A Finesse for "Vitesse"

Photo by James Williams

Mastering the Maze of V-speeds

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Maverick: *I feel the need…*
Maverick/Goose: *…the need for speed!*
— *Top Gun (1986)*

Where would our jargon be without *Top Gun*? Although it's not a great idea to emulate every Maverick move (e.g., buzzing the tower never ends well), the need for speed is both a thrill and a necessity when it comes to aviation. That's why clever airspeed-related sayings abound. My favorites include "airspeed is life," "maintain thy airspeed lest the ground rise up and smite thee," and of course Chuck Yeager's advice to make sure you "never run out of altitude, airspeed, and ideas at the same time."

That's also why instructors and evaluators make such a big deal of memorizing your V-speeds. In Title 14 Code of Federal Regulations (14 CFR) part 1, there are 35 defined V-speeds. A quick Google search on the term brings up an absolutely dizzying array of additional $V_{subscript}$ options. And then there are the V-speed definitions in 14 CFR part 23 and part 25, which are used for aircraft certification and design (though not operational use).

So where to start and what do you really need to know? Obviously there's no need to memorize Mach-number V-speeds if your flying (like mine) is confined to piston-powered planes, but it's important to know — and even more important to *understand* — the major V-speeds for the make(s) and model(s) that you do fly.

"V" is for …?

First, a fun fact about the term itself: do you know what "V" stands for? Most native speakers of English assume that V is for velocity, and that mostly works. To be precise, though, the word velocity means "speed in a particular direction." Technically, V stands for "vitesse," another aviation term borrowed from the French; "vitesse" being the French word for "speed" or "rate."

Now for the definition: V-speeds are the airspeeds defined for specific maneuvers in specific aircraft at specific configurations (e.g., flaps, gear). The actual speeds represented by the V-designator are true airspeeds (TAS) expressed as indicated airspeeds (IAS), which allows the pilot to read them directly from the airspeed indicator. To assist the pilot in this task, the airspeed indicator in most general aviation aircraft has color-coded arcs and lines that demarcate some (but not all) of the most commonly used and most safety-critical airspeeds.

How are V-speeds determined? Aircraft designers and manufacturers perform flight tests to help determine aircraft performance and limitations. They use the resulting flight test data to help determine specific best speeds for safe operation of the aircraft. Once the designers and manufacturers have done their part, government flight inspectors verify the data during type-certification testing.

Which Ones Do I *Really* Have to Know?

We've already noted that 14 CFR part 1 includes definitions for 35 separate V-speeds (see sidebar). You also know that 14 CFR section 91.103 requires you to be familiar with "all" available information concerning a flight. Technically that means that you need to know all the V-speeds in terms of both definition and value — but some are more important than others. For simplicity, I have limited the list to speeds used for a single-engine airplane, and for convenience, I've grouped them in terms of performance speeds, and limitation speeds.

	Performance:
V_R	Rotation speed. As stated in 14 CFR part 23, V_R is "the speed at which the pilot makes a control input, with the intention of lifting the airplane out of contact with the runway or water surface." To reduce the possibility of an inadvertent stall during takeoff, regulations state that V_R cannot be less than V_{S1}.
V_X	V_X represents the airspeed for best angle of climb, and it results in the greatest amount of altitude over the shortest distance. You'll want to use this speed for a short-field takeoff, especially if you need to clear obstacles in the departure path. It's important to practice this maneuver (and flying at this airspeed) on a regular basis, because lack of experience and/or proficiency in short-field / obstacle clearance operations could lead to an inadvertent takeoff/departure stall.
V_Y	V_Y is the airspeed for best rate of climb, which produces the greatest amount of altitude gain over the shortest period of time. V_Y is the "standard" airspeed to establish during the post-takeoff climb and departure phase of flight.

