Multiengine Aerodynamics

multiengine Aerodynamics

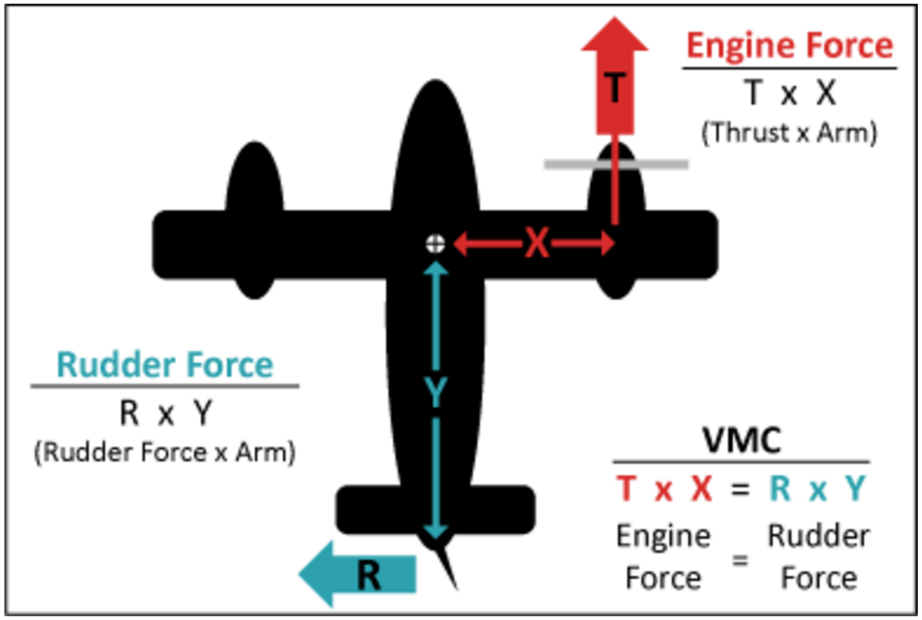
Conventional Rotating Propellers - Left Engine Critical
Counter-Rotating Propellers - No Critical Engine

Rudder Effectiveness - Counteracts negative turning tendencies when one engine is inoperative

Centerline Thrust - the closer the trust is to the longitudinal axis, the more stable the airplane

Longer arm = More Leverage
Shorter arm = Less Leverage

Airspeed is king!



