Multi-Engine Add on Rating
Lesson Plans

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Multiengine Aerodynamics

Attention/Motivation: Understanding multiengine Aerodynamics allows a pilot to understand the behavior and flight characteristics of aircraft. More importantly, provides a basis of understanding for limitations of aircraft which if ignored could lead to disastrous consequences. A basic understanding of these principles will allow th pilot to rationally operate an multiengine aircraft within its normal operating envelope and thus provide a margin of safety for flight.

Objective

To teach basic multi-engine aerodynamic principles to the student pilot to aid in decision making and rational for safe operating procedures of aircraft.

Elements

- Terms and definitions
- Performance and limitations
- Engine inoperative flight principles

Schedule

Discussion 2:00 hours

Equipment

Model aircraft, Drawing board or paper

Instructor Actions Discuss the following:

Accelerate stop distance x=Vr and stop, engine fails at Vr
Compare flight conditions to runway length
Accelerate –go distance x=climb to 50 ft, engine fails at Vr
Let's you know if you have a chance to climb out or not
All engine service ceiling vs absolute ceiling 100 ft/min Vy=Vx
Single Engine Service ceiling **50 ft/min**
(Should know if at high density altitude airport)
Use above to pre-flight plan, adjust weight, fuel, go-no go, emergency landing areas etc

Vr (Vlof) rotation speed (VMC +5)
Vxse
Vsse
Vyse (blue line) minimum rate of descent vs best rate single engine climb!!!
Vmc (red line) determined by manufacture STD day, Sea Level:
full power, critical engine in op,
max 5 degree bank, **(part 23.149**)
Unfav weight and Cg, take off config, gear up, 20 degree loss lateral control
ACTUAL Vmc varies on several conditions. See later in lesson.

Engine inoperative flight principles

<u>Determining Critical engine conventional vs counter rotating</u>

1) P factor x arm R > L from CG – "Yaw Torque"
2) Accelerated slip stream – lift x arm R > L from CG – "Roll Torque"
3) Torque- from both engine rotates counter clockwise "Counter Torque"
4) spiral slip stream on Rudder L > R, rudder authority "Rudder Torque"

(Drag of prop equal on either side)

<u>Forces acting on aircraft with engine inop</u>

1) Yaw-Turn tendency (**correct with rudder**)
   Asymetric thrust and drag
2) **Roll** tendency (correct with aileron)
   Loss of Accelerated Slip stream >>>loss of lift on dead side
3) **Side Slip** toward dead engine increases drag and reduces climb ability

<u>Factors affecting climb/descent with one engine in-op</u>

1) Correct airspeed (blue line, Vyse)
2) Excess power from level flight (lose 80% excess power with loss of one engine)
3) Drag –flaps, gear, un feathered prop, ***side slip*** (see below)
4) Weight of aircraft

Drag Factors: (effect on climb ALL NEGATIVE)

Un feathered prop-	600-800 ft min
Gear down	600 ft min
Full Flaps	400-500 ft min
Side Slip	200-400 ft min

Loss of one engine = 80% loss of climb power at SEA LEVEL, more at higher altitude (Denver)

Side Slip- yaw string for "Zero Side slip" see below
(2-3 degrees lowest drag)
Gear/flaps
Prop un feathered

ZERO SIDE SLIP- 2-3^0 bank into good engine, **use rudder to hold heading** (ball ½ out),
more bank decreases Vmc but also DECREASE CLIMB from excess drag
Error is to bank more than 2-3 degrees and climb suffers
Banking less than 2-3 degrees increases Vmc and increases DRAG!

Response to Failed engine (see specific lesson plans)
Control aircraft, bank and rudder toward operative engine
Identify, dead foot dead engine
Verify with throttle reduction inop engine
Use appropriate check list
Engine instruments may all be normal or nearly so on in operative engine.

Vmc- occurs as airspeed deteriorates, loss of rudder authority. See above

Recognizing and recovering from Vmc
Loss of directional control or any sign of impending stall (horn or buffet)
Reduce power and nose down

Factors affecting actual Vmc First Three are the MOST important!

