Multi-Engine Training Packet
BE-95-95

<u>Commercial-Multi Maneuvers</u>

Slow flight
Steep Turns
Stalls (power off/on/accelerated)
Engine Failure (takeoff/climb/cruise)
VMC Demo – Loss of directional control demonstration
Emergency Descent
Short Field Takeoff and Landing
Normal Takeoff and Landing
Single-Engine instrument approach (If adding instrument privileges)
Full engine shutdown and restart
Single engine pattern and landing

SKYVIEW
AVIATION, LLC

Flying Light Twins (General)

The most important phase of multi-engine flying is: Preflight Planning
Most critical phase of light twin flying is **Takeoff**

FAR Part 23 puts forth certification requirements for light twins with a max gross weight of less than 12,500 lbs.

Certification Requirements:

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

6001 – 12,500 lbs. –
Must climb clean at 5,000' ISA
Rate of climb (ROC) = (.027 x Vso^2)

6,000 lbs. or less –
If Vso = 61 kts CAS or greater.
Must perform a positive ROC (.027 x Vso^2)

If Vso = less than 61 kts
Does not have to do anything. Can be a negative ROC.

Examples:

C-310
5,300 lbs.
Vso = 63.9 kts.
63.9^2 x .027 = 110.2 fpm ROC
Reality ROC = 119 fpm

BE-76
3,900 lbs.
Vso = 60 kts.
Reality ROC = 50 fpm

Climb Performance

Climb performance is dependent on the excess power needed to overcome drag. When a twin-engine airplane loses an engine, the airplane loses 50% of its available power. This power loss results in a loss of approximately 80% of the aircraft's excess power and climb performance.

Drag is a major factor relative to the amount of excess power available. An increase in drag (such as the loss of one engine) must be offset by additional power. This additional power is now taken from the excess power, making it unavailable to aid the aircraft in climb.

When an engine is lost it is essential to achieve optimum single engine climb performance by:

Maximizing thrust- full power
Minimizing drag- flaps & gear up, feather prop

Drag Factors:

1. Full Flaps- 400 fpm approx.
2. Windmilling Prop- 400 fpm approx.
3. Gear Extended- 150 fpm approx.

Single Engine Aerodynamics

A twin-engine aircraft that has both propellers rotating the same direction (usually clockwise as viewed from inside the cockpit) is called a **conventional twin.** Since the same left-turning tendencies of a single engine airplane affect a multi-engine airplane, **counter-rotating** propellers have been developed to help combat those tendencies. The p-factor and torque from counter-rotating propellers cancel each other out which results in less rudder needed to oppose these tendencies.

What happens when an engine fails?

When an engine fails, there are two things that will happen: **Yaw** and **Roll.**
An aircraft with a failed engine will yaw and roll towards the dead engine due to asymmetric lift, thrust, and drag.

1. Asymmetric thrust will cause a yawing moment around the C.G. towards the dead engine.

2. Accelerated slipstream (or induced flow) is extra lift created by air accelerated from an operating engine forced over the wing. There is a lack of this induced flow over the wing with the failed engine. This results in a rolling moment around the C.G. toward the inoperative engine.

To counteract the roll and yaw, you must apply rudder towards the operating engine!

DEAD FOOT, DEAD ENGINE!

Zero Sideslip

Just using rudder to maintain direction will put the aircraft into a sideslip, which introduces the fuselage to the relative wind creating a large amount of drag. We need to minimize this drag as much as possible while still maintaining heading. The solution is to improve performance by using a zero-sideslip condition.

When the aircraft is banked 2°- 5° toward the operating engine, the dihedral of the wing will create a horizontal component of lift. This will minimize the rudder deflection required to align the longitudinal axis of the airplane to the relative wind. With this bank, the appropriate amount of rudder deflection will be indicated on the inclinometer by the ball being halfway deflected toward the operating engine.

RAISE THE DEAD!

Service Ceiling- This is the maximum density altitude where the best rate of climb airspeed (Vx) will produce a 100 fpm climb with **both** engines at max continuous power.

Absolute Ceiling- This is the maximum density altitude that the airplane is capable of attaining or maintaining at max gross weight in the clean configuration and max continuous power. As altitude increases, Vx increases, while Vy decreases. Where these two speeds converge is absolute ceiling.

