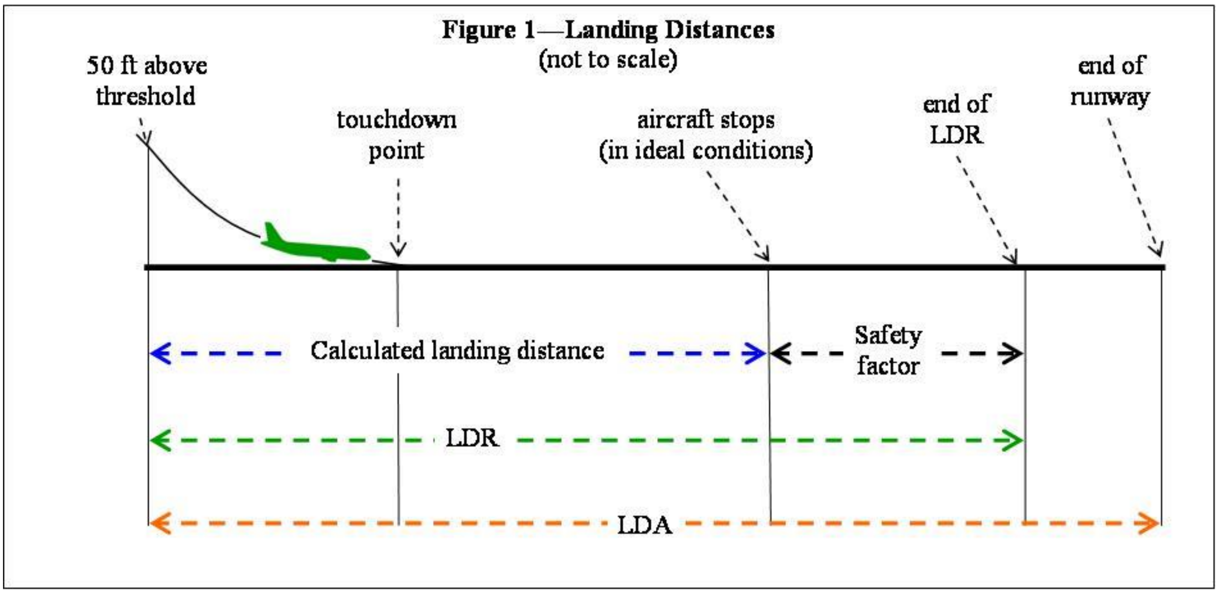
Kap4: Single Engine Piston (SEP)

V_S Stalling speed or minimum steady flight speed at which the aircraft is controllable
V_{S1} Stalling speed or minimum steady flight speed obtained in a specific configuration
V_{S0} stalling speed or minimum steady flight speed in the landing configuration