1) Prop- (feather = 90% reduction in drag, dramatic drop in Vmc)

2) Power- (density altitude and throttle position)

3) Bank Angle – Vmc decreases w/ increase bank
Bank > 2-3^0 decreases VMC, increases side slip/drag, decreases climb!
Bank <2-3^0 increases VMC, more side slip/drag- poor climb
Wings level increase Vmc 15-20 kts

4) CG- aft CG reduces rudder authority (smaller arm, less Torque)

5) Weight- horizontal lift in bank decreases Vmc
6) Flaps, gear, cowl flaps, color of aircraft, daylights savings- all nominal effect.

Critical Density Altitude: Vmc=Vs. DANGER! Stall + Roll = SPIN- (not recoverable in twin)
VMC decreases with altitude vs Stall speed remains constant IAS

FAR 23.67 single engine climb performance: not required for MGW < 6,000 lbs

Evaluation

Lesson is complete when student can demonstrate fundamental understanding of aerodynamics through discussion of outlined principles, answer questions related to these principles.

References

FAA-H-8083-25 Pilot's Handbook of Aeronautical Knowledge (PHAK) Chapter 4, FAA-H-8083-3A Airplane Flying Handbook Chapter 4, Aeronautical Information Manual (AIM) 7-3-1, 14 CFR 23.149

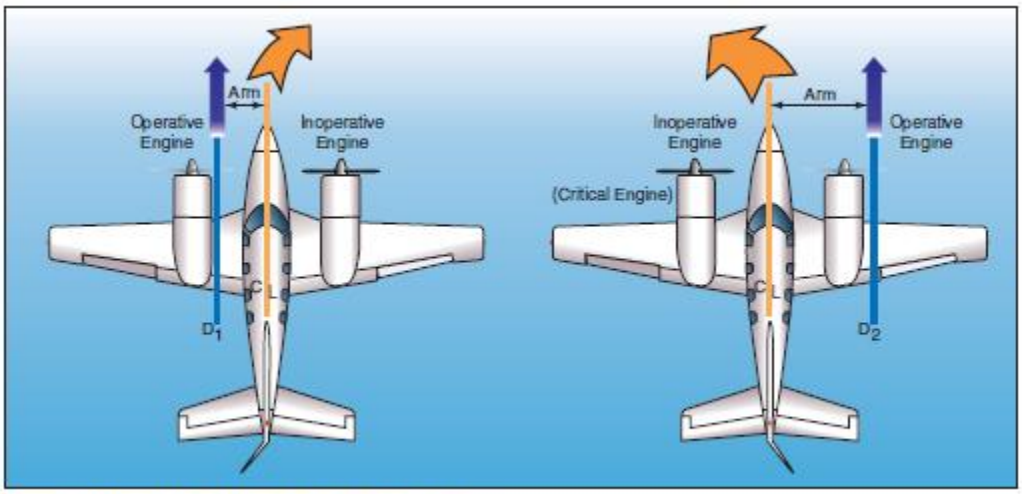
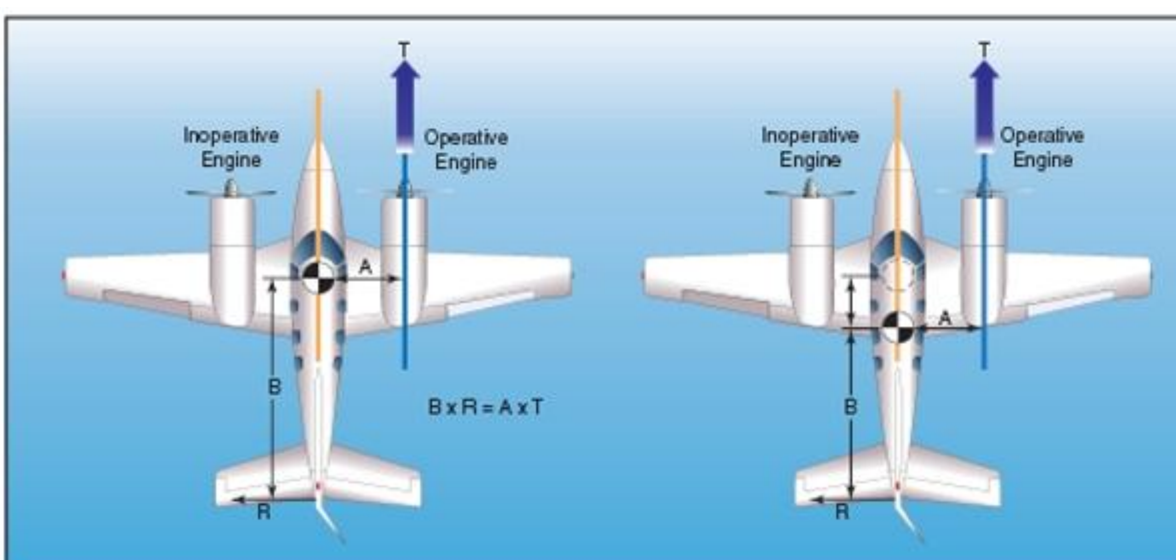
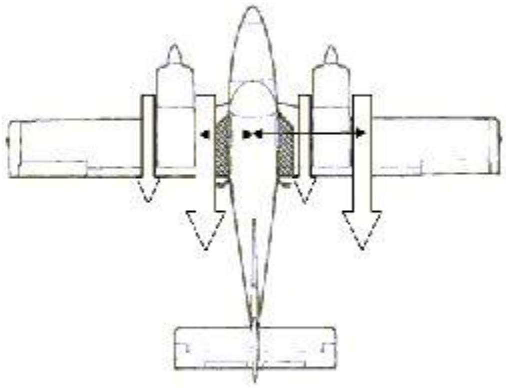


