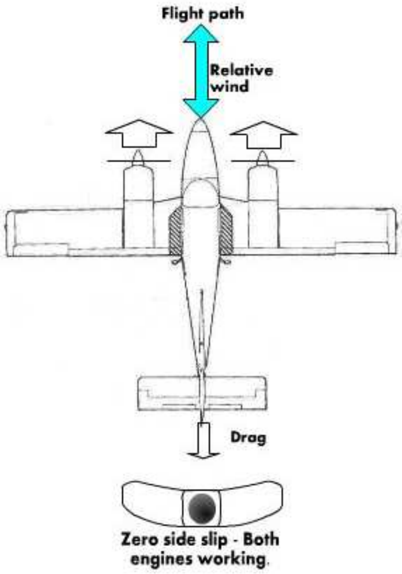
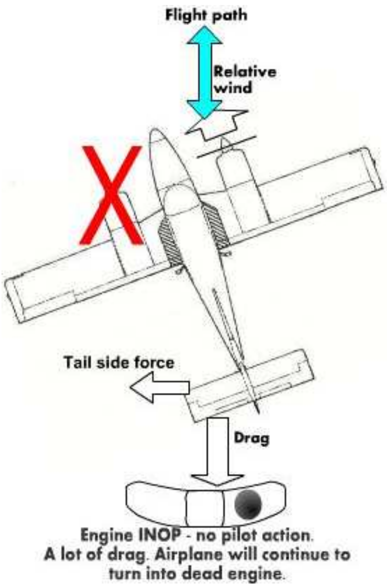
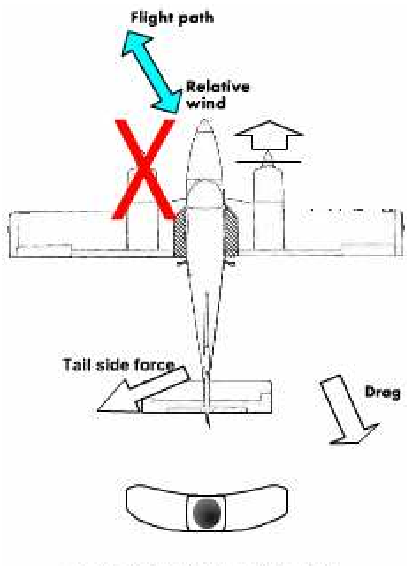
Multiengine: engine-inoperative principles

Side slip vs. zero side slip

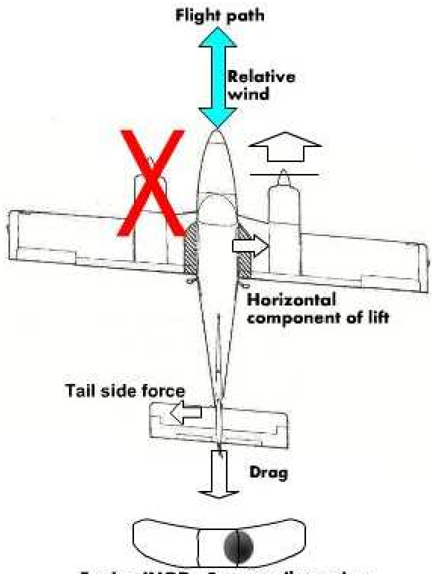


- With a multiengine airplane with all its engines operating, sideslip is eliminated by keeping the ball in the inclinometer centered, just the same as done with a single engine airplane. This is called zero sideslip and is the condition where the airplane is presenting the smallest profile to the relative wind, creating minimum drag.
- On a multiengine airplane with an inoperative engine a centered ball is no longer an indication for zero sideslip as a result of asymmetrical thrust.
- Even with the ball centered, on a multiengine airplane producing asymmetrical thrust, we are still flying in a side slip due to the lateral force created by the rudder.
- The only equipment that can indicate slip in an asymmetrical thrust condition is a yaw string attached to the windshield.
- To achieve zero side slip with one engine inoperative we should use both rudder and ailerons. Place 1/2-1/3 of the ball out of its cage towards the operative engine and use about 2° of bank towards the operative engine ("raise the dead" engine). The opposing forces of horizontal component of lift and rudder side force will eliminate the sideslip.
- Zero side slip will give us best performance and directional control.
- Remember that loss of directional controlled is caused by asymmetrical thrust. The reduction of power will restore the directional control, but will also decrease performance.
- When a light twin loses an engine, it loses 80% of its climb performance, due to the increased drag and decrease in excess power required for a climb.





Engine INOP - Wrong pilot action. Rudder applied to center the ball but the airplane is still in a side slip due to the rudder force and the asymmetrical thrust, creating a lot of drag.

