## II.P. OEI PERFORMANCE

**OBJECTIVE & COMPLETION STANDARDS**

The learner develops knowledge OEI performance, and the associated factors as required in the ACS.

The learner understands the nuances of a multiengine airplane as well as the concepts involved associated with engine failures, the critical engine, performance & limitations, and $V_{MC}$, and can apply these concepts in the airplane.

**KEY POINTS**

- Left Engine is Critical - PAST
- $V_{MC}$: Reduce Power, Increase Speed
- Zero Sideslip – 1-3° Bank, ½ ball slip

**ELEMENTS**

1. OEI Aerodynamics
2. Performance & Limitations
3. Engine Failure: Best Course of Action

**REFERENCES**

- Airplane Flying Handbook

**SCHEDULE**

- Introduction
- Development
- Conclusion

**EQUIPMENT**

- Board
- Markers
- References

**INSTRUCTOR**

- Present Content
- Ask/Answer Questions
- Assign Homework

**STUDENT**

- Participate in learning
- Take notes
- Ask/Answer Questions

# LEGEND & ABBREVIATIONS

**SECTION HEADER FOR EACH LESSON ELEMENT**

*Light blue for **Main points and/or brief section summary***

- **Orange** text is used for mnemonics or things to remember
- **RM**: Teal RM denotes an ACS Risk Management concept
- **CE**: Red CE shows an Airplane Flying Handbook listed Common Error

*IA: Instructor Action (ex. hop out of the lesson & review a checklist) – Coming soon!*

*Light gray for notes, examples, extra details & explanations, etc.*

## INTRODUCTION

### ATTENTION

Interesting fact or attention-grabbing story

Every single Knowledge & Risk Management task is annotated! Find whatever info you need.

### OVERVIEW

Review Objectives, Elements, and Key Points

### WHAT

Having an additional engine is helpful for better climb performance and greater speeds, but failure of one of the engines is very different from losing an engine in a single engine airplane.

In this lesson you will learn which engine has a more adverse effect on control and performance when lost and why, as well as what the minimum controllable airspeed is, and the best course of action after an engine failure, based on the phase of flight.

### WHY

An airplane with two engines behaves very differently than an engine with one.

In the case of an engine failure, it is essential that the pilot understands how performance and control are affected, and how to continue to safely pilot the aircraft.

## HOW

### 1. OEI AERODYNAMICS

AI.II.P.K5

#### A. Critical Engine

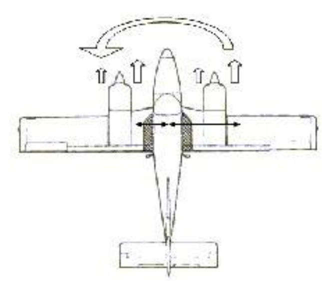
AI.II.P.K5a

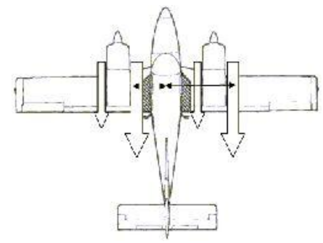
i. **What is it?**

- The engine whose failure most adversely affects performance & handling qualities of an aircraft
- In a conventional twin, with both props rotating clockwise, this is the **LEFT engine**
  - Other twins overcome the problem of a critical engine with counter-rotating propellers

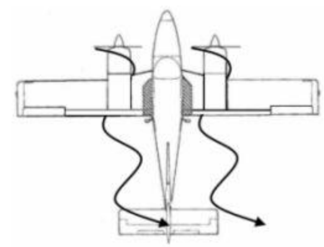
ii. **Why is the Left Engine Critical? (PAST)**

- **P-Factor**
  - Descending blade of each propeller produces more thrust than the ascending blade
    - Therefore, the center of thrust is offset to the right of each engine
  - There is a greater distance (arm) between the center of thrust and the longitudinal axis on the right engine than on the left
    - The greater the distance, or arm, the greater the leverage
  - If the right engine fails, the leverage associated with P-Factor is not as great as if the left engine fails
  - If the left engine fails, the yaw from P-Factor is most adverse, therefore the left engine is critical