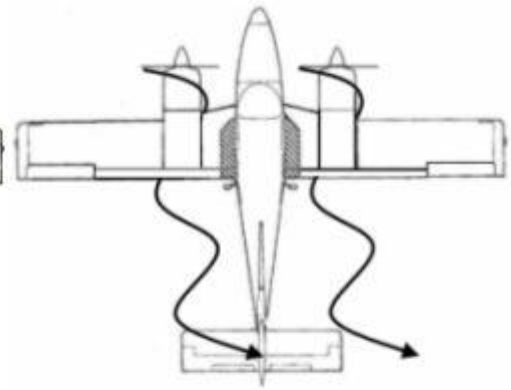
Figure 12-19. Forces created during single-engine operation.

More YAW TORQUE from Right engine



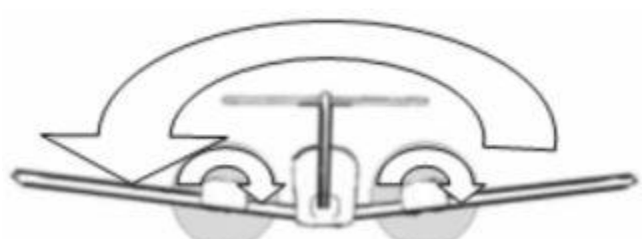
LESS Rudder "Torque" and less rudder authority with AFT CG



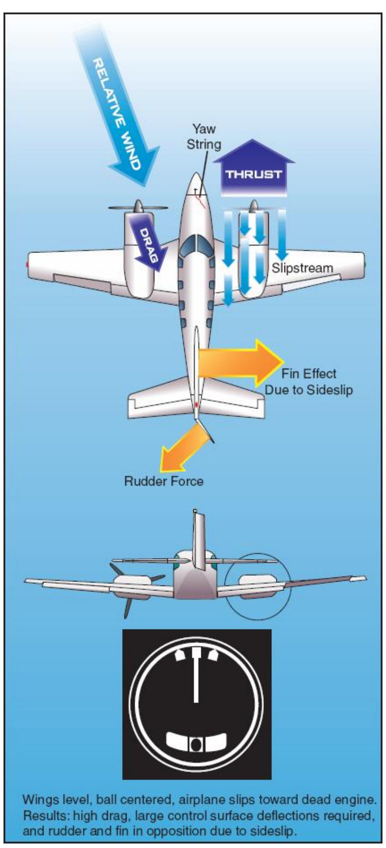


Accelerated Slip Stream- right side
Has longer lever than left, therefore
Right side has more "ROLL TORQUE:

Spiral Slip Stream from LEFT engine
Strikes Rudder, Right does not.
Lose left engine, lose left Rudder yaw (Torque) .

