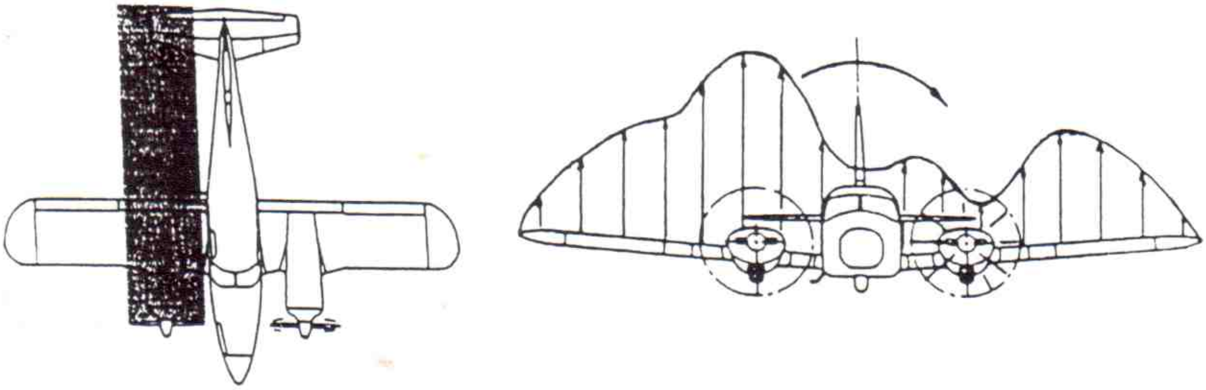
Aerodynamics for Light Twins

One of the primary reasons the FAA insists on having a multi engine rating is that a potentially severe directional control problem exists if one engine suddenly becomes inoperative. When a multi-engine aircraft has an engine failure, there will be unbalanced turning forces and turning moments about the CG. Directional control effects include:

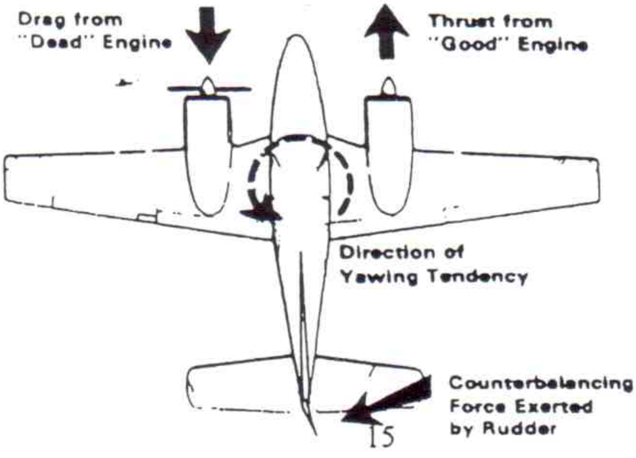
ROLL

Loss of the accelerated slipstream air over the wing with the inoperative engine results in a loss of lift from that wing. Therefore, the aircraft will tend to roll into the dead engine, due to asymmetrical lift. This requires additional aileron into the operative engine.



YAW

Asymmetrical thrust causes yaw. This will require rudder towards the operative engine. (Remember: Dead foot - Dead engine)