Take-off speed at **50ft** must NOT be less than **$1.2V_{S1}$**

Private: TOD < TODA
Commercial: T**OD < 80% of TODA**

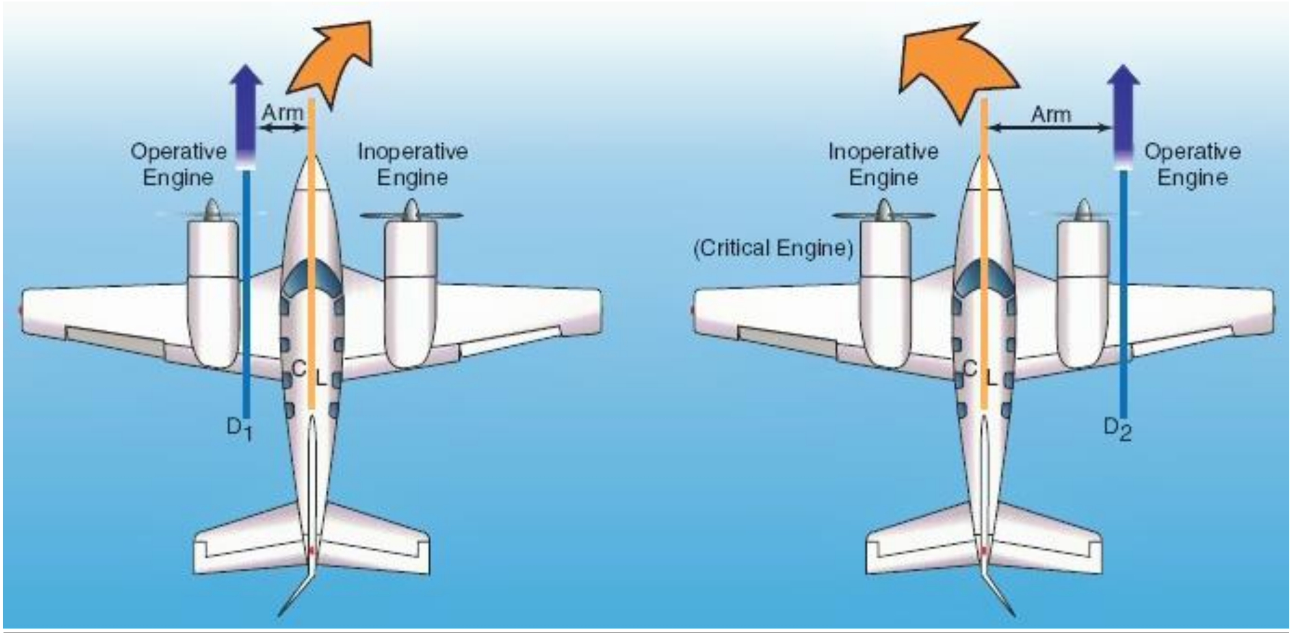


Landing speed at **50ft** must NOT be less than **$1.3\ V_{S1}$**
Reference landing approach speed (**V_{REF}**) must NOT be less than **$1.3\ V_{S0}$**

Landing Distance Required (LDR) **max 70%** of Landing Distance Available (LDA)
In flight planning for landing requirements: **No correction for wind!**

Performance - notes

Kap5: Multi Engine Piston (MEP)



VMC – Minimum Control Speed

- Maintain **heading**
- Sudden failure of critical engine
- Most unfavourable CG (usually back)

VMCA – Minimum Control Speed Airborne (**Red radial line** on airspeed indicator)

VXSE – Best <u>Angle</u> of Climb Speed Single Engine (higher than VX)
VYSE – Best <u>Rate</u> of Climb Speed Single Engine **"blue line speed"** (lower or equal to VY)

Performance - notes

Kap6: Take-Off (Class A)

V_{SR} – Reference Stall speed
V_{MC} – Minimum Control speed. May **not exceed 1.13** V_{SR}
V_{MCG} – Minimum Control speed Ground. OEI control A/C without nose-wheel steering
V_{MBE} – Maximum Brake Energy speed. Depends on mass, temp, pressure, slope and wind
V_{EF} – Critical Engine Failure speed at which the critical engine is assumed to fail during take-off
V_1 - Take-Off Decision speed. Reject or continue take-off.

- Recognition time: **1 sec** from V_{EF} to V_1
- V_1 is decreased on a wet runway to account for the stopping case.
- $V_{MCG} \leq V_1 \leq V_R$
- May be limited by V_{MBE}

V_R – **Rotation speed**. Aeroplane rotated for lift-off. May **not be less than:**

- **V_1**
- **1.05** $V_{MC(A)}$

V_{MU} – Minimum Unstick speed. The speed at which the aircraft can safely lift off the ground (the speed during rotation, the nose wheel comes off the runway).
V_{LOF} – Lift Off speed. The speed at which the main wheels get airborne.
V_{TYRE} – Max Tyre speed (centripetal force)
V_2 – **Take-off safety speed** (CS 25) at 35 ft. not less than: (**1.2 V_S**)

- **1.13** V_{SR} for:
  - Two/three-engined turbo-prop
  - Turbo-jet (without prov. for obtain. signif. reduction in N-1 stall speed)
- **1.08** V_{SR} for:
  - Turbo-prop with more than three engines
  - Turbo-jet (with prov. for obtain. signif. reduction in N-1 stall speed)
- **1.1 $V_{MC(A)}$**

V_{FTO} – Final Take-Off speed. Must provide climb gradient of final segment. **Not less than 1.18** V_{SR}. Speed at the end of take-off path in the en-route configuration with OEI.