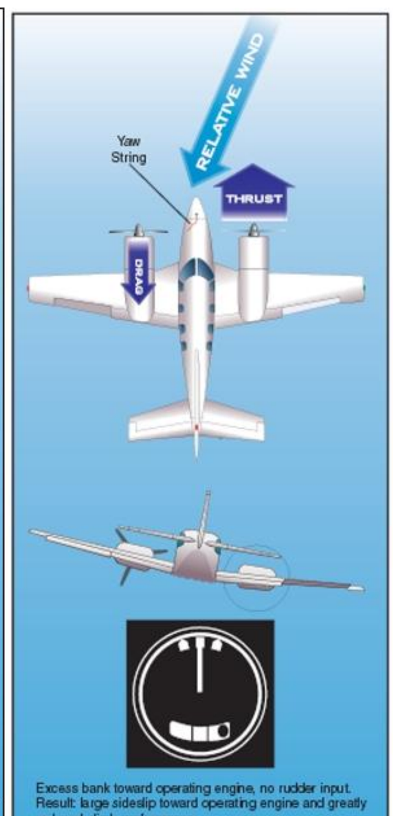


Torque reaction rolls plane to left. Loss of Left engine has more adverse effect than right on Roll control.



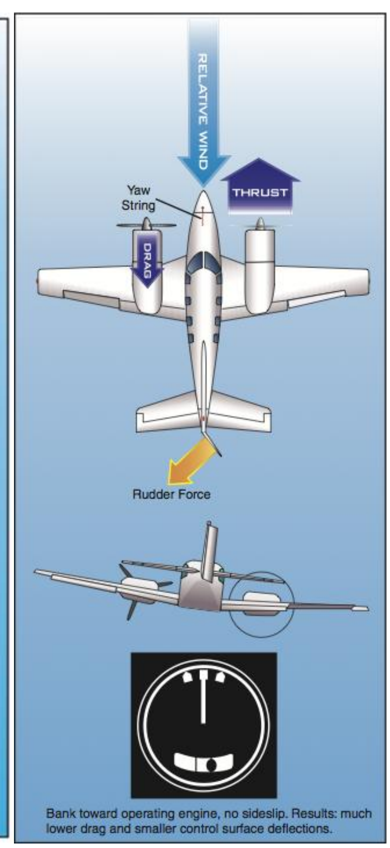
Wings level, ball centered, airplane slips toward dead engine. Results: high drag, large control surface deflections required, and rudder and fin in opposition due to sideslip.

USE mostly RUDDER
Level wings, excess rudder
Increased drag, Vmc high
POOR CLIMB



Excess bank toward operating engine, no rudder input. Result: large sideslip toward operating engine and greatly reduced climb performance.

USE mostly BANK
excessive bank, little rudder
Increase drag, Vmc Lower
POOR CLIMB



Bank toward operating engine, no sideslip. Results: much lower drag and smaller control surface deflections.

ZERO SIDE SLIP – best combo
Minimal bank (2-3^0), rudder to hold course.
LEAST DRAG, Vmc medium
BEST CLIMB