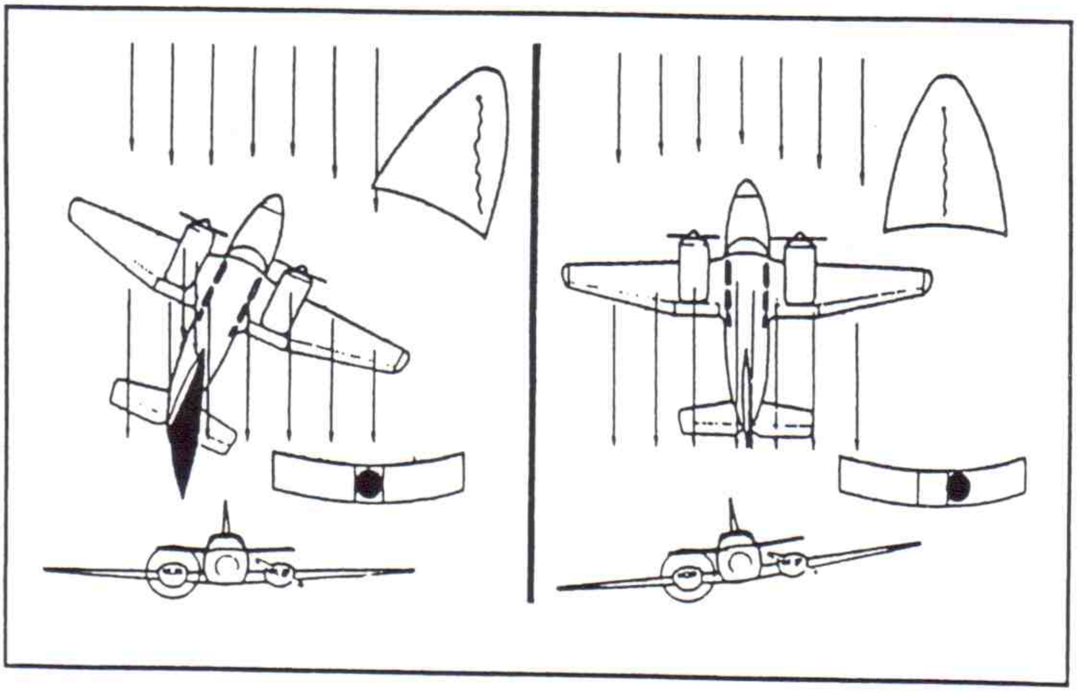
ZERO SIDE SLIP

Using rudder to keep the ball centered and counteract the roll and yaw forces caused by an inoperative engine creates another problem. With the wings level and the ball centered, the relative wind will strike the fuselage at an angle resulting in a slip, therefore, increasing drag.

However, banking into the good engine will create enough lift horizontally to oppose the lift created by the rudder thereby canceling all lateral forces. It is important, however, that the correct amount of bank is used - you need only enough to bank to counteract the lateral force created by the rudder. For best performance, use 2-3 degrees of bank and the ball should be ¼ to ½ out to the good engine. This provides two benefits:

1) Since the relative wind does not strike the fuselage at an angle, drag is reduced. This improves *PERFORMANCE.*

2) Since the relative wind does not strike the vertical stabilizer at an angle, less rudder is required to overcome the yaw. This improves *CONTROL.*



Defining the Critical Engine

The critical engine on a twin is the engine whose failure most adversely affects the performance and handling characteristics of the aircraft. For aircraft with:

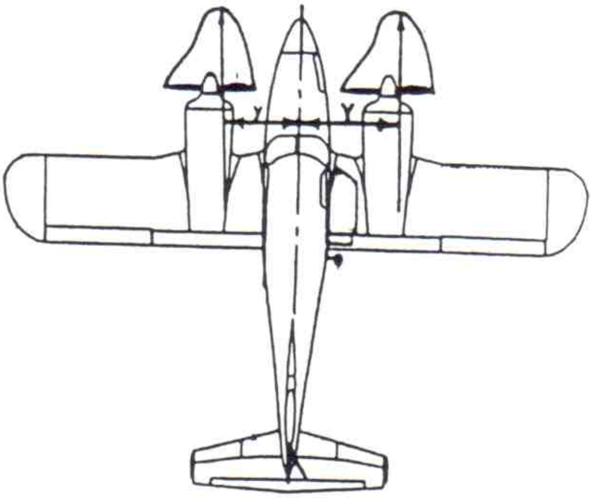
Clockwise rotating propellers (conventional twin), the LEFT engine is critical. Some examples include: Cessna 310, Beech Baron, Piper Aztec.

Counter-rotating propellers, there is NO critical engine. Some examples include: Piper Seminole, Beech Duchess.

