XII.F. ENGINE FAILURE AFTER LIFTOFF

OBJECTIVE & COMPLETION STANDARDS

The learner develops knowledge of the elements associated with engine failures while airborne.

The learner can describe and answer questions regarding the concepts. They can also apply the concepts to maintain aircraft control and choose the best course of action event of an engine failure.

KEY POINTS

- Fly First
- Zero Sideslip
- Don’t get close to V_{MC}

ELEMENTS

1. OEI Airspeeds & Performance
2. Managing an Engine Failure
3. Engine Failure After Lift Off Procedures
4. Takeoff Brief
5. Simulated Feathering
6. Common Errors
7. Hazards

REFERENCES

- Airplane Flying Handbook
- POH

SCHEDULE

- Introduction
- Development
- Conclusion

EQUIPMENT

- Board & Markers
- References
- Model Airplane

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

OVERVIEW

Review Objectives, Elements, and Key Points

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

WHAT

This lesson covers the elements involved with safely handling an engine failure after liftoff, whether that includes landing on the remaining runway, an inability to climb and a landing at the most suitable area or returning to land.

WHY

In the case of an engine failure, it is essential that a pilot understands the elements involved and can maintain control of the airplane, especially when close to the ground.

HOW

1. OEI AIRSPEEDS & PERFORMANCE

AI.XII.F.K2

A. V_{MC}

i. **What is V_{MC} (red line)?**

- 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*
- A lower V_{MC} is safer
  - The slower you can go and maintain control, the better
- V_{MC} deals strictly with maintaining directional control, irrespective of climb performance
- Published versus Actual V_{MC}
  - Published V_{MC}: Based on specific FAA mandated criteria
  - Actual V_{MC}: Varies based on the conditions, configuration & technique during an engine failure

ii. **Engine Failure during Takeoff & V_{MC}**

- A loss of control while close to the ground may not allow the time or altitude to recover
- Critical to maintain safe speeds (V_{YSE}, discussed below)

iii. **V_{MC} Factors & Certification Criteria** AI.XII.E.K1

- **Remember**
  - V_{MC} is not a fixed speed in all conditions – it's only fixed for specific criteria during certification

  - Lower V_{MC} is good & a Higher V_{MC} is bad
  - Anything increasing the yawing force toward the dead engine increases V_{MC}, and vice versa
  - Anything increasing the amount of force the rudder can produce decreases V_{MC}, and vice versa
- **Certification Criteria & V_{MC}**
  - **Critical Engine Inoperative** (left engine in conventional twins) – **Bad** for V_{MC}
    - The engine that has the most adverse effect on airplane control when failed
    - Rudder has more force to overcome than if the right engine failed, increasing V_{MC}
  - **Inoperative Engine Propeller Windmilling** – **Bad** for V_{MC}
    - A windmilling prop creates far more drag than a feathered prop
    - Increased drag creates a stronger yaw toward the dead engine requiring the rudder to overcome more force, increasing V_{MC}
  - **Maximum Available Takeoff Power** – **Bad** for V_{MC}
    - The more power on the operating engine, the greater the yaw toward the dead engine
    - The greater the yawing force, the earlier the rudder will lose control
    - V_{MC} increases as power is increased on the operating engine
  - **Sea Level Conditions** – **Bad** for V_{MC}
    - At sea level, the dense air allows the operating engine & prop to produce maximum thrust
    - More thrust means more force for the rudder to overcome, increasing V_{MC}
    - Higher density altitudes decrease V_{MC}
  - **Most Adverse Legal Weight** (Lightest Weight) – **Bad** for V_{MC}