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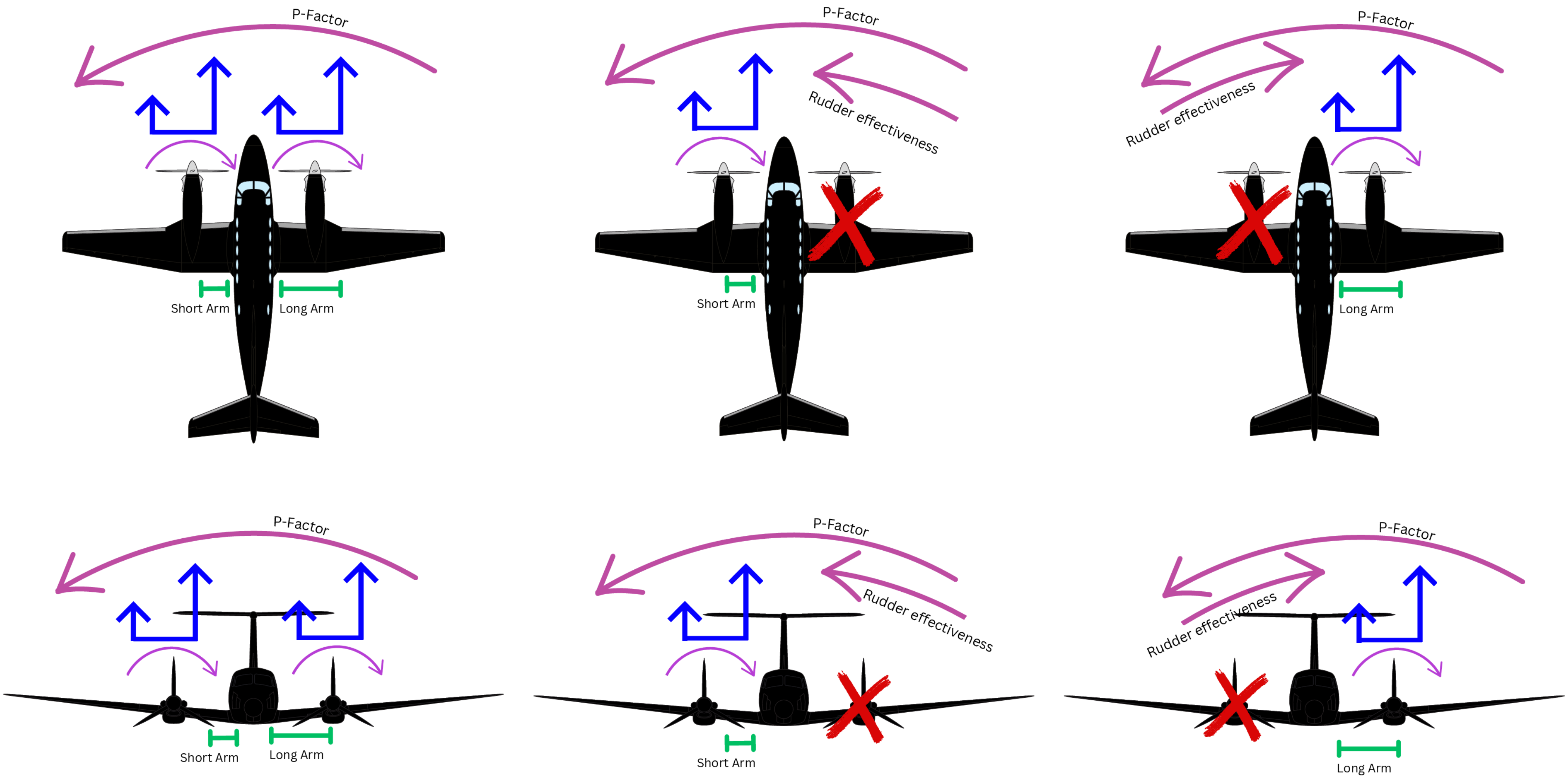
P-Factor

YAW



Conventional Propeller systems shown
As seen from above on top row
Adjust s seen from behind on bottom row

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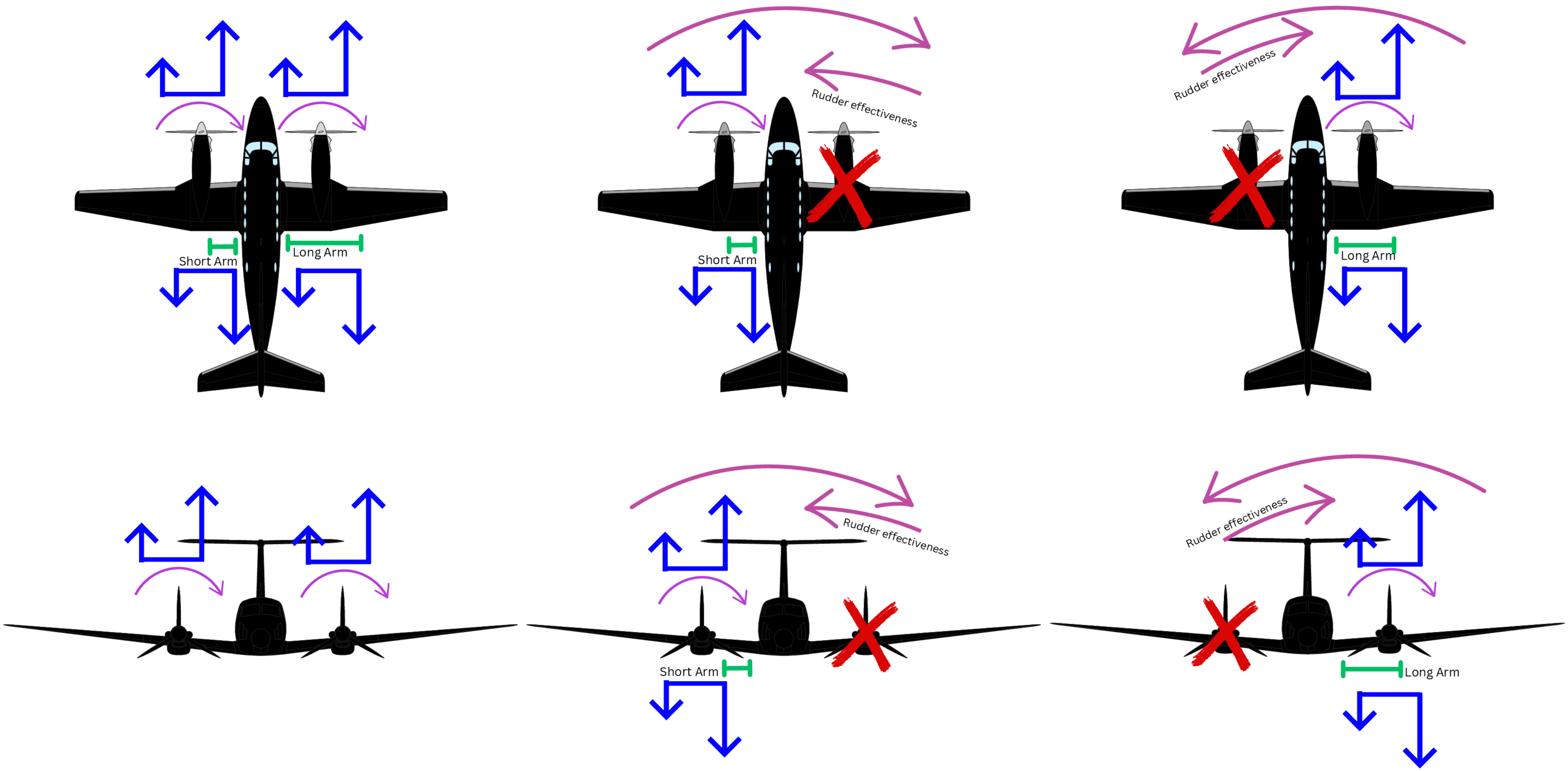
Accelerated Slipstream

