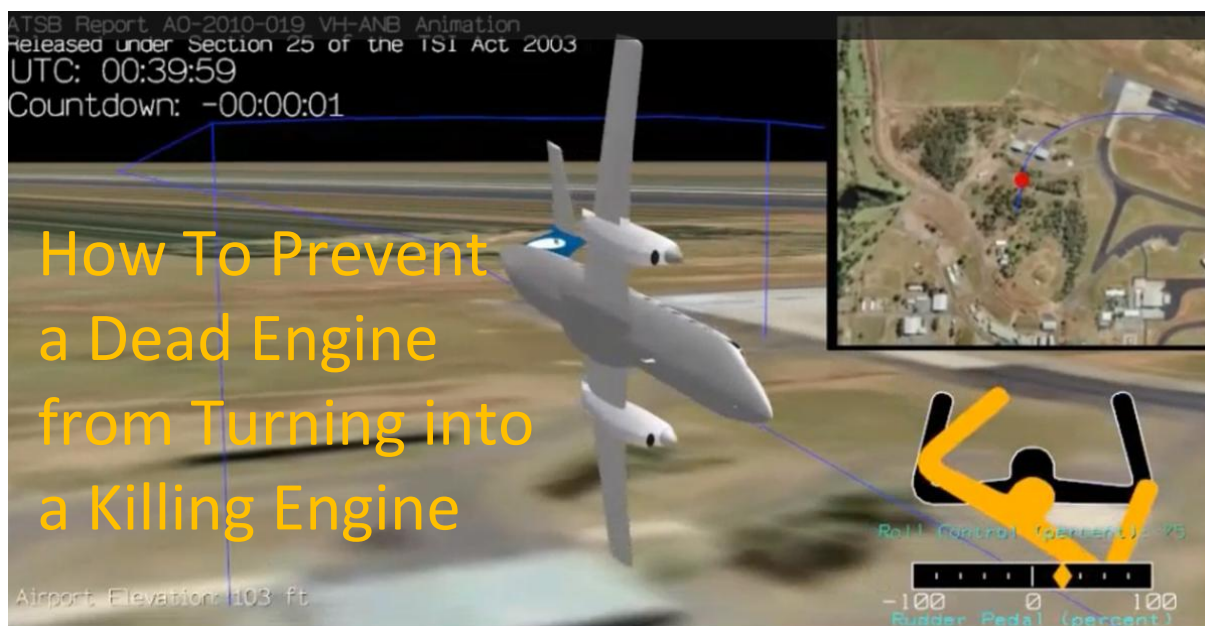




Loss of control EMB-120 after throttle cut #1 at V1 for training. ATSB Report AO-2010-019 [Animation](#).

How to prevent a dead engine from turning into a killing engine is what I learned at the USAF Test Pilot School in 1985 and need to share with you, because during the past 30 years 4,200+ pilots and their passengers died in 530+ unnecessary accidents after failure of one or two engines of a small or big multi-engine (ME) airplane. A quick answer to the question why these many accidents occurred and why the numbers are still increasing every month is that from 1975 the minimum control speed V_{mc} (or V_{mca}) and its associated conditions, which apply in anticipation of and following an engine failure, are neither correctly defined, nor explained in most Airplane Flight Manuals (AFMs) and Pilot Operating Handbooks (POHs), and are not in agreement anymore with Federal Aviation Regulation (FAR) and EASA Certification Specification (CS) § 23.149 either. In addition, engine emergency procedures fall short and true, calibrated, and indicated airspeeds are used inappropriately. The source of these errors is Specification No. 1 issued by the General Aviation Manufacturers Association (GAMA) in 1975, revised in 1996, although the FAA stated that the Specification meets the intent of the requirements in FAR 23, which is regrettably not the case. Consequence is that not only AFMs and POHs are incorrect, but also that errors occur in multi-engine rating course books, in posts on social media and in forums, in videos on YouTube, in articles on Wikipedia, in AI generated answers from chatbots, and even in recently added paragraphs in FAR and CS, because of unconscious knowledge poverty of the writers thereof on the subject.

Errors in the use of airspeeds will be discussed in a separate article. This article and the referenced academic college and downloadable test pilot school course books on the last page try to restore the knowledge of engine-out flight, improve V_{mc} definitions and introduce its associated conditions, and improve engine emergency procedures for pilots to be able to prevent a dead engine from turning into a killing engine, and save their own and many other lives, when an engine fails.