Single Engine Service Ceiling- This is the maximum density altitude at which the aircraft can maintain a 50 fpm climb with one engine operating at full power and one engine with a feathered propeller. This is critically important, especially when flying over mountainous terrain. If the aircraft is above the single engine service ceiling when an engine fails, it will slowly **drift down** to its single engine service ceiling. This should be determined during flight planning using the single engine service ceiling chart from the POH.

Example: Aircraft cruising altitude: 12,000’
MEA: 9,500’
Single engine service ceiling: 6,000’
If the aircraft has an engine failure at 12,000’, it will drift down to 6,000’. If you are IMC this could be very bad. **Always** plan for an engine to fail! Choose a different route with a lower MEA.

Vyse- This is best rate of climb single engine. Vyse is identified by the blue radial on the airspeed indicator. Always pitch for blue line when an engine fails. It will give you the best single engine performance, although it may not be a climb.

Vxse- This is best angle of climb single engine. If you have obstacles to clear with an engine failed, use Vxse. Once the obstacles are cleared, pitch for Vyse.

Vsse- This is the minimum speed at which an intentional engine cut can be performed. It gives a safety margin from Vmc for safe engine cuts while training.

Action when an engine fails- **Memorize this!!**

1. **POWER UP-** right to left: mixtures full, props full, throttles full
2. **CLEAN UP-** flaps up, gear up
3. **IDENTIFY-** Dead foot, Dead engine
4. **VERIFY-** cautiously retard throttle to idle
5. **RECTIFY-** Floor to the door:
   - Fuel selectors- on
   - Cowl flaps- close
   - Mixtures- rich
   - Aux pumps- on
   - Magnetos- check L,R and Both

   Do this if you have time and altitude. If you don’t, immediately skip to secure.
6. **SECURE-** feather the prop
   Mixture to idle cut-off
   Use the checklist!

CRITICAL ENGINE

A **critical engine** is the engine which, if lost, will most adversely affect the performance and handling characteristics of the aircraft. The effect of the critical engine is most significant when operating at low airspeeds with a high power setting, thus producing more p-factor and torque.

On conventional twins with the propellers rotating clockwise, the critical engine is the **left engine**.
On aircraft with counter-rotating propellers, such as the Beechcraft Duchess or Piper Seminole, there is no critical engine due to the turning tendencies cancelling each other out.

An engine can also be termed as a critical engine if important systems are operated off that engine. (i.e. landing gear, pressure system, etc.)

There are four factors used in determining a critical engine:

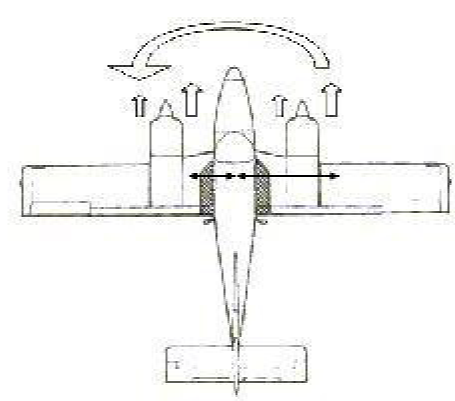
P- P-factor

A- Accelerated Slipstream

S- Spiraling Slipstream

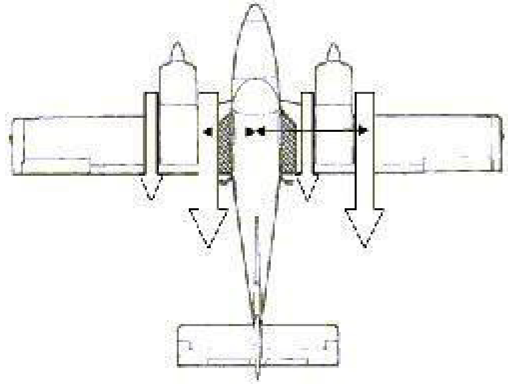
T- Torque

P-factor- The descending propeller blade is producing more thrust than the ascending blade.



