FLIGHT PRINCIPLES ENGINE INOPERATIVE

XIV. Task C.

JWH Aviation Services

OBJECTIVE:

To familiarize the student with the various flight principles related to single engine operation.

CONTENT:

1. Meaning of the term “critical engine.”
2. Effects of density altitude on the VMC demonstration.
3. Effects of airplane weight and center of gravity on control.
4. Effects of bank angle on VMC.
5. Relationship of VMC to stall speed.
6. Reasons for loss of directional control.
7. Indications of loss of directional control.
8. Importance of maintaining the proper pitch and bank attitude, and the proper coordination of controls.
9. Loss of directional control recovery procedures.
10. Engine failure during takeoff including planning, decisions, and single-engine operations.

Schedule:

- 2 Hours

Equipment:

- Ground Lesson Content
- FAR Part 61
- AC 61-65F
- Airplane Flying Handbook FAA-H-8083-38
- FAA-S-ACS-7A Commercial ACS

Instructor Actions:

- Discuss above elements and answer/ask questions

Student Actions:

- Take notes, and answer questions. Ask questions if any arise

Completion Standards:

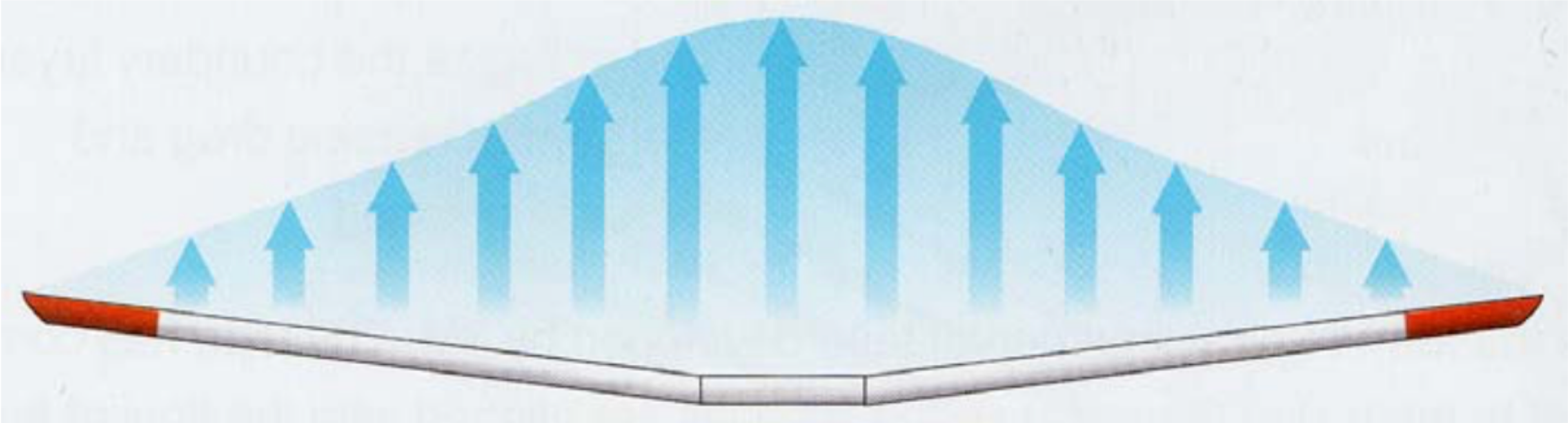
- The lesson is complete when the elements are discussed, and questions answered. Student should be able to answer questions related to elements in this lesson.

1. MEANING OF THE TERM "CRITICAL ENGINE."

MULTIENGINE AERODYNAMICS

INDUCED FLOW

Looking at the airplane without the engines and the fuselage, the amount of lift created by the wings would look like this:



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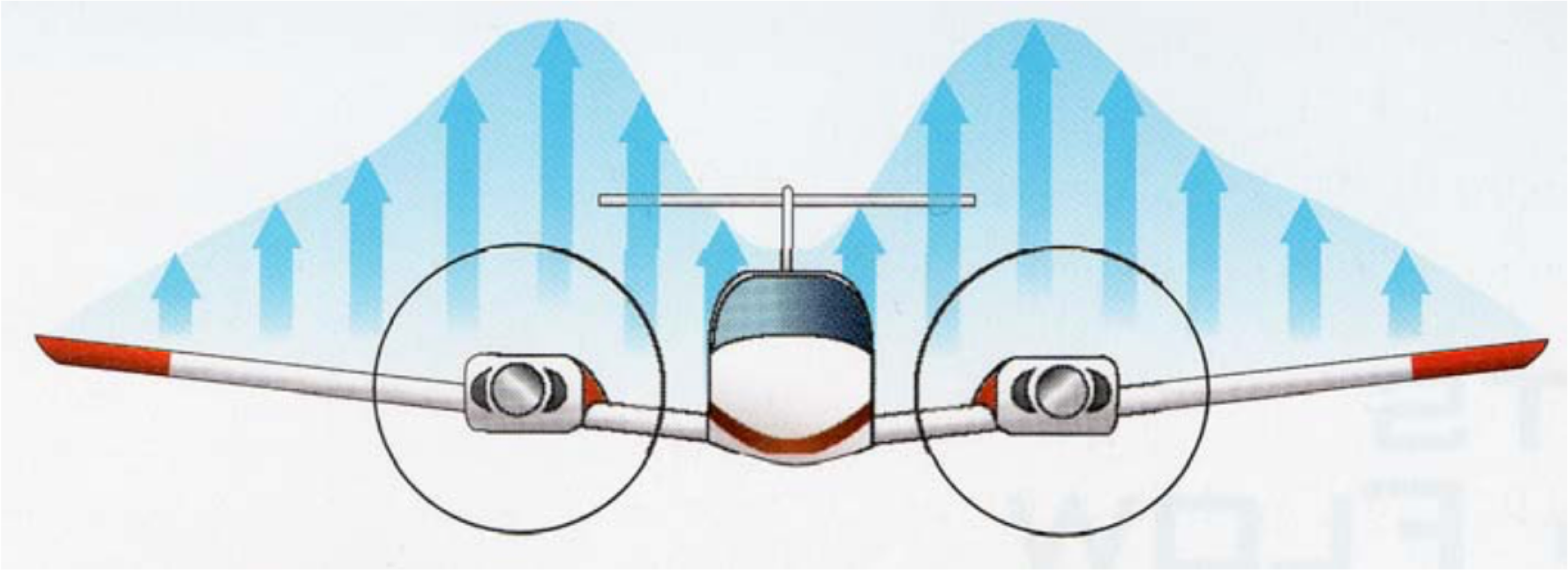
The propellers of the wing mounted engines create an accelerated flow or accelerated slipstream of air over the wings called induced flow. The amount of lift created by a multi engine airplane looks like this:



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Induced flow does occur in single-engine airplanes, but it is not as much of a factor because of the location of the engine in relation to the wings.

TURNING TENDENCIES

The turning tendencies that affect single engine airplanes

P | P-Factor

A | Accelerated Slipstream

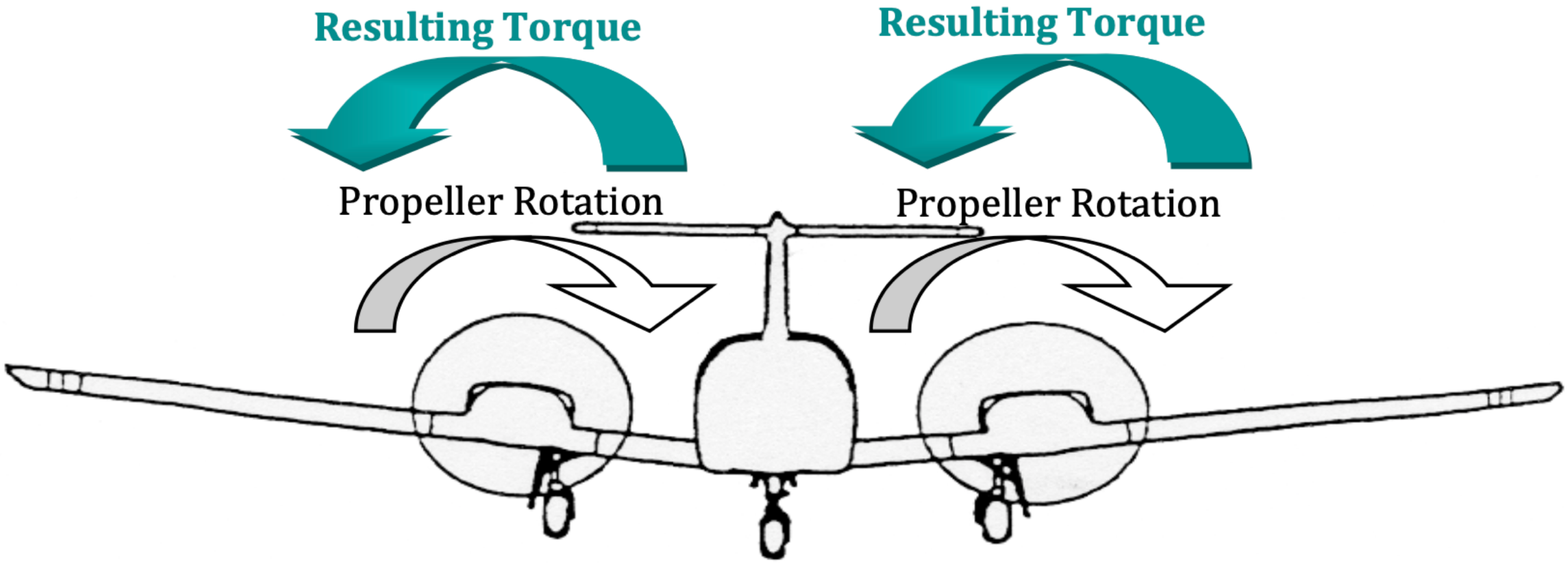
S | Spiraling Slipstream

T | Torque

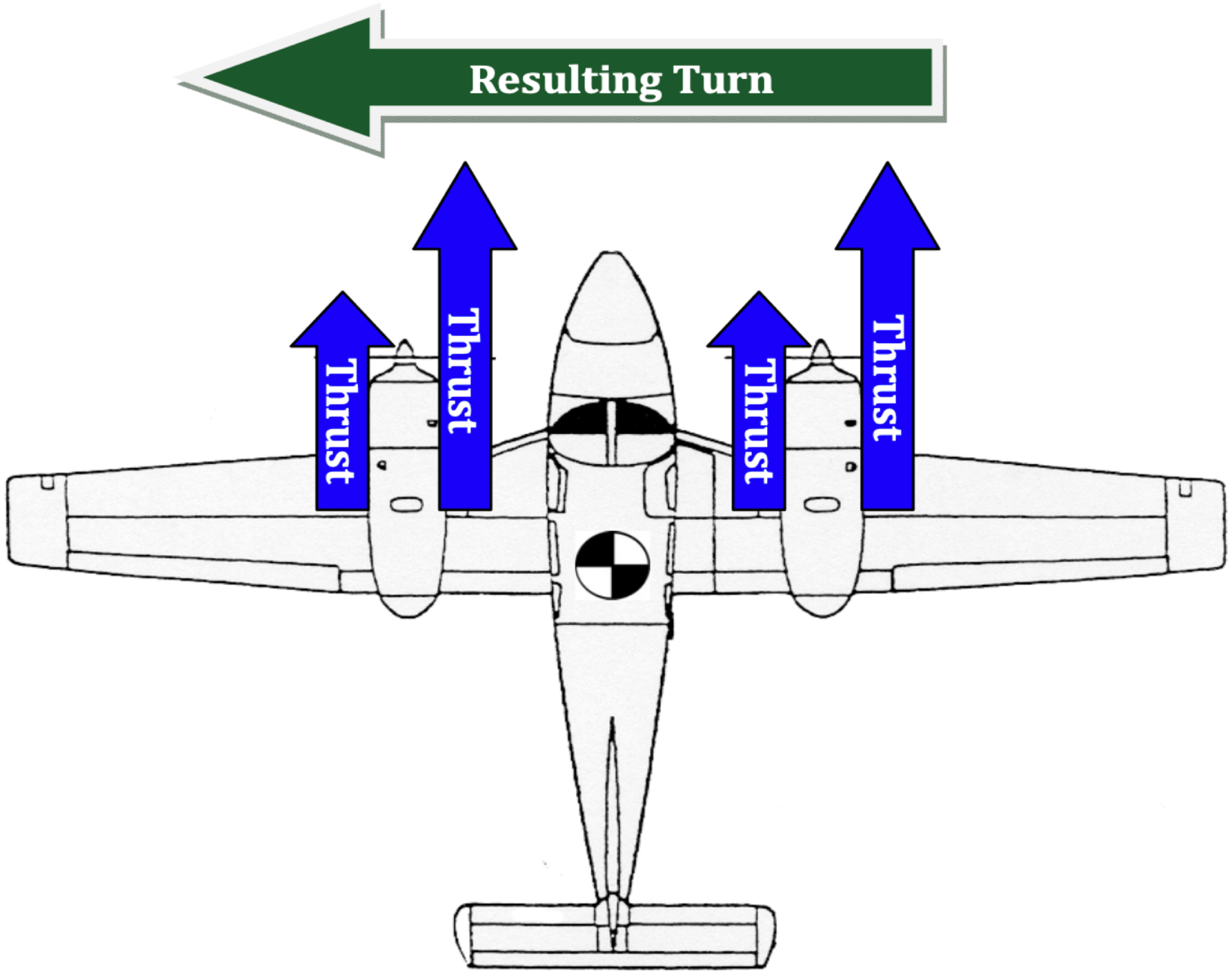
also affect multi-engine airplanes. Since the multi-engine airplane has at least two engines, these effects are increased.

A Conventional Twin

Result of Torque = Roll to the Left

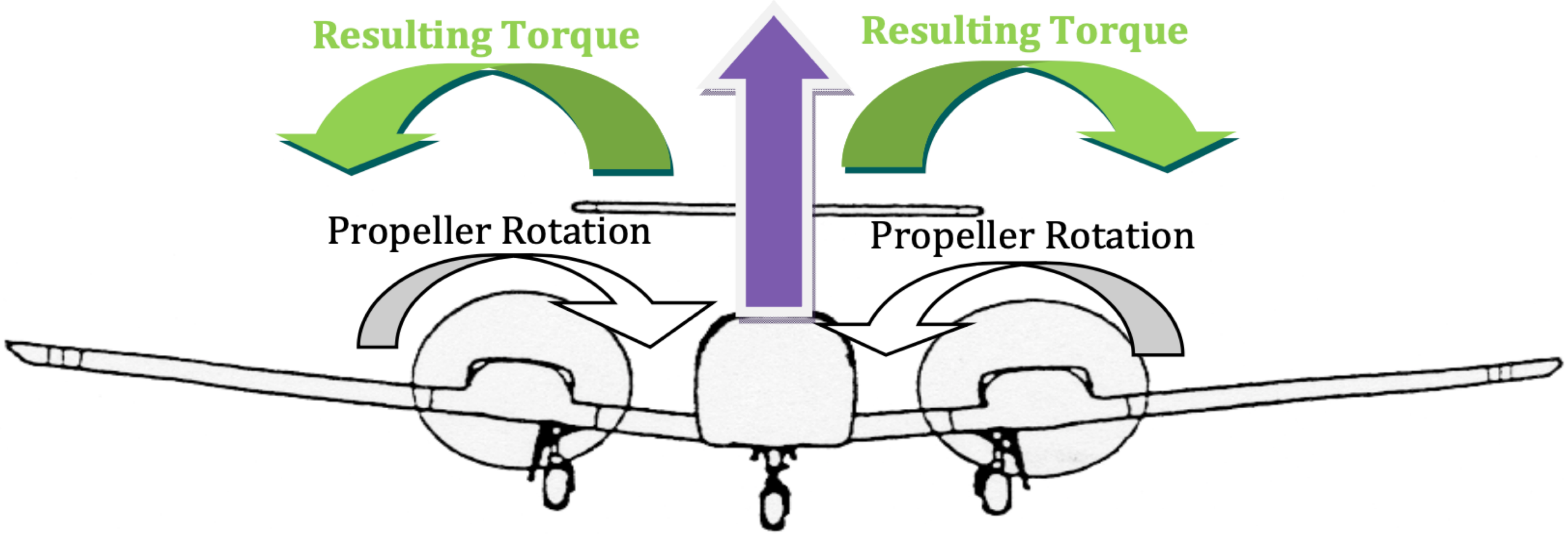


Result of P-Factor = Yaw to the left

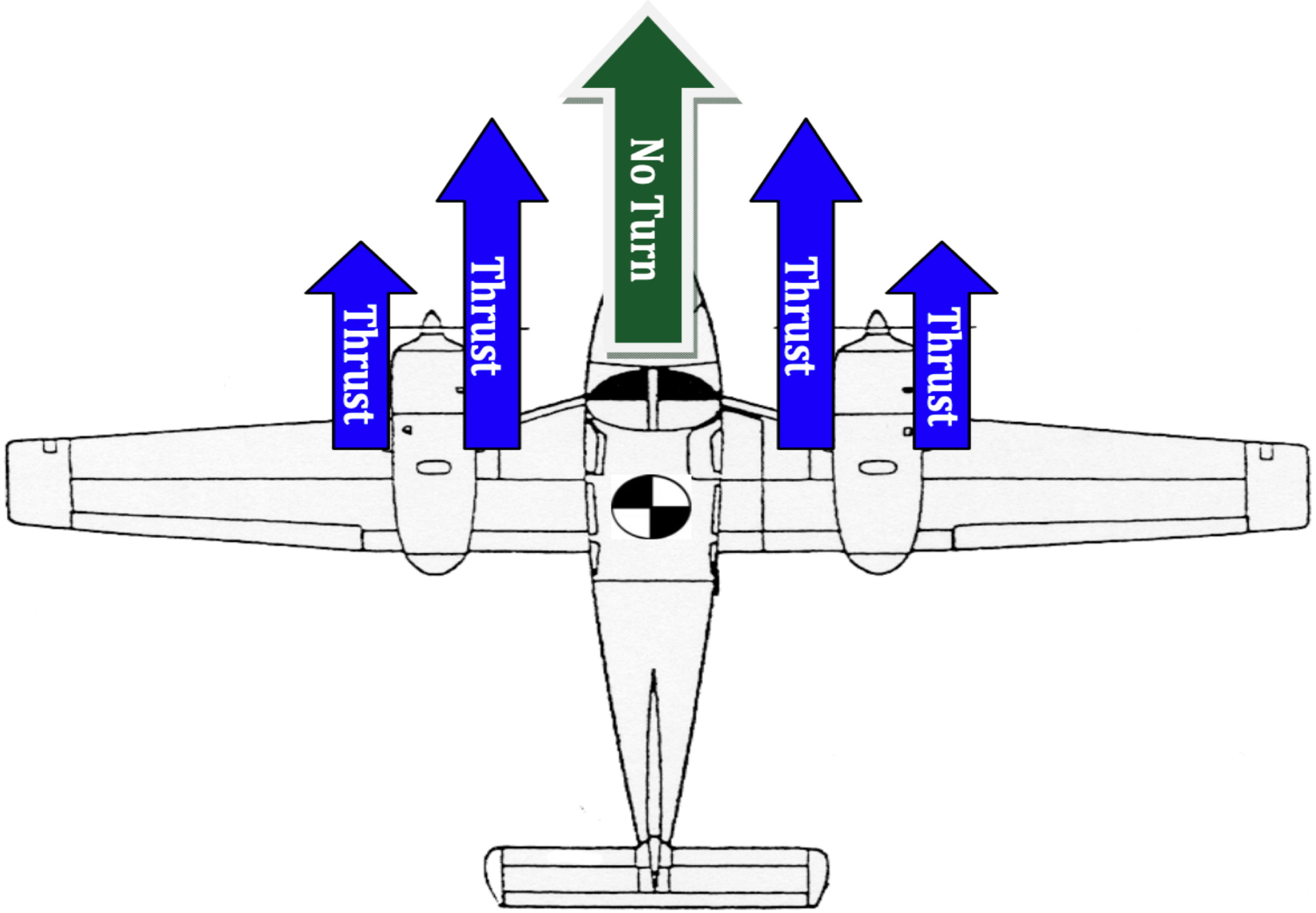


A Counter-Rotating Twin

Result of Torque = NONE = Both Engines Cancel Each Other Out.