Controllability After Engine Failure

If one of the engines of a multi-engine airplane fails, the airplane will yaw and subsequently develops a sideslip, which causes high drag and severely reduces climb performance. The airplane also rolls about its longitudinal axis in the direction of the failed engine. The yaw and roll must, and can be counteracted by the pilot using the rudder and the ailerons, provided the airspeed is high enough.

The aerodynamic control forces generated by these control surfaces are proportional to the square of the airspeed (V^2), hence airspeed has a large effect on controllability. Figure 1 left shows the most important lateral-directional forces and moments.

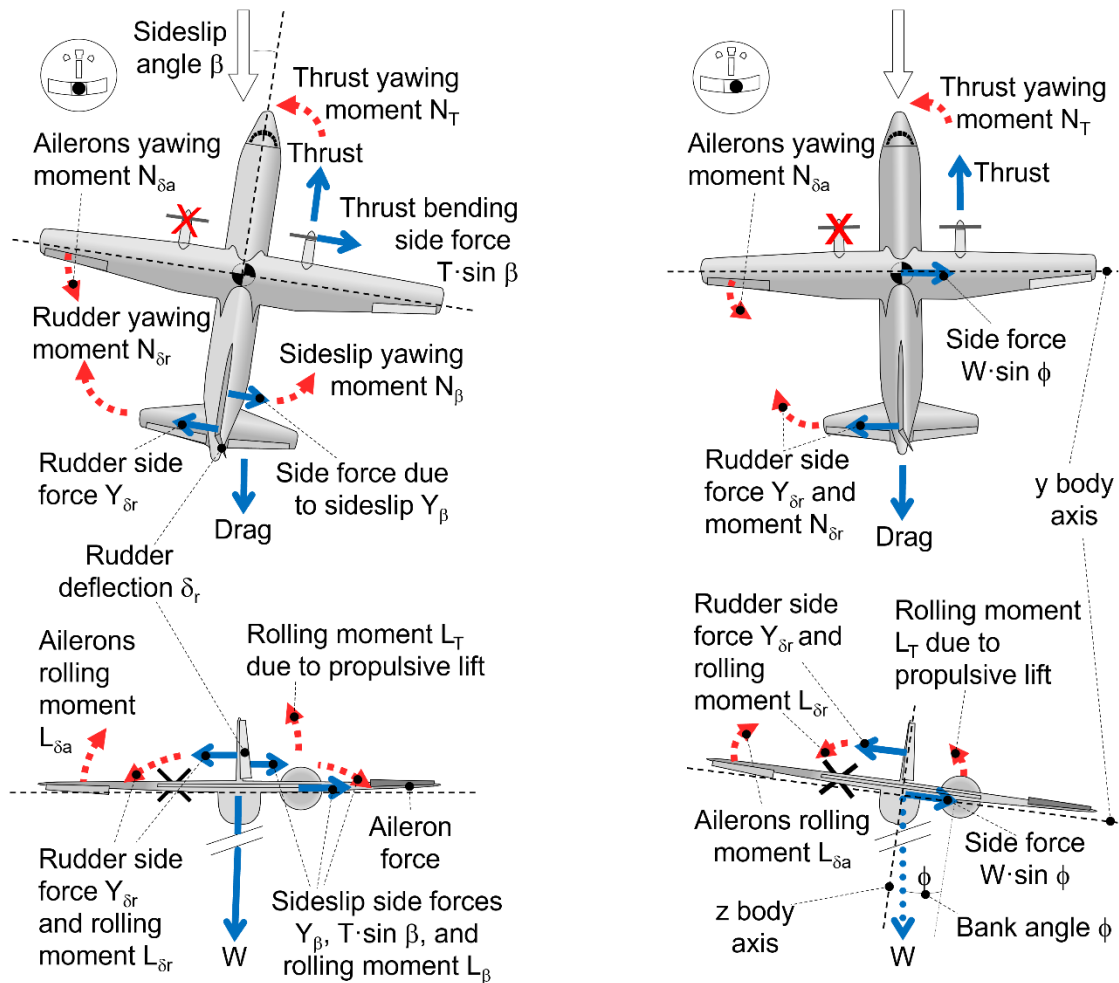


Figure 1. Some lateral-directional forces and moments in the body axis system, OEI, steady straight flight, bank angle 0° ($\beta \neq 0^\circ$) and 5° into good engine ($\beta \approx 0^\circ$).

The consequence of the dependance of controllability on the magnitude of the airspeed is that there is a lowest airspeed at which the aerodynamic controls rudder and ailerons generate just large enough forces and moments to act against the asymmetrical thrust and other lateral-directional forces and moments, and at which an equilibrium can barely be maintained and loss of control prevented. Such an airspeed is called a Minimum Control Speed, abbreviated V_{MC} or V_{MCA} for V_{MC} in the Air.