- **Accelerated Slipstream**
  - Due to P-Factor, there is greater airflow (more lift) over the wings on the right side of each engine
  - There is a greater distance (arm) between the excess lift and the longitudinal axis on the right engine than on the left engine
    - The greater the arm, the greater the leverage
  - If the left engine fails, there is a stronger rolling action than if the right engine fails, therefore the left engine is critical



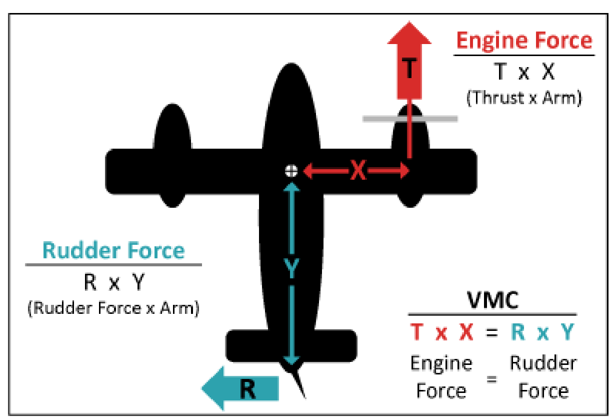
- **Spiraling Slipstream**
  - Each propeller produces a spiraling slipstream of air behind it
  - The left engine's slipstream strikes the rudder on the left side creating a left turning tendency
  - The right engine's slipstream has no affect on the aircraft
  - If the right engine fails, the left engine's slipstream will counteract some of the yaw toward the dead engine
  - If the left engine fails the airplane will yaw uninhibited toward the dead engine, therefore the left engine is critical

- **Torque**
  - Newton's 3rd law: For every action there is an equal & opposite reaction
  - When the propellers spin clockwise, torque causes the plane to roll counterclockwise (CCW)
  - If the right engine fails the plane will roll right, but the CCW torque will offset some of the force
  - If the left engine fails, the CCW torque will encourage the roll toward the left engine
  - The left engine is critical since torque most adversely affects control when the left engine fails

## B. $V_{MC}$ AI.II.P.K5b

### i. What is $V_{MC}$?

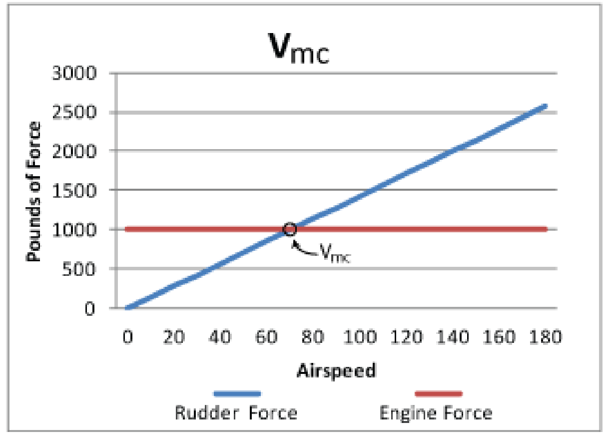
- Published $V_{MC}$ (in the POH): Speed at which the rudder no longer has the authority to overcome the yaw caused by the critical engine being inoperative, under specific criteria mandated by the FAA
  - FAA mandated criteria include, among other things, a max of 5° of bank into the operative engine (we'll return to this shortly)
- Actual $V_{MC}$ varies based on conditions, configuration, and pilot technique during the engine failure




### ii. What Causes $V_{MC}$? AI.II.P.K5d

- With an engine failed, the operating engine *(assume full power)* produces yaw toward the dead engine (T x X in the graphic)
- Rudder counters the yaw to keep the plane straight