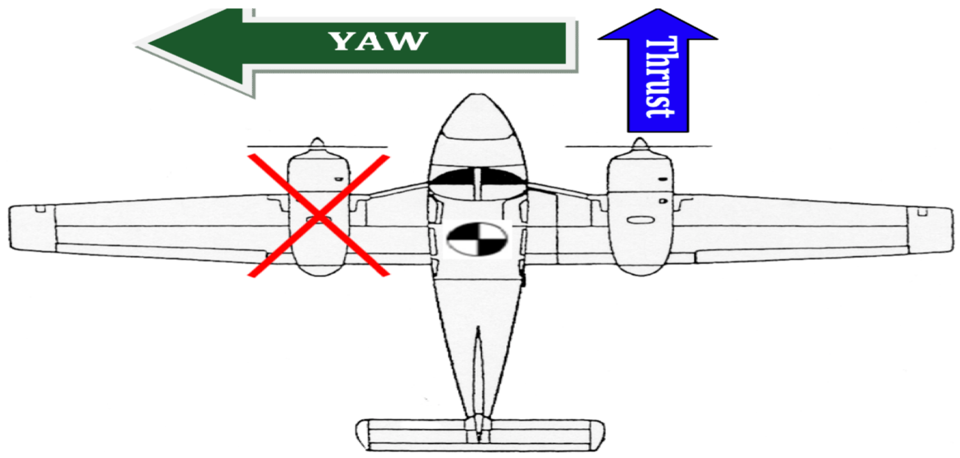
Result of P-Factor = NONE = Both Engines Cancel Each Other Out.



WHAT HAPPENS WHEN AN ENGINE FAILS

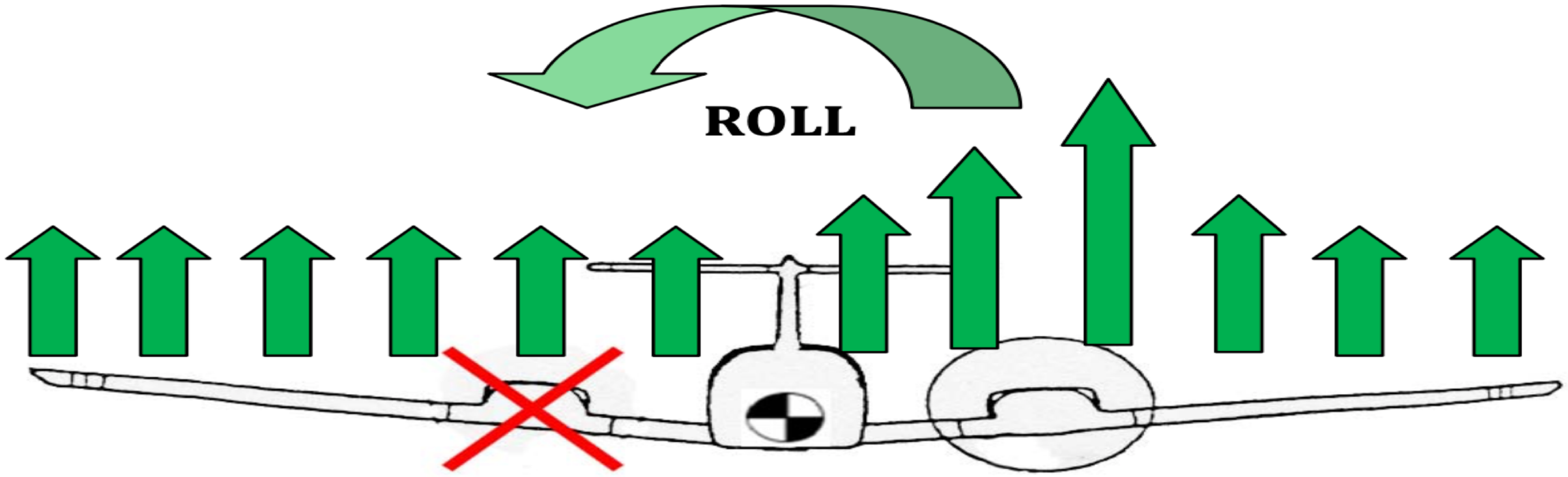
Two motions happen when an engine fails: YAW and ROLL.

- **YAW**- Asymmetrical thrust will cause a yawing moment around the C.G. towards the inoperative engine.



- **ROLL** – The yawing moment from above will cause the wing with the operating engine to move faster through the air as the airplane yaws. This causes a faster velocity of air over the wing with the operative engine meaning more lift on that wing and results in a roll towards the inoperative engine.

- **ROLL** – Induced flow (accelerated slipstream) over the wing from the operating engine and lack of induced flow (accelerated slipstream) over the inoperative engine causes asymmetrical lift on the wings, resulting in a rolling moment around the C.G. towards the inoperative engine.



CRITICAL ENGINE

- The critical engine is the engine that, if it were to fail, would most adversely affect the performance or handling characteristics of the airplane.

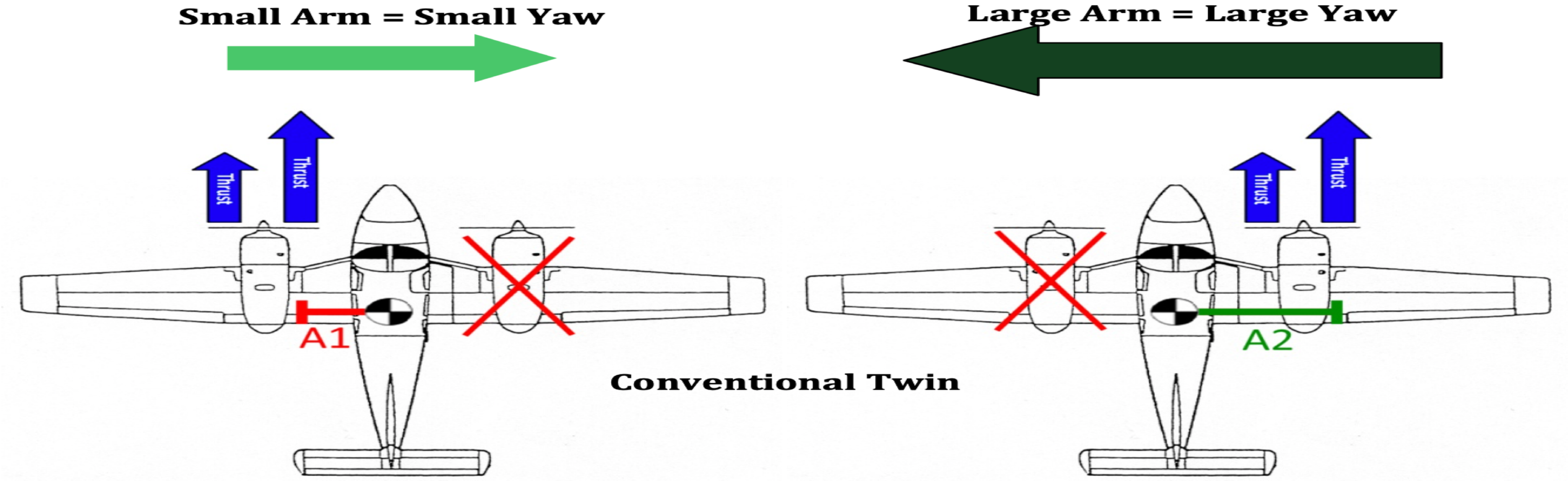
Conventional twins with propellers rotating to the right the critical engine is the **left engine**.

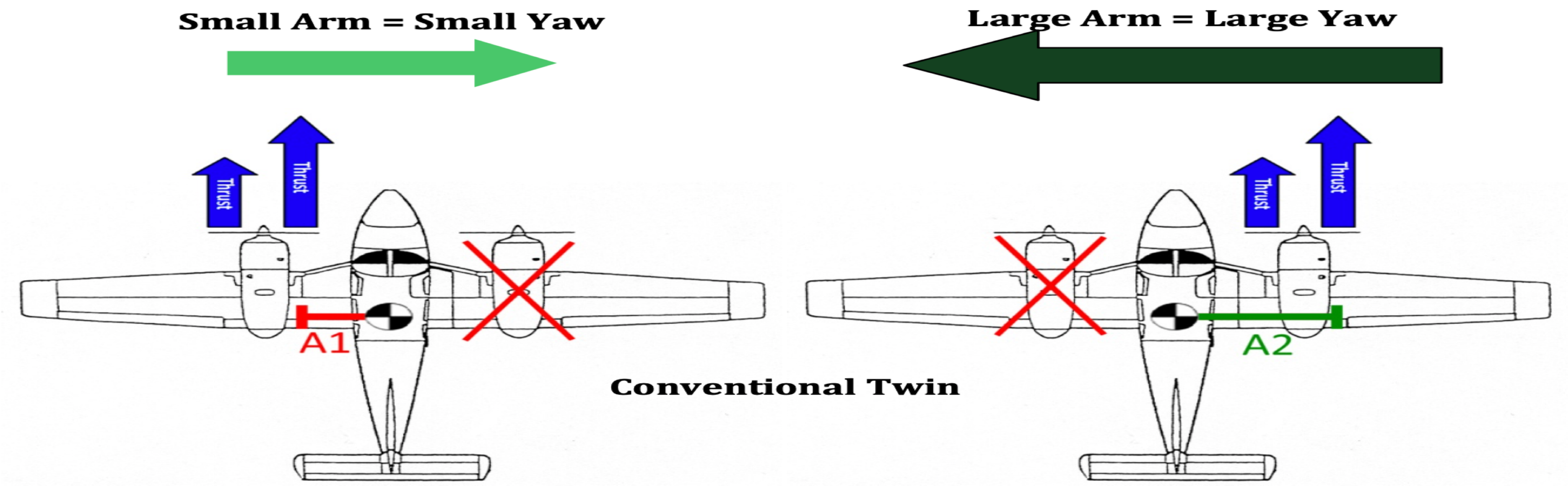
On a twin engine airplane with **counterrotating** propellers there is **not a critical engine** since the yawing and rolling effects of losing one engine will be identical no matter which engine fails.

There are Four factors that determine is an engine is critical.

- 1. P-Factor
- 2. Accelerated Slipstream
- 3. Spiraling Slipstream
- 3. Torque

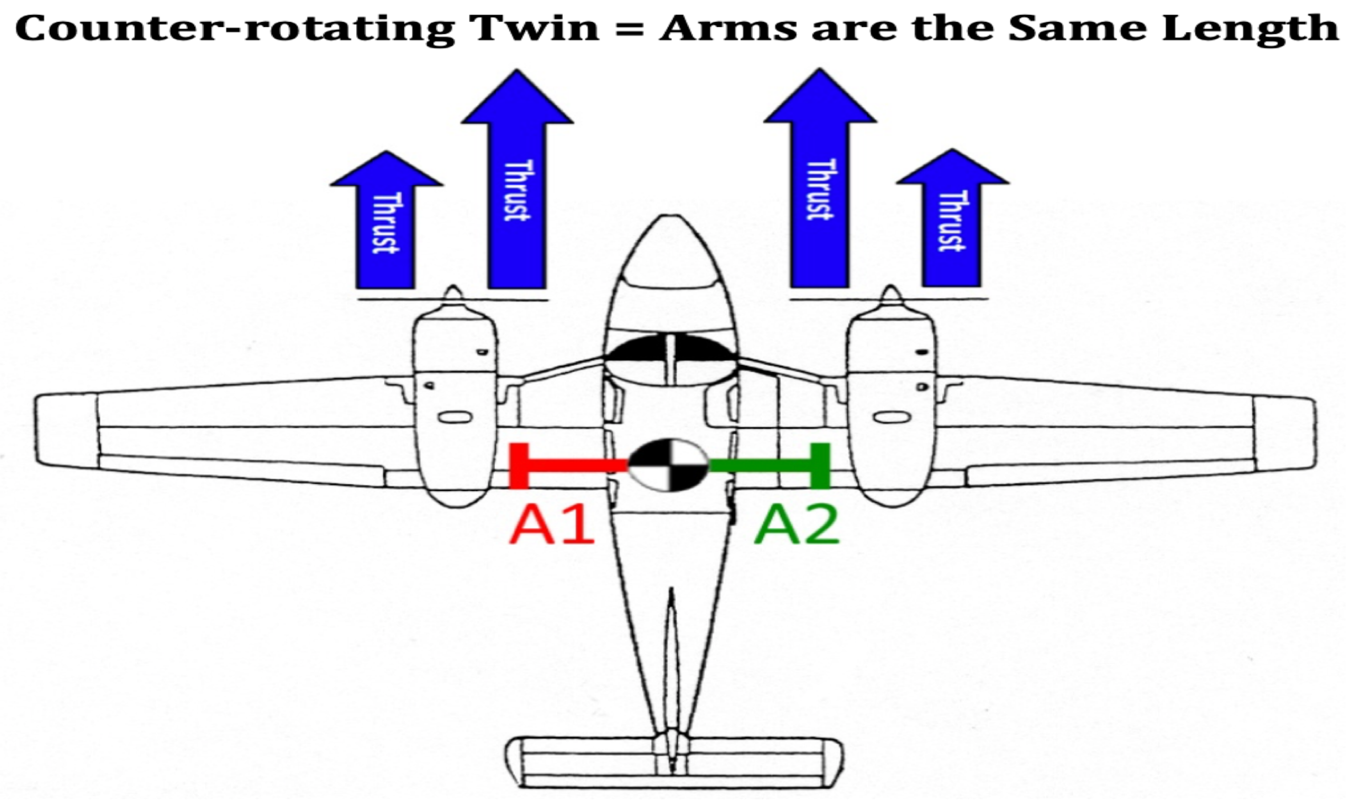
P-FACTOR | P-factor is where the descending propeller blade creates more thrust than the ascending blade. This causes asymmetrical thrust on each side of the propeller. To figure out the effect on the airplane, the formula **THRUST x Arm = Moment** can be used. This means that the longer the arm from the C.G. to the thrust, the larger the yawing moment will be.



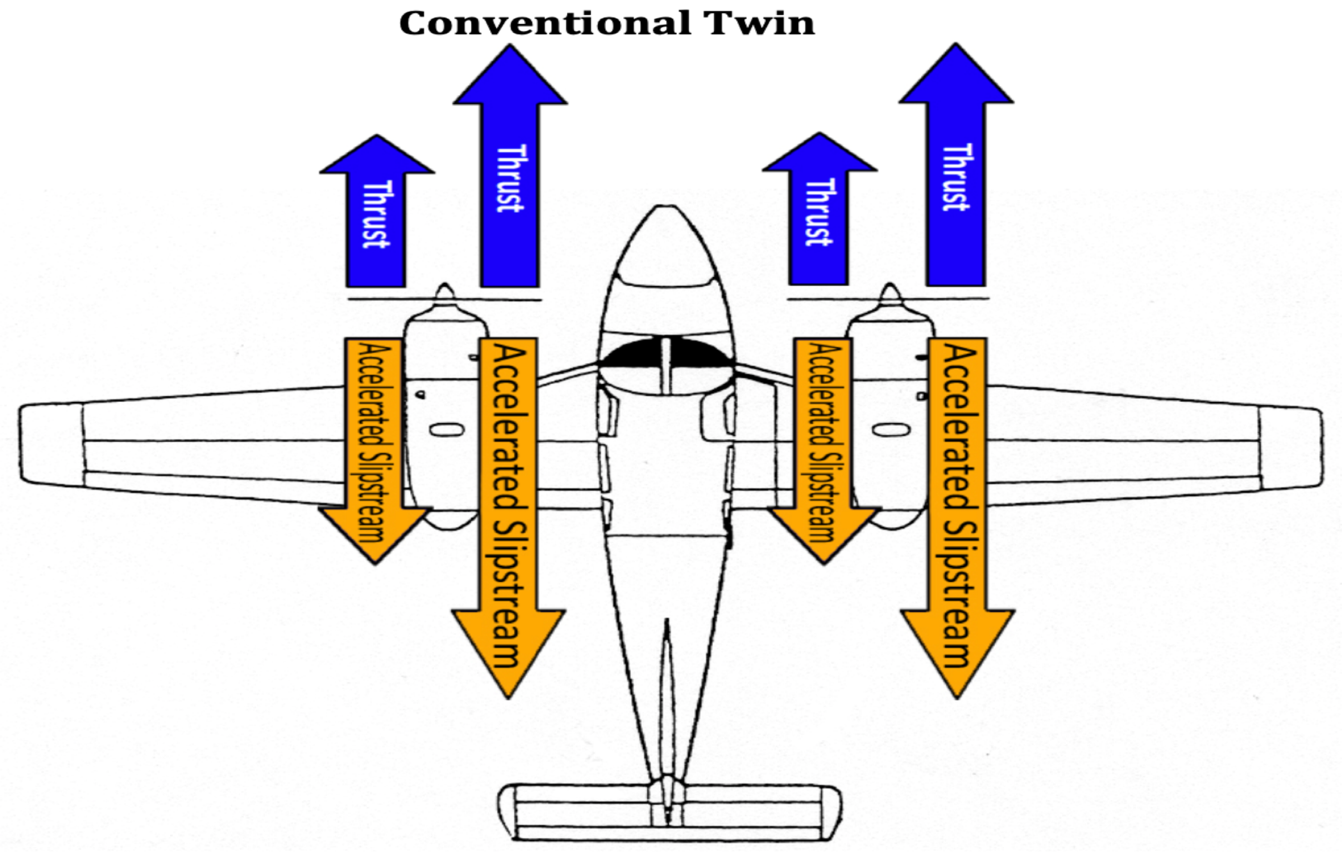


- Because the descending propeller blade on the right wing engine has a longer arm (A2) than the descending propeller blade on the left wing engine (A1), the airplane will have a greater yawing moment to the left if the left engine fails than if the right engine fails.
- Since the effect of the yaw is greater if the left engine fails, **the left engine is the critical engine**.