Minimum Control Speed V_{mc}

To understand the minimum control speed, a comparison with a rowboat with a coxswain might be useful. If, in a rowboat with a rower on each side, one of the rowers stops rowing, the boat starts to 'yaw', or turn (around). But if the speed through the water is high enough and the rudder large enough, the coxswain can still maintain the heading. But if the remaining rower puts in a little extra effort, the boat will yaw anyway, which can no longer be counteracted using the rudder, which is too small for the job. The speed at which the heading can just barely be maintained with full asymmetrical power and maximum rudder deflection is the minimum control speed of the rowboat. At lower speeds, the boat becomes uncontrollable if the remaining rower continues at maximum

power. However, the yawing can still stop if that rower slows down a bit. It is not different from a multi-engine airplane.

While a boat may stay afloat on the water, an airplane might lose altitude because of the increased drag due to the yawing; the asymmetrical propulsion causes a sideslip. The airplane will also descend if the pilot does not quickly decrease the sideslip by reducing the throttle of the remaining engine a little, temporarily, or by banking a few degrees away from the failed engine. Both options will be explained below.

Figure 1 shows the most important forces and moments acting on an airplane during straight flight with one engine inoperative (OEI). When keeping the wings level (Figure 1 left), the sideslip resulting from the rudder deflection (to counteract the asymmetrical thrust) generates an opposite side force due to sideslip. A heavily loaded airplane may consequently be unable to climb immediately after takeoff. The sideslip angle, and thus the sideslip-induced drag, can be reduced by maintaining a small bank angle in the direction away from the inoperative engine, but not more than 5° (Figure 1 right). This small bank angle generates a side force in the airplane's center of gravity (cg), which replaces the side force caused by the sideslip and hence, minimizes the sideslip angle hence drag, thereby maximizing climb performance after an engine failure (Figure 1 right). This small bank angle is therefore also called the favorable bank angle. The pilot now only needs to counteract the thrust yawing moment using the rudder, and not the sideslip side force anymore. Hence, the effect of the small bank angle is not only that the sideslip reduces, but also that the rudder deflection can be less, leaving room to reduce the speed until the rudder is again maximum deflected. In airworthiness regulations (FAR/CS 23.149), this lower speed, i.e. the speed at which straight flight with the favorable bank angle (of maximum 5°) and maximum rudder, and at maximum asymmetrical thrust in the takeoff configuration can just be maintained, is defined as minimum control speed V_{mc} .

FAR and EASA V_{mc} Definition

Certification Regulations FAR and CS define V_{mc} in § 23.149: " *V_{mc} is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane with that engine still inoperative, and thereafter maintain straight flight at the same speed with an angle of bank of not more than 5 degrees*".

In other words, FAR and CS 23 require a V_{mc} at which, after a sudden failure of the critical engine, the aerodynamic control surfaces rudder and ailerons generate just large enough forces to counteract the forces and moments due to the sudden asymmetrical thrust and maintain control, and *thereafter maintain straight flight* at V_{mc} while *also maintaining a small bank angle*, but not exceeding 5° . These two associated conditions are not communicated to pilots anymore.

Failure of the critical engine results in the highest, the worst-case V_{mc} after failure of any of the engines. V_{mc} after failure if any other engine is lower, is safer.

The airplane configuration for determining and using V_{mc} further includes but is not limited to: propeller feathered (only if auto-feather), maximum rudder and/or aileron control deflection (or a FAR/CS defined maximum control force), minimum all-up weight (see Figure 3 below), aft cg (for shortest rudder moment arm), a specific flap setting (usually takeoff), and the maximum thrust of the operating engine that a pilot can set with the throttle. The given values of these variables result in the worst-case, the highest V_{mc} for this, the takeoff, configuration which must be established as an operating limitation and furnished in the AFM or POH (FAR § 23.1583), and is to be red-lined on the airspeed indicator (FAR § 23.1545(b)(6)). This is in-fact the V_{mc} for takeoff and is therefore also used for calculating takeoff speeds V_R and V_2 . Refer to the FAA Flight Test Guide in Advisory Circular (AC)

23-8C.

An airplane has many more and also higher actual V_{mc} 's though, for configurations that deviate from the one in the FAR definition, because of deviating lateral-directional forces and moments, as will be explained below.