TORR is the greater of:

- All Engines Operation (AEO) TORR: **Gross x 1.15**
- One Engine Inoperative (OEI) TORR: Gross = net

One engine out take-off run is the distance between the brake release point and the middle of the segment between VLOF point and 35 ft point.

Decrease the take-off ground run:

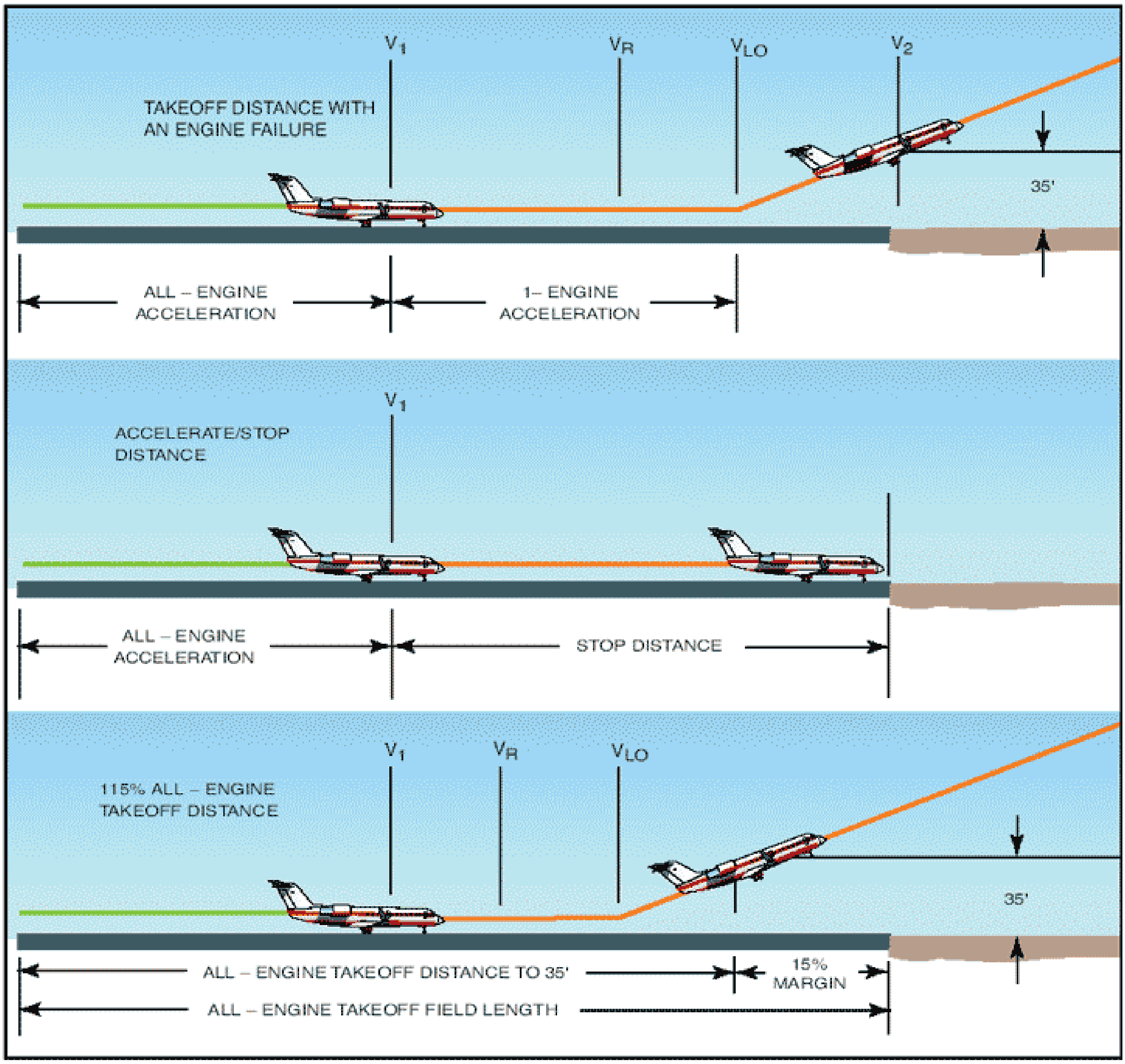
1. decreasing take off mass
2. increasing density
3. increasing flap setting
4. decreasing pressure altitude

