V-speeds and Takeoff Performance

Large Aircraft Operations


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JAL
JAL
AIR PACIFIC
Fiji
Fiji

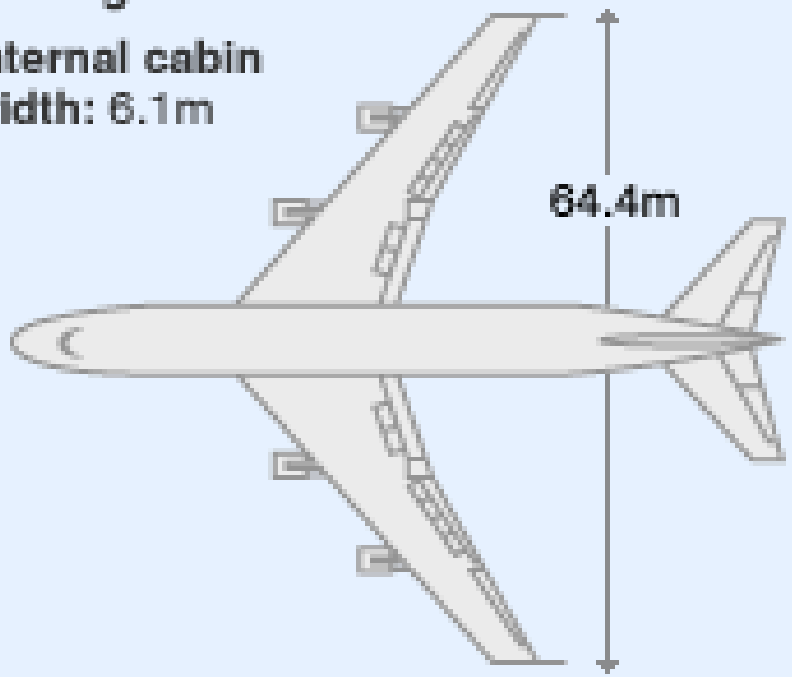

A380
A380 AIRBUS
© Gilles Collignon


AIRBUS
A380
AIRBUS

Boeing 747

Seating: 416

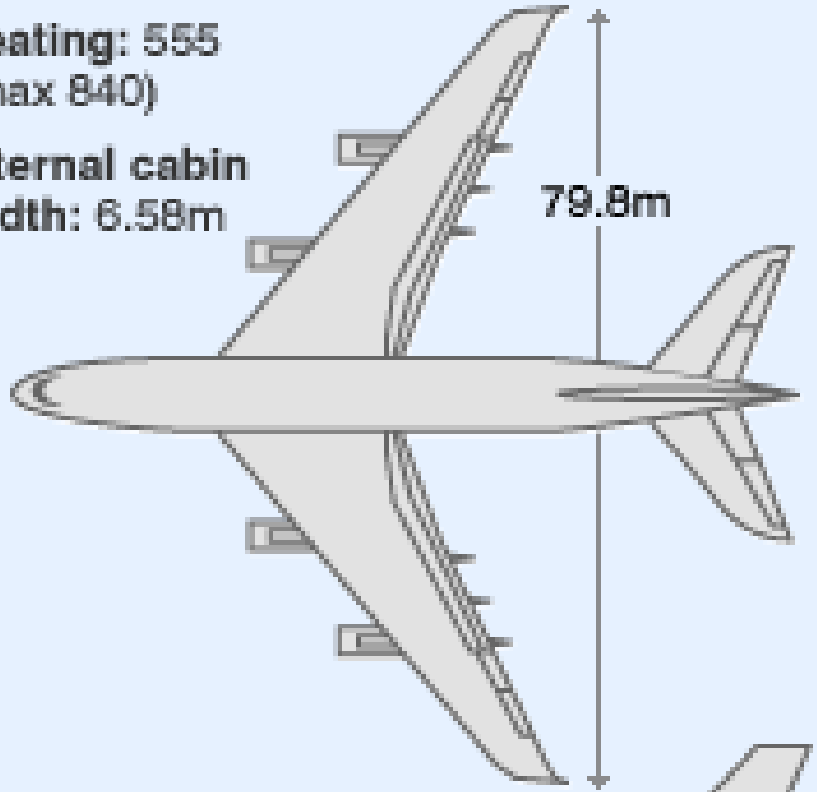
Internal cabin width: 6.1m

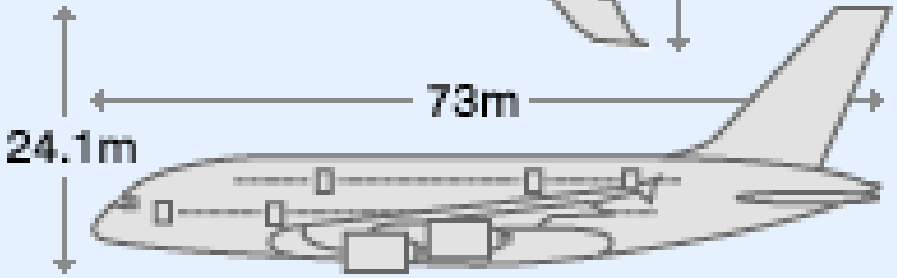


Airbus A380

Seating: 555 (max 840)

Internal cabin width: 6.58m





London bus to scale

Source: Airbus/Boeing


777
BOEING


A340-600
A340

What are V-speeds?