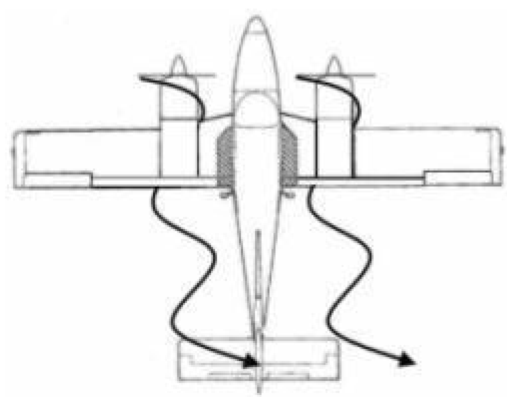
If the left engine fails, the p-factor being produced from the right engine is farther from the longitudinal axis of the aircraft, creating more of a yawing moment.

Accelerated Slipstream- The air being forced over the wing by the operating engine creates extra lift.



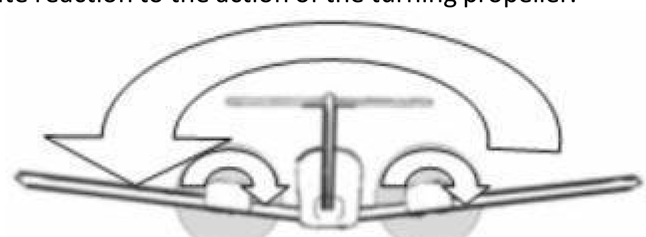
This is basically the equal and opposite reaction of p-factor. If the left engine fails, the effect of the p-factor creates more induced flow farther away from the longintudinal axis of the aircraft creating a rolling moment.

Spiraling Slipstream- The effect of the propeller being pulled through the air while rotating creates a spiraling stream of air behind the propeller.



This spiraling air from the left propeller, due to its direction of spiral, hits the rudder creating more airflow to make the rudder more effective. If the left engine fails, the spiraling slipstream from the right engine spirals away from the rudder.

Torque- This is the opposite reaction to the action of the turning propeller.



Torque tries to roll the airplane opposite of the propeller's direction of rotation. If the left engine fails, torque tries to roll the aircraft to the left, making it more difficult to **raise the dead** engine.

Vmc- Minimum Controllable Airspeed

FAR 23.149- Vmc is the calibrated airspeed, at which, when the critical engine is suddenly made inoperative it is possible to:

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

As airspeed decreases the rudder becomes less effective, eventually an airspeed will be reached where full rudder deflection will be required to maintain directional control. This airspeed is Vmc. Any further reduction in airspeed will result in loss of directional control. Published Vmc is defined by the red radial on the airspeed indicator.

Vmc guarantees directional control only!!

How does the manufacturer determine Vmc?

C- Critical engine failed and windmilling

O- Operating engine at maximum takeoff power

M- Maximum gross weight

B- Bank of no more than 5 degrees

A- Aft center of gravity

T- Takeoff configuration (gear up, flaps up)

S- Standard temperature (15°C) and pressure (29.92” Hg)

Critical engine failed and windmilling- A windmilling propeller creates much more drag than a feathered propeller. If the airplane is equipped with an autofeather system then propeller is feathered.

Operating engine at maximum takeoff power- With the engine at max power this will create more lift and produce more of a yawing tendency about the longitudinal axis, thus increasing Vmc.

Maximum gross weight- While a heavier airplane is more stable, it also requires the wing to produce more lift. This is really more of a standardization requirement for certification.

Bank of no more than 5°- This is also a standardization requirement.

Aft center of gravity- Since an airplane rotates around the CG, an aft CG decreases the distance (arm) between the CG and rudder, which decreases the leverage or effectiveness of the rudder.

Takeoff configuration- This includes flaps in normal takeoff position and landing gear retracted. While gear and flaps down creates drag, it also creates a keel effect which tends to stabilize the aircraft.

Standard temperature and pressure- The published Vmc and red line on the airspeed indicator are based on standard day at sea level. As density altitude increases, the red line becomes less reliable because Vmc decreases with altitude – which brings Vmc closer to stall speed.

Vmc is not a static number. It changes with any combination of the above variables. The red line is the highest speed that Vmc will be, in fact, it will most likely be lower. The object is to keep Vmc as low as possible. For certification, Vmc cannot be greater than 1.2 times stall speed with flaps in takeoff position and gear retracted.

Recognizing and recovering from Vmc

There are warning signs that Vmc is occurring or about to occur. These include:

Loss of directional control- The rudder pedal is depressed to its fullest travel and the airplane is still yawing or rolling toward the inoperative engine.