TODR – Take-Off Distance Required (longest of):

1. OEI: accelerate to V1 and continue to 35ft (wet RWY: 15ft)
2. AEO: **115%** of dist to bring aircraft to 35ft

Performance - notes

A field length is <u>balanced</u> when TODA = ASDA. A balanced field length provides the <u>minimum required field</u> length in the event of an engine failure. (**V_{1B} balanced**)



Stopway available: the RTOM can be increased, provided that <u>V1 is increased</u>. This increase on V1 must occur because the TODA has not increased and therefore to reach the screen height within the same distance with a heavier aeroplane the V1 must be faster.

Clearway available: the RLTOM can be increased provided the <u>V1 is decreased</u>. This is because the ASDA has not increased and therefore to accelerate to V1 and then reject the takeoff in a heavier aeroplane in the same ASDA the V1 must be slower.

Performance - notes

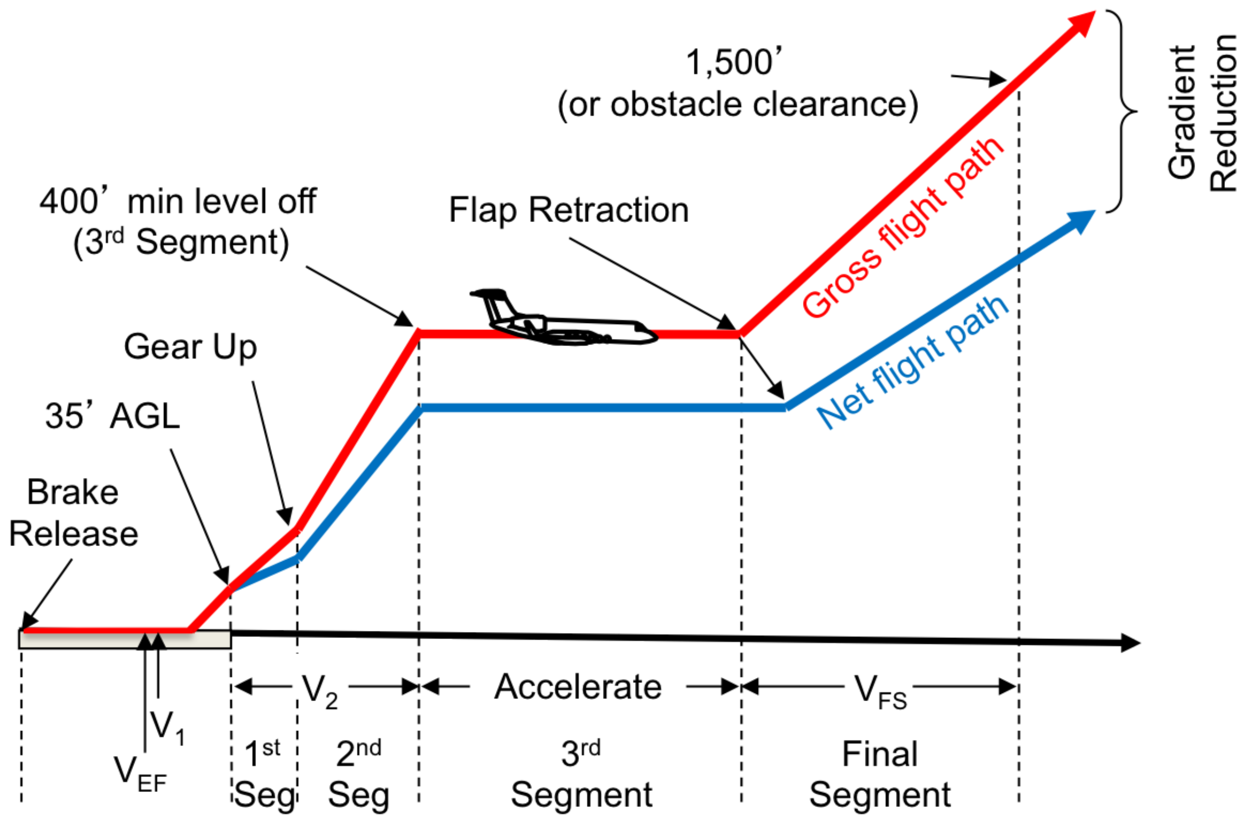
- **Uphill slope** increases the TODR more than the ASDR because of the continued acceleration after V1. We increase V1 with an upslope. **Positive slope increases the ASDR.**
- **Downhill slope** increases allowable take-off mass. It will be easier to accelerate the a/c assisted by the downhill component of weight therefore we can increase the mass and still make 35ft and V2 within TODA, however we will have to reduce V1 in case we have to stop with a heavier A/C. **Negative slope decreases the ASDR.**