    There's some discussion and disagreement over how weight impacts V_{MC}, but the overall point is that lighter weights are bad and increase V_{MC}
    - Possible reasoning includes:
      - A heavier plane is a more stable and controllable plane
      - The added weight of the airplane assists in establishing and maintaining a zero-side slip countering some of the yaw force toward the dead engine
  - **Most Adverse Legal CG** – **Bad** for V_{MC}
    - V_{MC} increases as the CG moves aft
      - The further aft the CG moves, the shorter the rudder's arm becomes
      - The shorter the arm, the less effective the rudder
    - VMC increases since the rudder produces less force than if the CG was forward
  - **Landing Gear Retracted** – **Bad** for V_{MC}
    - Extended gear aids in directional stability (like keel effect), which tends to decrease V_{MC}
    - V_{MC} increases when the landing gear is retracted
  - **Airborne and Out of Ground Effect** – **Bad** for V_{MC}
    - V_{MC} decreases in ground effect
    - Aircraft yaws & rolls toward the dead engine
      - Dead engine wing dips deeper into ground effect reducing drag/yaw toward dead engine
  - **Cowl Flaps in the T/O position** – **Good** for V_{MC}
    - Open cowl flaps will produce more drag on the operative engine, decreasing V_{MC}
  - **Maximum 5° of Bank** – **Good** for V_{MC}
    - V_{MC} is highly sensitive to bank angle
      - To prevent claims of unrealistic low speeds, bank into the operating engine is limited

    - The horizontal component of lift assists the rudder in countering the asymmetrical thrust
    - Tests have shown that V_{MC} may increase > 3 knots for each degree of bank less than 5°
  - **Flaps in the takeoff Position** - Could go either way
    - Most multiengine aircraft takeoff with flaps up, therefore there will be no effect
    - With numerous flap sizes, types, and settings, having the flaps down could help or hurt V_{MC}
    - Flaps down may decrease V_{MC} by producing more drag on the operating engine
      - Reduces tendency to yaw toward the inoperative engine
    - Flaps down may increase lift on the wing of the operating engine, increasing roll toward the dead engine and increasing V_{MC}
  - **Airplane Trimmed for Takeoff** – Could go either way
    - Varies between aircraft due to T-tails, low tails, type of elevator/stabilizer and trim settings

iv. For more details & specifics, see XIII.B. V_{MC} Demonstration

FACTOR	CONTROL	VMC
Critical Engine Inoperative	Decreases	Increases
Windmilling Propeller	Decreases	Increases
Max Takeoff Power	Decreases	Increases
Sea Level Conditions	Decreases	Increases
Most Adverse Legal Weight (Light)	Decreases	Increases
Most Adverse Legal CG (Aft)	Decreases	Increases
Gear Up	Decreases	Increases
Out of Ground Effect	Decreases	Increases
Cowl Flaps set for Takeoff (Open)	Increases	Decreases
Max of 5-degrees of Bank	Increases	Decreases
Flaps Set for Takeoff	Could go either way	Could go either way
Trimmed for Takeoff	Could go either way	Could go either way

B. V_{YSE}: Best rate of climb speed with OEI (blue line)

i. Used to maximize performance during OEI (or minimize descent above the SE service ceiling)

C. V_{SSE}

i. Safe, intentional OEI speed – Minimum speed to intentionally render the critical engine inoperative

ii. Not shown on airspeed indicator - Use V_{YSE} if V_{SSE} is not published

__ACS__: Must not simulate engine failure until at least 400' AGL and V_{SSE}, V_{XSE} (rarely published), or V_{YSE}

D. Accelerate-Stop Distance AI.XII.F.K3

i. Distance required to accelerate to V_R, experience an engine failure, and come to a complete stop
  - Can we stop on the runway if we lose an engine at the latest point of the takeoff roll?