Stall warning horn or buffeting of the controls- A single engine stall is very dangerous and could result in a spin. Light twins are not known for good stall/spin recovery.

A rapid decay of control effectiveness- This could lead to the loss of control of the aircraft.

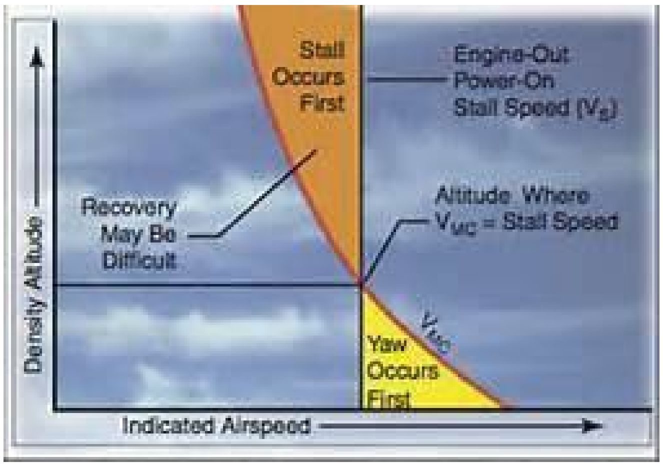
To recover from Vmc, you must simultaneously:

Reduce power on the operating engine- Reduce power on the operating engine reduces the asymmetric air flow.

Pitch down- Lowering the nose of the aircraft will get the air flowing again over the control surfaces and allow you to regain directional control.

Vmc vs. Stall

Normally aspirated engines lose efficiency as density altitude increases. Since the operating engine is not producing as much thrust as at sea level, asymmetrical airflow will be reduced, which will lower Vmc. We must remember, though, that stall speed is an indicated airspeed that will remain constant as altitude increases or decreases. Eventually the two speeds will be at the same point.



If both Vmc and stall speed are reached at the same time, a spin is almost inevitable.

Factors which effect Vmc

Vmc is defined using a very specific set of conditions. Published Vmc and actual Vmc can be two very different numbers. Vmc only addresses directional control and is not related to aircraft performance. While controllability is important, single engine performance is just as important. You must be able to balance both controllability and performance to keep a serious situation from getting out of control. In some cases, an element that provides an increase in controllability can actually hurt performance.

Factors:	**Effect**: (Remember, lower Vmc is better.)
Increase power on good engine	Increases Vmc- More yaw and roll
Increase temperature	Lowers Vmc- less dense, less power, less yaw
Decrease pressure	Lowers Vmc- less dense, less power, less yaw
Increase altitude	Lowers Vmc- less dense, less power, less yaw
Reducing bank	Increases Vmc- less AOA on rudder=less effectiveness
Windmilling propeller	Increases Vmc- more drag=more yaw
Feathered propeller	Lowers Vmc- less drag=less yaw
Aft CG	Increases Vmc- less distance between rudder & CG
Heavier weight	Lowers Vmc- more lift needed in turn=helps prevent turn
Flaps down	Lowers Vmc- more drag-creates keel effect
Gear down	Lowers Vmc- more drag-creates keel effect
Critical engine fails	Increases Vmc- more yaw, more roll
In ground effect	Lowers Vmc- less drag= less yaw and roll

The reverse of any above factors have a reverse on the effect.

V-Speeds – Know These!

Vr	Rotation Speed	85mph
Vx	Best Angle of Climb	90mph
Vy	Best Rate of Climb	110mph
Vxse	Best Angle 1 Engine	98mph
Vyse	Best Rate 1 Engine	108mph
Vso	Stall w/ Flaps down	70mph
Vmc	Min Control 1 Engine	80mph
Va	Maneuvering (Max Gross)	160mph
Vno	Max Structural Cruise	185mph
Vne	Never Exceed	240mph
Vle/Vlo	Max Gear Speeds	150mph
Vfe	Flap Extension	130mph
Best Glide	Max Gross	120mph

Zero Fuel Weight

Zero fuel weight is the maximum weight of passengers and baggage less the fuel weight that the airplane can withstand before structural damage occurs.