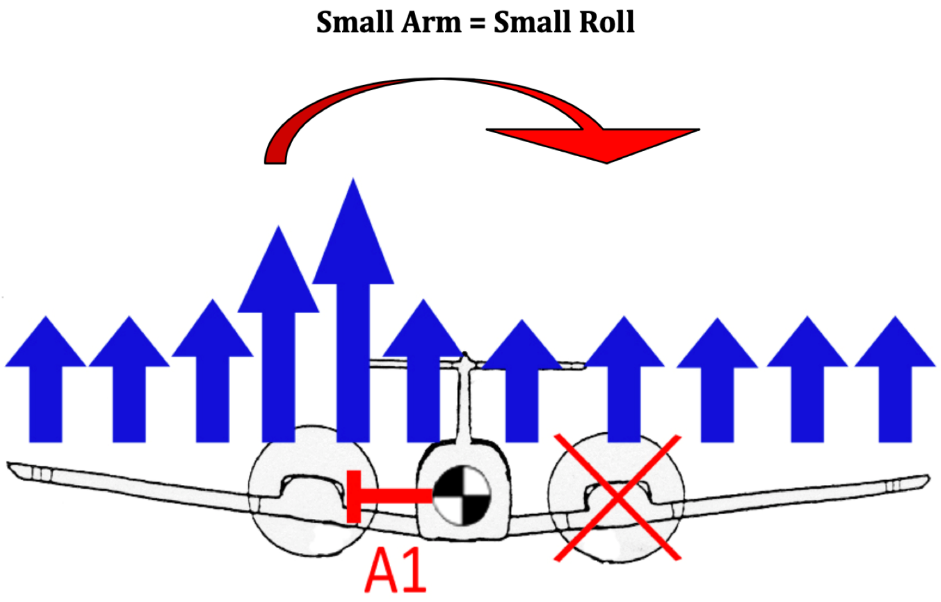
- On a counter-rotating twin-engine airplane, arms (A1, A2) to the descending propeller blades are the same length, resulting in the same amount of yaw regardless of which engine fails.

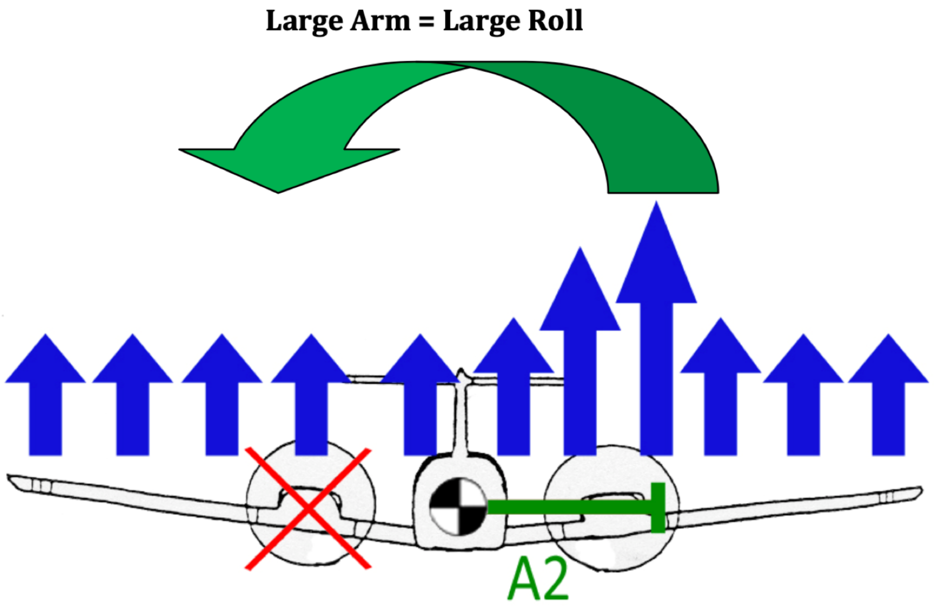


ACCELERATED SLIPSTREAM | The propellers will accelerate air over the wings. More lift is produced where the propellers accelerate the air over the wing. Just as P-factor causes asymmetrical thrust forward, it also produces the same effect in the asymmetrical airflow behind the propeller.

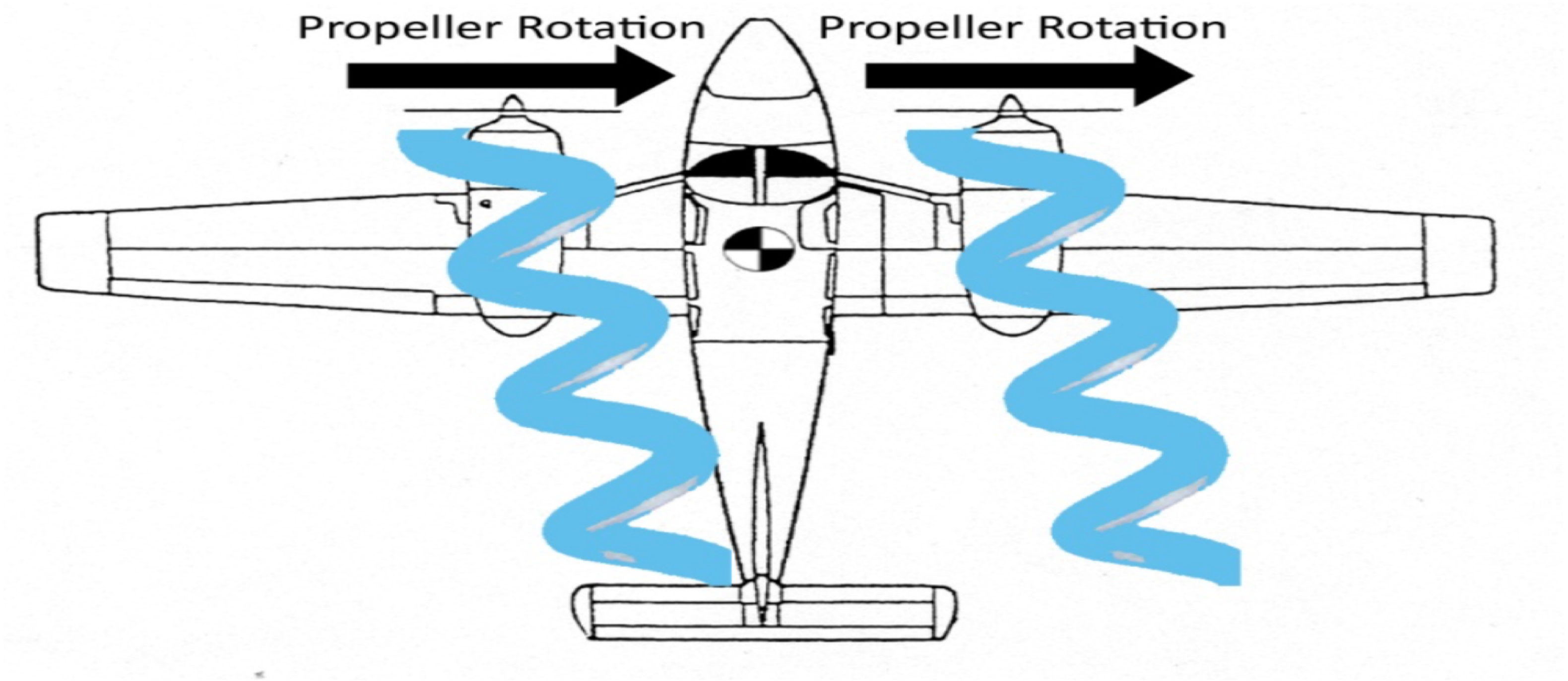


When one engine fails, the accelerated slipstream causes a roll towards the inoperative engine. To figure out the effect on the airplane the formula **LIFT x Arm = Moment** can be used. Just like P-factor, the arm to the right engine is longer than the arm to the left engine. This means that if the left engine fails, the roll moment will be greater to the left than if the right engine fails. **Therefore the left engine is the critical engine.**

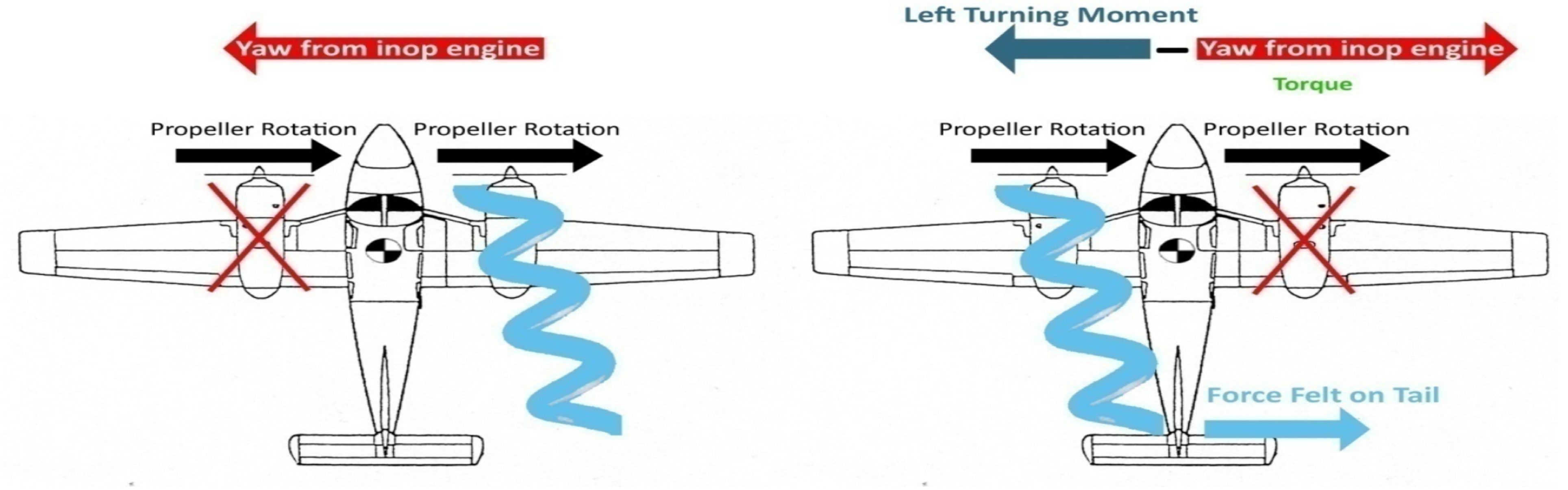




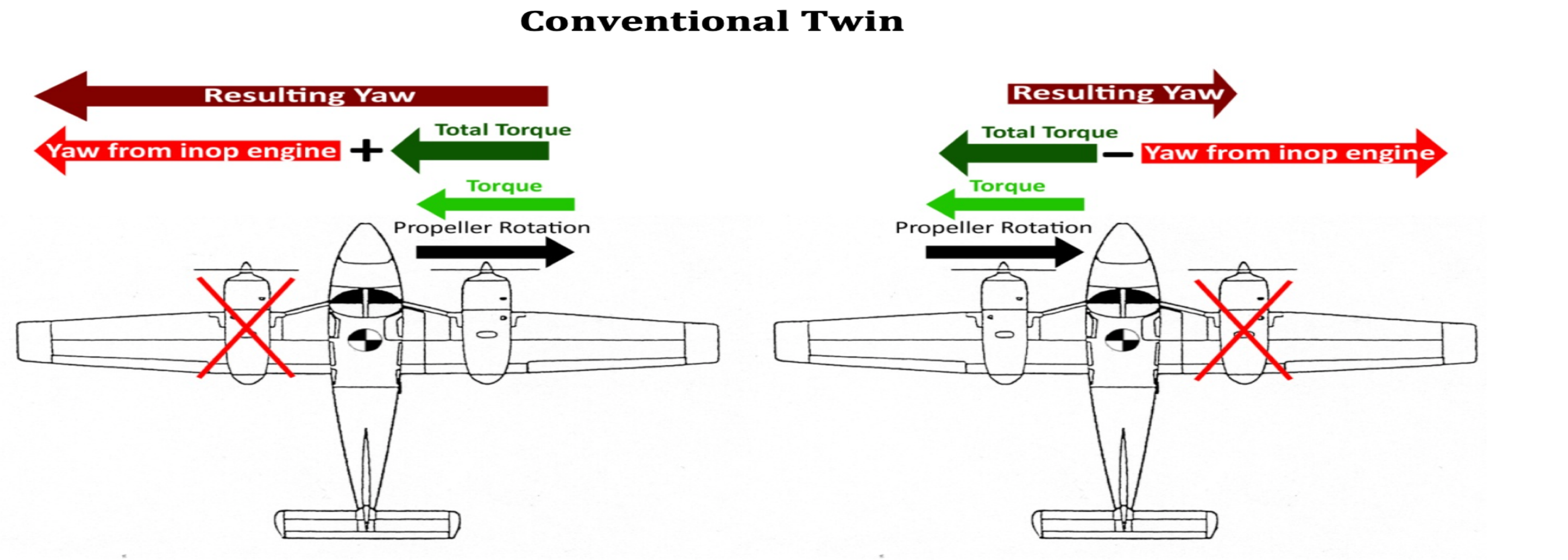
Spiraling Slipstream | The high-speed rotation of an airplane propeller gives a corkscrew or spiraling rotation to the slipstream. At high propeller speeds and low forward speed (as in takeoffs and approaches to power on stalls), this spiraling rotation is very compact and exerts a strong sideward force on the airplane's vertical tail surface.



If the left engine fails the spiral slipstream will not hit the tail at all, resulting in no additional yawing force. If the right engine fails the spiral slipstream will hit the left side of the tail causing a yaw to the left in the opposite direction of the yaw to the right caused by the failed engine. This yaw from the spiral slipstream will help oppose the yaw from the failed engine. This makes the left engine critical.



TORQUE | As the engine and propeller rotate in one direction, they, in turn, try to rotate the airplane in the other direction. This is due to Newton's third law which states, "*For every action there is an equal and opposite reaction*." This force also acts when an engine fails because there is still a second operating engine.



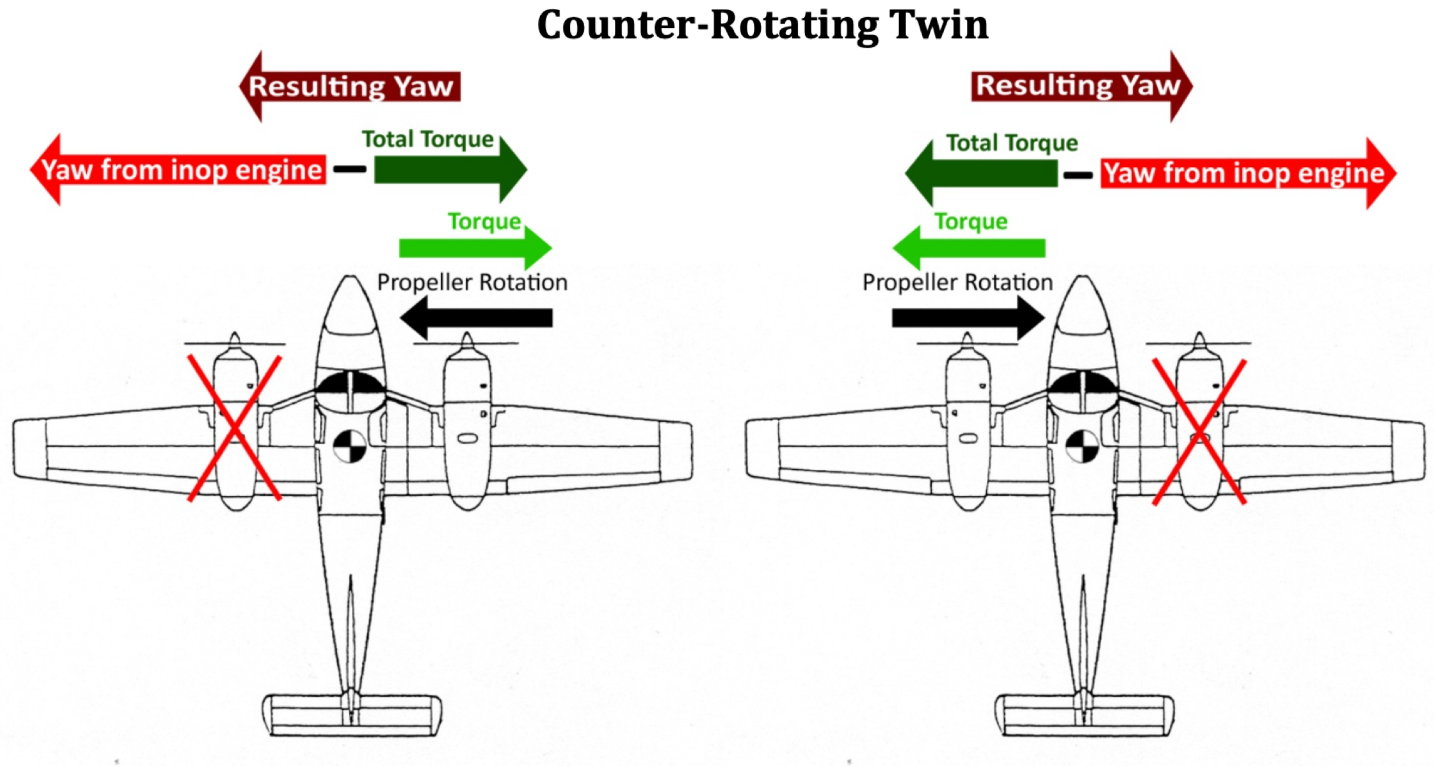
- The result of the torque is roll, but it will also combine with the other factors previously mentioned as well.