- The amount of rudder force is based on airspeed
  - R x Y in the graphic
  - The slower the aircraft, the less airflow over the rudder, and therefore the less force
- As an aircraft slows, and the rudder's force decreases, the yawing force remains constant
- There is an airspeed where the rudder's force is equal to the engine's force
  - This is $V_{MC}$ (T x X = R x Y) –shown on the graph
- If the aircraft slows beyond this speed, the rudder produces less force than the engine and the plane yaws uncontrollably to the dead engine




iii. **$V_{MC}$ Recovery**

- Reduce power (reduces yawing force) & lower the nose (increases airspeed & the rudder's force)
- Return to $V_{YSE}$, coordinated flight (zero sideslip – discussed next), & max power

iv. **$V_{MC}$ & Bank**

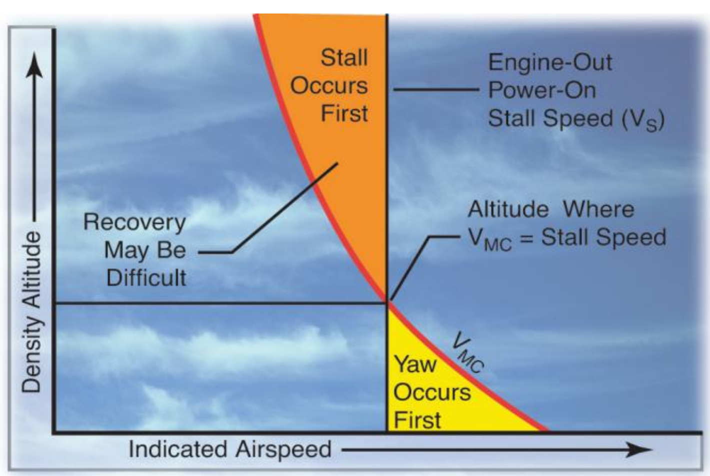
- $V_{MC}$ is highly sensitive to bank
  - Horizontal component of lift associated with bank assists the rudder in maintaining control
    - Reduces the rudder required to maintain control, lowering $V_{MC}$
  - $V_{MC}$ may increase more than 3 knots for each degree of bank reduction between 5° & wings level
- 5° maximum bank angle is a limit imposed to prevent unrealistically low $V_{MC}$ claims
  - It doesn't imply it's the best bank angle for OEI performance
  - The best bank angle is what produces the zero sideslip (or single engine coordinated flight)

  Note: Zero sideslips are discussed shortly

v. **$V_{MC}$ & Stall Speed**

AI.II.P.K6

- $V_{MC}$ decreases with altitude, while stall speed remains the same
  - The margin between $V_S$ and $V_{MC}$ decreases with altitude
- There is an altitude where $V_{MC}$ and $V_S$ are the same
  - Above this altitude, $V_{MC}$ will occur after a stall
- The altitude where $V_{MC} = V_S$ & above is extremely dangerous
  - A stall with asymmetrical power will likely enter a spin in the direction of the failed engine




  - Departure from controlled flight might be sudden - Strong yaw & roll could invert the plane
  - Twins are *not* required to demonstrate spin recovery & recovery characteristics are often poor

- RM: Exceeding Critical AOA AI.II.P.R1
    - Essential that the pilot controls pitch and airspeed during an engine failure
    - Know and establish the approximate pitch attitude for $V_{YSE}$
    - Maintain control - fly the airplane first!

### C. Zero Side Slip AI.II.P.K5c

#### i. Big Picture

- Best single engine performance is obtained at $V_{YSE}$ with maximum power & minimum drag
- A key element in minimizing drag is establishing zero sideslip (coordinated flight)

#### ii. Normal Flight – Both Engines Operating

- Sideslip is eliminated when the ball of the turn coordinator is centered
    - Airplane is presenting its smallest possible profile to the relative wind & drag is at a minimum
    - This is zero sideslip
- Zero sideslip can be visualized with a yaw string
    - Piece of string or yarn (18-36”) taped to the base of the windshield
    - In coordinated, zero sideslip flight, the relative wind aligns the string with the longitudinal axis
        - Slips & skids move the string to either side of the longitudinal axis, displaying relative wind