Flight Testing V_{mc}

Experimental V_{mc} flight-testing is conducted in accordance with the FAA Flight Test Guide AC 23-8C. Two V_{mc} 's are determined while the airplane is in the configuration as described in FAR 23 and AC 23-8C. After shutting down the critical engine and the other set at maximum thrust, the airspeed is slowly reduced until the heading can no longer be maintained. The speed at which this occurs is V_{mc} with the wings level. Then the bank angle is slowly increased to 5° away from the inoperative engine while also the airspeed is further decreased. The calibrated airspeed at which the heading again cannot be maintained, or at which the sideslip is zero, is the V_{mc} of the airplane that will be furnished in the AFM/POH after extrapolation to sea level. Some test pilots also determine V_{mc} for zero rudder (Figure 2), for which a larger bank angle into the good engine is required (and at which the sideslip is not zero). These flight tests confirm that V_{mc} varies with bank angle.

Following this static V_{mc} testing, the dynamic V_{mc} is determined by cutting the fuel to the critical engine at decreasing airspeed test points. The highest of static and dynamic V_{mc} is furnished as the V_{mc} of the airplane in the AFM/POH, which is usually the static V_{mc} . Refer to the FAA Flight Test Guides in Advisory Circulars AC 23-8C and AC 25-7D for more details.

Hence, V_{mc} varies with the bank angle and must only be measured during flight tests in straight-line flight, while maintaining the small favorable bank angle – but not exceeding 5° – in the direction away from the inoperative engine, for minimum sideslip.

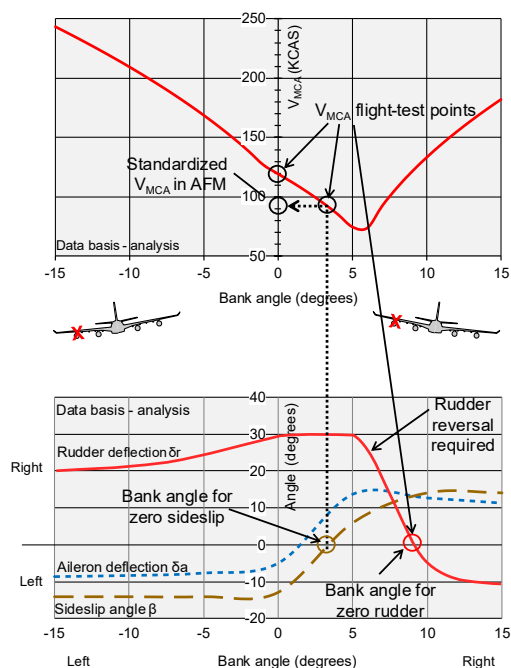


Figure 2. Effect of bank angle on V_{MCA} and on rudder, aileron, and sideslip angles during equilibrium flight at maximum thrust, of a sample airplane.

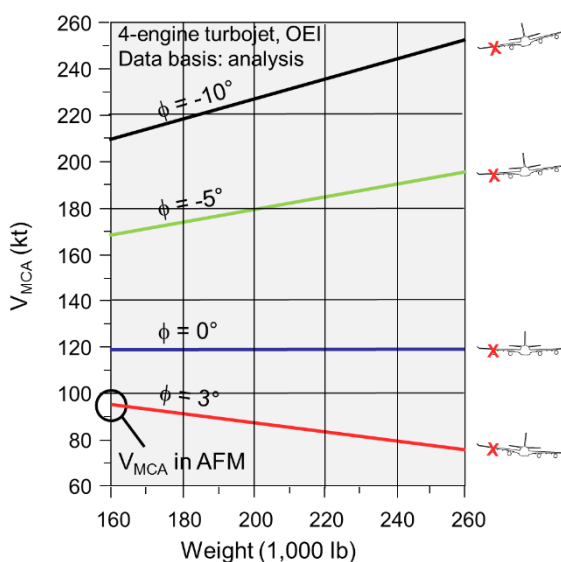


Figure 3. Effect of bank angle and weight on V_{MCA} .

NOTE. C-130 pilots know this figure, because it is like Figure 3-5, Bank Angle Effect on V_{MCA} , in the C-130 Performance Manual SMP-777.

Effect Of Bank Angle and Weight On Vmc

Because I became curious what Vmc would be at other bank angles into and away from the inoperative engine, I calculated Figures 2 and 3 using stability derivatives of a sample airplane in the (static) lateral-directional equations of motion, as also used to predict Vmc of new prototype airplanes before flight testing.