- If the left engine fails, the yawing moment from the right engine (thrust) and the total torque will both work together to yaw and roll the airplane to the left.

- If the right engine fails, the yawing moment from the left engine (thrust) and the total torque (opposite direction) will still result, although to a lesser degree (compared to failure of the left engine) due to a smaller moment arm, in a yaw and roll of the airplane to the right.

- This means that the yaw will be worse if the left engine fails which means that the **left engine is the critical engine**.

In the counter-rotating twin, the torque will oppose the yawing and rolling moment caused by an inoperative engine. The resulting yaw will be the same no matter which engine fails. Therefore, there is no critical engine.



WHAT IS VMC?

§23.149 Minimum control speed (Vmc)

VMC is the calibrated airspeed at which, when the critical engine is suddenly made inoperative it is possible to:

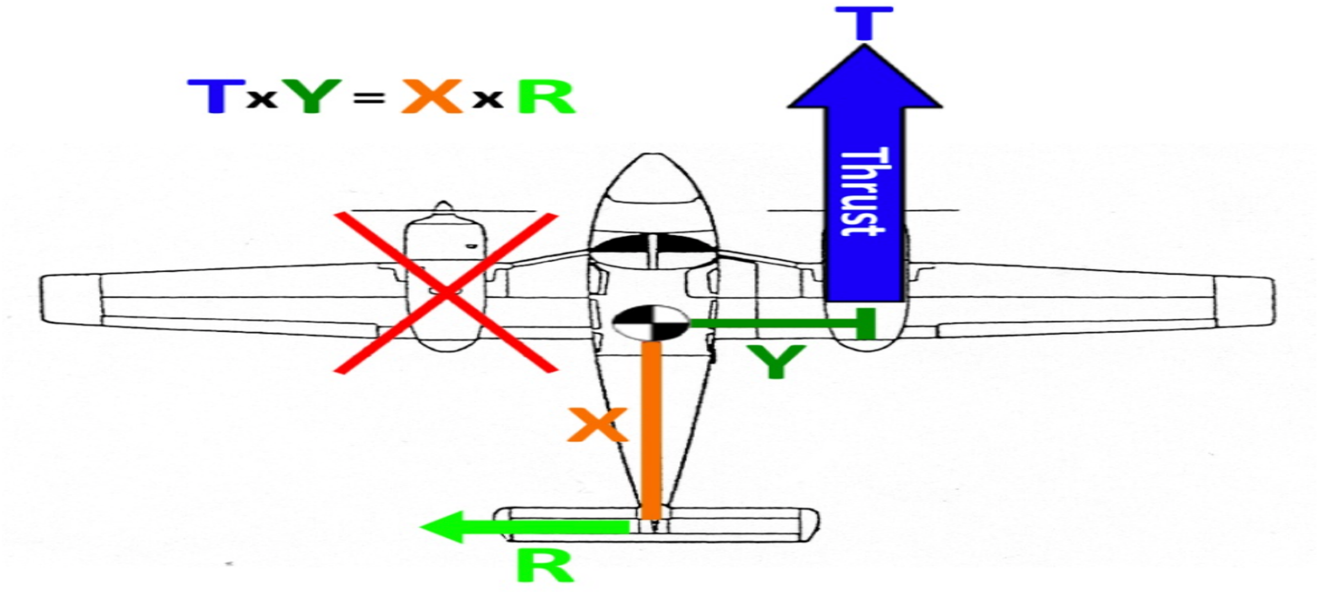
- Maintain control of the airplane with that engine still inoperative
- Maintain straight flight at the same speed with an angle of bank of not more than 5 degrees.

VMC can be defined as:

- Minimum control speed with the critical engine inoperative.
- The minimum speed at which directional control can be maintained under a very specific set of circumstances as outlined in 14 CFR Part 23.
- VMC is the speed at which it is still possible to maintain directional control with an engine inoperative.
- **NOTE … VMC only addresses directional control.**

- The method used to simulate critical engine failure must represent the most critical mode of powerplant failure expected in service with respect to controllability.
- VMC must not exceed 1.2 VS1 at maximum takeoff weight.
- FAR 23.149 also requires the calculation of a minimum speed to intentionally render the critical engine inoperative and to be designated as the safe, intentional, one-engine- inoperative speed, or VSSE.
- Remember, published VMC and actual VMC are two different speeds. There are many factors that can affect VMC speed and they will be covered in the following pages.

When a multi-engine airplane loses an engine it experiences a yaw and roll. To counteract this, the rudder can be used to stop the yaw and the resulting roll. As airspeed is decreased, the rudder becomes less effective. Therefore, more rudder deflection will be required to maintain directional control. Eventually, an airspeed will be reached where full rudder deflection will be required to maintain directional control. At this point, any further decrease in airspeed will lead to loss of directional control. It is this airspeed at which the airplane reaches VMC.



VMC FOR CERTIFICATION FAR 23.149

Every multi-engine airplane must go through a certification process which includes calculating a VMC speed. VMC is NOT a fixed airspeed under all conditions. VMC is a fixed airspeed only for the very specific set of circumstances under which it was determined during aircraft certification by FAR 23.149.

CERTIFICATION REQUIREMENTS:

At 5,000 ft. international standard atmosphere the airplane performance must be determined by the manufacturer for certification.

6001 – 12,500 lbs. / Or if Vso = 61 kts CAS or greater

- Must climb clean at 5,000' ISA
- Rate of climb (ROC) = (.027 x Vso^2)

6,000 lbs. or less –

- If Vso = less than 61 kts
- Must be determined. It can be a negative ROC.

WHEN RECOVERING FROM VMC:

- The rudder pedal force required to maintain control must not exceed 150 pounds.
- It must not be necessary to reduce power of the operative engine(s).
- The airplane must not assume any dangerous attitude.
- It must be possible to prevent a heading change of more than 20 degrees.

NOTE

VMC deals only with directional control not performance.

VMC MUST BE DETERMINED WITH:

- Standard Conditions
- Max Power on Operating Engine
- Aft C.G.
- Critical Engine Failed and Wind milling
- Flaps Up / Gear Up
- Up to 5 degrees of bank
- Most Adverse weight (light)
- Ground effect (out of ground effect)

- Critical Engine Wind-milling
- Operational Engine Full Power
- Out of Ground Effect
- Most adverse weight (light)
- Banked 5 degress toward operational engine
- Aft C.G
- Takeoff Configuration (gear up/ flaps up)
- Standard Temp and Density Altitude

FACTORS AFFECTING VMC

Effect on	V_{MC}	Performance
Power Increase	Up – more yaw.	Up – more power.
Temp Increase	Down – less dense, less power, less yaw.	Down - less dense, less power.
Pressure Decrease	Down – less dense, less power, less yaw.	Down – less dense, less power.
Density Altitude Increase	Down – less dense, less power, less yaw.	Down – less dense, less power.
Bank Angle – 0° bank – no turn	Up – sideslip plane – less AOA on rudder because of sideslip airflow – less rudder effectiveness- more rudder needed.	Down – more drag – slipping.
Zero Sideslip – 2-3° bank – no turn	Middle – Use horizontal lift to stop turn – not slipping – more rudder effectiveness.	Up – less drag – zero slip.
Bank Angle – 5° bank – no turn	Down – plane turning toward good engine + rudder used to stop turn = slip toward good engine – high AOA on rudder.	Down – more drag – slipping.
Windmilling Propeller	Up – more drag, more yaw.	Down – more drag.
Feathered Propeller	Down – less drag, less yaw.	Up – less drag.

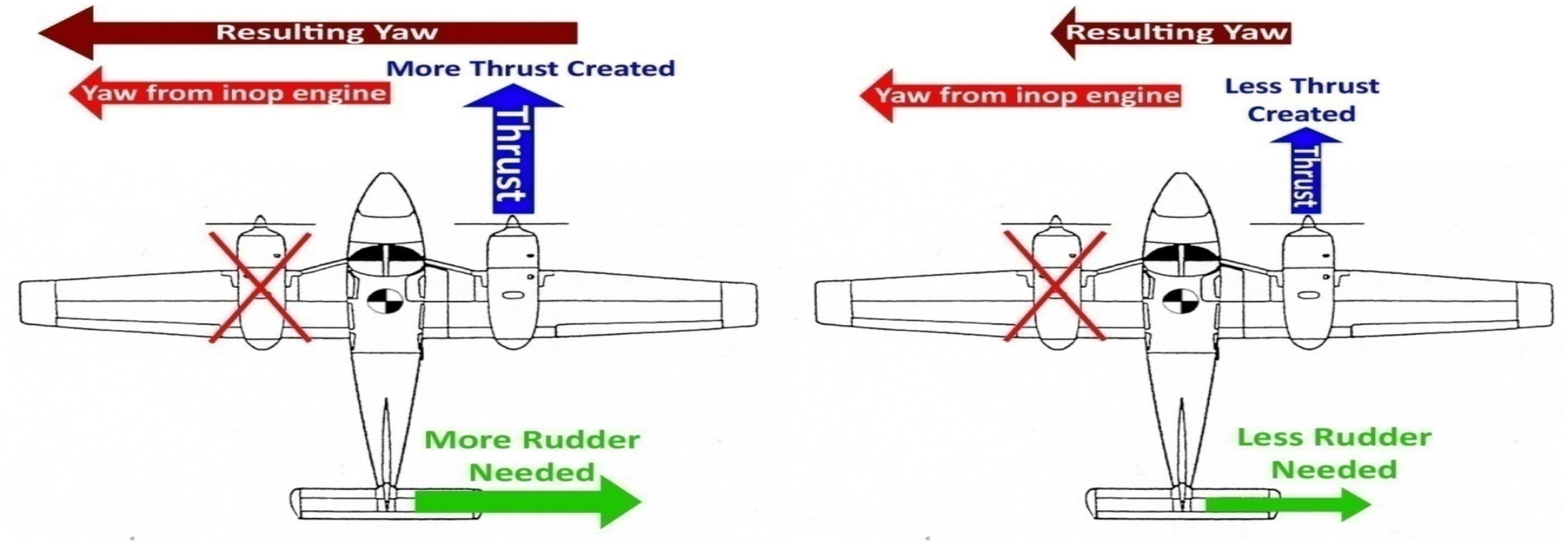
Aft C.G.	Up – less distance between rudder and C.G. – less rudder effectiveness.	Up- less tail down force required less induced drag Down – smaller arm on controls, less control effectiveness.
Heavier Weight	Down – more lift needed in level flight – more horizontal lift available during turn – helps prevent turn.	Down – more weight, more power required.
Flaps Down	Down – more induced drag from good engine side prevents yaw towards dead engine.	Down – more airflow over flap causes greater drag, causing increased yaw, causing increased roll, requiring more aileron to stop roll, creating more adverse yaw = more induced drag.
Gear Down	??? – depends on location of C.G. to gear & direction of travel – moves C.G. (V_{MC} Down – Keel Effect).	Down – more parasite drag.
Critical Engine Fails	Up – P-factor, Accelerated Slipstream, Torque make yaw worse.	Down – larger control inputs – more drag.
In Ground Effect	Up – less drag – more thrust available – more yaw.	Up – less drag.

V_{MC} down (slower) = good = more rudder available, or rudder more effective.
V_{MC} up (faster)= bad = less rudder available, or rudder less effective.

2. EFFECTS OF DENSITY ALTITUDE ON THE VMC DEMONSTRATION.

- As density altitude increases, temperature increases, pressure decreases, and/or humidity increases the output of the engine or thrust created by the engine decreases. The less thrust that is created, the less rudder input needed to oppose the yaw.

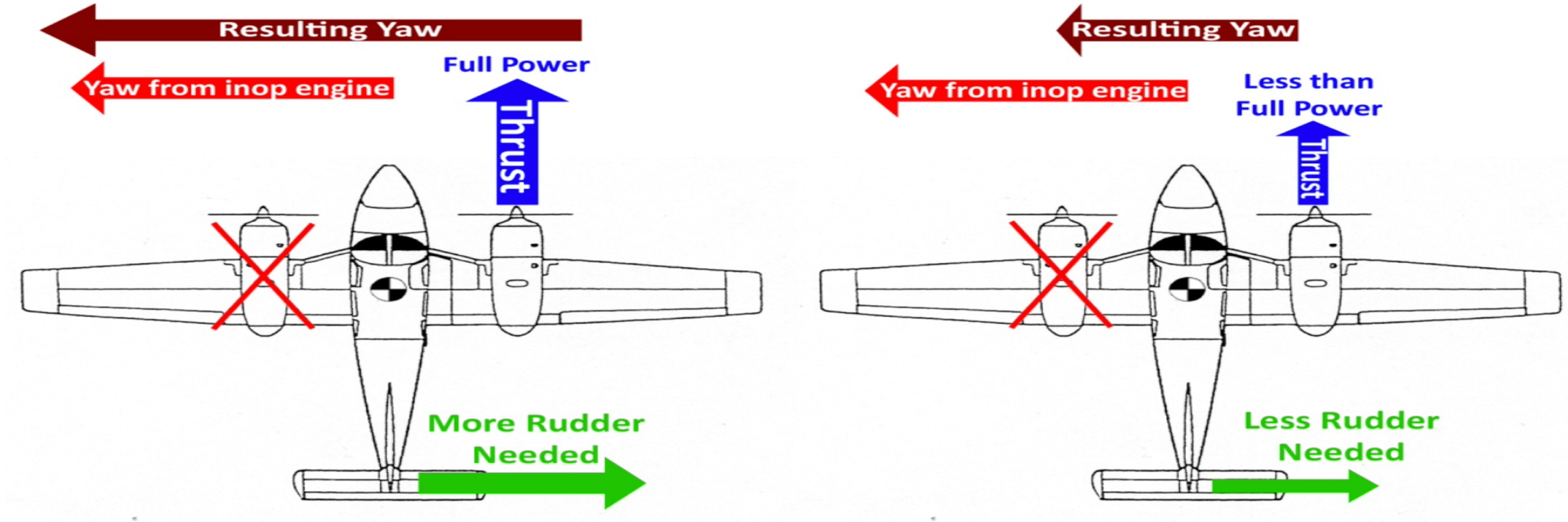
- Using less rudder leaves more rudder available to the pilot. Therefore, **VMC decreases.** So, as density altitude increases, temperature increases, pressure decreases, and/or humidity increases VMC decreases.



Performance decreases as density altitude increases, temperature increases, humidity increases, and/or pressure decreases. With air being less dense, not only does the engine become less efficient, but the propeller and wings also have decreased performance due to having less air molecules available to make thrust and lift.

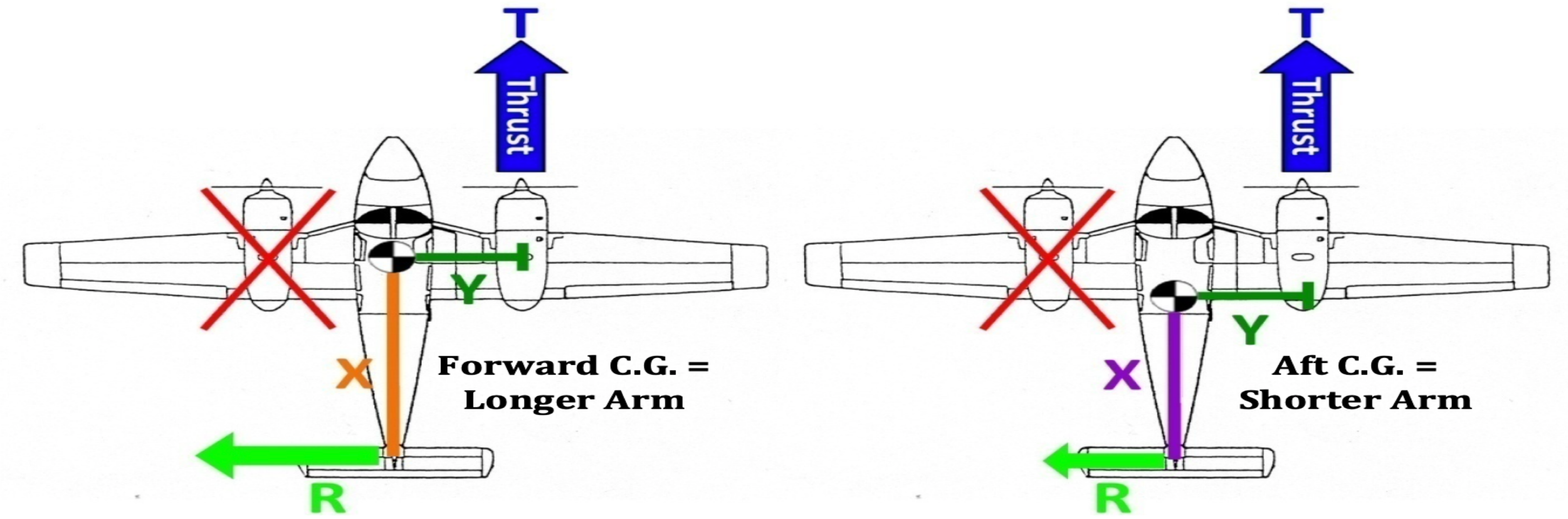
MAX POWER ON OPERATIONAL ENGINE

- The more power (thrust) on the operating engine, the more rudder is needed to stop the resulting yaw. Using more rudder leaves less available to the pilot = VMC speed increases as power on the operating engine is increased.



