

In aviation, **V-speeds** are standard terms used to define airspeeds important or useful to the operation of all aircraft.^[1] These speeds are derived from data obtained by aircraft designers and manufacturers during flight testing for aircraft type-certification. Using them is considered a best practice to maximize aviation safety, aircraft performance, or both.^[2]

The actual speeds represented by these designators are specific to a particular model of aircraft. They are expressed by the aircraft's indicated airspeed (and not by, for example, the ground speed), so that pilots may use them directly, without having to apply correction factors, as aircraft instruments also show indicated airspeed.

In general aviation aircraft, the most commonly used and most safety-critical airspeeds are displayed as color-coded arcs and lines located on the face of an aircraft's airspeed indicator. The lower ends of the white arc and the green arc are the stalling speed with wing flaps in landing configuration, and stalling speed with wing flaps retracted, respectively. These are the stalling speeds for the aircraft at its maximum weight.^{[3][4]} The yellow band is the range in which the aircraft may be operated in smooth air, and then only with caution to avoid abrupt control movement. The red line is the V_{NE} , the never-exceed speed.

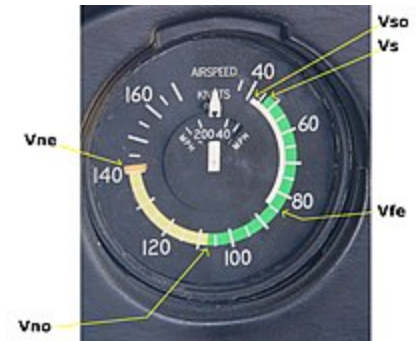
Proper display of V-speeds is an airworthiness requirement for type-certificated aircraft in most countries.^{[5][6]}

Regulations

The most common V-speeds are often defined by a particular government's aviation regulations. In the United States, these are defined in title 14 of the United States Code of Federal Regulations, known as the Federal Aviation Regulations (FARs).^[7] In Canada, the regulatory body, Transport Canada, defines 26 commonly used V-speeds in their Aeronautical Information Manual.^[8] V-speed definitions in FAR 23, 25 and equivalent are for designing and certification of airplanes, not for their operational use. The descriptions below are for use by pilots.

Regulatory V-speeds

These V-speeds are defined by regulations. They are typically defined with constraints such as weight, configuration, or phases of flight. Some of these constraints have been omitted to simplify the description.



A single-engined Cessna 150L's airspeed indicator indicating its V-speeds in knots

V-speed designator	Description
V_1	The speed beyond which <u>takeoff</u> should no longer be aborted. (See <u>V_1 definitions</u> below) ^{[7][8][9]}
V_2	Takeoff safety speed. The speed at which the aircraft may safely climb with one engine inoperative. ^{[7][8][9]}
$V_{2_{min}}$	Minimum takeoff safety speed. ^{[7][8][9]}
V_3	Flap retraction speed. ^{[8][9]}
V_4	Steady initial climb speed. The all engines operating take-off climb speed used to the point where acceleration to flap retraction speed is initiated. Should be attained by a gross height of 400 ft (120 m). ^[10]
V_A	Design maneuvering speed. This is the speed above which it is unwise to make full application of any single flight control (or "pull to the stops") as it may generate a force greater than the aircraft's structural limitations. ^{[7][8][9][11]}
V_{at}	Indicated airspeed at threshold, which is usually equal to the stall speed V_{S0} multiplied by 1.3 or stall speed V_{S1g} multiplied by 1.23 in the landing configuration at the maximum certificated landing mass, though some manufacturers apply different criteria. If both V_{S0} and V_{S1g} are available, the higher resulting V_{at} shall be applied. ^[12] Also called "approach speed". Also known as V_{th} ^{[13][14]} Davies defines V_{at} and V_{ref} as equivalent. ^[15]
V_B	Design speed for maximum <u>gust</u> intensity. ^{[7][8][9]}
V_C	Design <u>cruise</u> , also known as the optimum cruise speed, is the most efficient speed in terms of distance, speed and fuel usage. ^{[16][17][18]}
V_{cef}	See V_1 ; generally used in documentation of military aircraft performance. Denotes "critical engine failure" speed as the speed during takeoff where the same distance would be required to either continue the takeoff or abort to a stop. ^[19]
V_D	Design diving speed, the highest speed planned to be achieved in testing. ^{[7][8][9]}
V_{DF}	Demonstrated flight diving speed, the highest actual speed achieved in testing. ^{[7][8][9]}
V_{EF}	The speed at which the <u>critical engine</u> is assumed to fail during takeoff. ^[7]
V_F	Designed flap speed. ^{[7][8][9]}
V_{FC}	Maximum speed for stability characteristics. ^{[7][9]}
V_{FE}	Maximum flap extended speed. ^{[7][8][9]}
V_{FTO}	Final takeoff speed. ^[7]
V_H	Maximum speed in level flight at maximum continuous power. ^{[7][8][9]}
V_{LE}	Maximum landing gear extended speed. This is the maximum speed at which a retractable gear aircraft should be flown with the landing gear extended. ^{[7][8][9][20]}
V_{LO}	Maximum landing gear operating speed. This is the maximum speed at which the landing gear on a retractable gear aircraft should be extended or retracted. ^{[7][9][20]}
V_{LOF}	Lift-off speed. ^{[7][9]}
V_{MC}	<u>Minimum control speed</u> . The minimum speed at which the aircraft is still controllable with the critical engine inoperative. ^[7] Like the stall speed, there are several important variables that are used in this