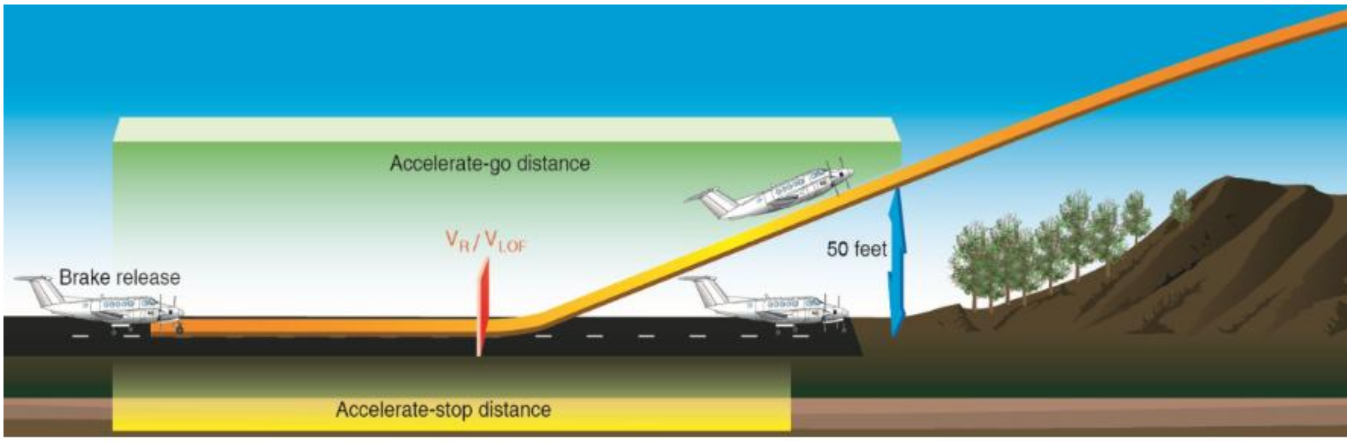
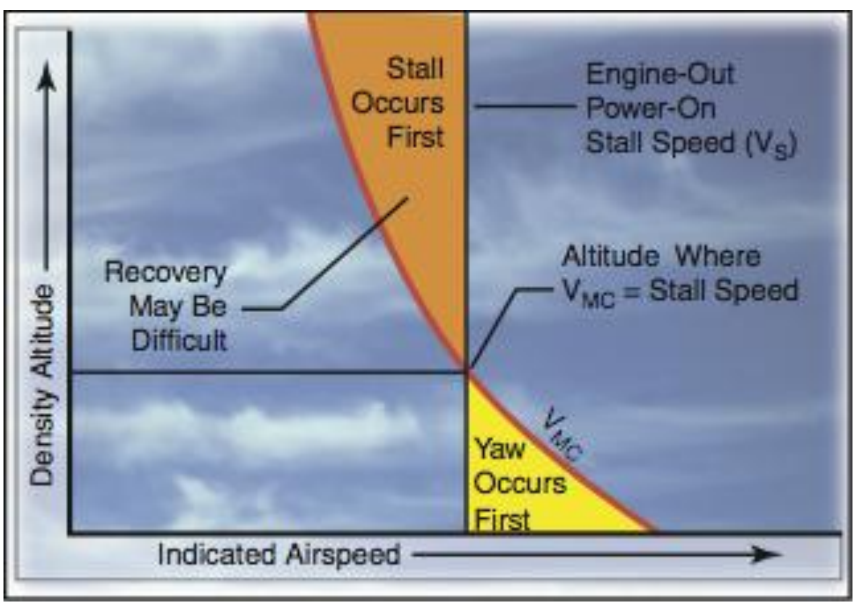


Figure 13-5A. *Accelerate-stop distance and accelerate-go distance.*



Critical Altitude- Stall occurs at Vmc. Danger!