#### iii. One Engine Inoperative Flight

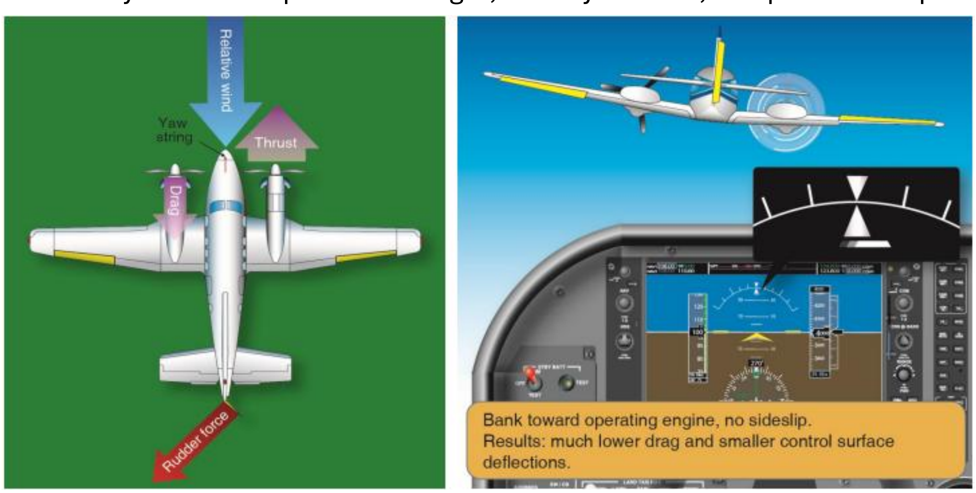
- Due to asymmetric thrust, the centered ball no longer indicates coordinated flight/zero sideslip
- Use the POH published bank angle and ball position to establish zero sideslip and minimize drag
    - Generally, 1-3° of bank and the ball displaced 1/3 to ½ toward the operating engine
    - This re-aligns the yaw string with the longitudinal axis
    - Centering the ball would move the yaw string off the longitudinal axis, increasing drag
- Maintain the same ½ ball position for turning flight

#### iv. RM: Loss of Directional Control AI.II.P.K5d, AI.II.P.R2

- Aileron and rudder are used in conjunction to establish the zero sideslip
    - Using only aileron or rudder degrades performance & increases $V_{MC}$
- **Rudder Only** (Wings level, ball centered)
    - Requires large rudder inputs toward the operating engine
    - Results in a moderate sideslip toward the operating engine
    - Sideslip reduces climb performance
    - With wings level, $V_{MC}$ is notably higher than published (no horizontal lift to assist the rudder)


- **Ailerons Only** (8-10° of bank, uncoordinated)
  - Ball is displaced well toward the operative engine creating a large sideslip
  - Climb performance is greatly reduced
  - Increased $V_{MC}$, and high risk of loss of control (should not be demonstrated)


- **Rudder & Aileron Together** (1-3° bank & ½ ball into the operating engine)
  - Zero sideslip & best performance (best climb performance or least rate of descent)
    - Ability to climb depends on weight, density altitude, and pilot technique




v. Any attitude other than zero sideslip increases drag and decreases performance

- $V_{MC}$ may be higher than published and the pilot may unsuspectingly lose control

**D. Single Engine Performance (not ACS required)**

i. In general, an engine failure results in a loss of 50% of power but 70-80% of performance
   - Performance is the ability of the airplane to climb and is based on excess thrust

ii. Simple Example *- meant to demonstrate the concepts, not necessarily technically accurate numbers*
   - Twin engine aircraft with two 200hp engines
   - Power: 400hp total – if one engine is lost, power is reduced to 200hp, or a loss of 50%
   - Performance
     - At the current airspeed, altitude, weight, etc., the aircraft requires 150hp to maintain level flight
     - 400hp minus the 150hp required for level flight leaves 250 excess hp available for climb
     - If an engine fails, 150hp to is still required for level flight, but now you only have 200hp total
       - We'll assume feathering and a zero sideslip evens out the level flight hp requirements
     - 200hp minus the 150 required for level flight leaves 50hp available for a climb
       - Reduction of 80% (decreased from 250 to 50hp)