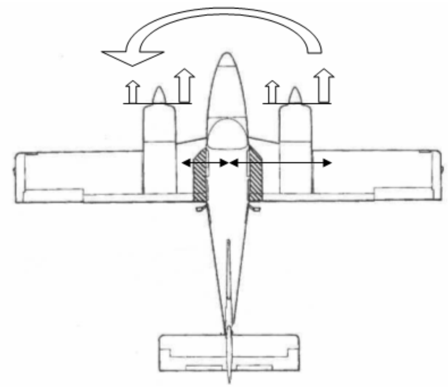


Engine INOP - Correct pilot action, resulting in a zero-sideslip. Bank 2-3 degrees towards the good engine. Rudder input is just enough to place 1/2-1/3 of the ball out of its cage.

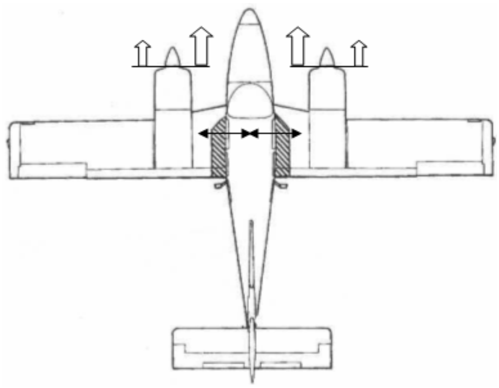
Critical Engine – The critical engine is the engine whose failure would most adversely affect the performance or handling qualities of the airplane. (FAR 1.1). On conventional light twins both propellers rotate clockwise (from pilot's point of view) making the left engine critical. Other twins overcome the problem, of having a critical engine, by having counter-rotating engines (right engine rotates counter-clockwise) and the effect of loosing either one of the engines would be the same.

Four factors that make the left engine critical on a conventional western twin:
P-Factor (asymmetric thrust)
Accelerated slipstream
Spiraling slipstream
Torque

P-Factor(yaw)
On high angles of attack, the descending blade (right blade) produces more thrust then the ascending blade (left blade). The descending, right, blade on the right engine has a longer arm from the CG than the descending (right) blade of the left engine, creating a yaw force to the left.

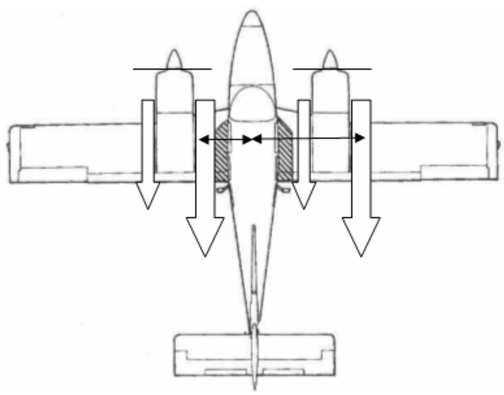


P- Factor causes a conventional twin to yaw to the left. Failure of the left engine will cause more loss of directional than loss of right engine because of the longer arm of the right engine's thrust from the CG.

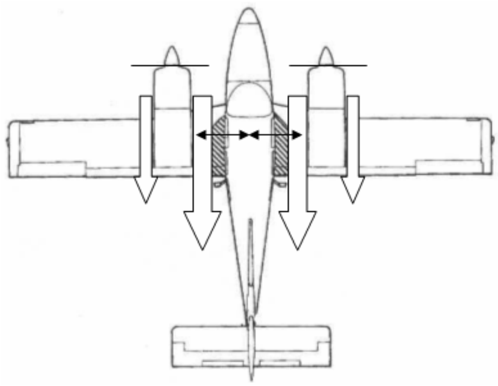


P- Factor counter-rotating engines, no yaw produced. Failure of either left or right engine will cause the same amount of directional control loss.

Accelerated slipstream (roll and pitch)
As a result of p-factor, stronger induced lift is produced on the right side of the right engine than on the left side of the left engine by the prop wash.

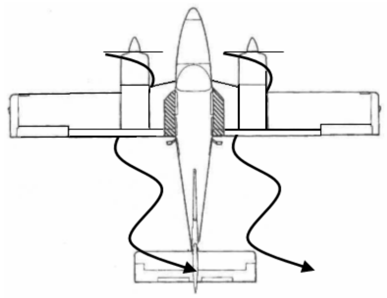


Accelerated slipstream. Conventional twin. In case of a left engine failure, there would be a strong moment rolling the plane to the left. Also on a failure of the left engine, less negative lift will be produced by the tail, resulting in a pitch down.

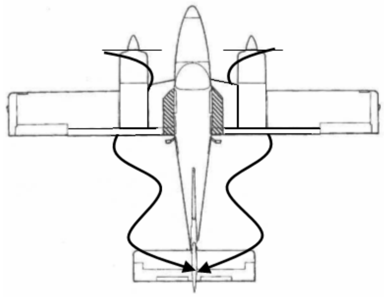


Accelerated slipstream. Counter-rotating engines. Failure of either engines will result in the same loss of control. The arms from the CG are much closer than they are in case of a left engine failure on a conventional twin.