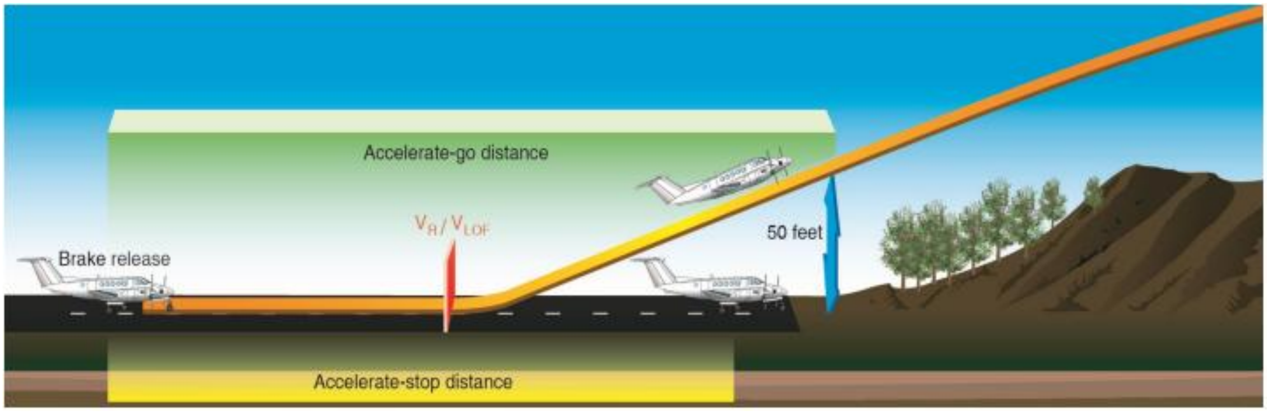
ii. Prior to every flight, ensure this distance is less than the runway available

E. Accelerate-Go Distance

AI.XII.F.K3

i. Distance required to accelerate to V_R, experience an engine failure, and climb to 50'
  - If we lose an engine at rotation speed, can we clear a 50' obstacle?

ii. Ensure accelerate-go distance is compatible with the runway, terrain, etc. prior to every flight



F. Performance Charts

i. Demonstrate the performance charts for accelerate-stop & go distances

ii. If these charts don't exist, demo the techniques used to estimate these distances

2. MANAGING AN ENGINE FAILURE

AI.XII.F.K4

***MATL** – **M**aintain Control, **A**nalyze Situation, **T**ake Proper Action, **L**and as Conditions Permit/Require*

A. Big Picture

i. Establish maximum power & minimum drag

AI.XII.F.K5

ii. Engine failure reduces power by 50%, and performance by 80% or more
  - Essential to minimize drag to maximize the remaining performance to climb away from the ground

    For details/explanation, see II.P.1.D Single Engine Performance

iii. Very likely the airplane cannot climb, and may descend, if drag is not reduced

B. Recognize the Engine Failure

i. The easiest way to recognize an engine failure is visually (if in V_{MC})
  - Un-commanded yaw in the direction of the dead engine
  - Visual recognition allows for better control

ii. In IMC, the engine failure will be recognized on the instruments
  - Aircraft will yaw toward the dead engine, nose will drop, engine gauges will indicate a failure

iii. CE: Failure to recognize an inoperative engine

C. Maintain Control

i. **Zero Sideslip**: 1-3° of bank, & a ½ ball slip toward the operating engine

- Add approximately 1-3° of bank toward the operating engine (counters the roll)
  - Memory Aid: "Raise the dead" – The dead engine should be "raised" with 1-3° of bank
- Maintain heading visually with rudder pressure (the aircraft will almost fall into a sideslip)
  - Verify ½ ball slip toward the operating engine
- Anything other than a zero sideslip increases drag, reducing performance

  Exact bank/slip varies based by aircraft, adjust as required

ii. **Pitch for V_{YSE}**: Essential, especially close to the ground, to pitch for the best rate of climb

D. Once in Control:

i. **Max Power**

- Throttles, Props, Mixture
- Increased power means increased rudder
  - Smoothly increase the power and rudder pressure (fast movements are hard to control)

ii. **Reduce Drag**

- Verify Gear and Flaps are UP
- Reducing drag is essential to prevent altitude loss AI.XII.F.K5

iii. **Identify**

- Dead Foot, Dead Engine
  - Whichever foot is not being used on the rudder correlates to the engine that has failed

iv. **Verify**

- Reduce the throttle on the dead engine to idle
  - There should be no change – this verifies you've selected the correct engine
  - Reduce the throttle gently – If you chose the wrong engine, it will be easier to control