ROLL



Conventional Propeller systems shown
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As seen from behind on bottom row

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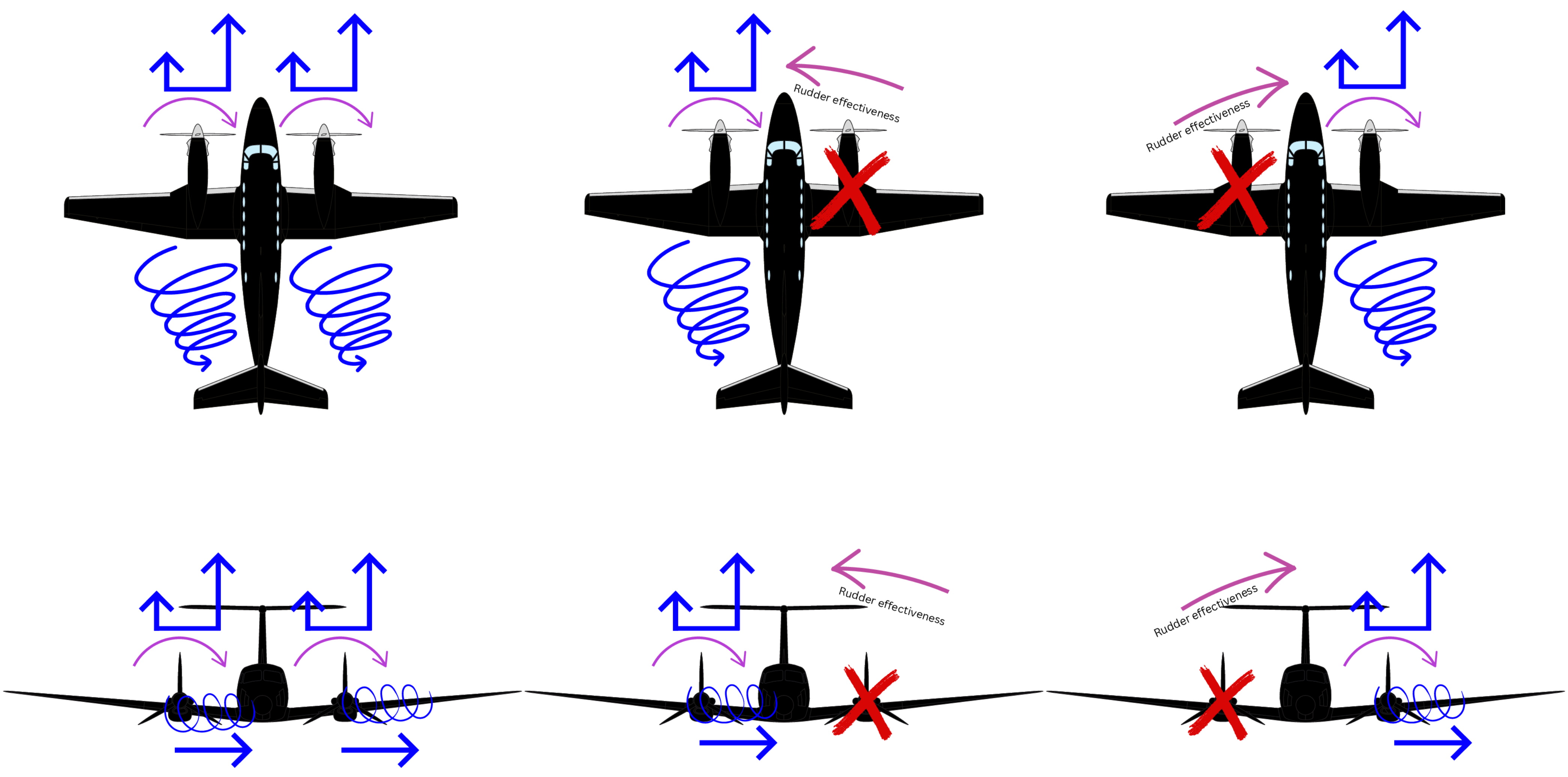
Spiraling Slipstream