Basic Single Engine Procedures

#1 Cardinal Rule – Maintain control and airspeed at all times

Apply max power to operating engine

Reduce drag to an absolute minimum

Secure failed engine and related sub-systems

Sample Take-off Briefing

1. We'll be using runway _____ and conditions are ________

2. Any loss of directional control we will reduce power to idle, use rudder to control the aircraft, and brake to stop.

3. Any loss of power prior to rotation, or if not reaching 70% of rotation speed by 50% of the runway, we will reduce power to idle, use rudder to control the aircraft, and brake to stop.

4. After rotation, gear still down, runway remaining, we will reduce power to idle, use rudder to control the aircraft, land, and brake to stop.

5. After rotation, and below 400' AGL, we will pitch for blueline and land straight ahead +/- 30 degrees. (NOTE: if conditions permit – see #6)

6. After rotation, gear up and above 400'AGL, we will pitch for blueline, maintain directional control, run the drill (mixtures, props, throttles, flaps up, gear up, identify, verify, feather), continue the climb to pattern and return and land.

Performance Charts

Know your performance!! Your CFI will cover the performance charts with you, but it's good to have a basic understanding of several of them before you start your flight training. Refer to the POH for these numbers.

Accelerate-Stop Distance

Accelerate-Stop distance is the distance required to accelerate to liftoff speed and, assuming failureof an engine at the instant liftoff speed is attained, bringing throttles to idle and stopping the airplane.

Accelerate-Go Distance

Accelerate-Go distance is the distance required to accelerate to liftoff speed and, assuming failureof an engine at the instant liftoff speed is attained, continuing the takeoff and climbing to 50'. Know before you try to takeoff whether you can maintain control and climbout if you lose an engine with the gear still down!

Takeoff Weight To Achieve A Positive Single Engine Rate Of Climb at Liftoff

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.

Remember, These charts were printed many years ago 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 andalways give yourself an out. Always fly under the assumption "what if".

Oral Exam Guide

Vmc

A thorough knowledge of Vmc is probably the most important subject on the oral exam.

1. Be able to define Vmc.
2. How does the manufacturer determine Vmc speed?
3. What happens to Vmc if the aircraft is loaded aft of the CG limit?

How is Vmc Determined?

COMBATS

Critical engine failed and windmilling
Operating engine at max t/o power
Max gross weight
Bank up to 5° into the good engine
Aft CG
Takeoff configuration
Standard day, 29.92" Hg, 15°C

Know the factors that affect Vmc

Lowers Vmc (good)

Add power to the critical engine
Reduce drag
Reduce power on the good engine
Forward CG
Gear down
Lower pressure
Higher altitude
Higher temperature

Increases Vmc (bad)

Reducing bank
Higher pressure
Lower temperature
Lower altitude

How will these affect your performance?

Critical Engine

Be able to define critical engine.
How is it determined?
Why do some airplanes have a critical engine and some don't?
Does the Travel Air have a critical engine?

Performance Charts

Know your performance!!

1. Takeoff distance
2. Accelerate-stop distance
3. Accelerate-go distance
4. Takeoff weight to achieve single engine climb
5. Climb performance: 2 engine, 1 engine
6. Cruise chart: TAS, fuel flow, range
7. Single engine service ceiling
8. Landing distance: flaps up, flaps down

Weight and Balance

Complete your weight & balance!
Be able to use the charts and graphs in the POH.
Explain zero fuel weight.

Aircraft Systems

Know your systems!
Starter limitations **(20sec, 30sec (x6), wait 30 min)**
Fuel system Landing gear Electrical system
Constant speed, full feathering props
(why use Nitrogen in unfeathering accumulators?)
Heater system **(risks using heaters?)**
Fuel cross feed **(cross-feed only on good engine)**
Pressure, O2, other systems (if any applicable)

Airspeeds

Red line
Blue line
Vy, Vx, Vyse, Vxse, Vmc, Va, Vlo, Vle, Vso, Vs1, Vsse, Vno, Vn

Maneuvers

Steep Turns (4,000 MSL min)
- **CLEAR THE AREA**
- Locate a suitable outside reference
- Set heading and bug
- Power 20" @ 2400rpm
- 45 or 50 degrees of bank +/- 5 degrees
- Two 360 degree turns, as directed