	Limitations:
V_A	V_A is the aircraft's design maneuvering speed. Flying at or below V_A, means that the airplane will stall before the structure is damaged by excessive loads. If you encounter a gust that causes a sudden, significant increase in load factor while flying above V_A, the aircraft could experience structural failure. Another important thing to understand is that V_A changes with the aircraft weight: V_A decreases as weight decreases, and it increases as aircraft weight increases. It is a mistake to assume that as long as you are at or below V_A, you can move the controls from stop to stop repeatedly without damaging the aircraft. To clarify this point, 14 CFR part 25 states that "flying at or below the design maneuvering speed does not allow a pilot to make multiple large control inputs in one airplane axis or single full control inputs in more than one airplane axis at a time without endangering the airplane's structure." Although GA aircraft are certificated under 14 CFR part 23, this point is still valid.
V_{FE}	Represented by the top of the white arc on the airspeed indicator, V_{FE} is the maximum flap extended speed. If you allow your airspeed to increase above V_{FE} with flaps extended, you may damage or even lose one or both flaps. Note that some aircraft are designed to allow partial flap extension above V_{FE}, so consult the Pilot Operating Handbook/Aircraft Flight Manual to be sure you understand the limitations for your specific make and model.
V_{LE}	V_{LE} represents the maximum airspeed for operating with the landing gear extended. A related speed is V_{LO}, which is the maximum speed for "operating" (extending or retracting) the landing gear.
V_{NE}	This one is easy – "never exceed" means exactly what it says. It is an absolute limit, and you should never, ever operate as if there were a "buffer" beyond this speed. Such assumptions are likely to result in structural failure.
V_{NO}	Maximum structural cruising speed — the highest speed that you can safely fly in smooth air — is shown as the upper limit of the green arc on the airspeed indicator. If you fly above V_{NO} — in the yellow arc or "caution range" — and you encounter air that is not smooth, you could cause damage to the aircraft.
V_S	V_S is the stalling speed, or the minimum steady flight speed at which the airplane is controllable — in other words, the airplane will stall if you fly any slower than this speed. Although the "stalling speed" part of the definition leads pilots to believe they can avoid a stall by flying at or above a specific numerical value, it is very important to understand that a stall results from exceeding the critical angle of attack. It's better to think of V_S not as a numerical value, but rather the point at which your airplane is at the critical angle of attack in straight-and-level flight. A stall can occur at any airspeed, in any attitude. V_S is the point at which the air flowing over the upper surface of the wing can no longer flow smoothly to the trailing edge.

Do V-speeds Change?

As illustrated by some of the V-speeds listed in the chart above, the short answer is yes. Conditions that can affect the numerical value of V-speeds include:

- Aircraft weight and configuration.
- Altitude
- Temperature (which has implications for pressure altitude)
- Runway conditions (e.g., contaminated runway)

V-speeds defined in 14 CFR part 1	
V_A	design maneuvering speed
V_B	design speed for maximum gust intensity
V_C	design cruising speed
V_D	design diving speed
V_{DF}/M_{DF}	demonstrated flight diving speed
V_{EF}	speed at which the critical engine is assumed to fail during takeoff
V_F	design flap speed
V_{FC}/M_{FC}	maximum speed for stability characteristics
V_{FE}	maximum flap extended speed
V_{FTO}	final takeoff speed
V_H	maximum speed in level flight with maximum continuous power
V_{LE}	maximum landing gear extended speed
V_{LO}	maximum landing gear operating speed
V_{LOF}	lift-off speed
V_{MC}	minimum control airspeed with the critical engine inoperative
V_{MO}/M_{MO}	maximum operating limit speed
V_{MU}	minimum unstick speed
V_{NE}	never-exceed speed
V_{NO}	maximum structural cruising speed
V_R	rotation speed
V_{REF}	reference landing speed
V_S	stalling speed or minimum steady flight speed at which the airplane is controllable
V_{S0}	stalling speed or minimum steady flight speed in the landing configuration
V_{S1}	stalling speed or minimum steady flight speed obtained in a specific configuration
V_{SR}	reference stall speed
V_{SR0}	reference stall speed in the landing configuration
V_{SR1}	reference stall speed in a specific configuration
V_{SW}	speed at which onset of natural or artificial stall warning occurs
V_{TOSS}	takeoff safety speed for Category A aircraft
V_X	speed for best angle of climb
V_Y	speed for best rate of climb
V_1	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. V1 also means the minimum speed in the takeoff, following a failure of the critical engine at VEF, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance.
V_2	takeoff safety speed
V_{2min}	minimum takeoff safety speed

Photos by James Williams

As you know (and as shown in the chart), V_A is one example, because the numerical value of V_A changes with weight. Another example concerns V_X and V_Y: as altitude increases, V_X increases slightly and V_Y decreases. V_X and V_Y are equal when the airplane reaches its absolute ceiling.

The Need for (Proper) Speed

Knowing and using the proper speeds for various phases of flight in your specific aircraft is obviously good airmanship. More fundamentally, it is important for safety, because airspeed control is the key to getting the maximum performance from your aircraft without violating limitations that could result in structural damage or failure.

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