v. **Fix or Feather**

- **Analyze the Situation** AI.XII.F.K5
  - If there is time and altitude, analyze the situation and attempt to fix the failed engine
  - For an engine failure after liftoff, there is no time or altitude to run checklists, feather the engine
    - Essential to reduce drag - Climb may be impossible without feathering
- **Take Proper Action**
  - Follow manufacturer procedures to feather the propeller
  - Before feathering the engine ALWAYS verify you have the correct engine
  - When feathered, rudder can be reduced
    - Yaw is reduced since the drag on the inoperative propeller is reduced
  - Adjust to maintain zero sideslip
  - Time & conditions permitting, secure the engine with the checklist
- RM: Divide attention - Don't fixate on the problem to the detriment of flying

vi. **Declare an emergency and Land as Conditions Require/Permit**

- The final step in MATL will be discussed below

Securing Failed Engine	
Mixture	IDLE CUT OFF
Magnetos	OFF
Alternator	OFF
Cowl flap	CLOSE
Boost pump	OFF
Fuel selector	OFF
Prop sync	OFF
Electrical load	Reduce
Crossfeed	Consider

E. Checklists

i. Technique: Whenever OEI, take a break from checklists every step or two to check airspeed, altitude, heading, zero sideslip and engine instruments

ii. With the aircraft under control and memory items complete, there's rarely any rush to get the checklist done - flying safely is the primary task

3. RM: ENGINE FAILURE AFTER LIFT-OFF — AI.XII.F.R1

A. Big Picture

i. **Takeoff (or go-around) is the Most Critical Time to Suffer an Engine Loss**

- Altitude and time are minimal, and drag is high

ii. **Preflight Planning & Performance are Crucial**

- Be proficient in performance charts and their use
- Ensure weight & balance limitations are observed, runway length is adequate, and the single engine climb performance clears all obstacles & terrain

iii. **An Engine Failure After Lift-off can be Summarized into 3 Scenarios**

- **Gear Down:** Land straight ahead on the remaining runway
- **Gear Up, Single Engine Climb Inadequate:** Landing must be made in the most suitable area
- **Gear Up, Single Engine Climb Adequate**: Continue the climb

iv. Do not attempt to continue flight when it's not within the performance capabilities

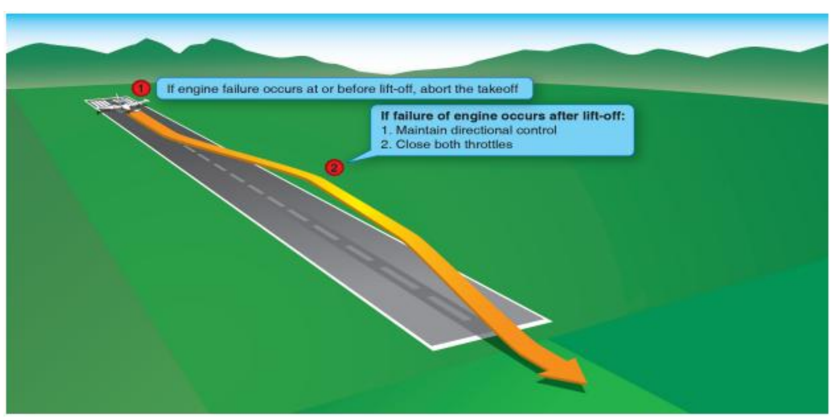
B. Engine Failure After Lift-Off with Gear Down

i. Gear is retracted with a positive rate of climb *AND* when remaining runway is not sufficient for landing

- If the gear is up, the decision has been made to continue the climb if an engine fails

ii. If the gear is still down:

- Keep the nose as straight as possible
- Close both throttles
- Pitch to maintain adequate airspeed
- Descend & land on the runway



iii. The chances of maintaining directional control while retracting gear and flaps, feathering the prop, and accelerating are minimal