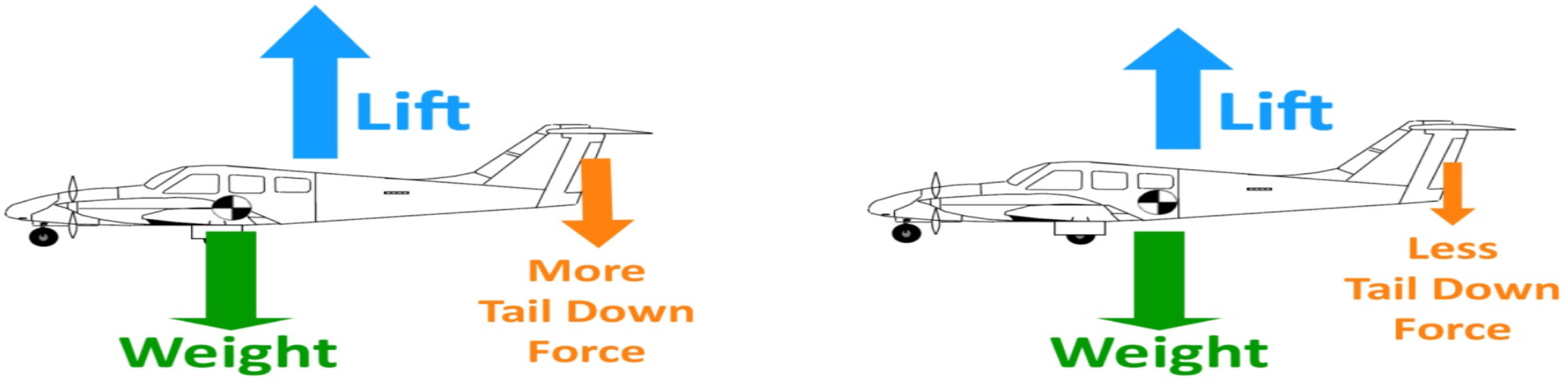
3. EFFECTS OF C.G ON CONTROL.

- The C.G. location changes the length of the arm to the rudder: the longer the arm, the more effective the rudder; the more effective the rudder, the lower VMC. As the C.G. moves forward, **VMC decreases; as the C.G. moves aft, VMC increases.**



- Performance increases as the C.G. is moved aft. As the C.G moves forward, more tail-down force is needed to keep the airplane level. The more tail-down force needed, the more total lift is required. When more lift is created (airplane flying at a higher angle of attack), more drag is also created. The increase in drag causes the overall speed to decrease.

Total Lift Required = Weight + Tail Down Force



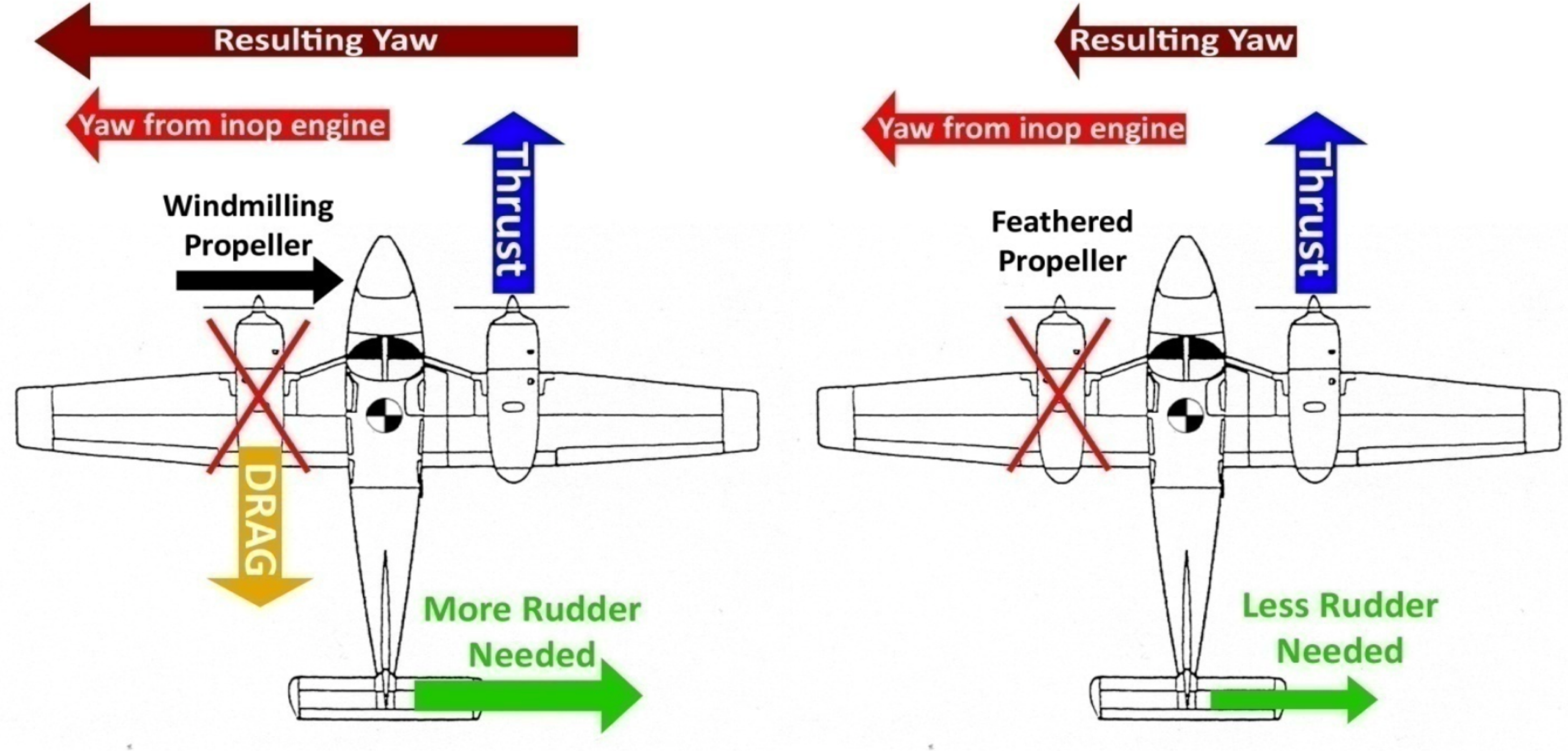
Effects of Forward C.G.

Rotation	More difficult	More weight toward front – harder to pull nose up.
Stall Speed	Higher	Forward C.G. causes higher AOA for level flight – more induced drag.
Cruise	Slower	Forward C.G. causes higher AOA for level flight – more induced drag.
Spin and Stall Recovery	Good	Forward C.G. helps make stall recovery easier.
Flare	More difficult	More weight toward front – harder to pitch nose up.
Endurance	Unchanged	Time aloft remains the same regardless of where the C.G. is located.
Range	Worse	Forward C.G. causes a higher AOA for level flight – more induced drag – slower airspeed.

Aft C.G. effects are just the opposite of the Forward C.G. effects.

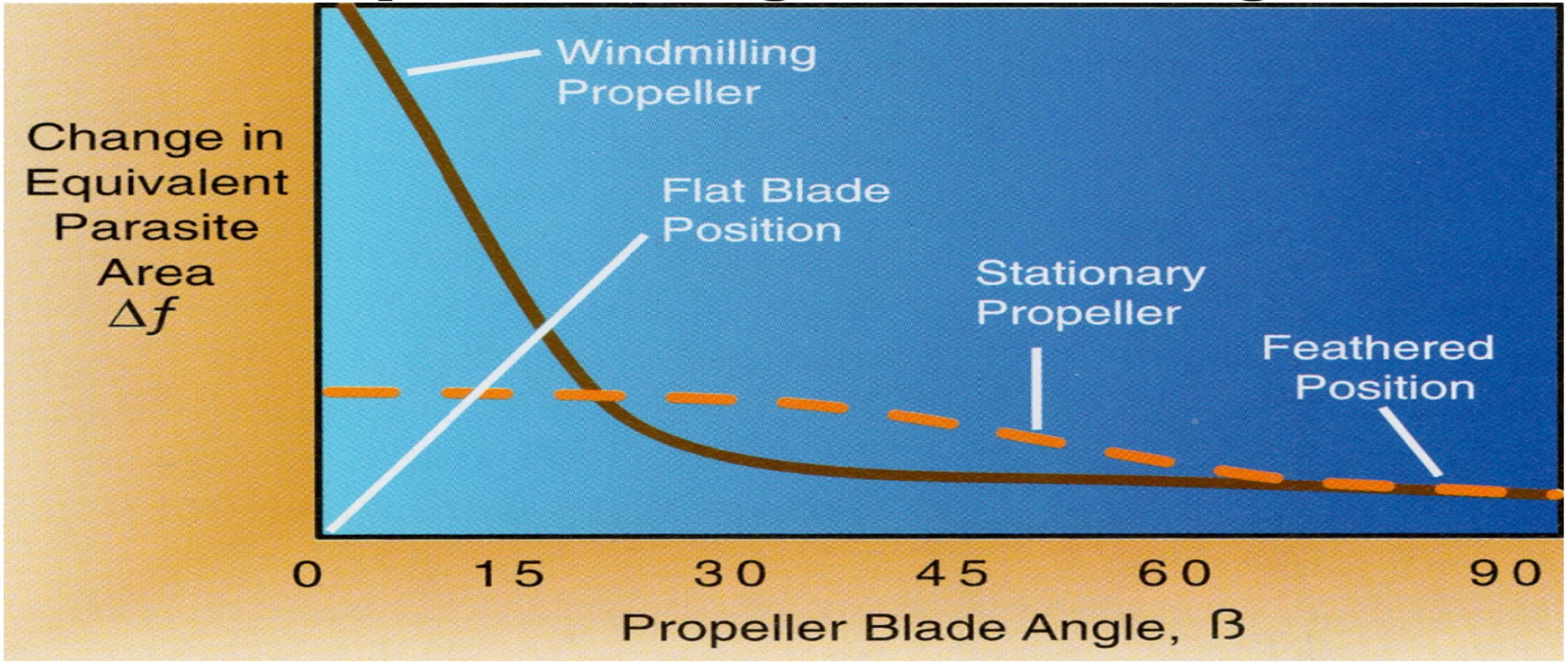
CRITICAL ENGINE WIND-MILLING

- A wind-milling propeller creates more drag than a feathered propeller. This extra drag adds to the yawing from a failed engine to make the total effect worse. This situation will require more rudder deflection to maintain directional control, which means that less rudder is available to the pilot, thereby increasing VMC.
- Once the propeller is feathered the drag is reduced, thereby reducing VMC.


Resulting Yaw
Yaw from inop engine
Thrust
Windmilling Propeller
DRAG
More Rudder Needed
Resulting Yaw
Yaw from inop engine
Thrust
Feathered Propeller
Less Rudder Needed

A wind-milling propeller decreases performance due to the parasite drag created by the propeller blades.

Propeller Blade Angle vs. Parasite Drag



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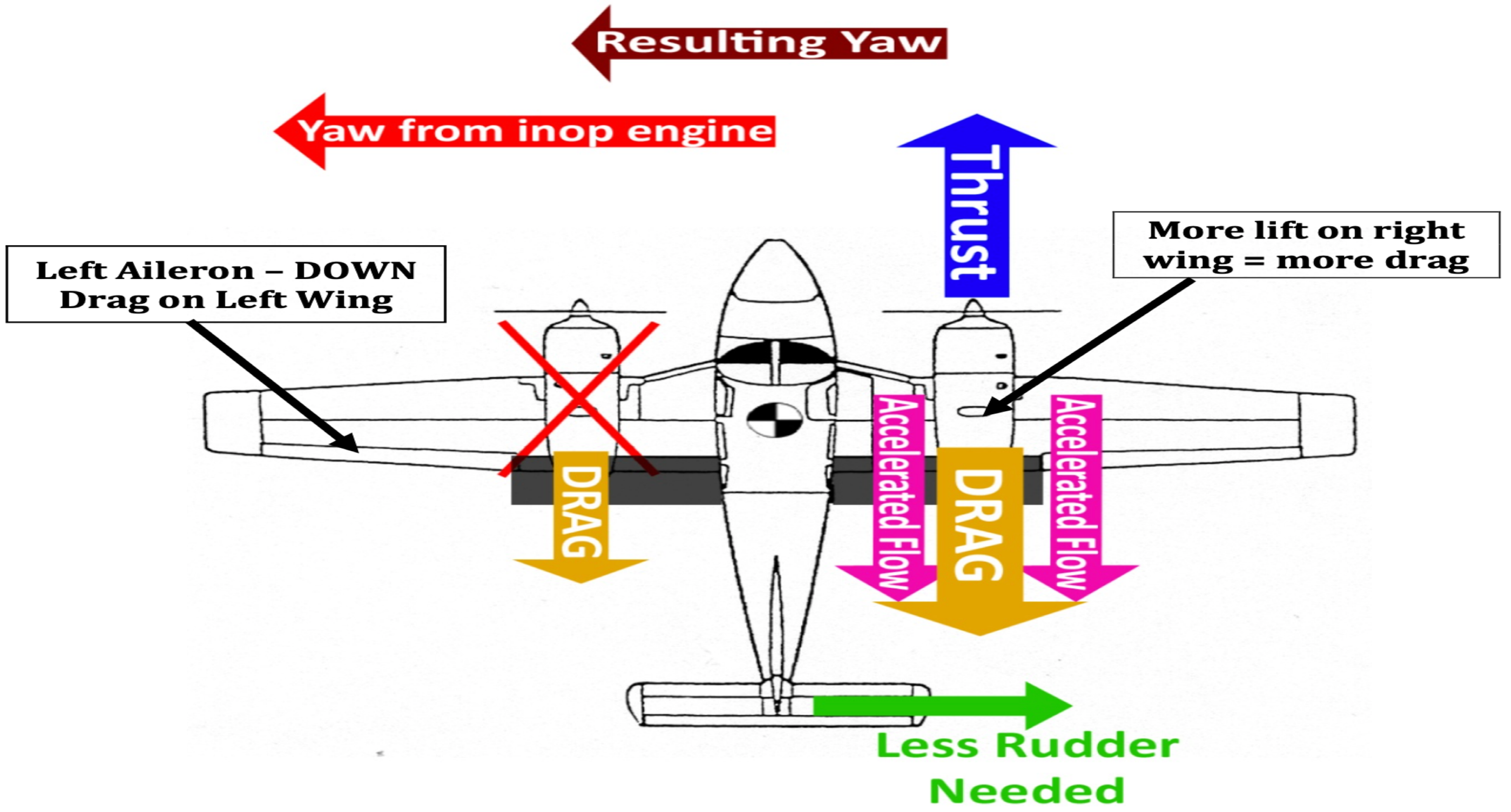
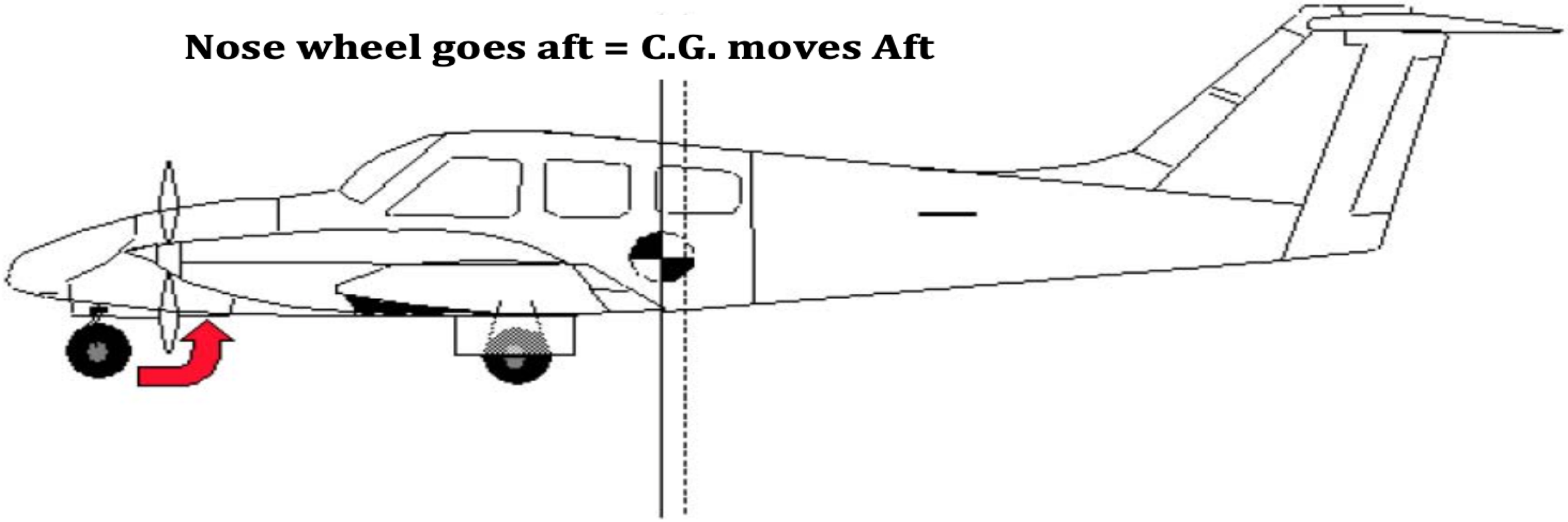
FLAPS UP / GEAR UP

- When the flaps are down the wings create more lift than if the flaps were up. However, when lift is created, drag is also created (as lift increase, drag increases).
- The side with the operating engine is creating even more lift because of the accelerated air flowing over the wing. When the flaps are extended, the drag caused by the accelerated flow opposes the yaw caused by the inoperative engine allowing the pilot to use less rudder to maintain heading. Having more rudder available to the pilot lowers VMC.
- It should be noted more lift on the right wing will cause a roll to the left. If ailerons are used to counteract the rolling of the airplane, the drag from the adverse aileron yaw will actually increase the yaw towards the inoperative engine.

Flaps Down


Resulting Yaw
Yaw from inop engine
Thrust
Left Aileron – DOWN
Drag on Left Wing
More lift on right
wing = more drag
DRAG
Accelerated Flow
DRAG
Accelerated Flow
Less Rudder
Needed

- As the landing gear operates to retract or extend, the C.G. location moves in the direction of travel of the nose gear.
- The change in C.G. affects VMC speed just as stated before. In the extended (down) position, the landing gear can also act like the keel of a boat, giving the airplane a stabilizing effect. This stabilizing effect helps prevent a turn, thereby lowering VMC.