## 2. PERFORMANCE & LIMITATIONS

**A. Be very familiar with performance & limitations to make informed decisions. Examples include:**

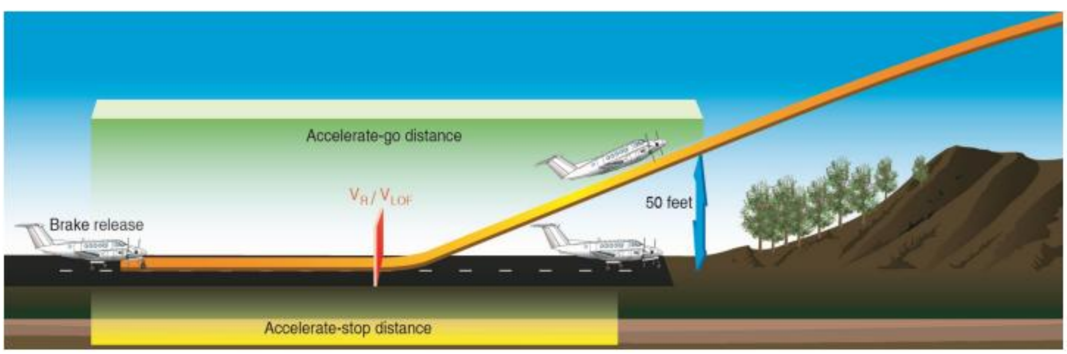
i. Engine failure on takeoff
   - Can the airplane stop on the runway?
   - Can the airplane climb/clear obstacles at the density altitude and weight?

ii. Engine failure enroute
   - What altitude can the airplane maintain?

**B. Multiengine Performance Terms**

i. **Accelerate-Stop Distance**
   - Distance required to accelerate to $V_R$, experience an engine failure, and come to a complete stop

ii. **Accelerate-Go Distance**
   - Horizontal distance required to continue a takeoff and climb to 50' assuming an engine failure at $V_R$




iii. **Service Ceiling** (both engines operating): Highest altitude a 100-fpm steady climb can be maintained

iv. **Absolute Service Ceiling:** Climb is no longer possible
v. **Single-Engine Service Ceiling:** Can no longer maintain a 50 fpm climb with OEI
vi. **Single-Engine Absolute Service Ceiling**: When climb is no longer possible
- If an engine failure occurs above the service ceiling, the aircraft will lose altitude
- $V_{YSE}$ minimizes loss
- Actual altitude maintained depends on performance and pilot control/technique

vii. All these performance factors should be determined prior to every flight

**C. Atmospheric Conditions & Performance** AI.II.P.K3

- **Atmospheric Pressure**
  - Since air is a gas, it can be compressed or expanded, affecting density
  - Air density affects performance - As density increases, performance increases & vice versa
- **What Changes Air Density** (DA)? Barometric Pressure, Temperature, Altitude, and Humidity
  - Density varies directly with pressure - As pressure increases, density increases & vice versa
  - Density varies inversely with temperature - As temp increases, density decreases & vice versa
  - Density varies inversely with altitude - As altitude increases, density decreases & vice versa
  - Density varies inversely with humidity – As humidity increases, density decreases & vice versa

    *As humidity increases some dry air is replaced by water vapor. The molecular weight of dry air is about 29 grams/mol, while the molecular weight of water vapor ($H_20$) is about 18 grams/mol. As the proportion of water (humidity) increases, the density (weight/volume) of the air decreases.*
- **How it affects Performance**
  - As the air becomes less dense, it reduces:
    - **Power**, since the engine takes in less air
    - **Thrust**, since the propeller is less efficient in thin air (less air is moved for every rotation)
    - **Lift**, because the thin air exerts less force on the airfoils