In compliance with FAR 23, the aerodynamic controls rudder and ailerons are only sized for maintaining straight flight after engine failure, while also maintaining a small (favorable) bank angle of 3° to 5° away from the inoperative engine, which not only decreases Vmc, as shown in Figure 2 and explained below, but also the sideslip angle, hence the drag. Most pilots don't know about the required small favorable bank angle anymore and believe to have to keep the wings level to within 5° to either side. Some pilots believe Vmc is always lower than 1.2 Vs, which is a requirement in FAR/CS 23.149(b), but this limit is for design engineers to ensure that the rudder is not sized too small. A smaller rudder requires a higher airspeed to generate the side forces for counteracting the asymmetrical thrust and the sideslip side force; hence, the minimum control speed Vmc is then higher. As shown in the Figures 2 and 3, Vmc will exceed 1.2 Vs during banking to either side. Smaller control surfaces do indeed save structural weight (hardware) and hence cost, but require an appropriate Vmc definition and emergency procedures in the AFM/POH (software), which should include maintaining straight flight and a small favorable bank angle when the airspeed is as low as or close to Vmc, including VR and V2 or Vyse, and a warning that Vmc increases with banking to either side.

Figure 2 also shows that the rudder needs to be reduced when the bank angle increases above 5°, is zero at 9° and needs to be reversed at larger bank angles into the good engine(s) for maintaining the balance of forces and moments, i.e. for not losing control, more specifically to prevent the fin with deflected rudder from stalling, due to the large side slip angle on a maximum cambered fin with rudder. These must be the reasons for limiting the bank angle to 5° into the good engine in FAR § 23.149 when the airspeed is Vmc and the asymmetrical thrust is maximum. A bank angle into the failed engine increases the sideslip to that side and requires maintaining a large rudder input and a higher airspeed for equilibrium of forces and moments, for maintaining control.

Figure 3 shows that Vmc is highest at low weight hence, is the worst-case weight but only when maintaining the FAR required small favorable bank angle, that should be maintained during takeoff.

Actual Vmc

As shown in Figures 2 and 3 above, bank angle has a large effect on both Vmc and on the resulting sideslip angle due to the asymmetrical thrust, not only during takeoff, but also in-flight when an engine is inoperative. The other mentioned configuration changes also affect the lateral-directional forces and moments and might require a higher speed to counteract.

Hence, Vmc and the sideslip angle/drag are adversely affected, i.e. increase to a (much) higher actual value, not only when banking away from the favorable 3° to 5° bank angle, as shown in Figures 2 and 3 above, but also by any asymmetrical configuration change in-flight, such as an inoperative auto-feathering propeller, an open cargo door, an accidentally deployed thrust reverser, an open engine cowling, a camera mounted on a wing tip, asymmetrical stores, unbalanced wing fuel, a separated engine, or by less than maximum rudder pedal travel, etc. Then the minimum speed for the control surfaces to generate the forces and moments required to maintain the balance of forces and moments, hence to maintain straight flight or to not lose control, is higher. The actual Vmc for the

actual configuration, weight and bank angle might be much higher than the AFM/POH furnished Vmc.

New Vmc Definition

In the new post-2017 FAR/CS 23.2135(c) the definition of Vmc is: *"Vmc is the calibrated airspeed at which, following the sudden critical loss of thrust, it is possible to maintain control of the airplane. For multiengine airplanes, the applicant must determine Vmc, if applicable, for the most critical configurations used in takeoff and landing operations."* A single engine airplane does not have a Vmc, only ME airplanes do. It seems not a requirement to be able to maintain control when any other engine than the critical engine loses thrust. And what about one engine inoperative performance, more specifically the requirement to reduce the sideslip during initial climb for which a small bank angle is definitely required but not larger than 5° which also prevents the pilot from having to reverse the rudder which is hard to learn. A ME airplane in the cruise configuration also has an actual Vmc as shown above – it's physics. *Maintaining control*, including during turns, requires much larger control surfaces than required in the old FAR/CS 23. So, are we going to see multi-engine airplanes with huge vertical tails and ailerons in the near future, or a § 23.2135(c) that is improved with appropriate knowledge of engine-out flight? The rule makers obviously did and still do not understand Vmc, and do not realize that requiring to maintain control after a sudden failure alone is not enough. An actual Vmc applies during the whole flight, both in anticipation of and following an engine failure, during straight flight and while banking. Manufacturers need knowledgeable guidance, as accident statistics and improper definitions of Vmc in current AFMs/POHs prove. The new § 23.2135 is deficient.