4. EFFECTS OF BANK ANGLE ON VMC.

Bank angle can affect VMC and performance both positively and negatively. When an engine fails, the horizontal component of lift can be used to stop the yaw, but that is not the only affect of bank angle. Bank angle is related to VMC and performance in a few ways:

- Amount of Horizontal Lift
- Rudder Effectiveness
- Drag From Relative Wind
- Lift Created BY FUSELAGE

AMOUNT OF HORIZONTAL COMPONENT OF LIFT

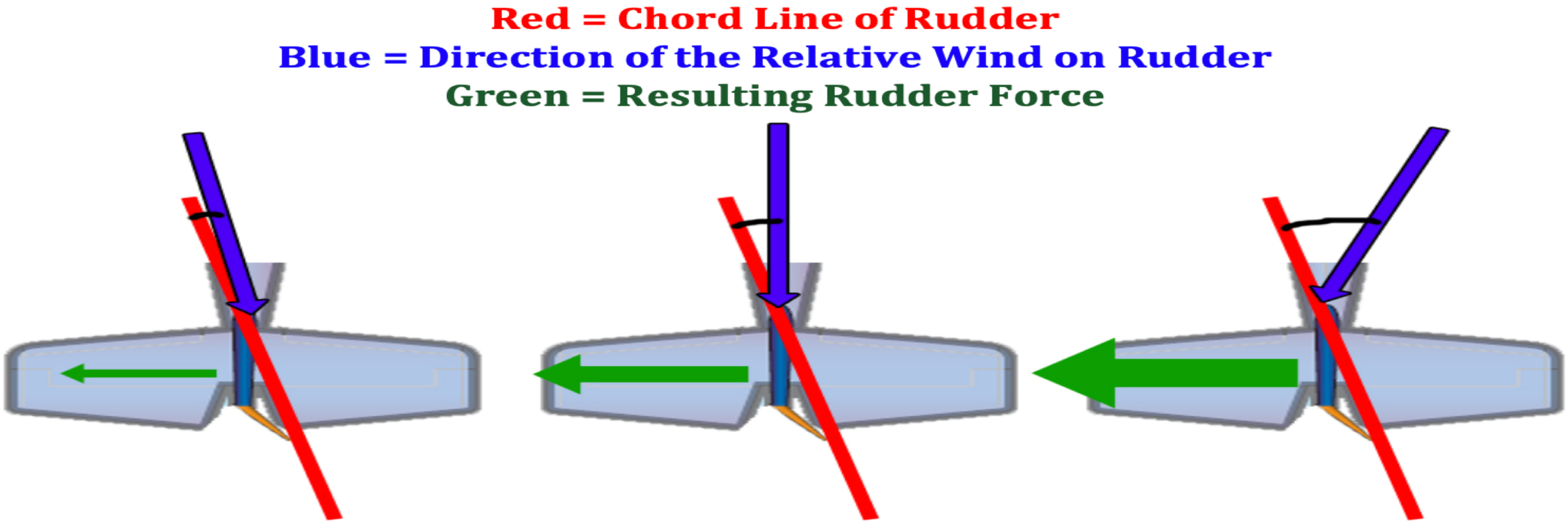
This chart shows bank angle and the amount of lift in both the horizontal and vertical directions. Notice that at a 5° bank, a loss of 14 lbs. of vertical lift equals to a turning force of 314 lbs.

Bank Angle	Total Lift	Vertical Lift	Horizontal Lift
0	3600	3600	0
1	3600	3599	63
2	3600	3598	126
3	3600	3595	188
4	3600	3591	251
5	3600	3586	314
10	3600	3545	625
15	3600	3477	932
30	3600	3118	1800
45	3600	2546	2546
60	3600	1800	3118

Vertical Component of Lift = Cos(Bank Angle) x Weight
Horizontal Component of Lift = Sin(Bank Angle) x Weight

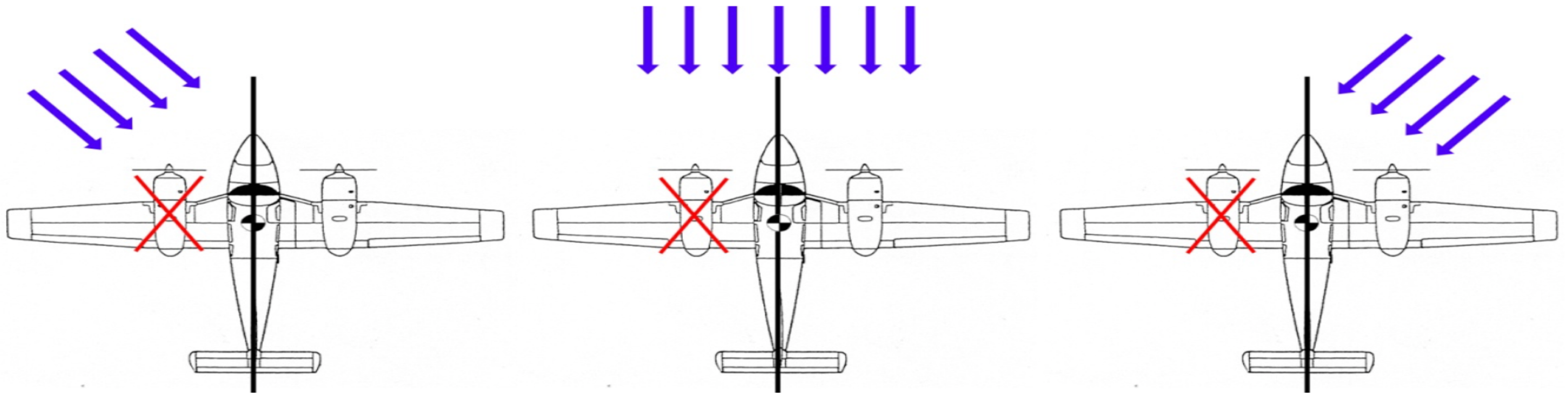
RUDDER EFFECTIVENESS

The angle of attack on the rudder determines how much force the rudder can create. It is dependent on the angle of the relative wind to the chord line of the rudder. The larger the angle of attack, the larger the force produced by the rudder. When the airplane is banked, rudder forces will act both in the vertical and horizontal directions.



DRAG FROM RELATIVE WIND

Anytime the relative wind is not parallel to the longitudinal axis of the airplane more drag is created.



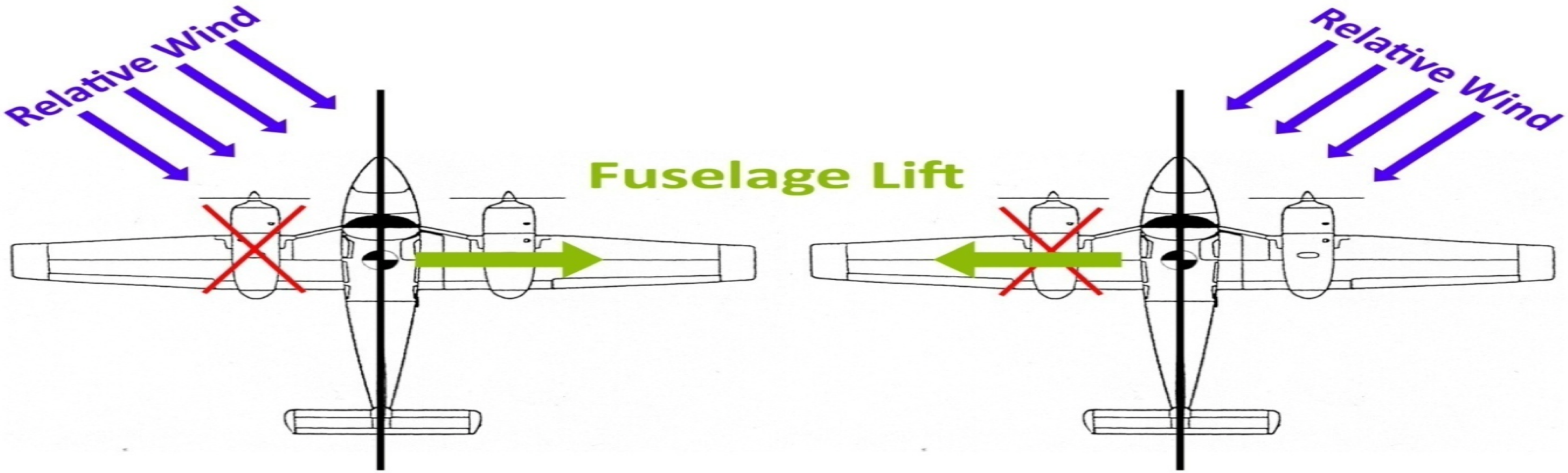
Wings level or banked toward inoperative engine
More Drag

2°-3° Bank
(Zero Sideslip)
Least Drag

Wings banked more than 3° toward operating engine
More Drag

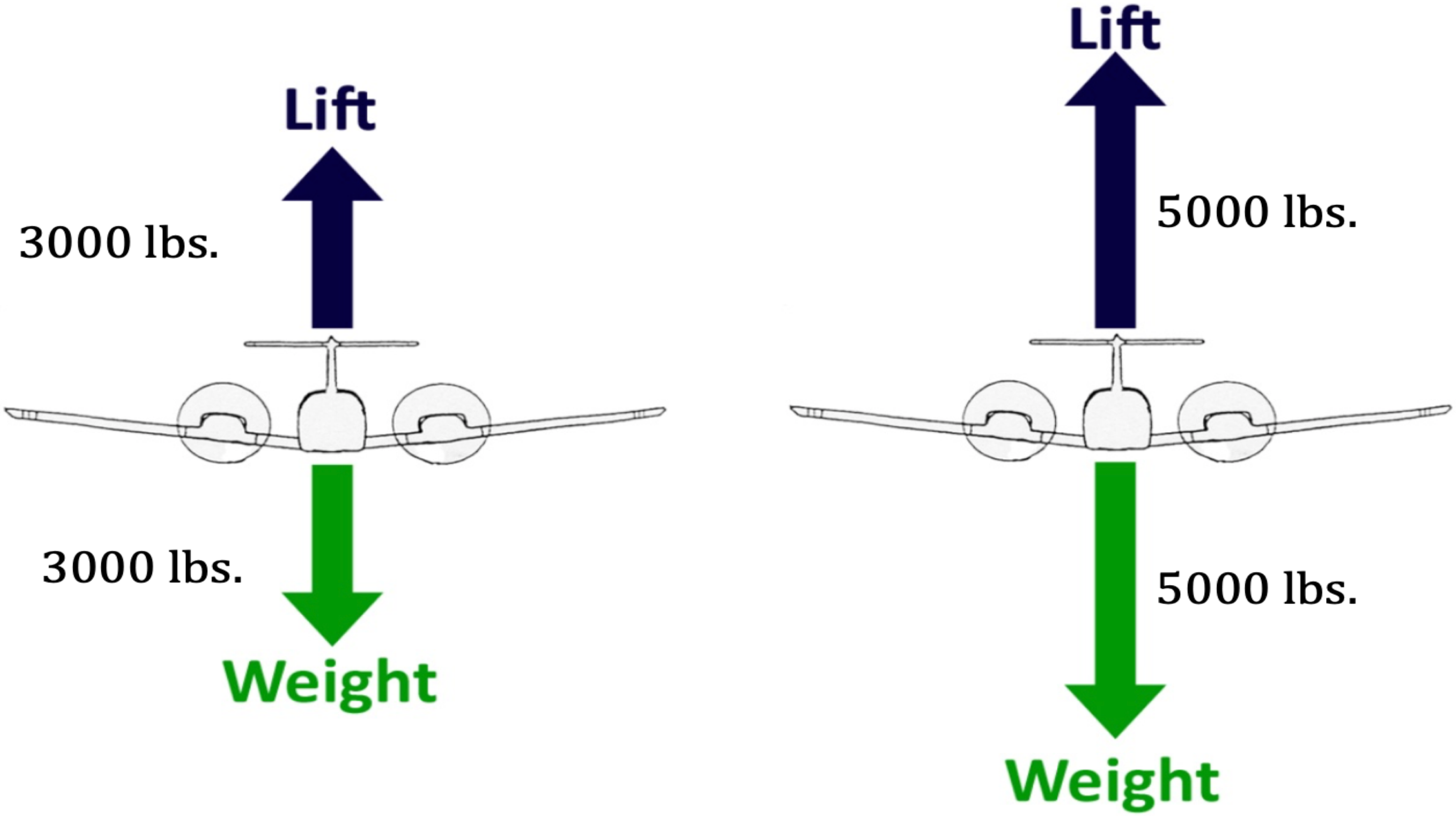
LIFT CREATED BY FUSEFLAGE

Just like the wings, the fuselage produces lift. However, the fuselage is just not as efficient at making lift as the wings. Fuselage lift is more noticeable when the relative wind is not flowing directly parallel to the longitudinal axis of the airplane.

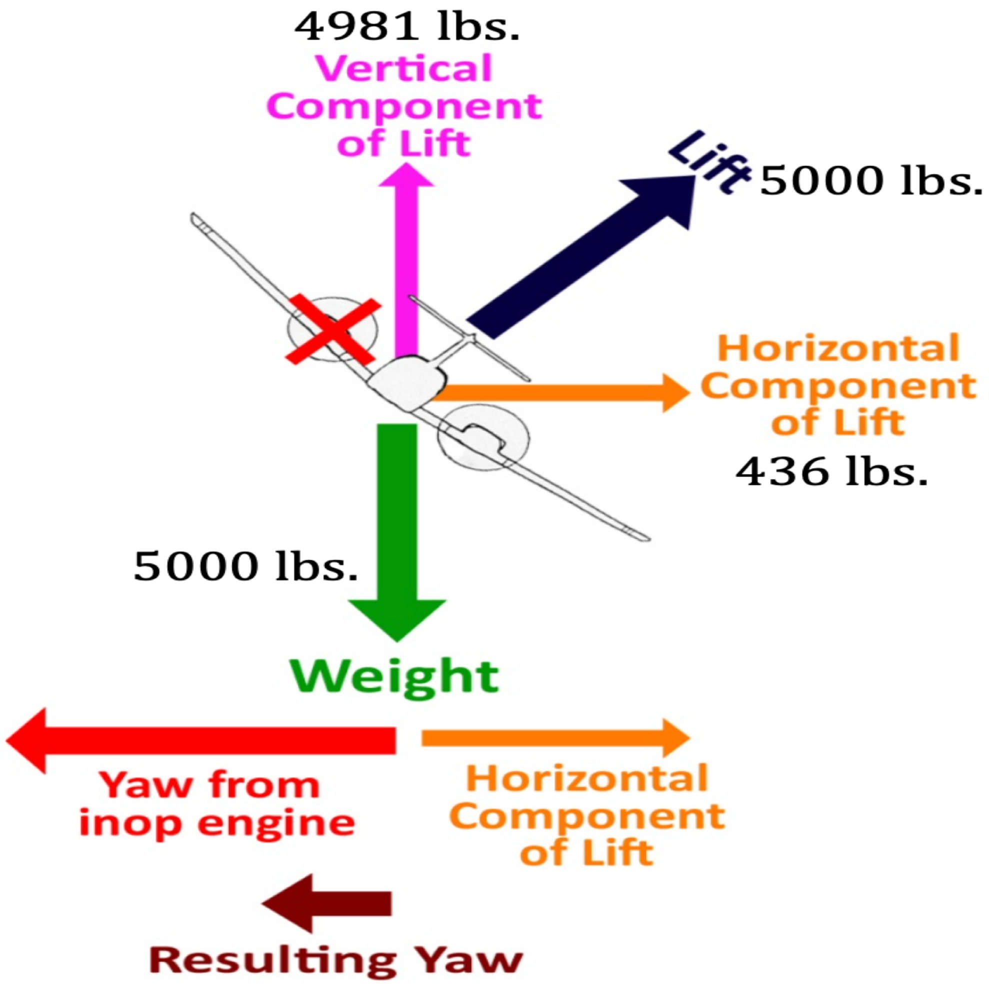


AFFECTS OF WEIGHT ON VMC

- The weight of the airplane determines the amount of total lift required by the airplane to maintain level flight. As the airplane is banked, the lift is separated into horizontal and vertical components of lift.
- The horizontal component of lift (the force that causes the airplane to turn) will help oppose the yaw due to an inoperative engine. The more weight, the more horizontal lift is available to oppose the turn from the inoperative engine.
- This means that horizontal lift can be used along with rudder to stop the turn. When more horizontal lift is available, less rudder is needed, which means more rudder is available to the pilot and VMC decreases. So, as weight increases, VMC speed decreases. As weight decreases, VMC increases.