Net Take-off flight Path begins **35ft** above the surface at the end of TODR
Gross take-off flight path reduced by gradient:

- **0.8%** for two-engine
- **0.9%** for three-engine
- **1.0%** for four-engine

Segments in Net Take-Off Flight Path Profiles

- 1. segment: **V2** (screen height 35ft.) – **Gear Up**
- 2. segment: **Gear Up** – gross height **min. 400ft**. (level off)
- 3. Segment (transition): **400ft** – **Flaps Up/Vfto** (T/O to Clean config)
- 4. segment (final): **Flaps Up/Vfto** (clean config. 1.25Vs)



Maximum Take-off Thrust (usually 5 mins AEO and 10 mins OEI.) may limit the maximum clean-up height in initial climb

Performance - notes

Net Take-Off Flight Path Funnel – Obstacle Accountability Area (dimensions):
1) End of TODA: 90m (or 60m + ½ wing span, if wingspan < 60m)
2) Expands at 0.125 x D (D = distance from TODR), **90m + (0.125 x D)**
3) Flight Path Funnel With
   a) Visual guidance (VMC day)
      i) Track 0-15°**: 300m**
      ii) Over 15°**: 600m**
   b) Other conditions (IMC or VMC night):
      i) Track 0-15°**: 600m**
      ii) Over 15°**: 900m**

Climb Gradient Requirements (OEI)				
	1st segment	**2nd segment**	**3rd segment**	**4th segment**
2 engines	Positive	**2.4%**	1.2%	1.2%
3 engines	0.3%	**2.7%**	1.5%	1.5%
4 engines	0.5%	**3.0%**	1.7%	1.7%

(2nd segment limit T/O mass)

Reduced take-off thrust (Assumed Temp Thrust Reduction, T_{ASS})
- Used to preserve engine life.
- Actual T/O weight less than maximum
- Max reduction is **25%** of max T/O thrust.
- Reduced T/O thrust is **not** permitted with:
  - Icy or very slippery runways
  - Contaminated runways
  - Anti-skid unservicable
  - Reverse thrust unservicable
  - Increased V2 procedure
  - With Power Management Computer (PMC) off
  - Inversion or windshear (in the climb out area)
- Assumed temp **is allowed** on wet runways

Wet / Contaminated Runway Take-off
- Reduced screen height from 35 ft. to **15 ft.**
- Reduced obstacle clearance from 35 ft. to **15 ft.**
- Use of **clearway not allowed** (15 ft. screen height)

Hydroplaning
- Viscous (most common) – thin layer of water and dirt
- Dynamic – standing water, high speed and smooth surface
- Reverted Rubber – locked wheel/wet RWY, touchdown zones

The **turn must not begin** until the aircraft has reached a height of at least **50ft**
The angle of bank thereafter must **not exceed 15°** up to **400ft**.

Performance - notes

The climb limited take-off mass can be increased by a lower flap setting for take-off and selecting a higher V2.

The engines are pressure limited at lower temperature, at higher temperatures they are temperature limited (the take-off performance climb limit graph show a kink).