**D. Performance Charts** AI.II.P.K1

i. **POH Chapter 5** – Review the use of performance charts for single engine operations
- Common OEI charts include Accelerate Stop/Go, Single engine climb performance, Service ceiling

ii. Consider weight & balance, performance (single/multiengine), runway length, slope, contamination, terrain and obstacles, weather conditions, and pilot proficiency

iii. RM: Terrain Avoidance (RM: Flying over terrain that exceeds the SE service ceiling) AI.II.P.R3
- Never plan to overfly terrain that exceeds the single engine service ceiling
- Never plan to takeoff/go-around if single-engine performance cannot clear the terrain & obstacles

**E. Limitations (Chapter 2 of the POH)** AI.II.P.K2

i. Review limitations associated with OEI – Common limitations: $V_{MC}$, $V_{YSE}$, $V_{SSE}$, Max weight, CG limits
ii. Limitations establish the boundaries in which the airplane can be safely operated
- Effects can be hazardous and include overstressing the aircraft, loss of control, stall, etc.

**F. Each Flight** – Analyze OEI performance charts to ensure required performance AI.II.P.K4

i. Calculate performance based on actual airplane & environmental conditions

- Accelerate Go, Accelerate-Stop, Service Ceiling, Single-Engine service ceiling

ii. Know what you are going to do in the event of an engine failure (discussed next)

iii. Brief the performance-based engine failure information and procedures prior to takeoff

**G. Specific to OEI performance & limitations, adverse effects can include** AI.II.P.K2

i. Attempting to takeoff without enough runway, or without the required OEI climb performance

ii. Attempting to clear an obstacle without the required OEI performance

iii. Inability to control the airplane

## 3. ENGINE FAILURE: BEST COURSE OF ACTION AI.II.P.K7

**A. Depends on the phase of flight, and performance information**

i. Based on runway and performance, brief the takeoff and emergency procedures

- See XII.E. Engine Failure during Takeoff before $V_{MC}$ for takeoff brief

ii. Enroute, based on single engine service ceilings, surrounding terrain, weather, and divert options

**B. Engine failure prior to rotation**

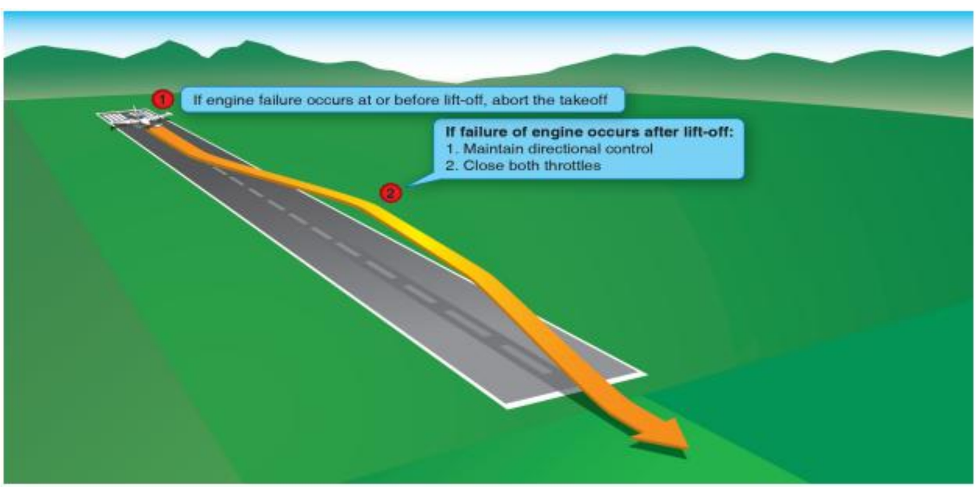
i. Abort the takeoff: Close the throttles (stops the yaw) & stop straight ahead