YAW



Conventional Propeller systems shown
As seen from above on top row
As seen from behind on bottom row

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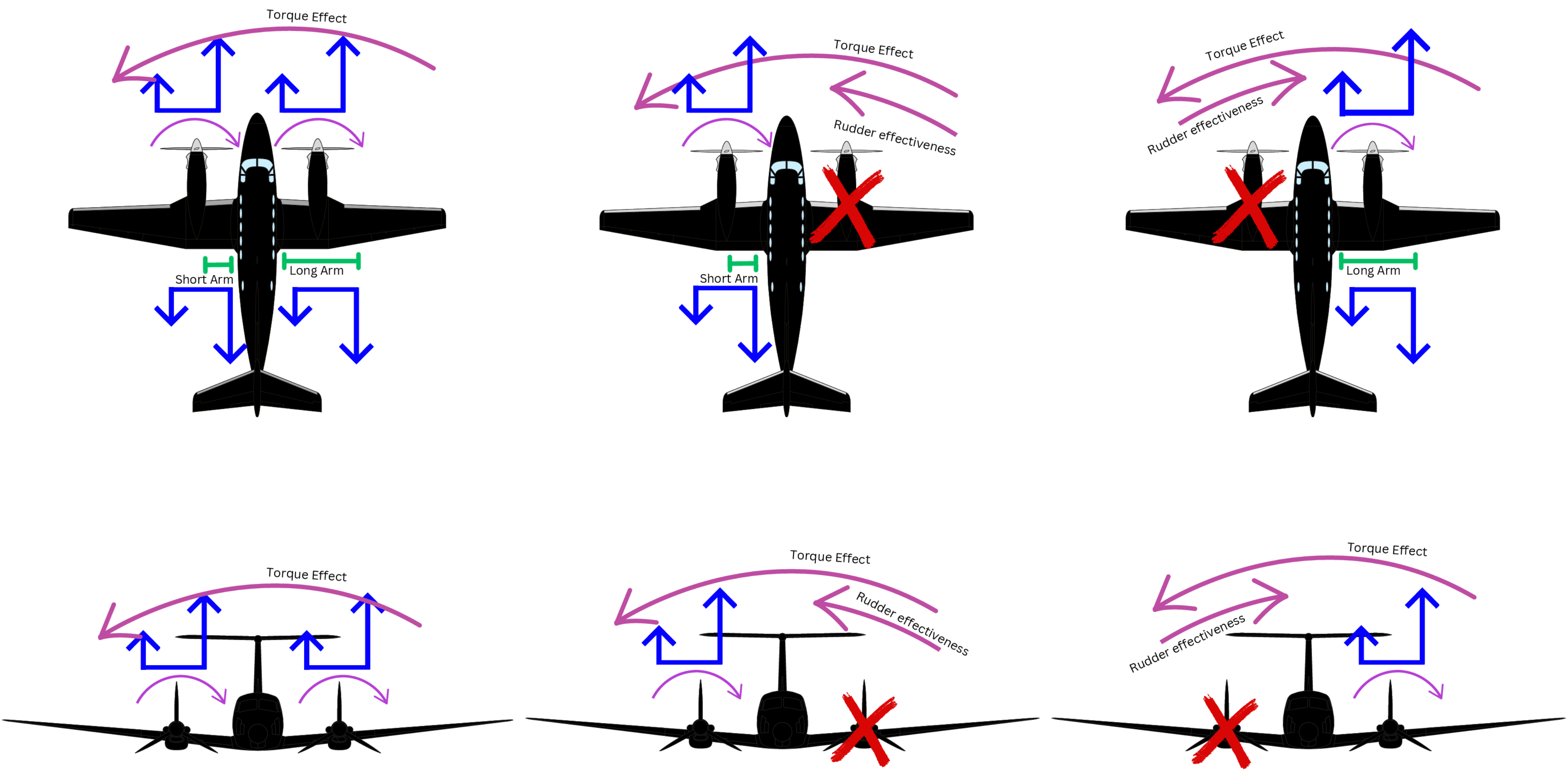
Torque