Performance - notes

Kap7: Climb (Class A)

$$Climb\ gradient = \frac{T - D}{W}$$

If the correction for acceleration is neglected, and lift ~ weight:

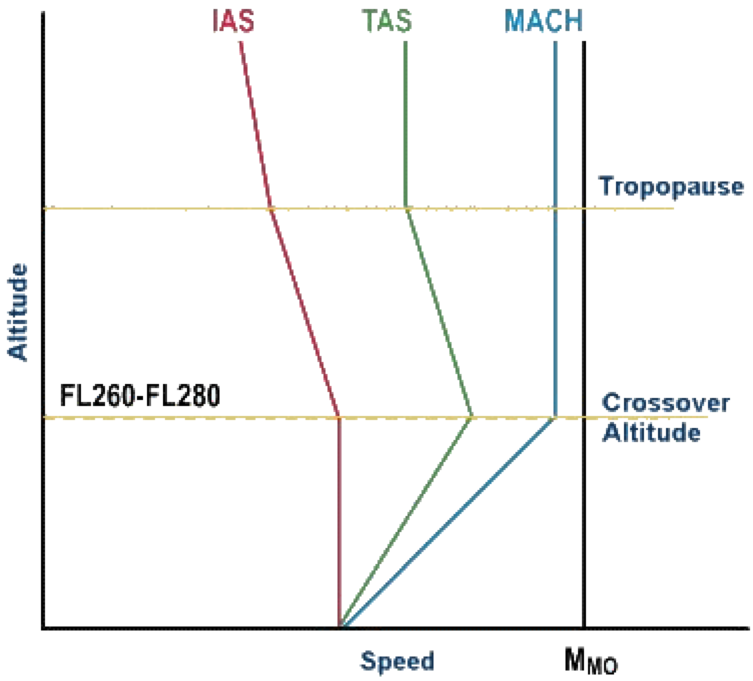
$$Glimb\ gradient = \frac{thrust}{weight} - \frac{drag}{lift}$$

Gradient (%) = ROC(fpm) / TAS (kts) x 6000/6080

For small angles; ratio of Climb Angle and Climb Gradient is 0.6:1
Climb Angle / 0.6 = Climb Gradient

V_Y will always be greater than or equal to **V_X** in the climb.

V_{MO}/M_{MO} – Maximum Operating Speed/Mach number (may not be higher than V_C)

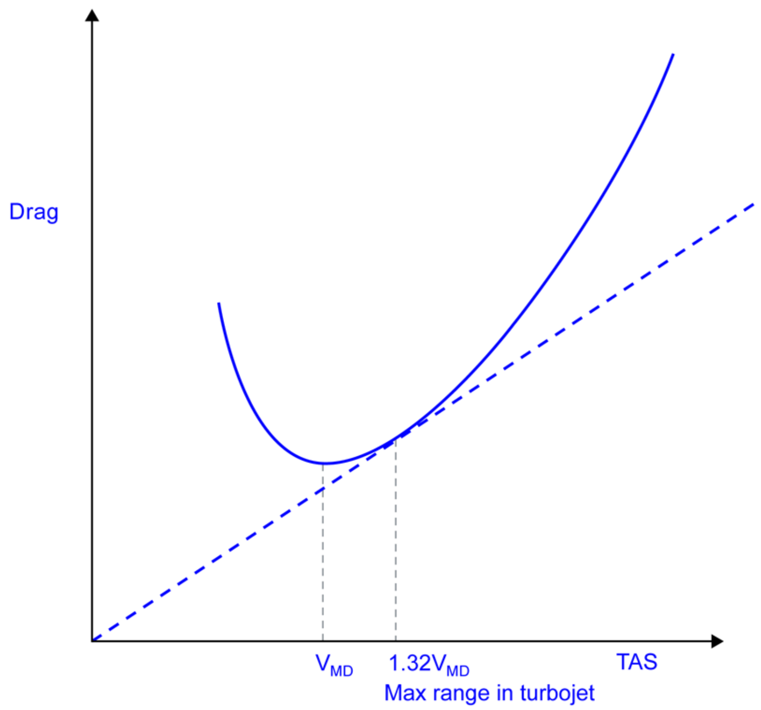


Crossover Altitude: transition from constant CAS (IAS) to constant Mach around **26.000-28.000ft.**

An increase in RoC of up to 30% can be observed in the transition from constant IAS to constant Mach climb.