	determination. Refer to the <u>minimum control speed</u> article for a thorough explanation. V_{MC} is sometimes further refined into more discrete V-speeds e.g. V_{MCA} , V_{MCG} .
V_{MCA}	<u>Minimum control speed air</u> . The minimum speed that the aircraft is still controllable with the critical engine inoperative ^[21] while the aircraft is airborne. V_{MCA} is sometimes simply referred to as V_{MC} .
V_{MCG}	<u>Minimum control speed ground</u> . The minimum speed that the aircraft is still controllable with the critical engine inoperative ^[21] while the aircraft is on the ground.
V_{MCL}	<u>Minimum control speed in the landing configuration</u> with one engine inoperative. ^{[9][21]}
V_{MO}	Maximum operating limit speed. ^{[7][8][9]} Exceeding V_{MO} may trigger an overspeed alarm. ^[22]
V_{MU}	Minimum unstick speed. ^{[7][8][9]}
V_{NE}	Never exceed speed. ^{[7][8][9][23]} In a helicopter, this is chosen to prevent <u>retreating blade stall</u> and prevent the advancing blade from going <u>supersonic</u> .
V_{NO}	Maximum structural cruising speed or maximum speed for normal operations. Speed at which exceeding the limit load factor may cause permanent deformation of the aircraft structure. ^{[7][8][9][24]}
V_O	Maximum operating maneuvering speed. ^[25]
V_R	<u>Rotation</u> speed. The speed at which the pilot begins to apply control inputs to cause the aircraft nose to pitch up, after which it will leave the ground. ^{[7][26][Note 1]}
V_{rot}	Used instead of V_R (in discussions of the takeoff performance of military aircraft) to denote rotation speed in conjunction with the term V_{ref} (<i>refusal speed</i>). ^[19]
V_{Ref}	Landing reference speed or threshold crossing speed. ^{[7][8][9]} Must be at least $1.3 V_{S_0}$. Must be at least V_{MC} for reciprocating-engine aircraft, or $1.05 V_{MC}$ for commuter category aircraft. ^[28] In discussions of the takeoff performance of military aircraft, the term V_{ref} stands for refusal speed . Refusal speed is the maximum speed during takeoff from which the air vehicle can stop within the available remaining runway length for a specified altitude, weight, and configuration. ^[19] Incorrectly, or as an abbreviation, some documentation refers to V_{ref} and/or V_{rot} speeds as " V_r ." ^[29]
V_S	Stall speed or minimum steady flight speed for which the aircraft is still controllable. ^{[7][8][9]}
V_{S_0}	Stall speed or minimum flight speed in landing configuration. ^{[7][8][9]}
V_{S_1}	Stall speed or minimum steady flight speed for which the aircraft is still controllable in a specific configuration. ^{[7][8]}
V_{S_R}	Reference stall speed. ^[7]
$V_{S_{R_0}}$	Reference stall speed in landing configuration. ^[7]
$V_{S_{R_1}}$	Reference stall speed in a specific configuration. ^[7]
V_{SW}	Speed at which the stall warning will occur. ^[7]
V_{TOSS}	Category A rotorcraft takeoff safety speed. ^{[7][23]}
V_X	Speed that will allow for best <u>angle of climb</u> . ^{[7][8]}
V_Y	Speed that will allow for the best <u>rate of climb</u> . ^{[7][8]}

Other V-speeds

Some of these V-speeds are specific to particular types of aircraft and are not defined by regulations.