YAW & Roll



Conventional Propeller systems shown
As seen from above on top row
As seen from behind on bottom row

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FAR 23.149 vs. 25.149

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, and thereafter maintain straight flight at the same speed with an angle of bank of not more than 5 degrees.

23.149 -Vmc certification that aircraft like the Seminole, Seneca, Geronimo, Twin Comanche, and Aztec were certified under and thus still adhere to this regulation up to about 1978.

25.149 - Pertains to transport category aircraft, which we are not.

A note on counter-rotating propeller-equipped multiengine aircraft:
14 CFR 1.1 defines critical engine as “Critical engine means the engine whose failure would most adversely affect the performance or handling qualities of an aircraft.”
However....
Per 23.149 We have a Vmc speed
and....
in 14 CFR 1.2 it defines Vmc as “minimum control speed with the critical engine inoperative.”

So, in counter-rotating propeller-equipped multiengine aircraft, do we have a critical engine?

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Vmc Certification Requirements 23.149

	Parameter	Change	Vmc	Controllability	Performance	Explanation
S	Std Day (29.92 15°C)	Density Altitude Increases	↓	↑	↓	With the Increase in Density Altitude (DA), power of the operating engine decreases so the power difference between engine decreases.
M	Maximum Power	Power Reduction	↓	↑	↓	If the power of the operating engine decreases, the power difference between the engines decrease.
A	Aft CG	CG Moves Forward	↓	↑	↓	As CG moves forward, there's a longer arm from the rudder to the CG. so controllability increases. But, more weight forward means that the horizontal stabilizer must exert a greater downforce, so performance decreases (effectively greater total weight).
C	Critical Engine Windmilling	Critical Engine Feathered	↓	↑	↑	Feathering the critical engine reduces its drag, (equivalent to increasing thrust). So reducing the difference between engines increasing controllability. Less drag means more performance.
F	Flaps Up, Gear Up, Trim Fwd or Aft	Flaps Down, Gear Down, Trim T.O	↓	↑	↓	Flaps - more overall drag (like reducing power) Gear - Lowers CG as well as Keel Effect Trim Forward or Aft - Added Drag -Nose pitching forward or aft of Takeoff (T.O.)
U	Up to 5° Bank	Wings Level	↑	↓	↓	Longitudinal axis aligned with relative wind. Performance is best with no sideslip, any roll position greater or less than 5° will decrease performance. Controllability actually benefits from horizontal component of lift toward good engine so more roll is better and less is worse.
M	Most Unfavorable Weight	Add Weight	↓	↑	↓	Adding weight decreases all available climb performance, however, less available power aids in controllability via decrease in performance difference between engines