Counterclockwise rotating propellers, the RIGHT engine is critical. i.e. Mitsubishi MU2

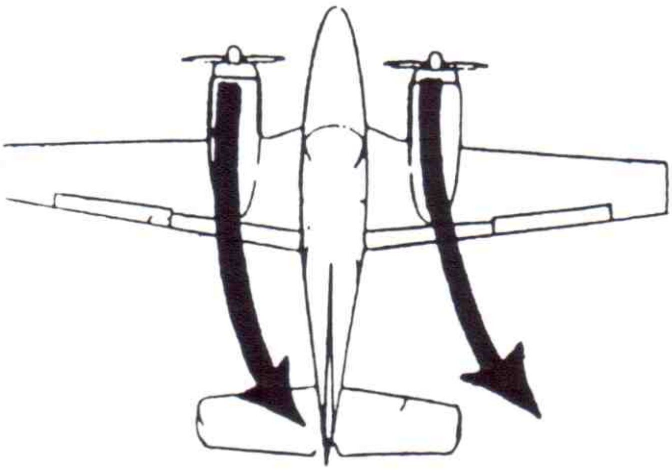
Factors that Make the Left Engine Critical

P-factor: In climbs, the descending blade produces more thrust than the ascending blade. The descending blade on the right engine has a longer moment arm than the descending blade on the left engine. Therefore, the yaw created by the left engine is less than that created by the right engine. Losing the left engine would be more critical than losing the right engine.



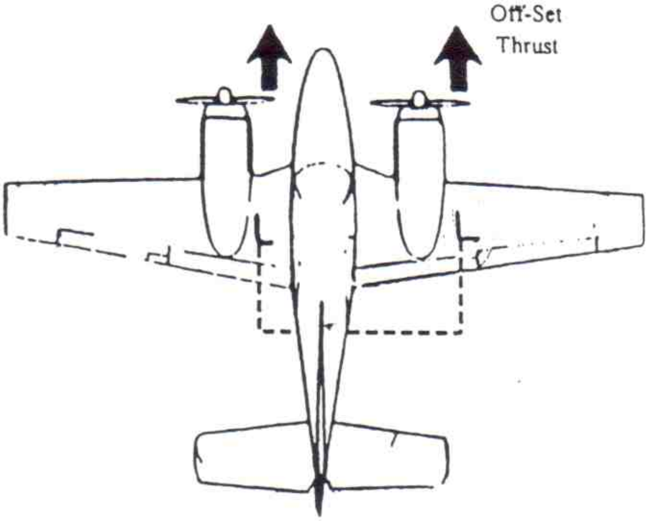
P-factor

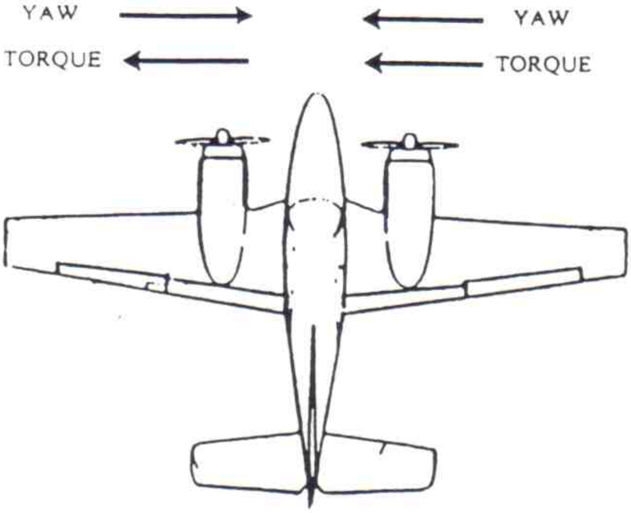
Spiraling Slipsteam: The spiraling slipstream from the left engine hits the vertical stabilizer on the left side, which counteracts some of the yaw created by the failure of the right engine. The spiraling slipsteam from the right engine doesn't hit the vertical stabilizer. Therefore, it can't help to counteract the yaw created by the failure of the left engine. This also makes the left engine critical.



Spiraling Slipsteam

Accelerated Slipstream: At positive angles of attack, P-factor moves the thrust centerline to the right. Movement of the center of thrust also moves the center of lift farther out on the right wing than on the left. As a result, the moment arm on the right wing is longer than the left. If the left engine fails, there will be a greater rolling tendency.