V-speed designator	Description
V_{APP}	Approach speed. Speed used during final approach with landing flap set. ^[30] V_{REF} plus safety increment, ^{[31][32][33]} typically minimum 5 knots, ^[34] and maximum 15 knots ^[30] to avoid exceeding flap limiting speeds. Typically it is calculated as half the headwind component plus the gust factor. ^[30] The purpose is to ensure that turbulence or gusts will not result in the airplane flying below V_{REF} at any point on the approach. ^[30] Also known as V_{FLY} .
V_{BE}	Best <u>endurance</u> speed – the speed that gives the greatest airborne time for fuel consumed.
V_{BG}	Best power-off glide speed – the speed that provides maximum <u>lift-to-drag ratio</u> and thus the <u>greatest gliding distance available</u> .
V_{BR}	Best <u>range</u> speed – the speed that gives the greatest range for fuel consumed – often identical to V_{md} . ^[35]
V_{FS}	Final segment of a departure with one powerplant failed. ^[36]
V_{imd}	Minimum <u>drag</u> ^[37]
V_{imp}	Minimum power ^[37]
V_{LLO}	Maximum landing light operating speed – for aircraft with retractable landing lights. ^[9]
V_{LS}	Lowest selectable speed ^[38]
V_{mbe}	Maximum brake energy speed ^{[37][39]}
V_{md}	Minimum <u>drag</u> (per <u>lift</u>) – often identical to V_{BR} . ^{[35][39]} (alternatively same as V_{imd} . ^[40])
V_{min}	Minimum speed for instrument flight (IFR) for helicopters ^[23]
V_{mp}	Minimum power ^[39]
V_{ms}	Minimum sink speed at median wing loading – the speed at which the minimum descent rate is obtained. In modern gliders, V_{ms} and V_{mc} have evolved to the same value. ^[41]
V_p	Aquaplaning speed ^[39]
V_{PD}	Maximum speed at which <u>whole-aircraft parachute</u> deployment has been demonstrated ^[42]
V_{ra}	Rough air speed (turbulence penetration speed). ^[9]
V_{SL}	Stall speed in a specific configuration ^{[9][39]}
$V_{s_{1g}}$	Stall speed at 1g load factor ^[43]
V_{sse}	<u>Safe single-engine speed</u> ^[44]
V_t	Threshold speed ^[39]
V_{TD}	Touchdown speed ^[45]
V_{TGT}	Target speed
V_{TO}	Take-off speed. (see also V_{LOF}) ^[46]
V_{tocs}	Take-off climbout speed (helicopters) ^[23]
V_{tos}	Minimum speed for a positive rate of climb with one engine inoperative ^[39]
$V_{t_{max}}$	Max threshold speed ^{[39][47]}

V_{wo}	Maximum window or canopy open operating speed ^[48]
V_{XSE}	Best angle of climb speed with a single operating engine in a light, twin-engine aircraft – the speed that provides the most altitude gain per unit of horizontal distance following an engine failure, while maintaining a small bank angle that should be presented with the engine-out climb performance data. ^[44]
V_{YSE}	Best rate of climb speed with a single operating engine in a light, twin-engine aircraft – the speed that provides the most altitude gain per unit of time following an engine failure, while maintaining a small bank angle that should be presented with the engine-out climb performance data. ^{[20][44]}
V_{ZF}	Minimum zero flaps speed ^[49]
V_{ZRC}	Zero rate of climb speed. The aircraft is at sufficiently low speed on the "back of the <u>drag curve</u> " that it cannot climb, accelerate, or turn, so must reduce drag. ^[39] The aircraft cannot be recovered without loss of height. ^{[15]: 144–145}

Mach numbers

Whenever a limiting speed is expressed by a Mach number, it is expressed relative to the local speed of sound, e.g. V_{MO} : Maximum operating speed, M_{MO} : Maximum operating Mach number.^{[7][8]}

V_1 definitions

V_1 is the critical engine failure recognition speed or takeoff decision speed. It is the speed above which the takeoff will continue even if an engine fails or another problem occurs, such as a blown tire.^[9] The speed will vary among aircraft types and varies according to factors such as aircraft weight, runway length, wing flap setting, engine thrust used and runway surface contamination, thus it must be determined by the pilot before takeoff. Aborting a takeoff after V_1 is strongly discouraged because the aircraft may not be able to stop before the end of the runway, thus suffering a runway overrun.^[50]

V_1 is defined differently in different jurisdictions, and definitions change over time as aircraft regulations are amended.

- The US Federal Aviation Administration defines it as: "the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance. V_1 also means the minimum speed in the takeoff, following a failure of the critical engine at V_{EF} , at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance."^[7] V_1 thus includes reaction time.^[26] In addition to this reaction time, a safety margin equivalent to 2 seconds at V_1 is added to the accelerate-stop distance.^{[51][52]}
- Transport Canada defines it as: "Critical engine failure recognition speed" and adds: "This definition is not restrictive. An operator may adopt any other definition outlined in the aircraft flight manual (AFM) of TC type-approved aircraft as long as such definition does not compromise operational safety of the aircraft."^[8]

See also

- ICAO recommendations on use of the International System of Units

- Balanced field takeoff

Notes

1. Most pilots often call out "rotate," instead of V_R . The "rotate" callout has the same meaning of V_R and V_{rot} .^[27]

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Further reading

- *Getting to grips with aircraft performance* (<https://www.skybrary.aero/bookshelf/books/2263.pdf>) (PDF). *Flight Operations Support & Line Assistance*. Airbus Customer Services. January 2002.
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