Blue Line= Vyse

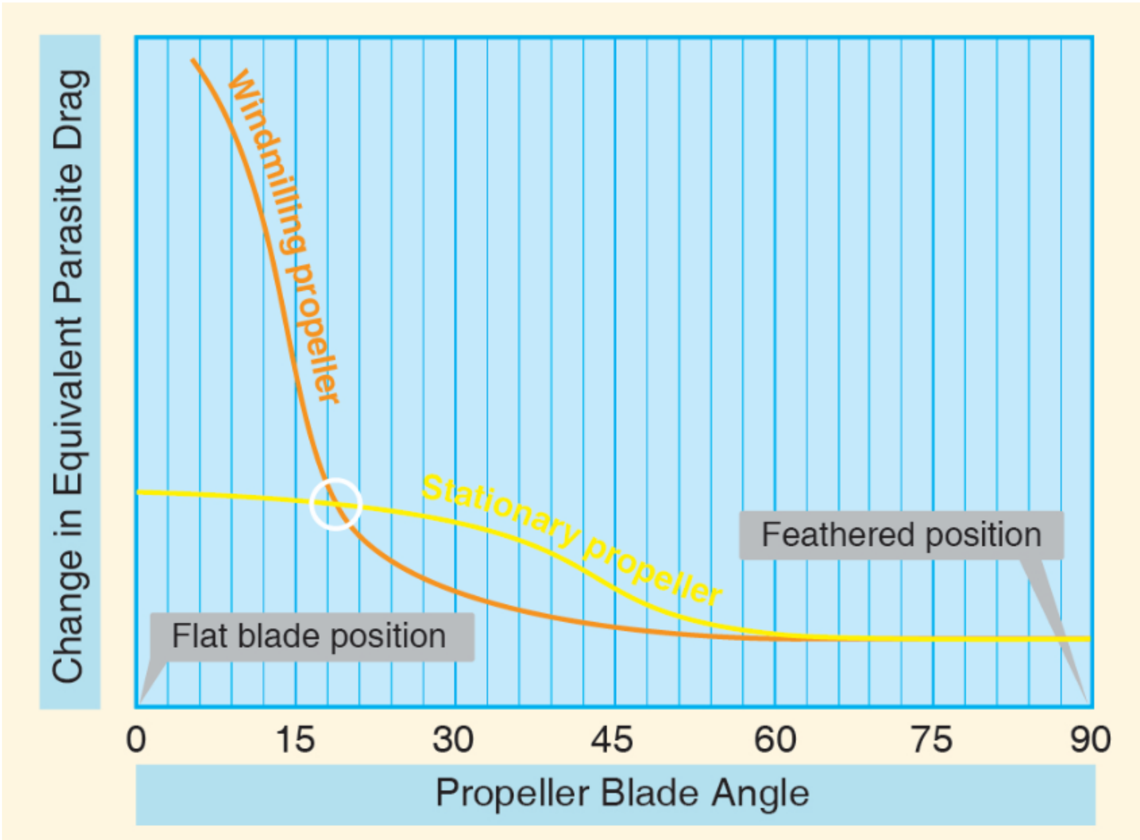


Figure 13-3. *Propeller drag contribution.*

Rejected Take Off and Engine Failure after Lift Off

Attention/Motivation: Takeoff can be aborted for many reasons prior to lift off. These may include door opening, flat tire, unusual noise or an engine failure. Loss of an engine on take off roll and before Vmc is a vulnerable time for loss of lateral control of the aircraft. Take off or Go-around is the most critical time to suffer an engine failure, especially if flaps and gear are extended. Only practice and rapid action will improve the likelihood of a survivable landing.

Note: *Simulated engine failure of the most critical engine shall be demonstrated after liftoff. However, the failure of an engine shall not be simulated until attaining at least VSSE/VXSE/VYSE and at an altitude no lower than 500 feet AGL. Engine failure on take off roll must not be simulated at greater than 50% of Vmc.*

Objective: teach the operational elements and procedures for aborted take offs and inoperative engine just after takeoff, up to and including traffic pattern altitude.

Elements

Preflight- Density altitude and Single engine ceiling/performance
Determine accelerate-stop, Accelerate-go, Runway length
Evaluate surrounding Terrain for emergency landings
Rejected Takeoff- (before Vr) : close both throttles, aggressive rudder/brake

Engine Failure after rotations, below 500 ft AGL:

close throttles, land straight ahead

Engine Failure at or above 500ft AGL: -

Cram/Control/Clean-
Identify, Verify, Feather.
Climb straight ahead to safe altitude, gain speed for safe maneuvering
Complete check list if able
Land at nearest airport with RWY 100 ft wide, 5000ft length if possible

Consider High density altitude airport take off. If near or above Single engine ceiling. Pre-flight emergency landing spots to make decisions.

Engine Failure En-route- see other lesson plan

Alternate Method Engine failure after rotation:

Wheels Down- **Go down**
-close both throttles, land directly ahead
Wheels UP – inadequate climb ability (high alt airport)
-Land directly ahead, or use Blue line to make controlled landing
Wheels UP – Go UP- terrain and climb ability permitting.

Instructor: Reviews pre-flight considerations, discusses and demonstrates rejected take off, engine inoperative after lift off

Student: Determines preflight performance limitations, discusses and performs elements and tasks for rejected take off and engine inoperative after lift off.

Discussion: Loss of an engine shortly after rotation is generally not expected. The startle response before intervention varies based on experience, recency of training and individual stress response. On check rides, where engine failures are expected, the average time from engine failure (sans startle response) till feather, zero side slip, clean up and start of climb is about 45 to 60 seconds. In actual engine failures we have to add the startle response (5 to 15 seconds?). In this time interval, most GA light twins (at density altitudes at or just above sea level) will have a descent rate of 200-400 fpm or more. At higher density altitudes the descent rate maybe significantly higher. If at or above the Single engine service ceiling or terrain may preclude the option to feather and return to the airport. The time to determine climb ability, terrain and obstacles is during pre-flight planning, not in the middle of an emergency. Consequently, every take off, consideration should be made as to the single engine climb ability, terrain, and obstacles to determine minimum altitude required to have sufficient time to feather prop, clean up, zero side slip and return to airport. Arbitrary altitudes or simply using “gear up to go up” or “no useable runway” are potentially false hopes and a deadly trap. Consider departures at low flat land areas such as Florida or Midwest and contrast with departures at airports in mountainous terrain at high altitude densities. See article at the end of lesson plan.