ii. Accelerate-Stop distance should always be less than runway available

**C. Engine failure after rotation, gear still down**

i. Gear should remain down until there is no longer sufficient runway to land on

ii. Reduce power, maintain adequate airspeed, land on the remaining runway

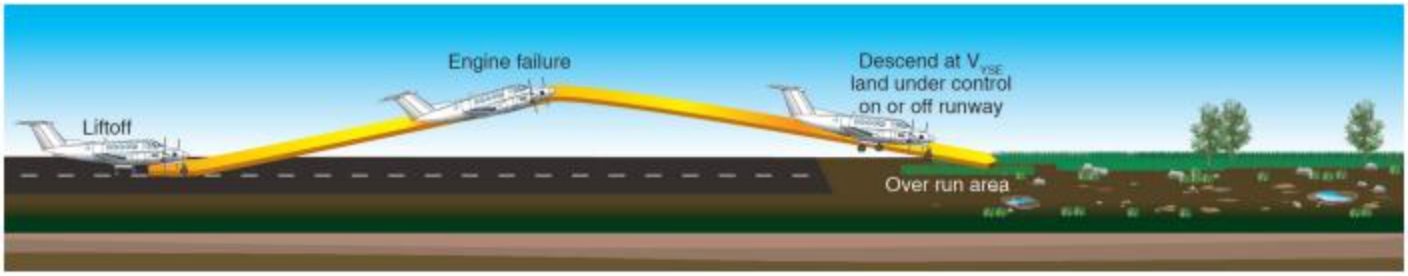



**D. Landing gear up, single engine climb performance inadequate**

i. Avoid this situation – do not attempt takeoff if performance doesn't support OEI climb

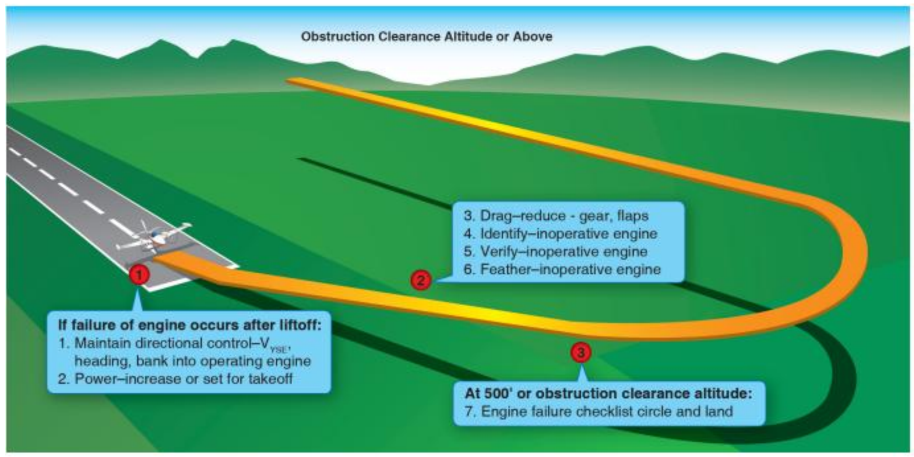
ii. Landing must be accomplished on whatever lies ahead

iii. A descent at $V_{YSE}$ is possible to extend the time before reaching the ground
iv. Greatest Hazard: Attempting to fly when it's not within the performance capabilities – could be fatal




**E. Landing gear up, single engine climb adequate**

i. **Control** - Stop the yaw, Stay above $V_{MC}$, Zero sideslip, $V_{YSE}$
ii. **Configuration** - Full Power, Gear up, Flaps up, Identify, Verify, Feather
iii. **Climb** - Zero sideslip, $V_{YSE}$
iv. **Checklists** (If time) – At a safe altitude, emergency & regular checklists
v. Circle & land




**F. Enroute**

i. **Control** - Stop the yaw, Zero sideslip, $V_{YSE}$ as necessary (aircraft control is easier at cruise speeds)
ii. **Configuration** - Full Power, Gear up, Flaps up, Identify, Verify, Fix or Feather
iii. **Climb** - Zero sideslip, $V_{YSE}$ as required
iv. **Checklists** – Emergency and regular checklists, as applicable

- RM: Fuel Management AI.II.P.R4
  - Crossfeed (and balance) fuel for extended single-engine operation
    - Allows use of the fuel in the opposite tank and balances the weight
  - If a suitable airport is close, there is no need to crossfeed

**Conclusion:** Brief review of the main points