GAMA Vmc Definition

GAMA recommends manufacturers to use the following Vmc definition in the Pilot Operating Handbooks of their multi-engine (ME) airplanes: *"Air Minimum Control Speed is the minimum flight speed at which the airplane is directionally and laterally controllable, determined in accordance with the Federal Aviation Regulations. Airplane certification conditions include one engine becoming inoperative and windmilling (or, in airplanes with autofeathering devices, feathered), not more than a 5° bank toward the operative engine, takeoff power on the operative engine, landing gear up, flaps in the takeoff position, and the most critical C.G."*

There are two potentially killing errors in this GAMA Vmc definition, which are: *"Vmc is the minimum flight speed at which the airplane is directionally and laterally controllable"*, and the bank angle should be *"not more than 5° toward the operative engine"*. As already explained above, FAR 23 requires the airplane to be certified to be able to recover from a sudden failure and thereafter to only maintain straight flight, while maintaining a small bank angle (away from the failed engine) which may not exceed 5° and hence, FAR 23 does not require the airplane to be controllable, neither during wings-level flight, nor when exceeding 5° of bank, nor during banking to the other side while the airspeed is Vmc and maximum thrust is set on the operating engine. Figure 2 above shows the required increase of the minimum flight speed (the actual Vmc) for maintaining the equilibrium of forces and moments, i.e. for not losing control during banking to either side, which is required because of the increase of the sideslip angle to prevent the vertical fin with deflected rudder from stalling. Engine-out flight is not coordinated flight. An airplane is not controllable at Vs either, but can only maintain straight flight. When the stall horn sounds or the stick shaker activates, no pilot will change the rudder and aileron inputs because control will be lost if they do. The EMB-120 accident

proves that the airplane is not controllable at the higher takeoff speed V_2 either. Using "controllable" in a V_{mc} definition is incorrect, causes accidents because pilots then expect controllability.

Other errors are that GAMA does not recommend V_{mc} (and V_s) to be furnished in knots Calibrated Airspeed (but in IAS, therewith ignoring the instrument errors). FAR 23 requires the maximum thrust a pilot can set from the cockpit; takeoff power might be set lower.

A pilot must not make a turn or allow the airplane to bank when the airspeed is as low as, or close to V_{mc} , which is killing. The small bank angle is for minimizing (actual) V_{mc} and for reducing the sideslip, hence is required for maintaining control and for maximizing the remaining climb performance, as explained above. Not maintaining this bank angle also renders the takeoff speeds that were calculated with the AAFM/POH-furnished V_{mc} invalid, i.e. too low. The one-engine inoperative climb performance data in an AFM/POH is valid only when maintaining a small bank angle at climb speed V_{yse} . The GAMA V_{mc} definition is definitely not correct and does not prevent fatalities when an engine fails. The GAMA writer did not understand V_{mc} either. Many if not all ME-rated flight instructors and pilots flying today learned to interpret V_{mc} the wrong way, which must have led to many fatal accidents. Refer to the review of the GAMA Specification No. 1 on the Downloads Page of website AvioConsult.com (#14) and to paper #18 on airspeeds TAS, CAS and IAS (and V_{mc}).

Suggested V_{mc} Definition and Emergency Procedure Improvements in Pilot Manuals

After reading the above, it will be obvious that the definition of V_{mc} for (airline) pilots should be different from what GAMA recommends and is provided in the airplane certification FAR/CS 23.149. A V_{mc} definition for pilots could be: *" V_{mc} is the minimum speed in anticipation of, and after failure of any engine at which recovery is possible, and thereafter only straight flight can be maintained while also maintaining a small bank angle, but not exceeding 5° , away from the failed engine, while rudder and/or ailerons are maximum deflected and the (asymmetrical) thrust is maximum. V_{mc} varies with bank angle, controls deflection, and asymmetrical thrust level"*.

The associated conditions of V_{mc} , which are of life-saving importance to pilots, are *straight flight* and a *small bank angle away from the inoperative engine*. Other bank angles to either side increase the actual V_{mc} to a much higher value, because the bank angle increases the sideslip which can only be counteracted with a higher airspeed if the ailerons (and rudder) are already maximum deflected. V_{mc} is higher when banking and hence, is controlled by the pilot (if control is not yet lost).

In engine emergency (takeoff) procedures, a warning should be included to maintain straight flight and bank 5° into the good engine, to the same side as rudder pressure, or 3° at V_{yse} . Also, a warning on the increase of V_{mc} during turns to either side when the asymmetrical thrust is, or is increased to maximum in all flight phases will prevent accidents after engine failure.