Lift
3000 lbs.
3000 lbs.
Weight
Lift
5000 lbs.
5000 lbs.
Weight

With a 5° Angle of Bank:

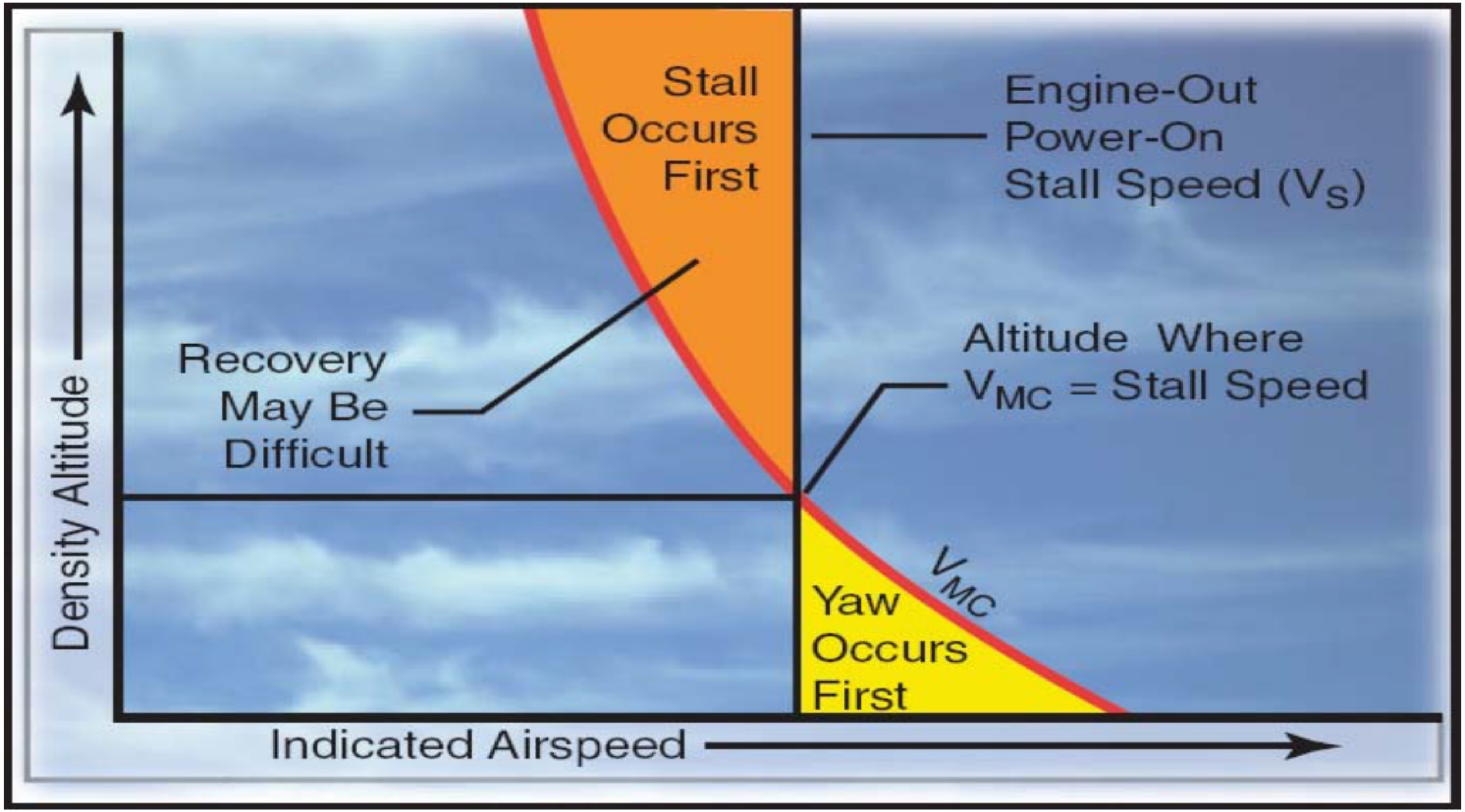


5. RELATIONSHIP OF VMC TO STALL SPEED.

- As density altitude increases, VMC speed decreases due to the fact that as density altitude increases engine power will decrease.
- The decrease in engine power results in less asymmetrical thrust, meaning the yawing from a failed engine will be less at a high density altitude than a lower density altitude.
- Stall speed is an indicated airspeed and will remain constant as altitude increases or decreases.
- At high density altitudes the stall typically occurs before loss of Vmc. (To simulate loss of Vmc often the rudder is blocked from full travel by MEI)

DANGER WHEN VMC AND STALL SPEED MEET

- Vmc is not a fixed speed but rather is in relation to density altitude not a set speed.
- Stall speed is always a set speed for a given configuration
- Awareness must be given when high density altitude exists.
- If Vmc and stall speed occur at the same time the aircraft will both stall and lose direction control at the same time resulting in an inadvertent spin.
- Recovery from a spin in a multiengine aircraft is often deadly
  - See video


Stall
Occurs
First
Engine-Out
Power-On
Stall Speed (V_S)
Recovery
May Be
Difficult
Altitude Where
V_{MC} = Stall Speed
V_{MC}
Yaw
Occurs
First
Density Altitude
Indicated Airspeed

6. REASONS FOR LOSS OF DIRECTIONAL CONTROL.

- Engine Failure – Improper Response & Configuration
- Vmc Demo – Improper Response & Configuration
- Improper Planning & Exceeding Aircraft performance & limitations

ENGINE FAILURE

- Failure to respond and configure aircraft appropriately on Engine failure according to POH

  - Failure to promptly identify inoperative engine and maintain directional control
  - Failure to bank 5 degrees towards operative engine
  - Improper rudder input to minimize side slip
  - Improper pitch for Vyse airspeed
  - Failure to feather inoperative engine
  - Failure to reduce drag, flaps, gear, cowl flaps, increasing drag increases Vmc
  - Failure to apply take off power on operating engine

VMC DEMO

- Failure to recognize signs of loss of Vmc and proper recovery
  - Stall warning horn, buffeting, increase yaw, failure to maintain heading within 20 degrees
- Failure to immediately reduce pitch of aircraft increasing airspeed
- Failure to immediate reduce power on operative engine , reducing turning tendency towards inop engine
- Failure to recognize non-standard (high) density altitude placing the aircraft in a position to stall and lose Vmc simultaneously
- Improper recovery from loss of Vmc demonstration advancing throttle too rapidly.

EXCEEDING AIRCRAFT PERFORMANCE & LIMITATIONS

- Failure to consult performance charts and limitations in preflight planning for an engine failure on takeoff roll, takeoff climb out, en-route climb, descent, approach to landing, single-engine climb rate*
- Failure to plan for an engine failure in various phases of flight
- Attempting to exceed performance and limitations for takeoff, climb, en-route, descent landing
- Attempting to maintain flight when an engine failure occurs close to the ground rather than land.
- Attempting to maintain altitude resulting in flight below Vyse to clear obstacles in the case of a loss of engine resulting in a drift down.

OTHERS

- Engine failure in IMC leading to disorientation
- Distraction
- Loss of situational awareness
- Task Saturation
- Not current in Single Engine operations and Single Engine EP’s

7. INDICATIONS OF LOSS OF DIRECTIONAL CONTROL.

- **Loss of directional control** – the rudder pedal is depressed to its fullest travel and the airplane is still turning towards the inoperative engine.
- **Stall warning horn** – a single-engine stall could be just as dangerous as running out of rudder authority and could even result in a spin.
- **Buffeting before the stall** – same reason as the stall warning horn.
- **A rapid decay of control effectiveness** – any loss of control effectiveness could result in loss if control of the airplane.

9. RECOVERING FROM VMC

To recover from VMC, two actions must occur (simultaneously):

- **Reduce power on the operating engine** – this will reduce the asymmetrical thrust causing the VMC in the first place. Reducing the power all the way to idle may help stop the VMC, but the loss of power and resulting loss of airspeed could lead to a stall.

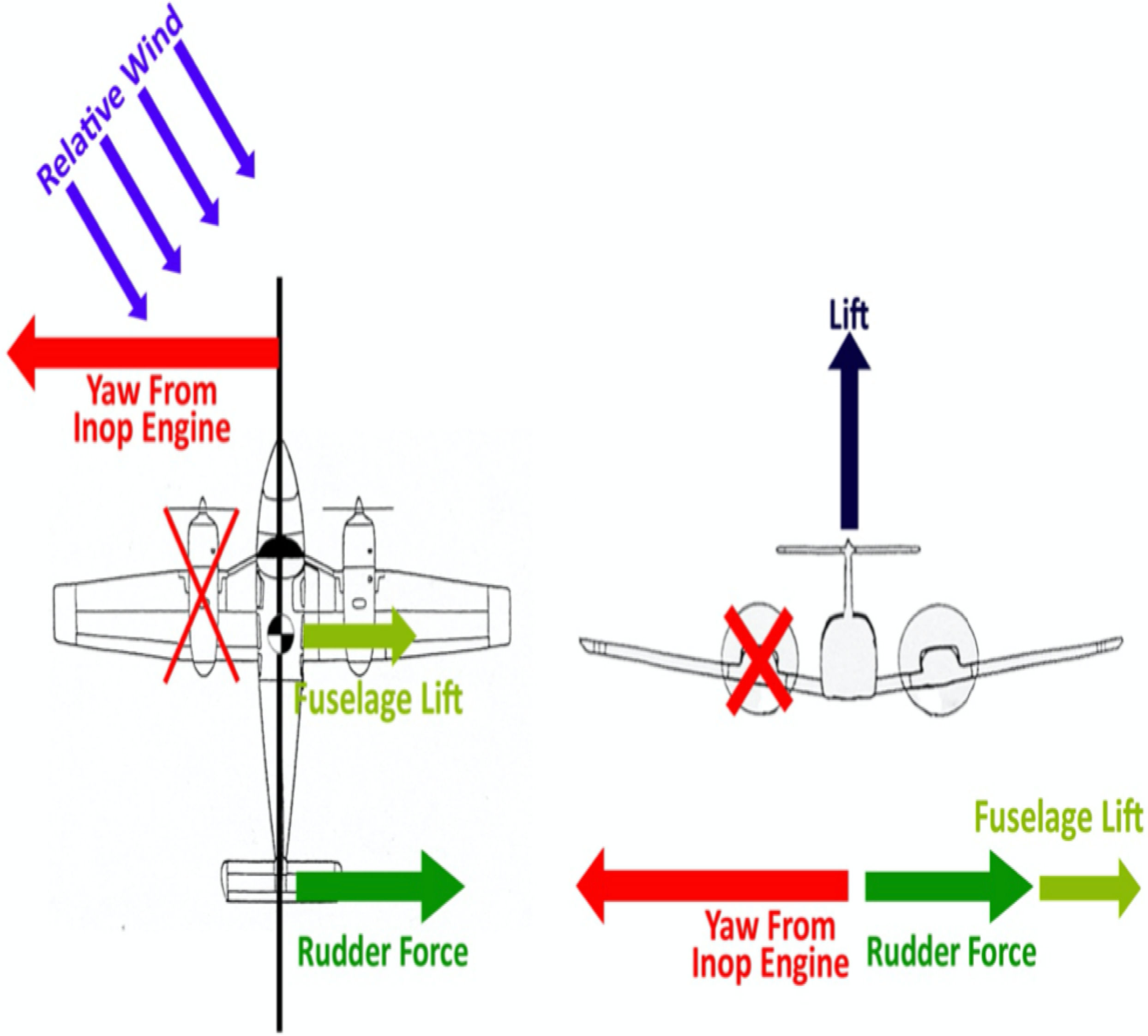
- **Pitch down** – Lowering the nose of the airplane will increase the forward airspeed making the rudder more effective in regaining and maintaining directional control.

8. PROPER PITCH, BANK, COORDINATION

By putting all these factors together, it is possible to see the overall effects of bank angle and how these factors affect both VMC and performance. To compare the effects of VMC and performance it is necessary to use a few different examples. In the following examples, the airplane is maintaining a constant heading after experiencing a failed left engine.

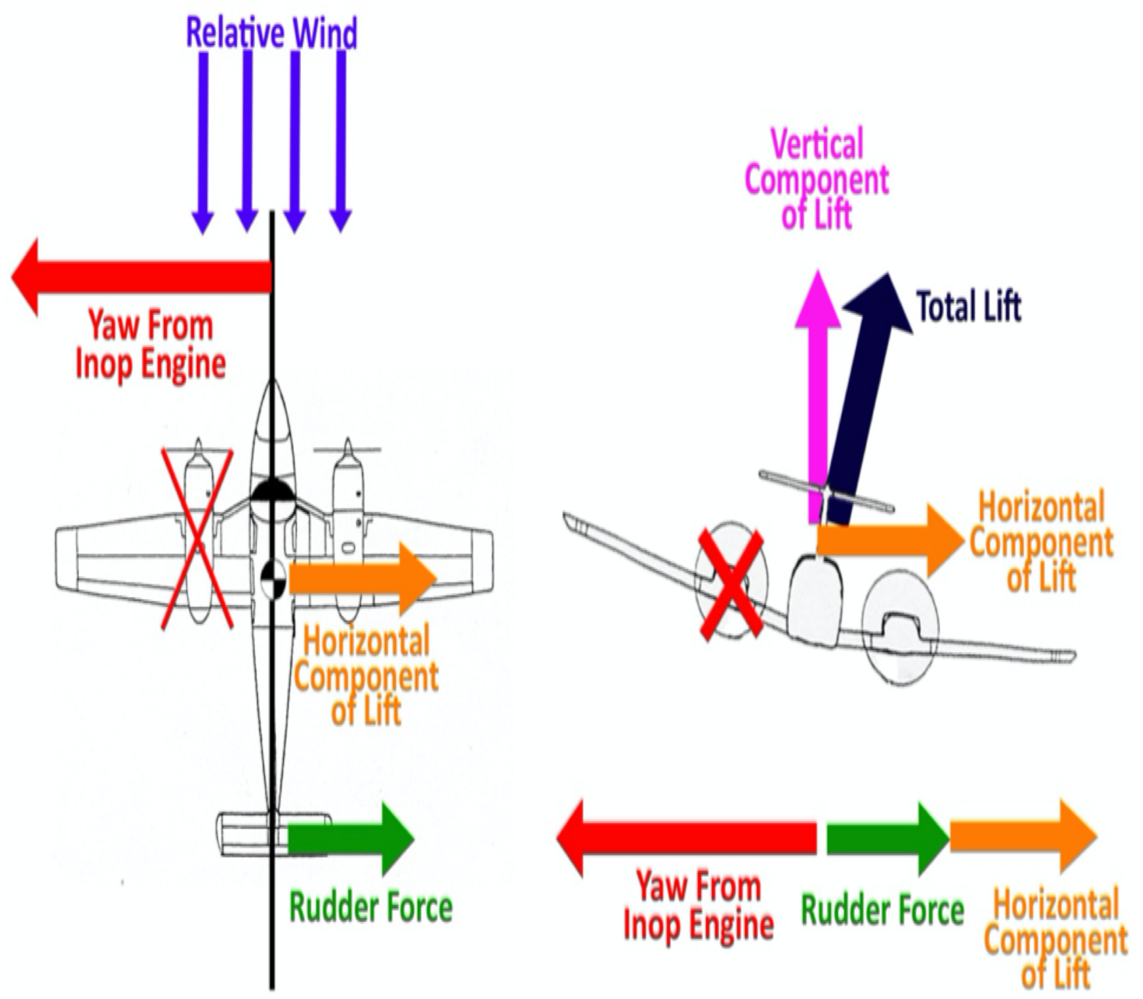
0 DEGREES BANK

- The relative wind, coming from the left of the nose, will cause the airplane to be in a slip. This causes the angle of attack on the rudder to be small and, therefore, makes it less effective.
- It also creates fuselage lift in the direction opposite of the yaw from the inoperative engine. Since the angle of attack on the rudder is small, the amount of rudder required to maintain a constant heading is quite large. This makes VMC a moderately high airspeed. Up to 20 knots
- The slipping condition of the airplane will result in a moderate amount of drag which lowers overall performance.



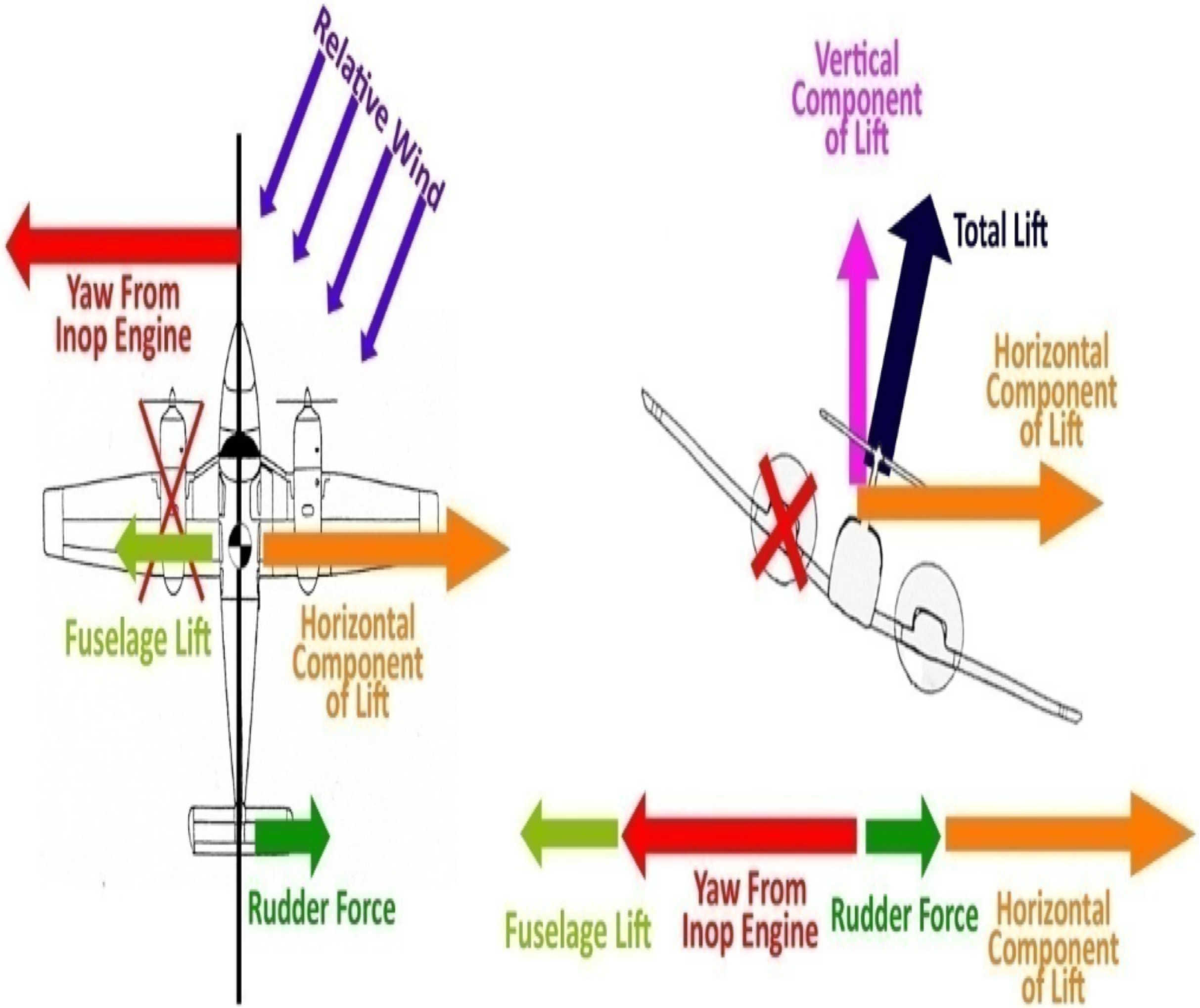
2-3 DEGREES OF BANK

- This bank angle results in a **Zero Sideslip** condition. A Zero Sideslip condition exists when the relative wind is directly parallel to the longitudinal axis of the airplane. This condition results in the minimum amount drag possible when an engine is failed.
- VMC speed will be lower in this case (compared to 0° bank) for two reasons:
  - 1. The angle of attack on the rudder is larger making it more effective.
  - 2. The amount of rudder needed and used is less than in the 0° of bank scenario since it is more effective. Also, the horizontal component of lift is now helping to oppose the yaw from the inoperative engine (meaning less rudder will be required).
- The result is more rudder is available to the pilot which will lower VMC. Performance will increase due to the smaller amount of drag.