C. Landing Gear Up, Single Engine Climb Inadequate

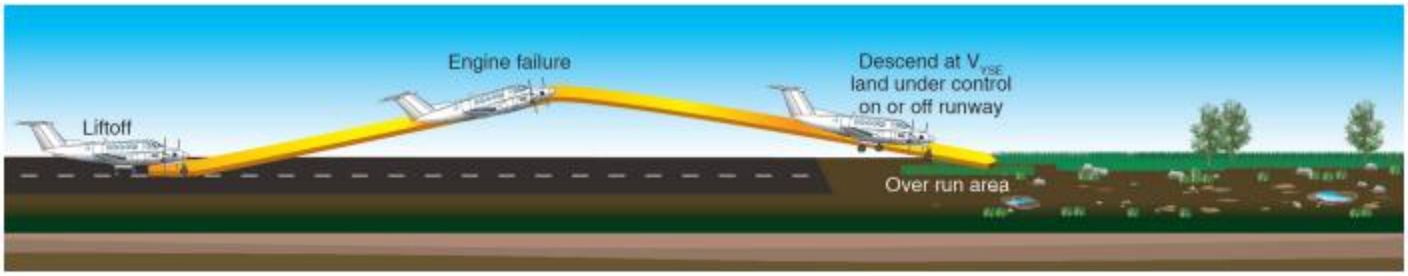
i. A landing must be accomplished on whatever lies ahead

- Maintain control, clean up excess drag, establish zero side slip, maintain adequate airspeed

ii. Landing under control is paramount

- A descent at V_{YSE} can increase the distance the aircraft can fly before reaching the ground
- Remaining airborne and bleeding speed to maintain altitude is likely going to be fatal

iii. If necessary (and better than landing gear up), lower the gear for landing



D. Landing Gear Up, Single Engine Climb Adequate

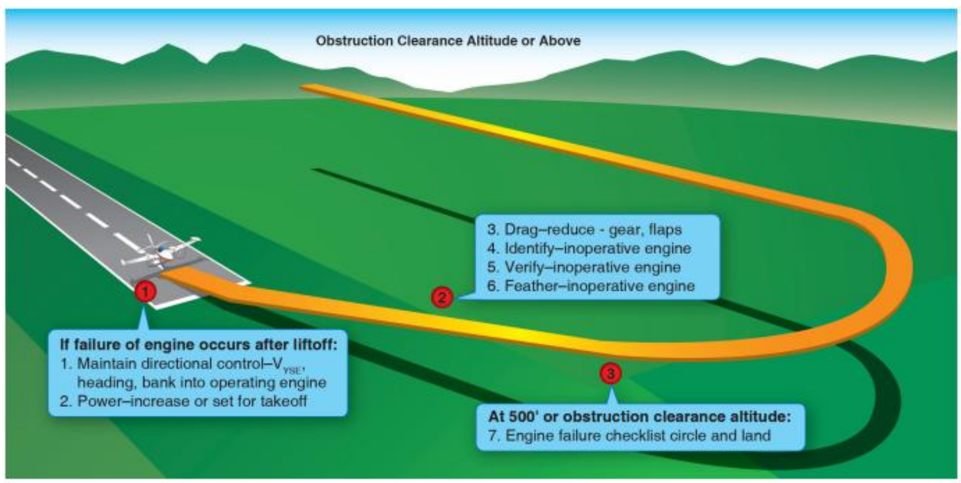
5 areas of concern: Control, Configuration, Climb, Checklists, Communicate

i. **Control:** Use rudder and aileron to maintain control & establish zero sideslip

- Fly the plane first

ii. **Configuration:** Full Power, Gear up, Flaps up, Identify, Verify, Feather

- Do not attempt to fix the engine, feather the propeller, and climb at V_{YSE}



iii. **Climb :** Maintain V_{YSE} & a zero sideslip

- Anything other than V_{YSE} & a zero sideslip reduces performance
- Climb to at least 400' AGL before attempting to return to land

iv. **Checklist:** With memory items complete, accomplish the securing engine, or applicable checklist(s)

- Aircraft control should not be sacrificed to execute checklist items
- Few, if any, remaining checklist items will adversely affect performance

v. **Communicate:** Time and conditions permitting, inform ATC and declare an emergency

vi. **Circle & Land**

4. RM: TAKEOFF BRIEF (RM: Potential engine failure after liftoff) AI.XII.F.R1

***Have a plan**: Apply the engine failure after liftoff knowledge and procedures to every takeoff briefing*

A. Airspeeds

i. V_R, V_Y, V_{YSE} - Announce the speeds

B. Runway & Performance

i. "Takeoff on runway XX, we have X,XXX' of runway, performance shows we need X,XXX' for takeoff. Accelerate-stop distance is X,XXX feet and accelerate-go distance is X,XXX feet"