Summarizing

Only one V_{mc} , the V_{mc} for the takeoff configuration, for straight flight while banking 3° to 5° away from the inoperative engine and the opposite engine at maximum asymmetrical thrust is required to be determined by FAR/CS 23.149 during experimental flight-testing and is to be furnished in the AFM/POH. This V_{mc} is a constant and is also used to calculate takeoff speeds V_R and V_2 . The actual V_{mc} in-flight however, is not a constant, but varies with many variables of which the most important ones are asymmetrical thrust level, bank angle, and magnitude of control inputs. Hence, the actual V_{mc} in-flight is controlled by the pilot and can be much higher than the AFM/POH furnished V_{mc} . An airplane is not controllable at V_{mc} , but can only maintain straight flight with the small 3° to 5° bank

angle away from the inoperative engine.

Compare V_{mc} with stall speed V_s which varies with flap setting and also with bank angle; when the stall horn sounds or the stick shaker is activated, no pilot will bank an airplane. V_{mc} though, is a silent killer and is not announced by a sound or a shaker, and therefore requires a simple rule: When rudder and/or ailerons are (near) maximum deflected, and maximum asymmetrical thrust is set or required, maintain straight flight while also maintaining a small 5° bank angle away from the inoperative engine, or 3° when at V_{yse} . If the airplane does not respond to control inputs, reduce the thrust (temporarily).

The minimum control speed, in general, is the lowest airspeed in any configuration and condition at which the aerodynamic controls rudder and ailerons generate just large enough forces and moments to maintain an equilibrium of all acting lateral-directional forces and moments, and hence prevent the loss of control. Both straight flight and the small favorable bank angle (between 3° and 5° away from the inoperative engine) decrease V_{mc} to the lowest possible actual value, decrease the sideslip angle, hence the drag and result in the maximum achievable rate of climb (Figure 2).

Incident Boeing 707, and Accident Boeing 747 After Engine Separation

An example of controlling V_{mc} and of the significance of knowing how to control V_{mc} are included in the following two abbreviated accident reports:

The distribution of engine thrust for keeping the actual V_{mc} under control, and for allowing safe turns when one or more engines are inoperative, was applied by a competent Boeing 707 flight crew after both engines #3 and #4 separated off the right wing above the French Alps (31 March 1992). During the turns for the approach, the copilot reduced the thrust of outboard engine #1 a bit and increased the thrust of inboard engine #2, thus reducing the sum of the asymmetrical thrust yawing moments while maintaining the same total thrust level. He in fact decreased the actual V_{mc} of the airplane. He also recommended a minimum speed of 200 kt to the captain, who was the pilot-flying, and selected flaps-one to unlock the outboard ailerons, therewith increasing the lateral control power. They landed safely on Airbase Istres in France. Knowledge of forces and moments saved their lives. Well done! Not all pilots consider managing V_{mc} by means of forces and moments.

Six months later, on 4 Oct. 1992 a Boeing 747 freighter also lost the two right engines #3 and #4, six minutes after takeoff from Amsterdam Airport at 6,500 ft. Despite the damaged leading edge of the right wing, the airplane remained controllable and completed nearly two full descending turns at less than maximum thrust on engines #1 and #2. When, during a right-hand standard turn to position for the approach, the thrust on both left-hand engines was increased to maximum, control was lost and the airplane went down in a suburb of the city. The asymmetrical thrust yawing moment had increased above the level that could be counteracted by the aerodynamic controls, even at an airspeed of 250 kt (Figure 2). The pilots were obviously never made aware of the effect of bank angle, weight, and thrust on the actual V_{mc} of their airplane. The investigators of the accident interviewed the Boeing 707 pilots, but regrettably did not conclude the increase of V_{mc} due to the inappropriate increase of both thrust levers while banking, as cause of the accident. Forces and moments were obviously not analyzed; the increase of actual V_{mc} with bank angle and thrust was also unknown. Investigators also need better training on airplane control after engine failure.

How Do I prevent a Dead Engine from Turning into a Killing Engine?

Remember that the AFM/POH furnished V_{mc} is for straight flight only while maintaining a small 3° to 5° bank angle away from the inoperative engine. Any other bank angle will increase V_{mc} to a higher actual value.

If an engine fails during takeoff, respond ASAP with adequate opposite rudder to maintain straight flight (not necessarily the runway heading), attain the favorable bank angle which the manufacturer should have provided (3° to 5° away from the inoperative engine for minimum sideslip and lowest actual V_{mc}), increase speed to V_{yse} and maintain until reaching a safe altitude. Don't turn.

When the airplane does not respond adequately to rudder and/or aileron inputs, the airspeed is below (actual) V_{mc} , leaving only three options to survive: increase the airspeed, or decrease V_{mc} by immediately reducing the asymmetrical thrust a little, temporarily, until straight flight with a small bank angle is established, or close the throttles and land straight ahead in the dirt with the wings-level, which is more survivable than with a wing tip first (which is what Lockheed also recommends for the C-130).