Spiraling Slipstream. The spiraling slipstream from the left engine hits the tail from the left. In case of a right engine failure on a conventional twin, this tail force will counteract the yaw towards the left dead engine; but in case of a left engine failure, the slipstream does not hit the tail to counteracts the yaw, so there is more loss of directional control.

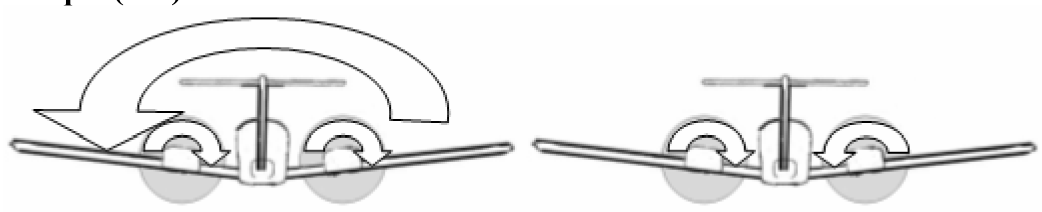


Conventional twin.



Counter-rotating engines.

Torque (roll)



Conventional twin. Counter-rotating engines.

For every action there is an opposite an equal reaction (Newton 3rd law of motion). As a result of the propellers turning clockwise on a conventional twin, there is a left rolling tendency of the airplane. If the right engine fails, this left roll tendency will help us maintain control and resist the right roll towards the right, dead engine, caused by asymmetric thrust; but if the left engine fails, the left roll tendency by torque will add to the left turning force caused by asymmetric thrust, making it much more difficult to maintain directional control. This makes the left engine critical.
On a counter-rotating twin, No matter which engine fails, torque will oppose the roll created by asymmetric thrust.

VMC

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. The method used to simulate critical engine failure must represent the most critical mode of powerplant failure expected in service with respect to controllability. (FAR 23.149)

- Published Vmc is marked as a red line on the airspeed indicator.
- Actual Vmc changes with different factors, while **published** Vmc remains the same.
- Published Vmc is <u>close</u> to the worst case scenario, actual Vmc may be lower, especially after feathering the inoperative engine's propeller. Don't bet your life on that fact, Vmc may be higher than you assume it is.
- Vmc, as defined by 23.149 must not exceed 1.2 Vs1.
- **Vsse** is the Single engine safety speed. This speed is slightly higher than published Vmc and creates a safety buffer from Vmc for intentional engine out operations. We should never fly the airplane below Vmc or Vsse, if published, under single-engine operations.
- **Why is directional control affected by airspeed?**
  The faster the airspeed the more force the rudder can produce to resist the yawing tendency caused by asymmetrical thrust.

Conditions by which Vmc for takeoff is determined by the manufacturer <u>for certification of the airplane</u>: (FAR 23.149. Airplane Flying Handbook p. 12-28)

1. Standard atmosphere. (FAR 23.45)
2. Most unfavorable CG and weight.
3. Out of ground effect.
4. Critical engine INOP.
5. Bank no more than 5° towards operating engine.
6. Max available takeoff power on each engine initially.
7. Trimmed for takeoff.
8. Wing flaps set to takeoff position.
9. Cowl flaps set to takeoff position.
10. Landing gear retracted.
11. All propeller controls in takeoff position. (INOP engine windmilling)
12. Rudder force required by the pilot to maintain control must not exceed 150 pounds.
13. It must be possible to maintain heading ±°20.

<u>How different factors affect Vmc and performance</u>:

Factor	Vmc	Performance
Increase in density altitude	Decreases (good)	Decreases (bad)
Increase in weight	Decreases (good)	Decreases (bad)
Windmilling prop (vs. feathered)	Increases (bad)	Decreases (bad)
Aft CG	Increases (bad)	Increases (good)
Flaps extended	Decreases (good)	Decreases (bad)
Gear retracted	Increases (bad)	Increases (good)
Up to 5° Bank towards good engine	Decreases (good)	Increases (good)

You can see that directional control and performance are completely different things. Factors that are good for Vmc, or directional control, are not necessarily good for performance.

On the occasion of an engine failure we should establish Vyse, since it will give us best climb performance. This best climb performance in the specific conditions may still only be a descent. A climb is not guaranteed for light multi engine airplanes.

Certification requirements to determine climb performance: (FAR 23.67)
-Multiengine aircraft with a maximum certified weight of less than 6,000 lbs with a Vso of less than 61 knots have no minimum climb performance requirement by the FARs. The performance at 5,000 feet only has to be determined but is not required to result in a climb.
-Multiengine aircraft that have a maximum weight of more than 6000 lbs or Vso more than 61 knots must be able to climb at 5,000 feet.