Slow Flight (4,000 MSL min)
- **CLEAR THE AREA**
- Power 16"
- Mixture/Prop Forward
- Gear down below 150mph
- Flaps down below 130mph (incrementally)
- At 105mph, Power 19"-20" (hold altitude)
- Airspeed 95mph (min 90mph)
- Remember: pitch for IAS, power ALT

Slow Flight Recovery
- Add Power as needed
- Maintain Altitude
- Pitch for Blue Line
- Clean Up - Flaps, Gear, Flaps

Power Off Stall (4,000 MSL min)
- **CLEAR THE AREA**
- Power 16"
- Gear down below 150mph
- Flaps down below 130mph (incrementally)
- Mixture/Prop Forward below 110mph
- Establish a stabilized descent
- Power to idle at 100 mph
- Pitch attitude for landing
- Recover at 1st indication

Power Off Stall Recovery
- Pitch - nose just below the horizon
- Power – **Smoothly** apply Full Power
- Drag – FLAPS-GEAR-FLAPS
- Climb - Blue Line

Power On Stall (minimum 4,000 MSL)
- **CLEAR THE AREA**
- Clean configuration
- Power 16" MP Slow Down to 120
- Mixture/Prop Forward below 110mph
- Power 20" MP (simulated power on)
- Attitude - nose just above the horizon
- Recover at first indication

Power On Stall Recovery
- Pitch - nose just below the horizon
- Power – **Smoothly apply** Full Power
- Climb - Blue Line

Accelerated Stall (4,000 MSL min)
- **CLEAR THE AREA**
- Locate a suitable outside reference
- Set heading and bug
- Power idle or 16" @ 2400rpm
- At 120 mph, 45 degree bank and apply back pressure smoothly to stall then recover
- Pitch – nose just below horizon, wings level, smoothly apply Full Power

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(3,000 AGL minimum Alt
SKYVIEW at 4,000 AGL for safety.)

Maneuvers

Vmc Demonstration (minimum 4,000' AGL)

- **CLEAR THE AREA**
- Reduce to 16"
- Flaps up, Gear up
- Critical engine – idle (guard the good)
- Right Engine – Max Power
- Slow to initial loss of control (1 MPH / sec)

(First Indication – stall light, warning, roll, yaw)

- Reduce Power - idle on the good (< Rudder)
- Pitch - blue line (108MPH)
- Full Power SMOOTHLY Right Eng at blue line
- Maintain airspeed & direction w/rudder

Drag Demo - for MEI Check-ride only
(minimum 4,000' AGL)

- **CLEAR THE AREA**
- Power - full (smoothly)
- Mixture Prop Throttle - full (smoothly)
- Critical engine - idle "guard the good"
- Maintain airspeed & directional control
- Gear down below 150mph
- Flaps down below 130mph (incrementally)
- Maintain blue line - Note VSI
- Gear Up - Blue Line - Note VSI
- Flaps Up - Blue Line - Note VSI
- Sim Feather - 12" - Blue Line - Note VSI

Emergency Descent (Recover per DPE)

- **CLEAR THE AREA**
- Chop - power idle (pitch <150mph)
- Drop - gear down (Below 150 MPH)
- Prop - full forward (Mixture, rich)
- Pitch for 150mph, bank away from the burning engine, 30-45 degrees

Vspeeds MPH			
Vr	85	Vmc	80
Vx *	90	Vxse	98
Vy *	110	Vyse	108
Va	160	Vsse	108
Vne	240	Vle	150
Vno	185	Vfe	130
Vso	70	*Increased from POH	

Engine Failure in Flight

- **Maintain Directional Control**
- **Pitch for Blue-Line**
- **Mixtures, Props, Throttle (max)**
- **Flaps UP – Gear UP**
- **Identify (Dead Foot – Dead Engine)**
- **Verify (Cautiously Retard Dead)**
- **Feather dead engine prop**

Secure if below 3,000 AGL

- **Mixture**

If above 3,000 AGL - Rectify

- **Mixture, Fuel Pumps, Fuel Sel**
- **Ignition (Magnetos)**
- **Alternate Air**
- **Secure the Engine**
- **Checklist**

Engine Failure on Runway

- "Abort - Abort - Abort"
- Chop - power idle
- Maintain directional control
- Stop - apply brakes
- Complete stop on runway