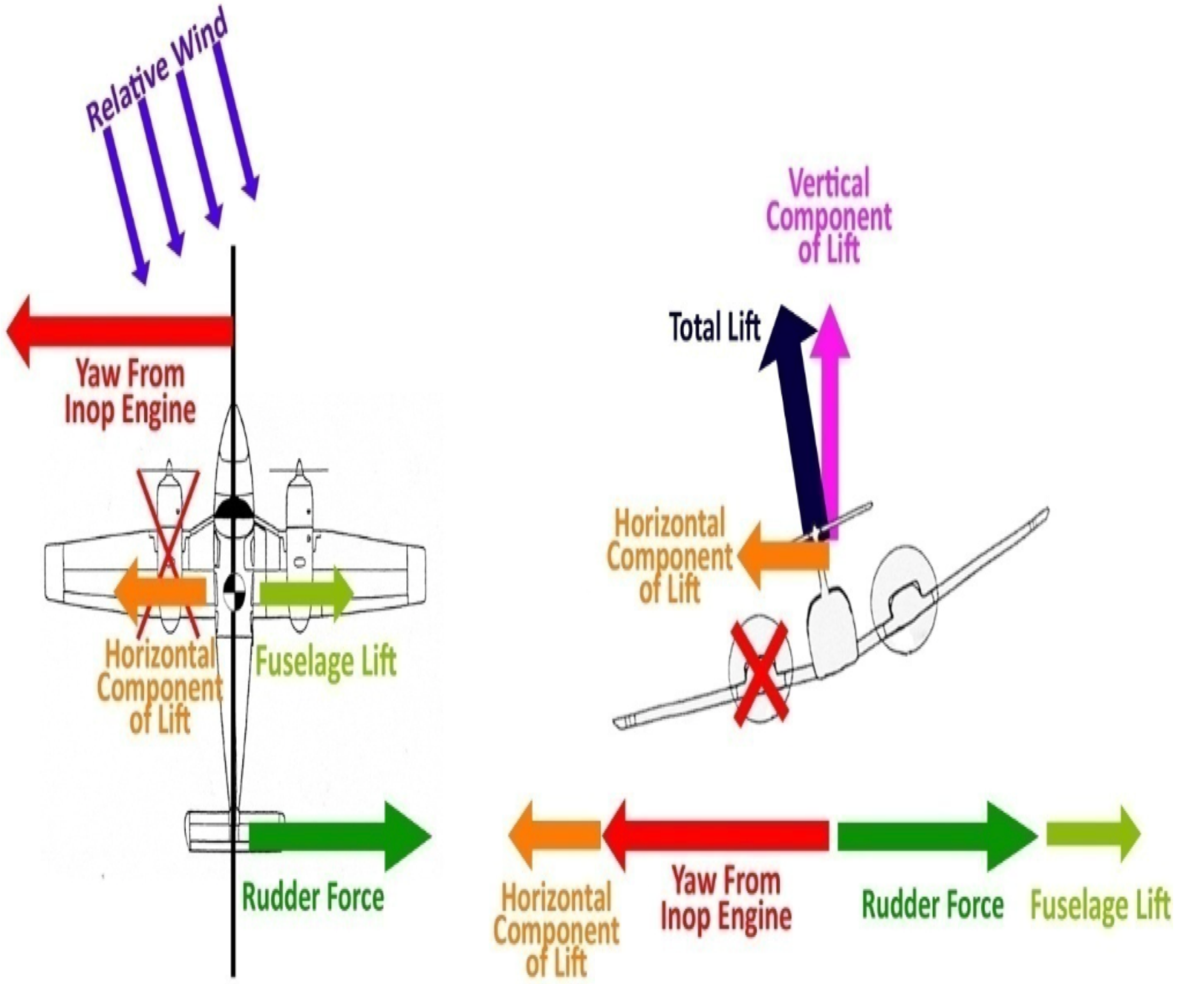
8 DEGREES BANK

- The direction of the relative wind will create a large angle of attack on the rudder. This makes it more effective resulting is less rudder input needed by the pilot. Also, the greater amount of horizontal lift means that less rudder will be needed to maintain heading. This results in a lower VMC.
- The performance of the airplane will decrease because the angle of the relative wind will result in a slipping condition that produces a large amount of drag on the airplane.



5 DEGREES TOWARD OPERATIVE ENGINE

- Banking towards the inoperative engine will cause the horizontal lift from the wings to add to the yaw from the inoperative engine. The relative wind will create a fuselage lift that opposes the yaw. The angle of the relative wind with the rudder will create a small angle of attack making the rudder less effective. To maintain heading the pilot will have to use a very large amount of rudder. This increases VMC significantly.
- The performance of the airplane will decrease because the angle of the relative wind will result in a slipping condition and cause a large amount of drag on the airplane.



SUMMARY OF BANK ANGLE RELATING TO V_{MC} SPEED AND DRAG

Bank Angle	V_{MC} Speed	Drag
5° bank towards inoperative engine	High	Moderate
0° bank	Moderate	Moderate
2°-3° bank toward operating engine (Zero Sideslip)	**Low**	**Minimum**
8° bank towards operating engine	Lower	High

10. ENGINE FAILURE PLANNING & DECISIONS SINGLE ENGINE OPS

- Failure on Takeoff Roll
- Failure after Takeoff Rotation
- Failure on Takeoff Climb
- Failure En-route
- Failure on Approach & Landing

FAILURE ON TAKEOFF ROLL

The takeoff in a multiengine airplane should be planned in sufficient detail so that the appropriate action is taken in the event of an engine failure. The pilot should be thoroughly familiar with the airplane's performance capabilities and limitations in order to make an informed takeoff decision as part of the preflight planning. That decision should be reviewed as the last item of the "before takeoff" checklist.

- Takeoff Distance
- Accelerate Stop Distance

Light Twin Takeoff Control & Performance Briefing

Density altitude =			
Runway length =		**Vmc =**	
Takeoff wt =		**Vr =**	
Takeoff dist =		**Vyse =**	
Accel-stop dist =		**Vy =**	
SE climb rate =			
SE svc ceiling =			

- If an engine fails below _____ (Vmc) or _____ (Vr), I will retard the throttles and abort the takeoff.
- If an engine fails after liftoff and the landing gear is down, I will close both throttles and land straight ahead.
- If an engine fails after liftoff (at/above Vxse) and the landing gear is retracted, I will follow the Airplane Flight Manual procedures to:
  - Control (pitch & power for Vyse)
  - Configure (flaps, gear, prop)
  - Climb (maintain Vyse; zero sideslip)
  - Checklist (upon reaching 400 AGL)

TAKEOFF DISTANCE GROUND ROLL

- Takeoff Distance Ground Roll is the distance required to reach Vr / Vlof
- Takeoff Ground Roll Distance shall be briefed on the pre-takeoff brief prior to every takeoff.
- Note the distance from the performance chart.
- Note a visible mark on the runway by which takeoff ground roll distance can be determined.
- If the aircraft has not reach Vr at the determined point or ½ way point on runway, consider this an engine abnormality, abort takeoff
- If an engine fails below VMC while the airplane is on the ground, the takeoff must be rejected. Directional control can only be maintained by promptly closing both throttles and using rudder and brakes as required.

ACCELERATE STOP DISTANCE

- Accelerate-Stop distance is the distance required to accelerate to liftoff speed Vr (71) and, assuming failure of an engine at the instant liftoff speed is attained, bringing throttles to idle and stopping the airplane.

- The FARs do not specifically require that the runway length be equal to or greater than the accelerate-stop distance. Most AFM/POH publish accelerate-stop distances only as an advisory. It becomes a limitation only when published in the limitations section of the AFM/POH. Using runway lengths of at least the accelerate-stop distance is a good operating and safety practice.

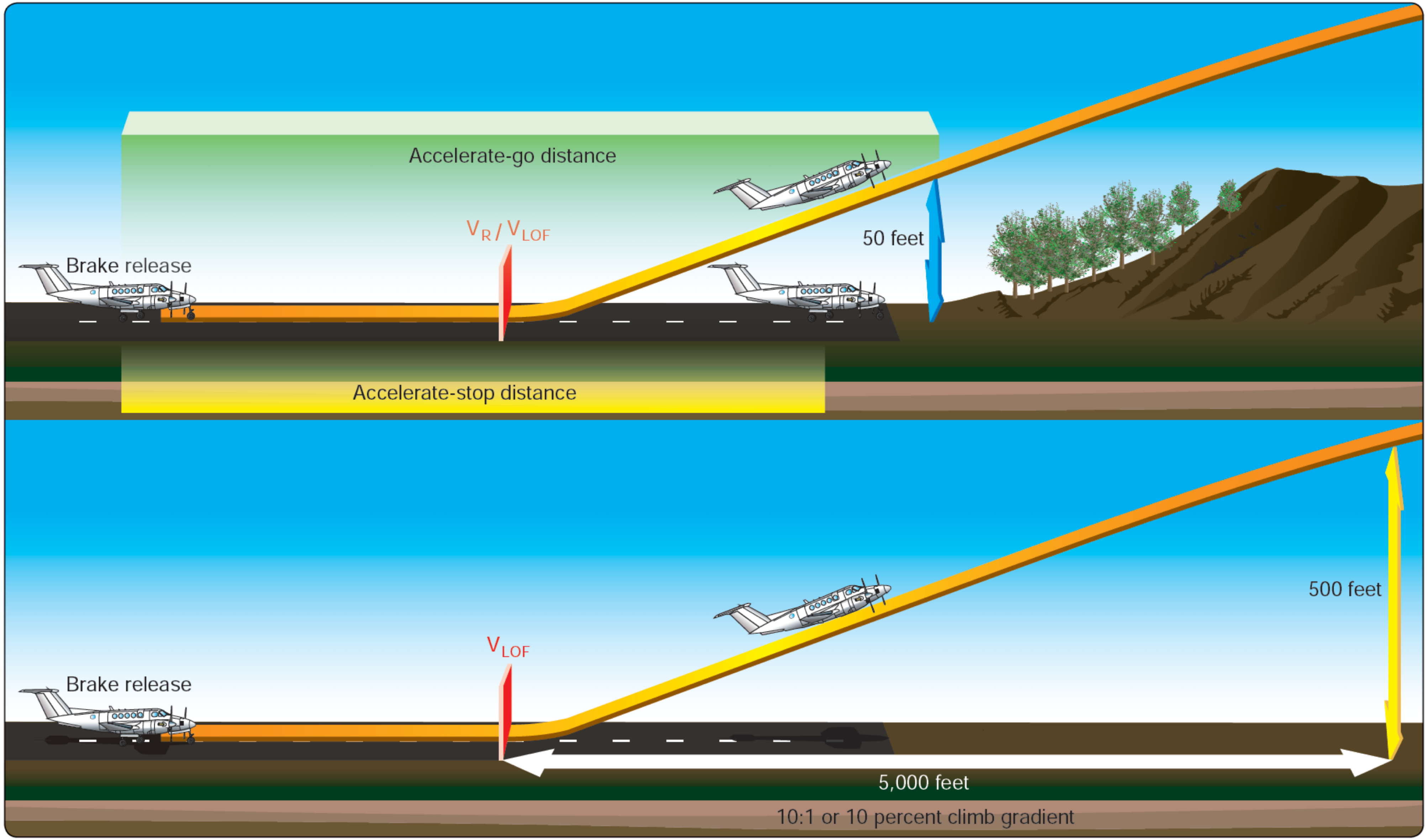


Figure 12-5. *Accelerate-stop distance, accelerate-go distance, and climb gradient.*

ACCELERATE GO DISTANCE

- Accelerate-Go distance is the distance required to accelerate to liftoff speed Vr (71) and, assuming failure of an engine at the instant liftoff speed is attained, continuing the takeoff and climbing to 50’.
- If an engine fails below VMC while airborne, directional control is not possible with the remaining engine producing takeoff power. On takeoffs, therefore, the airplane should never be airborne before the airspeed reaches and exceeds VMC.
- Know before you try to takeoff whether you can maintain control and climb out if you lose an engine with the gear still down!
- *See Single Engine Rate of Climb. If single engine rate of climb is less than 0 , DON”T TAKEOFF! In the event of an engine failure you have not choice but to land!

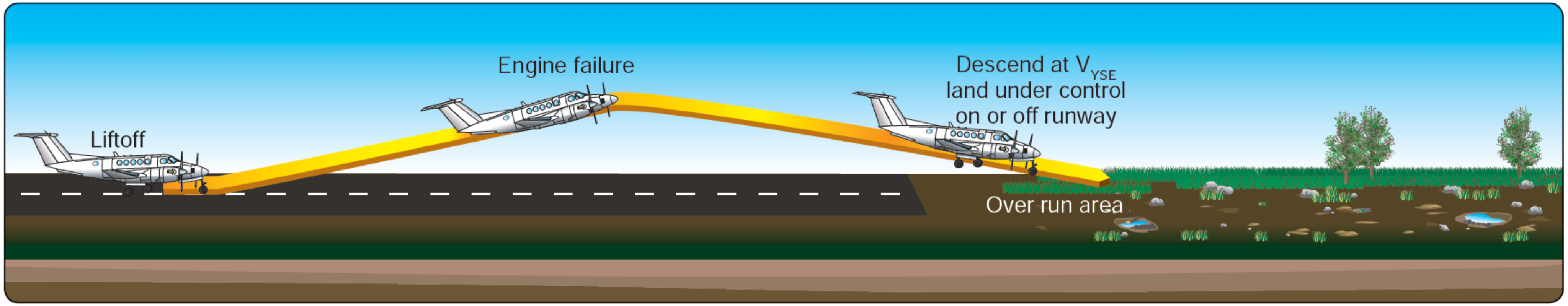


Figure 12-12. *Engine failure on takeoff, inadequate climb performance.*

- The accelerate-go distance, under ideal circumstances = 50 feet above the takeoff elevation.
- To achieve even this meager climb, the pilot had to instantaneously recognize and react to an unanticipated engine failure, retract the landing gear, identify and feather the correct engine, all the while maintaining precise airspeed control and bank angle as the airspeed is nursed to VYSE. Assuming flawless airmanship thus far, the airplane has now arrived at a point little more than one wingspan above the terrain, assuming it was absolutely level and without obstructions.

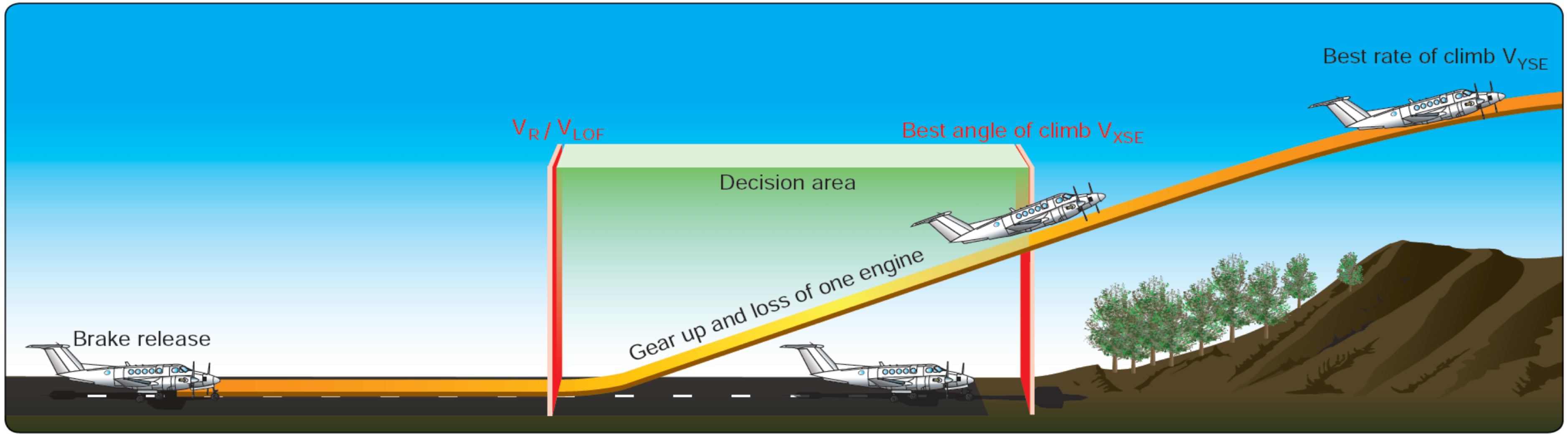


Figure 12-6. *Area of decision for engine failure after lift-off.*

SINGLE ENGINE CLIMB RATE

- This chart is for exactly what the title implies. Plug in your weight from the weight & balance to determine if you will be able to climb at liftoff, period. If you can't, then you are committed to pulling throttles to idle and stopping the airplane. Accelerate-Go would be impossible in this case.
- These charts were printed in 1980 when the airplanes were new. Always assume that your airplane will not live up to the performance stated in the charts. Always plan for worst case scenario and always give yourself an out. Always fly under the assumption "what if".

SINGLE ENGINE CLIMB RATE IFR SID/ODP

- Do not only assume the Single Engine Climb Rate chart is for immediate takeoff. It also helps in decision making and single engine operations in the IFR environment
- Engine failure in IMC drastically increases pilot task saturation. Know before you go if you experience an engine failure that you can still adhere to the SID/ ODP for obstacle clearance.
- It would be foolish to accept an IFR clearance that required a Climb rate that your aircraft can not obtain under single engine operations.

SINGLE ENGINE SERVICE CEILING

- The highest altitude at which the airplane can maintain a steady rate of climb of 50 fpm with one engine operating at full power and one engine's propeller feathered.
- During the enroute preflight planning segments consider obstacle clearance, MEA's, MCA's, OROCA's, MSA's in relation to the expected Single Engine Service Ceiling.
- If your Single Engine Service Ceiling will not allow you to meet required altitudes change your routing!

SINGLE ENGINE ABSOLUTE CEILING

- The altitude where climb is no longer possible with one engine operating at full power and one engine's propeller feathered.
- If the airplane is flying above the single-engine service ceiling and one engine fails in flight, the airplane will drift down from its current altitude to the single-engine service ceiling.
  - Above the single-engine absolute ceiling, VYSE yields the minimum rate of sink.
  - For example if an airplane's single-engine absolute ceiling is 5,000 ft. and while cruising at 9,000 ft. an engine fails, the airplane will drift down (descend) to 5,000 ft.
  - Planning must be made to ensure terrain clearance, MEA's, MCA's, ect. in the case of an engine failure en-route during pre-flight planning

ENGINE FAILURE ON APPROACH & LANDING

- Fly approach and landing the same as a normal approach and landing
- Maintain Vyse 85 as approach speed.