Common Errors Related to engine failure before Vmc

a failure to follow prescribed emergency procedure.
b. failure to promptly recognize engine failure.
c. failure to promptly close throttles following engine failure.
d. faulty directional control and use of brakes.

Common errors related to engine failure after lift-off by describing:
a. failure to reduce pitch to proper attitude for Vyse
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. Attempting turns before feathering, safe altitude and airspeed.
f. failure to establish and maintain zero side slip for best climb performance.

Completion Standards: Determines preflight performance limitations, discusses and performs elements and tasks for rejected take off and engine inoperative after lift off.

References: POH, FAA-H-8083-3, 8083-25

Gear up to Go up? Making the decision for continued flight after an engine failure in a multi-engine piston.

Many decades of traditional multi-engine training has re-enforced a common rubric "Wheels up to go up" for determining if the pilot should continue flight after sustaining a low altitude engine failure soon after aircraft rotation. This concept is required mantra for training and passing the Multi check ride along with running "The Drill". This article explores the risk factors for continued flight in a light piston twin sustaining an engine failure shortly after rotation.

Risk Analysis of engine failure after rotation.

Startle response: This is 10 or 15 seconds in well trained pilots, with recent emergency training and high proficiency.

Time from engine failure to feathered prop, zero side slip and climb. On check rides with pilots just completing training is 45 to 60 seconds (my personal observation). It is rare to see this accomplished in 30 seconds or less.

Gear position to determinate to feather and continue vs land straight ahead.

"Gear down to go down" is widely accepted as an indication to reduce power and land roughly straight ahead regardless of landing surface available. This is because the drag penalty and time to clean up and then have an effective climb in a light twin is unlikely. This makes intuitive sense as the gear is generally down in low proximity to the surface. The problem is pilots then assume that if the "gear is down to go down", then clearly the opposite must also be true "gear up" should be "go up". This is faulty and potentially deadly logic.

"Gear up to Go up" is commonly used as an indication for feathering and continuing flight. The difficulty is determining when to bring the gear up. Some use "no remaining usable runway" others use "Blueline and positive rate of climb". The problem is there is no objective way to determine if there is usable runway. Usable runway changes with runway length, aircraft climb performance and the pilot's best guess. "Blue Line and Positive rate of climb" happen very quickly in most light twins. In either case, gear is typically retracted anywhere from 50 to 200 ft. Higher if we get distracted or forget. What if we forget to retract gear and we are 1000 ft AGL, should we pull power and land straight ahead? In most cases not.

Additionally, using "gear up to go up" does not consider the startle response, recency of training, proficiency of the pilot, obstacles, terrain, density altitude and other aircraft performance factors. In fact, this type of training creates false confidence such that the pilot is less likely to consider other risk factors. For example, most light twins taking off at a mountain airport where density altitude is near or above the single engine service ceiling, a low altitude engine failure is more likely to lead to CFIT and mortal outcome if the pilot opts for continued flight.

Risk of landing gear up or gear down. I think everyone would agree landing gear down on the runway is the preferred option. However, aircraft frequently land gear up more often than they have engine failures. The fatality and injury rate for a gear up landing is not much different than landing gear down. Then we have to consider off airport landings. It is difficult to determine for any given terrain or topography if it is better to have gear up or down for impact. For wet or muddy, we tend to think gear up. For rough terrain we think gear down to absorb impact. Water is probably better gear up. Given the urgency and limited time in a crisis, we have to ask how important this is in making the decision to land straight ahead or continue flight. The real risk factor is not the gear position but rather if we impact terrain at minimum airspeed,

in a Vmc roll, or at blue line. In this case, landing at minimum control airspeed has my vote with gear position a much less important risk factor. At this point, the risk analysis favors "Gear down to go gown" but we still have to assess other risks to see if "gear up to go up works".