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BEST Conditions for Single Engine Operations

F	Flaps: Down	Vmc Increases - Retracted Vmc Decreases - Extended	More drag, Less Power available, stabilizing effect, air flow from operational prop aids drift effect
L	Landing Gear: Down	Vmc Increases - Gear Up Vmc Decreases - Gear Down	Keel effect, More drag, less power, stabilizing effect
A	Altitude: High	Vmc Increases - Low DA Vmc Decreases - Higher DA	Higher density altitude (DA), less performance, more time for troubleshooting & checklists
P	Power: Less	Vmc Increases - Power + Vmc Decreases - Power -	Less Power means less asymmetric thrust, less yaw and less roll
G	Ground Effect: In	Vmc Increases - Out Vmc Decreases - In	Less drag, more rudder authority, gear is likely down and near the ground, therefore landing is likely ideal
A	Angle of Bank: Up to 5°	Vmc Increases - Toward Operational Vmc Decreases - Toward Inop	Exchange of vertical to horizontal component of lift to aid asymmetric thrust, longitudinal axis aligned into relative wind
P	Prop Feathered on Inoperative Engine	Vmc Increases - Windmilling Vmc Decreases - Feathered	Less drag, less yaw more rudder authority, longer arm for more effective tail down force (TDF)
C	CG: Forward	Vmc Increases - Aft Vmc Decreases - Forward	Less angle of attack (AoA) more airflow on wings, rudder and thus more ruder authority
R	Rudder Trim: Neutral	Vmc Increases - Used Vmc Decreases - Neutral	Less drag means more rudder authority
E	Engine: Critical Engine Operative	Vmc Increases - Critical Vmc Decreases - Non-Critical	More controllability and thus rudder authority (conventional props)
W	Weight: More/Max	Vmc Increases - Less Vmc Decreases - More/Max	More tail down force (TDF), More horizontal component of lift to assist yaw and roll

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Vmc and Vs Relationship

"Except for a few models, published Vmc is almost always higher than Vs. At sea level, there is usually a margin of several knots between Vmc and Vs, but the margin decreases with altitude and, at some altitude, Vmc and Vs are the same"
(Flying Light Twins Safely, FAA.gov)

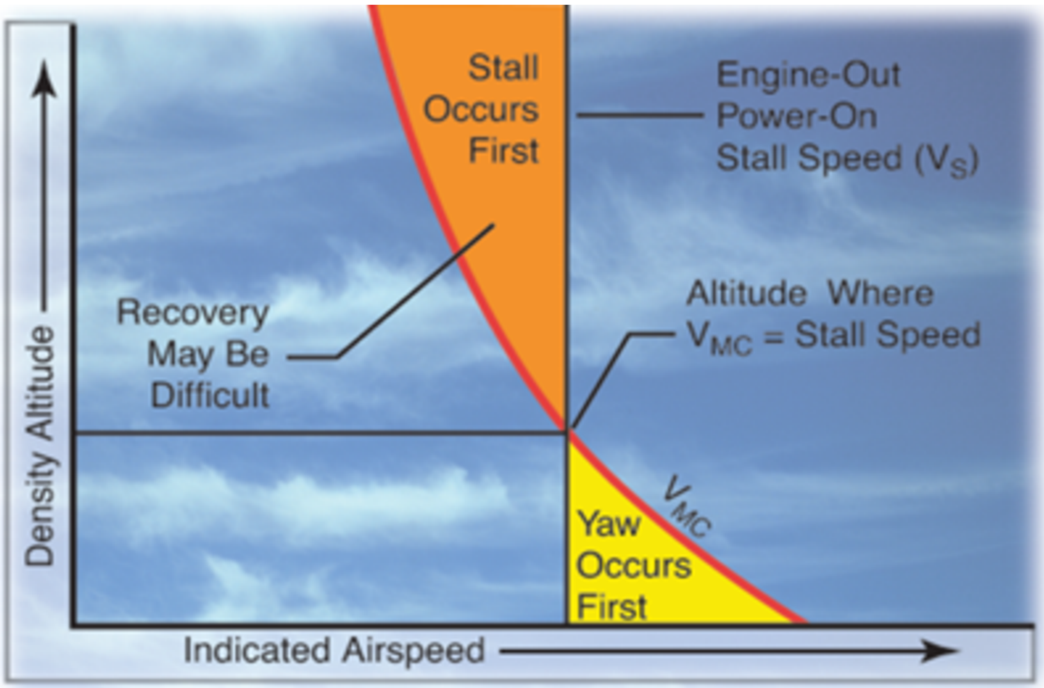

Figure 13-14. *Graph depicting relationship of V_{MC} to V_S.*

Image Credit: FAA Pilot's Handbook of Aeronautical Knowledge

The Relationship Between Vmc and Vs

Safety Margin:

- For safe single-engine operations, Vmc must be higher than Vs. If Vmc is below Vs, the aircraft could stall before reaching a controllable speed. This would be catastrophic, especially during engine-out scenarios at low altitudes.

Configuration Dependence:

- Flap and gear positions affect both Vmc and Vs. Lowering the gear or extending flaps increases drag, potentially lowering Vmc but raising Vs.
- Multiengine airplanes are designed so that Vmc is typically close to but still safely above Vs in critical configurations.

Pilot Considerations:

- When operating near Vmc, the pilot must maintain sufficient airspeed to ensure both controllability (Vmc) and performance (Vs).
- During a simulated or actual engine failure, pilots manage power and pitch to stay above both speeds.

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PERFORMANCE CEILINGS

Absolute Ceiling The altitude at which a climb is no longer possible.

Service Ceiling The maximum density altitude where the best rate-of-climb airspeed will produce a 100 feet-per-minute climb at maximum weight while in a clean configuration with maximum continuous power.

Single Engine Absolute Ceiling The altitude that a twin engine airplane can no longer climb with one engine inoperative.

Single Engine Service Ceiling The altitude that a twin engine airplane can no longer climb at a rate greater than 50 fpm with one engine inoperative.

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Accelerate Go Distance

The accelerate-go distance in multiengine aerodynamics is the distance it takes for an airplane to:

- Accelerate to the decision speed (Vr or Vlof) while both engines are operating.
- Lose one engine at Vr (critical engine failure at that instant).
- Continue the takeoff using the remaining engine(s), climb to a specified height (usually 50 feet.

There is no guarantee that under all conditions a light twin would be capable of continuing a takeoff and climbing out after an engine failure. Before taking the runway, you should know if the airplane could reasonably be expected to continue its climb following an engine failure.

In Simple Terms:

It's the runway length you need to safely keep going and take off, even if one engine fails at the worst possible moment (just as you reach the takeoff speed).

80% to 90%loss of climb performance and sometimes even more is lost when losing an engine.

Calculating Accelerate Go

((50 / (se roc x 60 / ground speed)) x 5280) + Takeoff Distance

a. se roc x 60 = a
b. a / ground speed = b
c. 50 / b = c
d. c x 5280 = d
e. d + TakeoffDistance = Accelerate-Go Distance
(where d is the distance from rotation to clear 50' obstacle)

FIGURE 13-5A

Accelerate-stop distance and accelerate-go distance.