Performance - notes

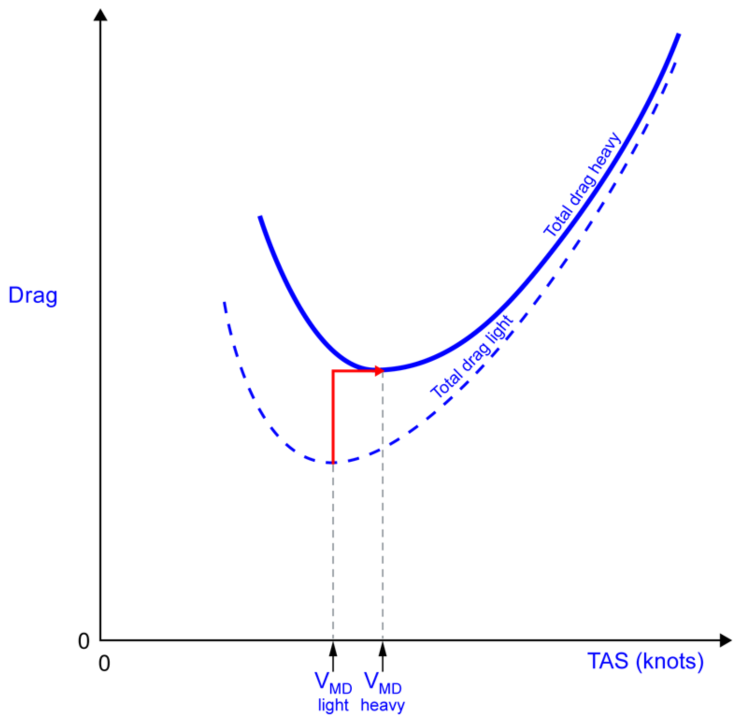
Kap8: Cruise (Class A)



Maximum Endurance (V_{MD}) (bottom of drag/speed curve)

Maximum Range (1.32 x V_{MD}) (tangent from origin to drag/speed curve)

The lighter an aircraft the less the drag, and the IAS for V_{MD} also decreases.



Performance - notes

Specific Range (SR) – flight distance per fuel quantity (NM/kg)

$$Specific\ Range\ (SR) = \frac{True\ Airspeed}{Fuel\ Flow} = \frac{Still\ air\ distance}{Fuel\ quantity}$$

Long Range Cruise speed (V_{LRC}) is defined as the speed above Maximum Range Cruise (V_{MRC}) that will result in a **1% decrease in fuel mileage** in terms of nautical miles per kilogram or pound of fuel burned. LRC is beneficial to the overall economy of the operation as far as the airline is concerned when taking into account all the other costs, and gives **99% of maximum range for a 4% increase in speed,** but from a pure performance point of view it does not give best economy with regard to range flying.

The LRC speed decreases with decreasing mass (at const. alt)
The LRC speed increases with altitude (at const. mass)

The **fuel burn** of a jet aircraft increases or decreases directly in proportion to the aircraft changes of weight.

At constant thrust and constant altitude, the **fuel flow** of a jet engine increases slightly with increasing airspeed (ram effect).

Optimum altitude increases as mass decreases (fuel burn) and is the altitude at which the

- An aeroplane sometimes flies above the optimum cruise altitude, because ATC normally does not allow to fly continuously at the optimum cruise altitude.
- **"Stepped climbs"** are used on long-distance flights to fly a profile as close as possible to the optimum altitude as the aeroplane mass reduces.
- Below the optimum cruise altitude the Mach number for long range cruise decreases continuously with decreasing altitude.
- Cruise altitude is usually at the optimum altitude to reduce fuel consumption, but if there's a favourable wind, you may prefer to fly at different altitude.