- *Large aircraft operate under a wide variety of weights, conditions and configurations.*
- *Operators are subject to strict regulations governing aircraft performance during all phases of flight. (field length, net climb gradients)*
- *Certain performance speeds are relative to operating conditions, and therefore change depending on the situation; these are known as V-speeds.*

Conditions Affecting V-speeds

- *V-speeds change relative to aerodrome conditions, aircraft weight and configuration.*
- *Gross takeoff weight, pressure altitude, and temperature all affect aircraft performance.*
- *WAT- weight, altitude, temperature.*
- *Aircraft configuration affects V-speeds (flap setting, slat setting, bleeds, anti-ice, a/c off/on, anti-skid inoperable), and can be used to improve performance.*
- *Runway conditions also affect V-speeds. (contaminated runway)*

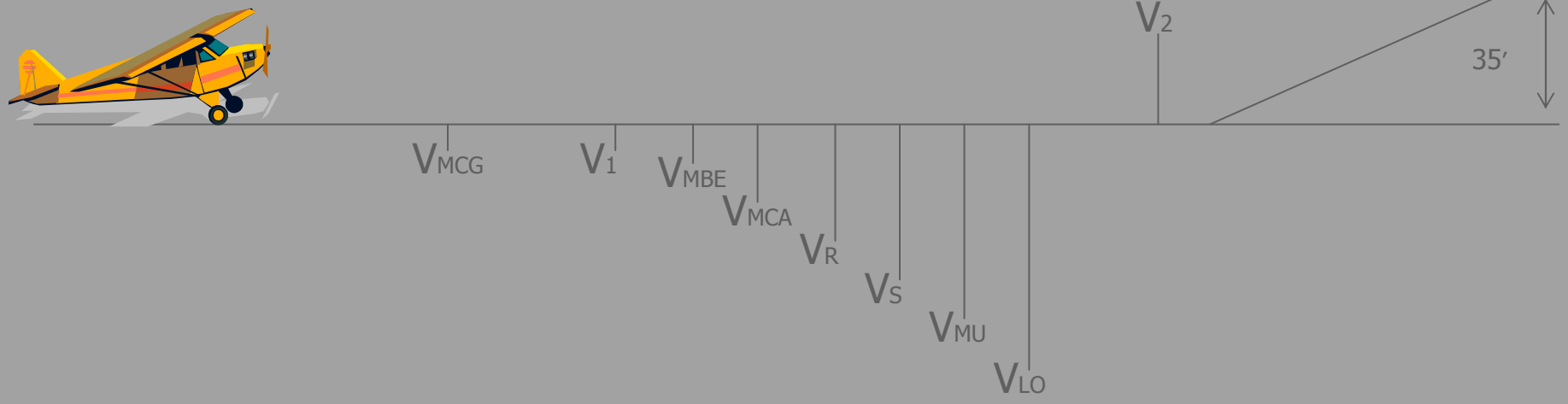
V-speed Definitions

- *V_1- Takeoff Decision Speed- the speed which dictates whether a malfunction during the takeoff roll results in rejecting the takeoff, or continuing. (go or no go speed)*
- *V_R- Takeoff Rotation Speed- the speed at which aircraft rotation is initiated by the pilot.*
- *V_2- Minimum Takeoff Safety Speed- one engine inoperative climb speed for takeoff configuration.*
- *V_{MCG}- Ground Minimum Control Speed- minimum speed which provides directional control on the ground during failure of the critical engine.*

- *V_{MCA}- Air minimum Control Speed- minimum speed which provides directional control in the air during failure of the critical engine.*
- *V_{MU}- Minimum Unstick Speed- minimum speed the aircraft can lift off without demonstrating hazardous characteristics while continuing the takeoff.*
- *V_{LO}- Lift Off Speed- speed at which the aircraft will lift off.*
- *V_{MBE}- Maximum Brake Energy Speed- maximum speed an aircraft can initiate a rejected take off from and remain within heat limitations of the braking system.*

Relationships Between V-speeds

- *V_1 must always be $>V_{MCG}$, $<V_{MBE}$, $\leq V_R$*
- *V_R must always be $\geq V_1$, $>V_{MCA}$*
- *V_{LO} must always be $\geq V_R$, $>V_{MCA}$, $>V_S$, $>V_{MU}$*
- *V_2 must always be $>V_{MCA}$, $>V_S$, $>V_R$*
- *These relationships will always hold true, but the speeds themselves will change according to aircraft weight, atmospheric conditions, aircraft configuration, and runway conditions.*
- *V_1, V_R, and V_2 will float between their minimum and maximum limits dependant on conditions and requirements.*
- *The specific speeds are obtained by consulting the performance charts or quick reference cards.*