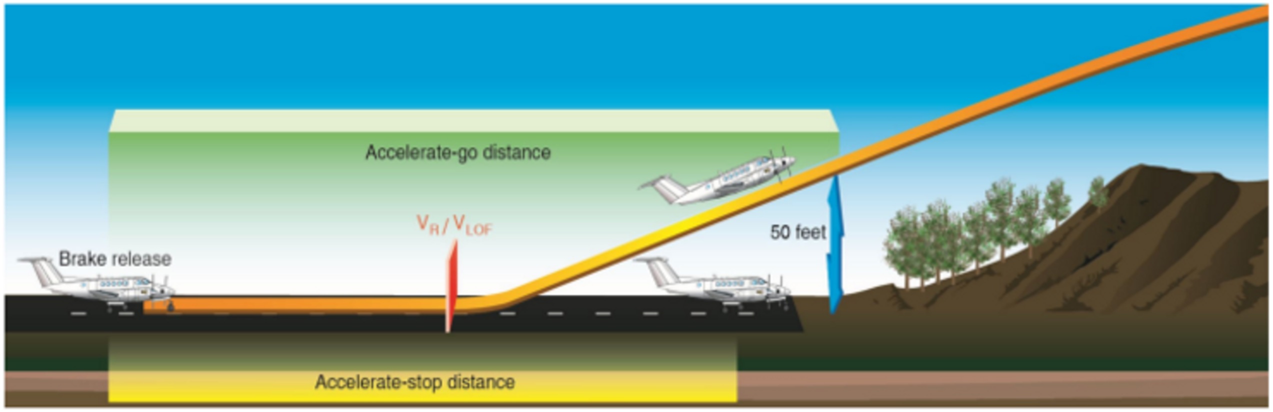

Image Credit: FAA Pilot's Handbook of Aeronautical Knowledge

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Accelerate Stop Distance

The accelerate-stop distance in multiengine aerodynamics is the distance it takes for an airplane to:

- Accelerate to the decision speed (Vr or Vlof) while both engines are operating.
- Decide to stop instead of taking off if an engine fails at Vr.
- Apply the brakes and bring the airplane to a complete stop on the runway.

In Simple Terms:
It’s the runway length you need to safely stop the plane if something goes wrong at the last possible moment before takeoff.
This distance is crucial for safety, ensuring there's enough runway to either take off or stop, depending on what the pilot decides at Vr.

FIGURE 13-5A

Accelerate-stop distance and accelerate-go distance.

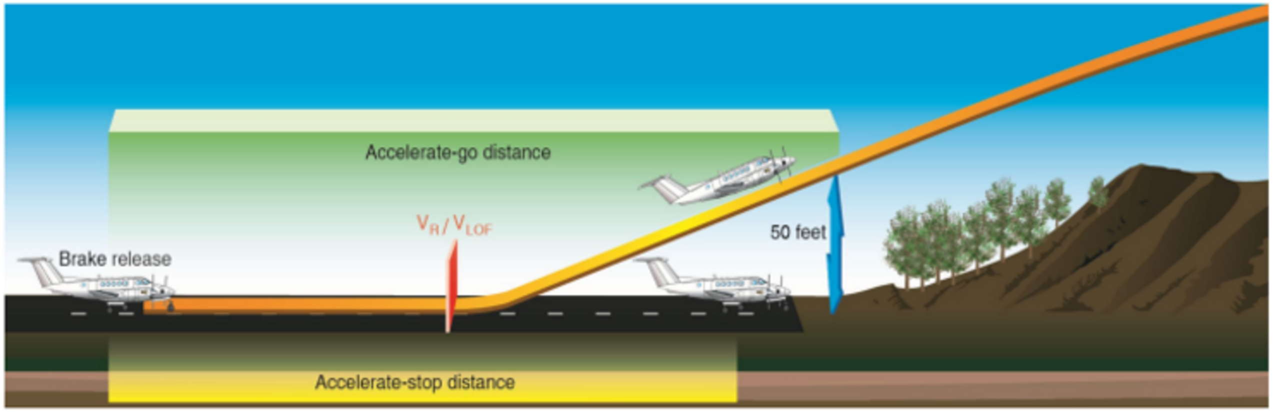

Image Credit: FAA Pilot’s Handbook of Aeronautical Knowledge

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Keel Effect

Chapter 5 of the Pilot's Handbook of Aeronautical Knowledge:

Keel Effect and Weight Distribution

A high wing aircraft always has the tendency to turn the longitudinal axis of the aircraft into the relative wind, which is often referred to as the keel effect. These aircraft are laterally stable simply because the wings are attached in a high position on the fuselage, making the fuselage behave like a keel exerting a steadying influence on the aircraft laterally about the longitudinal axis. When a high-winged aircraft is disturbed and one wing dips, the fuselage weight acts like a pendulum returning the aircraft to the horizontal level.

Laterally stable aircraft are constructed so that the greater portion of the keel area is above the CG. *[Figure 5-31]* Thus, when the aircraft slips to one side, the combination of the aircraft's weight and the pressure of the airflow against the upper portion of the keel area (both acting about the CG) tends to roll the aircraft back to wings-level flight.

Figure 5-31. *Keel area for lateral stability.*

Image Credit: FAA Pilot's Handbook of Aeronautical Knowledge

Also known as the pendulum effect.

Helps to counteract the turning tendency with one engine inoperative.
Keel Effect increases drag and decreases VMC

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