Torque: For every action, there is an equal and opposite reaction. If the right engine fails, the aircraft will yaw right, but roll left due to torque. These forces will partially cancel each other out. If the left engine fails, the aircraft will yaw and roll to the left. Again, the left engine is critical.

Defining Minimum Control Speed (Vmc)

Vmc is the slowest airspeed in which DIRECTIONAL CONTROL can be maintained with the critical engine suddenly made inoperative with takeoff power on the operating engine. Vmc is marked on the airspeed indicator with a red radial line.

Airspeed control must be precise. By maintaining a speed faster than the published Vmc, the pilot should be able to maintain DIRECTIONAL CONTROL of the aircraft.

FAR 23.149 discusses the method by which Vmc shall be determined by the manufacturer. For reciprocating engine powered airplanes, Vmc may not exceed 1.2 Vs1 under the following conditions:

Condition	Effect on Directional Control	
1) Takeoff power on the operating engine	Adverse	RAISE VMC TO HIGHER AIRSPEED
2) Cowl flap open on operating engine	Adverse	
3) Critical Engine windmilling	Adverse	
4) Landing Gear Up	Adverse	
5) Most adverse CG position (generally aft)	Adverse	
6) Sea Level/Standard Day	Adverse	
7) Airborne and out of ground effect	Adverse	
8) Trim in the takeoff position	Neutral	
9) Flaps in takeoff position	Neutral	
10) Not more than 5° of bank into the operative engine	Positive	LOWERS VMC TO SLOWER AIRSPEED
11) Maximum gross weight	Positive	

Factors Affecting the Airspeed at which Vmc Occurs

(Assume full rudder deflection)

MAKE VMC
AS HIGH AS POSSIBLE

Takeoff Power on the Operating Engine MORE POWER HIGHER VMC

This condition creates the most adverse yaw to overcome. Decreasing power will decrease the amount of turning moment and therefore, decrease Vmc.

~~Cowl Flap Open on the Operating Engine~~ COOL ENGINE = MORE POWER = HIGHER VMC

This maximizes engine efficiency and the power it can produce. If the cowl flap were closed, the engine would not operate as efficiently which would reduce the turning moment and reduce Vmc.

Critical Engine Windmilling MORE DRAG = HIGHER VMC

A windmilling engine creates drag on the side with the inoperative engine thereby increasing yaw into the inoperative engine. Feathering the failed engine would reduce the drag, reduce the turning moment, and reduce Vmc.

Landing Gear Up = HIGHER VMC

When the gear is down, the gear doors and wheels provide "keel effect" which resists the yawing moment. Lowering the landing gear will reduce turning moment and, therefore, reduce Vmc.

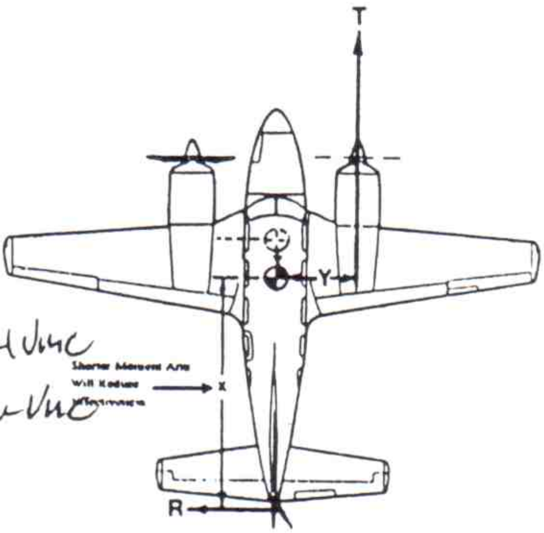
DOWN = LOWER VMC

Most Adverse CG Position

This is generally the aft position. As the CG moves aft, it decreases the moment arm between the CG and the rudder. This gives the rudder less leverage, reduces rudder effectiveness and increases Vmc. Moving the CG forward will increase rudder leverage, increase rudder effectiveness, and decrease Vmc.