OEI Cruise regulations – continue flight from cruise alt. to aerodrome

- Clear obstacles **5NM** (or **10 NM** if reduced navigation accuracy)
- Vertical clearance:
    - **1000 ft.** if ROC ≥ 0 (cruise/climb)
    - **2000 ft.** if ROC < 0 (descent)
    - Positive slope **1500 ft.** above RWY

Drift Down – The net flight path must permit the A/C to continue flight from the cruising altitude to an aerodrome with the net flight path clearing vertically, by at least **2000 ft.** all terrain and obstructions along the route within **5NM** on either side of the intended track.

Performance - notes

The **maximum drift down altitude** is the altitude to which, following the failure of an engine above the one engine inoperative absolute ceiling, an aeroplane will descend and maintain, whilst using max available thrust/power on the operating engine.

Extended Range Twin operations (ETOPS)
Definition: ETOPS is the minimum flying time from a suitable airport in still air, with one engine inoperative at the one engine out cruise speed.

Performance - notes

Kap9: Descent (Class A)

Normally flown at idle thrust

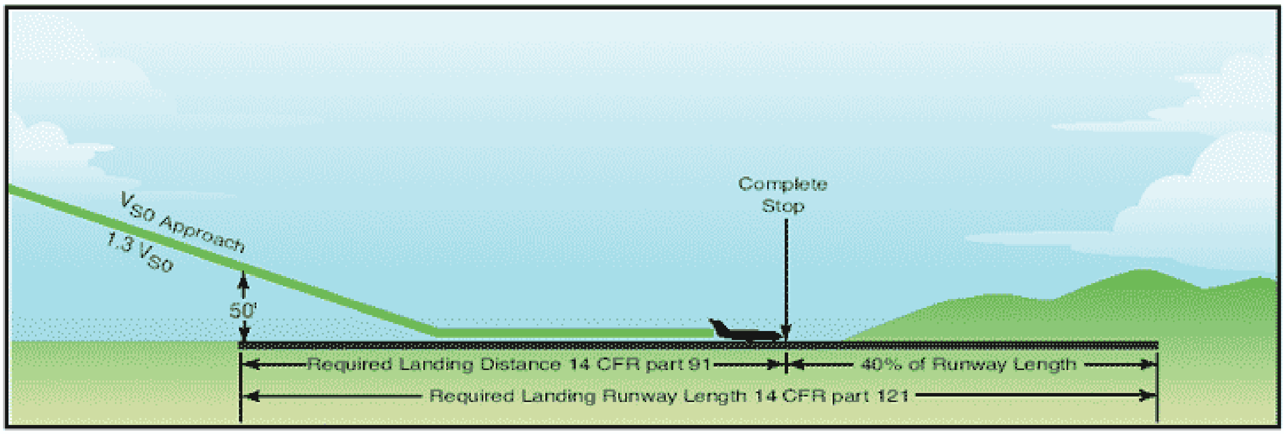
Rate of Decent decreases with altitude

If the correction for acceleration is neglected, and lift ~ weight:

$$Descent\ gradient = \frac{drag}{lift} - \frac{thrust}{weight}$$

Misses approach: normally **2.5% slope** for obstacle clearance

Full stopp landing from **50ft** above the threshold (for wet RWY: add 15%):
- Turbo-jet: within **60%** of landing dist. available (faktor of 1.67)
- Turbo-prop: within **70%** of landing dist available (faktor 1.43)



Minimum speed on short final:
- **1.3** x **V_{S0}** (stall speed in landing configuration)
- or **1.23 V_{SR0}** (stall reference speed)

Displaced Threshold is calculated by **1:20 rule**

Performance - notes

Missed Approach

- **Landing Climb Requirement** – landing flaps, gear down, AEO at go-around thrust
  - Climb gradient **not less than 3.2%** with speed of **1.23% V_S**
- **Approach Climb Requirement** – approach flap, gear up, OEI and remaining eng. at go-around thrust:
  - **1.5 V_S**
  - Gradient
    - Two engine aircraft: **2.1%**
    - Three engine aircraft: **2.4%**
    - Four engine aircraft: **2.7%**

Pavement Classification Number (PCN) overloads allowed:

- **10%** on flexible pavements
- **5%** on rigid pavements

Abbreviations

OEI – One Engine Inoperative
AEO – All Engine Operative
A/C – Aircraft
T/O – Take-off