If an engine fails or is inoperative in-flight, avoid making turns when high asymmetrical thrust is set, or is required, at airspeeds below $V_{mc} + 20$ or more for small twins. When you need large control inputs, loss of control is imminent (if a high thrust setting is maintained).

V_{mc} In the Takeoff Briefing

Ensure that the Calibrated Air Speed (CAS) values in AFM/POH of V_1 , V_R , V_2 and V_{mc} are corrected with both the position and the instrument errors to Indicated Air Speed (IAS) values, if applicable, to prevent too low takeoff speeds. Set bugs, or write on the Takeoff Data Card.

During the takeoff briefing, not only V_1 , V_R , and V_2 should be reviewed besides the other standard subjects, but also V_{mc} and the engine emergency procedures that are applicable during takeoff and initial climb. A suggestion: *"In case an engine fails before reaching V_1 (or V_R), close the throttles immediately. After engine failure above V_1 , apply rudder to maintain straight flight and bank 5° into the good engine, to the same side as the rudder pedal, and climb at V_{yse} (blue line) with 3° of bank until reaching a safe altitude, and continue with the checklist or QRH. If the airplane does not respond adequately to maximum control inputs, either increase the airspeed, reduce the asymmetrical thrust a little temporarily (to decrease V_{mc}) until straight flight with 3° to 5° bank is attained, or close the throttles and land wings-level straight ahead; there is only 4 to 5 seconds time to decide. Remember that banking away from the 5° increases V_{mc} and causes loss of control. The remaining Single Engine Rate of Climb can be very small; take your time and resist turning back for landing too soon. Don't turn at maximum asymmetrical thrust setting at speeds lower than $V_{mc} + 20$ (or more) for small twins."*

Fly safely,

AvioConsult - Harry Horlings

Graduate Flight Test Engineer of the USAF Test Pilot School (Class 85A).

<https://www.avioconsult.com>

The EMB-120 accident of the picture above is briefly analyzed in my YouTube video:

<https://www.youtube.com/watch?v=Wbu6X0hSnBY>.

The reviewed ATSB Safety Report with many remarks and a link to the full animation can be downloaded here: [https://www.avioconsult.com/downloads/Review report accident EMB-120ER 2010-03-22 AO2010019.pdf](https://www.avioconsult.com/downloads/Review%20report%20accident%20EMB-120ER%202010-03-22%20AO2010019.pdf).

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- *Limited Review of GAMA Specification No. 1 for Pilot's Operating Handbook*, Harry Horlings, AvioConsult, <https://www.avioconsult.com/downloads/GAMA Specification No.1 for Pilot's Operating Handbook, Limited Review.pdf> (#14).
- *Safety-Critical Procedure Development Requires High Level Multi-Disciplinary Knowledge*, a paper presented at the Safety Forum in Brussels, June 2019, Harry Horlings, AvioConsult, <https://www.avioconsult.com/downloads/Safety-critical Procedure Development.pdf> (#12).
- *Reviews of POHs/AFMs*, <https://www.avioconsult.com/downloads>, from #15.
- *Airplane Control and Analysis of Accidents after Engine Failure*, Harry Horlings, AvioConsult, <https://www.avioconsult.com/downloads/Airplane Control and Analysis of Accidents after Engine Failure.pdf> (#3).

College books, Test Pilot School course books, and Flight Test guide:

- Airplane Design, Part II: *Preliminary Configuration Design and Integration of the Propulsion System*, Chapter 11, Dr. Jan Roskam, University of Kansas, DARcorporation.
- Airplane Design, Part VII, *Determination of stability, control, and performance characteristics*, Dr. Jan Roskam, University of Kansas, DARcorporation.
- *Pitot-Statics and the Standard Atmosphere*, 4th edition (Jul 2020), Russell E. Erb, USAF Tet Pilot School, <https://apps.dtic.mil/sti/pdfs/AD1115005.pdf>.
- *Flying Qualities Textbook*, Volume II, USAF Test Pilot School, 1986.
Part 1, https://ia800107.us.archive.org/32/items/DTIC_ADA170959/DTIC_ADA170959.pdf,
Part 2, https://ia801001.us.archive.org/17/items/DTIC_ADA170960/DTIC_ADA170960.pdf. Chapter 11 is on flight with asymmetrical thrust.
- *FAA Flight Test Guide Part 23 Airplanes* (Controllability and Maneuverability, including V_{MCA} testing, in Section 4.4 § 23.149), https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_23-8C.pdf.