V2
35′
VMCG
V1
VMBE
VMCA
VR
VS
VMU
VLO

Takeoff Performance

- *During the certification process of an aircraft the manufacturer must comply with strict regulations concerning aircraft performance. Performance calculations are done assuming an engine failure at V_1, a failure before or after will result in better than indicated performance.*
- *Transport and Commuter aircraft takeoff field length is limited by the longer of:*
  - *Accelerate/stop distance- the distance required to accelerate to V_1 with all engines operating normally, experience the loss of the critical engine and bring the aircraft to a stop.*
  - *Accelerate/go distance- the distance required to accelerate to V_1 with all engines operating normally, experience the loss of the critical engine and continue with the takeoff and reach 35 feet above the runway at V_2.*
  - *All-engine takeoff runway length- 115% of the distance required to reach 35 feet above the runway with all engines operating normally.*

Declared Distances AIM AGA 3.8

- *In the determination of available runway length for take off the CAP aerodrome chart must be consulted.*
- ***Takeoff Run Available (TORA):*** *The length of runway declared available and suitable for the ground run of an aeroplane taking off.*
- ***Takeoff Distance Available (TODA):*** *The length of the takeoff run available plus the length of the clearway, where provided. (max. clearway length allowed is 1000 feet.)*
- ***Accelerate Stop Distance Available (ASDA):*** *The length of the takeoff run available plus the length of the stopway where provided.*

Clearways and Stopways

- *Clearway- A defined rectangular area on the ground or water under the control of the appropriate authority, selected or prepared as a suitable area over which an aeroplane may make a portion of its initial climb to a specified height. (TODA-TORA)*
- *Stopway- A defined rectangular area on the ground at the end of the runway in the direction of takeoff prepared as a suitable area in which an aeroplane can be stopped in the case of an abandoned takeoff (ASDA-TORA)*

Balanced Field Takeoff

- *A balanced field takeoff is a condition where the accelerate stop distance required (ASDR) is equal to the takeoff distance required (TODR) for a given WAT, aircraft configuration, and runway condition.*
- *When the takeoff field length is balanced it results in the shortest possible runway length for the given conditions.*
- *Performance charts are usually based on this balanced field concept as it allows for the highest takeoff weights to be achieved.*
- *The charts will give you the maximum takeoff weight allowable to depart a specific length of runway given the current conditions.*
- *The V-speeds generated by the charts assure adequate performance under the given conditions.*

Conditions Affecting Performance

- ***The takeoff field length is dependant on the speed to which the aircraft has to be accelerated and the acceleration available.***
- ***WAT:*** *weight, pressure altitude, and temperature. Increased weight, pressure altitude, and temperature decrease performance.*
- ***Engine thrust:*** *Higher temperatures and lower air density reduce the amount of available thrust. Systems like A/C, bleed air, and anti-ice decrease available thrust. Thrust may be decreased purposely in order to maximize engine life if the runway length and aircraft weight allow it. (de-rated or reduced thrust takeoff)*
- ***Flap setting:*** *flap configuration will depend on the limiting takeoff factor. Lower flap settings require longer takeoff distances but provide better climb out gradient capability.*

- ***Wind:*** *A headwind will positively affect performance, decreasing both ASDR and TODR. A tailwind has a negative affect on performance. Performance charts are permitted to take credit for 50% of headwinds and 150% of tailwinds.*
- ***Runway slope:*** *A down slope improves takeoff performance as long as brake energy doesn't become limiting.*
- ***Surface condition:*** *Contaminated runways will increase ASDR.*
- ***Anti-skid:*** *An inoperative anti-skid system will increase ASDR.*

Questions

- *If we increase V_1, what effect will it have on ASDR and TODR?*
- *It will increase ASDR and decrease TODR.*
- *If we decrease V_1, what effect will it have on ASDR and TODR?*
- *It will decrease ASDR and increase TODR.*
- *What effect will a wet runway have on ASDR?*
- *It will increase ASDR.*
- *What conditions have an effect on V_{MBE}?*
- *Temperature, weight, runway slope, wind.*
- *Will cooler temperatures increase or decrease V_{MBE}?*
- *Increase.*
- *Will increase in weight increase or decrease V_{MBE}?*
- *Decrease.*
- *Will an upslope runway increase or decrease V_{MBE}?*
- *Increase.*

- *Is V_{MBE} always greater or less than V_1? Why?*
- *It is always greater than V_1 to ensure maximum brake temperatures are not exceeded during a RTO.*
- *Does the existence of a stopway or clearway allow for increased takeoff weights?*
- *Yes.*
- *In the above example will V_1 change, if so will it increase or decrease?*
- *Yes it will increase to maximize use of a stopway, or decrease to maximize use of a clearway.*
- *Define balanced field takeoff.*
- *A balanced field takeoff exists when the ASDR is equal to the TODR.*
- *When would a reduced thrust takeoff be performed?*
- *Anytime aircraft weight, aerodrome conditions, and runway length allow it.*