AFT CG = LESS RUDDER AUTHORITY - HIGH VMC

FORWARD CG. = MORE AUTHORITY = LOWER VMC



Sea Level/Standard Day

As density altitude increases, the operative engine and propeller will produce less thrust. The reduction in yawing force therefore decreases Vmc. Remember, however, Vmc will always occurs at the same *indicated airspeed*

LOW DENSITY ALT = MORE POWER = HIGH VMC

HIGH DENSITY ALT - LESS POWER - LOW VMC

~~Outside of Ground Effect~~

Ground effect reduces induced drag and "increases" lift, therefore reducing Vmc.

~~Takeoff [illegible]~~

This has no effect on Vmc.

Flaps in the Takeoff Position

This has no effect on Vmc.

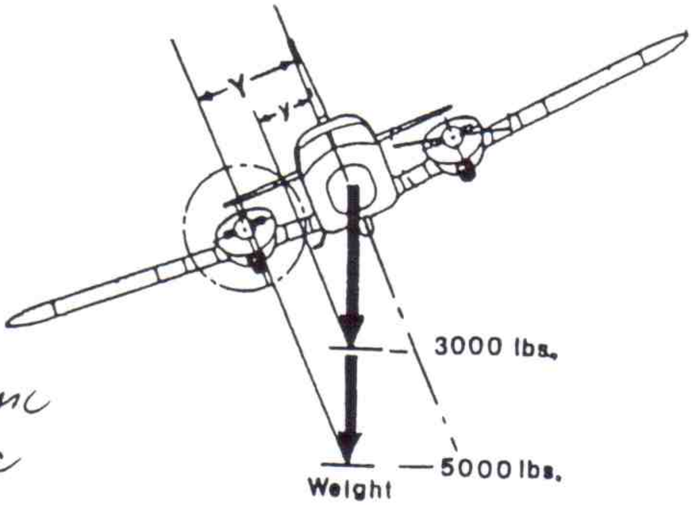
Up to 5° of Bank into the Operative Engine

Banking into the operative engine reduces the workload of the rudder, therefore reducing Vmc. This improves control. Vmc will decrease approximately 3 knots for each degree of bank used, but it is important to understand that too much bank will hurt *performance*. For best *performance*, zero side slip must be maintained.

Bank = Lower Vmc

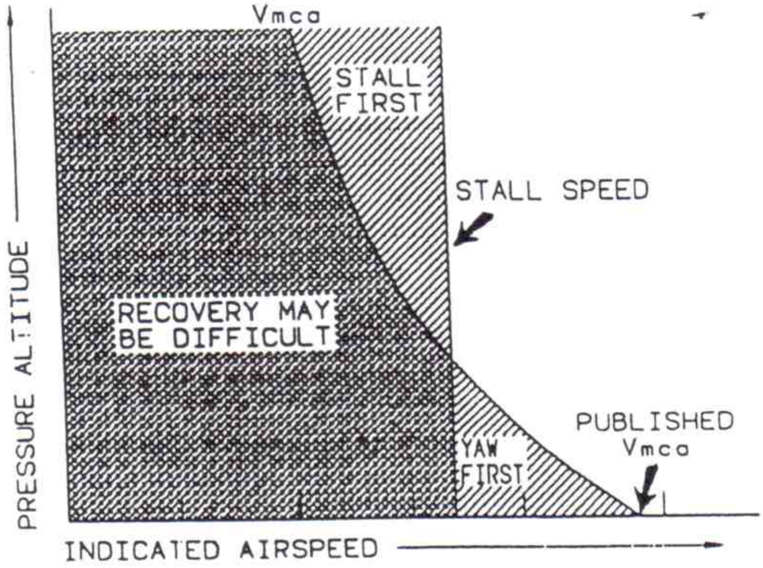
Maximum Gross Weight

When the airplane is banked, a component of weight acts horizontally along the wing into the operative engine. As aircraft weight increases, this component of weight increases and counteracts the turning moment created by the inoperative engine. This increased force helps to reduce Vmc. Reductions in weight will reduce the horizontal component and increase Vmc.



Higher Weight · Lower Vmc
Low Weight - High Vmc

Vmc vs. Stall Speed



Relationship Between Stall Speed and Vmc
For Aircraft with Normally Aspirated Engines