C. Emergency Procedures

i. If we lose an engine on the roll:
   - Close the throttle, and maintain control with the rudder/brakes

ii. Lose engine after rotation with gear down and runway available
   - Maintain directional control, close the throttles, and pitch land on the remaining runway

iii. Lose an engine after rotation with gear up:
   - Maintain control, max power, pitch for V_{YSE}, gear up, flaps up, identify, verify, feather the propeller, and climb to 400' AGL before returning to land
     - Adjust altitude for local, terrain, obstacles, requirements, etc.

D. Normal Departure Procedure

i. Based on the flight

5. SIMULATED FEATHERING AI.XII.F.K6

A. ACS: Simulate feathering on the inoperative engine

i. Evaluator should establish zero thrust on the inoperative engine

B. Zero Thrust: Set power on the engine such that drag from its propeller = that of a feathered prop

i. Basically, the same performance as a feathered propeller without shutting down the engine

ii. Brief the zero thrust power setting

6. COMMON ERRORS AI.XII.F.K7

A. Failure to follow prescribed emergency checklist

B. Failure to properly identify and verify the inoperative engine

C. Failure to properly adjust engine controls and reduce drag

D. Failure to maintain directional control

E. Failure to establish and maintain a pitch attitude that will result in best engine inoperative airspeed, considering the height of obstructions

F. Failure to establish and maintain proper bank for best performance

7. RM: HAZARDS

A. Configuring the Airplane
AI.XII.F.R3

i. It is very likely that the airplane will not be able to hold altitude OEI with excess drag
- Critical that the gear & flaps are retracted, and the propeller is feathered

ii. Follow POH procedures – Perform engine failure after takeoff memory items to configure for climb:
- Generally, zero sideslip, V_{YSE}, max power, gear & flaps up, identify, verify, feather
- Continue with the checklist when safe

iii. Proper configuration reduces the odds of reaching V_{MC} and a loss of control (reduce drag, zero sideslip)

B. Low Altitude Maneuvering
AI.XII.F.R4

i. A small problem at high altitude can quickly become a big problem at a low altitude

ii. Quick, panicked maneuvers can result in a stall or loss of control close to the ground
- Especially important in engine failure emergencies
- Be aware of, and avoid, obstructions, towers, etc.

iii. **Low Altitude Stall/Spin**
- A low altitude stall or spin can leave little to no recovery time
  - ALWAYS maintain coordination, and airspeed at low altitudes
    - During engine failures, maintain best glide – Stalls could be catastrophic low/without power
  - If you get any indication of a stall at low level, recover, and climb (if able) to a safe altitude
    - Without power, recover from the stall and adjust as required to make an emergency landing
- Spin *(Different aircraft respond differently to spins and spin recoveries - follow POH procedures)*
  - A spin is a result of a stall + yaw
  - Prevention
    - Maintain coordination – don't cross the controls especially during an emergency landing
    - Do not use abrupt, excessive pressure inputs (especially back elevator pressure)
    - Stop whatever you're doing and recover at the first sign of a stall
  - Recovery (PARE)
    - Power - Idle
    - Ailerons - Neutral
    - Rudder - Full rudder opposite the spin direction
    - Elevator - Brisk, positive forward pressure (nose down)
    - When the spin stops, neutralize the rudders and raise the nose - be careful not to stall

iv. **CFIT** (Controlled Flight into Terrain): AC 61-134: General Aviation CFIT Awareness
- The solution to combating CFIT accidents starts on the ground
  - Common themes include proper planning, good decision making, and being able to safely operate the aircraft throughout its entire operating range
  - Don't push the envelope - if there's a possibility of CFIT, go around and try again
- Recommendations:

- Non-instrument rated VFR pilots should not attempt to fly in IMC
- Know and fly above minimum published safe altitudes
- If IFR, fly published procedures
- Verify proper altitude, especially at night or overwater, through use of a correctly set altimeter
- Verify all ATC clearances. Question potentially hazardous clearances
- Maintain situational awareness both vertically and horizontally
- Comply with appropriate regulations for your specific operation
- Don't operate below minimum safe altitudes if uncertain of position or ATC clearance
- Be extra careful when operating in an area which you are not familiar
- Use current charts, appropriate checklists & know your aircraft and equipment

C. Collision Hazards AI.XII.F.R2

i. **Collision Avoidance**

- Scanning
  - Short, regularly spaced eye movements bringing successive areas into the central visual field
  - Each movement should not exceed 10º, each area should be observed for at least one second
- Clearing Procedures
  - Climb/Descent: Use gentle banks to scan above/below the wings as well as other blind spots
  - Prior to any turn: Clear in the direction of the turn
- Operation Lights On (voluntary FAA safety program)
  - Turn on landing lights during takeoff and when operating below 10,000', day or night
- Right-of-Way Rules (FAR 91.113)
  - Pertinent to emergencies: An aircraft in distress has the right-of-way over all other traffic
  - Be cautious, other aircraft may not know you're in distress

ii. **Terrain**

- Study terminal charts and IFR/VFR chart altitudes, use Max Elevation Figures (MEFs)
- Be extra vigilant at night, when terrain may be impossible to see until it is too late
- Minimum Safe Altitudes (FAR 91.119)
  - Anywhere: Altitude allowing an emergency landing without undue hazard to persons or property
  - Congested Areas: 1,000' above the highest obstacle within 2,000'
  - Other than Congested Areas: 500' above the surface, except when over open water/sparsely populated areas, then no closer than 500' to any person, vessel, vehicle, or structure

iii. **Obstacles & Wire Strike**

- Research obstacles in the area - Charts, NOTAMs, Terminal procedures, etc.
- Antenna Towers can reach > 1,000-2,000' AGL and support guy wires can extend 1,500' horizontally
- Overhead Wires (may not be lit) and often span departures & landmarks pilots frequently follow
  - Lakes, highways, railroad tracks, etc.

iv. Airport Surface

- Scan vigilantly for aircraft and obstacles – Aircraft, Vehicles, Persons, Wildlife, etc.
  - Be alert for anyone/anything that may cause a hazard
- Check NOTAMs for work on the airfield

D. Distractions, Loss of SA, Disorientation, Task Prioritization AI.XII.F.R5

i. **Distractions**

- They're dangerous - Remove them from view or, if a person, explain the situation & ask them to stop
- Focus on aircraft performance & clear for traffic - If distracted, recognize the problem and fix it
- Fly first! Aviate, Navigate, Communicate
  - Especially important to avoid distractions in an emergency with numerous tasks to manage

ii. **Situational Awareness (SA) & Disorientation**

- Extremely important, lost SA has led to unsafe situations, mishaps, and incursions
- High task load during an emergency can lead to a loss of SA
- Maintain SA
  - Starts with preflight planning - Know what's coming next and stay ahead of the airplane
  - Divide attention between inside and outside references
  - If SA is lost, admit it, and fix the problem
  - Emergency Descent: Maintain SA in relation to the level-off altitude, emergency & associated procedures, airplane configuration, and the plan (diversion)
- Disorientation can be caused by, or lead to, an upset
  - **Push**: Apply forward pressure to unload the plane
  - **Roll**: Roll aggressively to the nearest horizon
  - **Thrust**: Adjust as required
  - **Stabilize**: Return to a safe flight condition

iii. **Task Prioritization**

- Divide attention between the aircraft, scanning, and communicating (ATC or CTAF)
  - No one responsibility should take your full attention for more than a short period
- Understand what tasks need to be accomplished and when
  - Organization is especially important in situations like this – many tasks, little time
- "Attack the closest alligator"
  - When tasks are piling up, handle the most threatening problem
- Proper task management can help prevent distractions, loss of SA, and disorientation
- Safety is the number one priority – Aviate, Navigate, Communicate

Conclusion: Brief review of the main points