What should we do in case of an engine failure in flight on a multiengine airplane?

- Maintain directional control.
- Airspeed – Vyse (blue line)
- Drag – reduce.
  - Flaps up
  - Gear up
- Identify the dead engine ("dead foot, dead engine")
- Verify that you recognized the correct engine by reducing its throttle.
- Decide: feather or trouble shoot(if you have enough altitude – troubleshoot; otherwise- feather)
- Troubleshoot (try restart, refer to your aircraft's POH)
- Feather inoperative propeller if necessary.
- Secure inoperative engine.

Two different sets of bank angles are used in an engine failure event (Airplane Flying Handbook p. 12-25):

- *To maintain directional control of a multiengine airplane suffering an engine failure at low speeds (such as climb), momentarily bank at least 5°, and maximum of 10° towards the operative engine as the pitch attitude for VYSE is set.*
- *To obtain the best climb performance, the airplane must be flown at VYSE and zero sideslip, with the failed engine feathered and maximum available power from the operating engine. Zero sideslip is approximately 2° of bank toward the operating engine and a one-third to one-half ball deflection, also toward the operating engine. The precise bank angle and ball position will vary somewhat with make and model and power available. If above the airplane's single-engine ceiling, this attitude and configuration will result in the minimum rate of sink.*

Vmc Demonstration

This maneuver demonstrates the loss of directional control that results from decrease in airspeed.

- Pre-maneuver checklist
- Altitude no lower than 3000 feet (5000' by BE-76 POH)
- Landing gear – up
- Flaps - set for takeoff
- Cowl flaps – takeoff position
- Trim – takeoff position
- Propellers – high RPM
- Power on critical engine –Idle
- Power on operating engine – Set for takeoff or max available power
- Establish single engine climb attitude with airspeed about 10 knots above Vsse
- Establish a bank towards the operative engine as required for best performance (normally about 2°-3°)
- Increase pitch attitude slowly at 1 knot per second. As airspeed decreases apply more rudder pressure to maintain directional control until full rudder is applied.
- Recognize and announce the first indication of a loss of directional control or a stall.
- Recover within 20° of the heading by reducing the power and decreasing the angle of attack to regain airspeed.
- Advance power smoothly and accelerate to Vxse or Vyse ±5 knots.

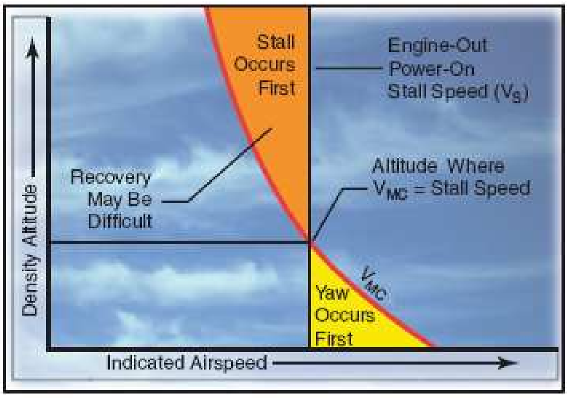


Figure 12-21. Graph depicting relationship of V_{MC} to V_S.

Critical density altitude

As the altitude increases, calibrated stall speed remains the same while Vmc decreases for airplanes with normally aspirated engines (not turbocharged). At a certain altitude Vmc is equal to the stall speed. At that critical altitude Loss of directional control will result at the same time with a stall, this may lead to a spin. Above the critical altitude, a stall will occur before the loss of directional control. When practicing Vmc Demo, it is important to be careful and recover at the first indication of a stall. You may still demonstrate Vmc at an altitude higher than the critical altitude by limiting the amount of rudder used to simulate full deflection.

Factors that affect climb performance:

- Airspeed: Best climb performance is achieved at Vyse.
- Power: More power=better performance.
- Weight: more weight = less performance
- Drag: more drag=less performance

Drag

Drag reduces both directional control (increase in Vmc) and performance. The main contributors to drag are, by order:

- The windmilling prop – normally produces most of the drag.
- Full flaps extended.
- Landing gear extended.
- First notch of flaps extended.

Drag demonstration

The objective of this maneuver is to demonstrate the effects of different configurations on the aircraft's performance.

- Pre-maneuver checklist
- Altitude no lower than 3000 feet
- Landing gear – up
- Flaps – up
- Establish zero thrust on critical engine (if applicable)
- Full power on other engine
- Establish Vyse
- Vary the speed from Vyse and note effect on performance.
- Maintain Vyse and demonstrate the effect of each of the following:
    Extension of landing gear
    Extension of wing flaps
    Extension of both landing gear and wing flaps.
    Windmilling of propeller (move throttle of simulated inop engine to idle)
- Restore power slowly on both engines
- Monitor engine gauges