In the moments immediately after an engine failure, we must consider the pilots' initial actions and effects.

Immediately after engine failure is the startle response, average of 10 seconds

The initial pilot response is to push the yoke forward and bank toward the good engine with bank angles in excess of 10^0 and far from zero side slip with over aggressive rudder use. Combined with a propellor that has not yet been feathered, aircraft climb rate is severely reduced. Pilots tend to focus on the airspeed indicator and ignore other duties till they recover from the startle effect. The net result is likely a descent rate of 200 to 400 fpm depending on the aircraft.

Then the process of running an engine failure drill can be protracted when facing a real emergency. During multiengine check rides pilots often repeat steps to be sure or go too fast and do the wrong thing despite intensive recency of training. The average time to complete these tasks is about 40 seconds.

Then the pilot has to concentrate on obtaining zero side slip and blue line to get maximum climb performance. In the best case we have 30 seconds struggling to maintain altitude and worse case 60 seconds of descending at 200 to 400 ft per minute. If we use "Wheels up to go up" and an engine failure happens shortly after, we are somewhere between 100 and 200 ft AGL descending at 200 to 400 fpm. It is highly likely we will impact terrain even at low density altitudes and with a recently trained and proficient pilot. How many GA pilots of light twins practice low altitude engine failures more than once a year or every two years?

The question becomes how much altitude is required give the pilot sufficient time to "run the drill", get the prop feathered, cleaned up, zero side slip and get a positive rate of climb. This also depends on many factors.

Then we should consider obstacles, terrain, density altitude, aircraft performance, and pilot proficiency.

Obstacles and Terrain can pose a hazard if in a low altitude flight path with marginal maneuvering capability. This especially dangerous before the prop is feathered. Any turn into an un-feathered prop to avoid an obstacle will likely result in a Vmc roll and fatal accident. Turns in any direction will likely cause a decrease in climb performance or even a descent.

Departing a high density altitude airport, the aircraft may have marginal climb or unable to maintain any altitude. Then the pilot has a choice to accept a landing at minimal airspeed or strike terrain or obstacle at Blue line. If touch down speed is at 60 to 70 kts and blue line is near 100 kts, the energy difference is at least double and the mortality rate higher striking terrain or an obstacle at blue line.

Aircraft Performance. There is a broad range of light piston twin performance. My experience is the POH values are very optimistic to what I see in practice. I often see light twin POH single engine service ceilings to be reported between 5000 and 8000 ft density altitude. During Check rides and training events, the average multi-engine trainers struggle to maintain density altitudes of 3000 AGL with many lower than this. Simulating low altitude engine failures during training is done with throttle reductions where the failure is expected and observed. Then the propellor is placed in “neutral thrust” or “simulated” feather. Applicants and instructors are then overconfident in their ability and aircraft performance with low altitude engine failures. This is a potentially deadly confidence.

Pilot Proficiency and recency of training. Pilots overestimate their proficiency. A lot. The internet is replete with videos of Vmc roll overs with engine failures shortly after liftoff. Most of these are professional pilots in high performance turboprops and piston twins that have demonstrated accelerate go performance. So what is happening? The pilots believe they can continue flight with limited altitude (time). Task overloaded in the few moments after liftoff, the pilot gets slow avoiding impact or trying to climb and results in a Vmc roll into a fire ball. These events even happen with turboprops that have auto feather. Consider the young aspiring pilot with a new multi-engine rating. How often do they fly twins and get recurrent training? How much time and altitude do they need to get the prop feathered, zero side slip and climb away? Is it wheels to go up or does the pilot need time and altitude to make it work?

Summary of risk analysis. Clearly, “gear down to go down” seems reasonable as we are likely low with few options and high coefficient of drag. However, “Gear up to Go up” does not consider the many other risk factors that should be considered such as pilot training, recency, proficiency, aircraft performance, density altitude, obstacles and terrain. Also, pilots need altitude (time) consistent with the previous risk factors outlined to allow them to continue flight if aircraft performance allows. Having “Gear Up” by itself does not mitigate the various other factors. I generally recommend pilots make the decision if continued flight is possible with engine failure under prevailing conditions before climbing into the aircraft. In low density altitude, no obstacles, to consider adding 500 ft (AGL) to the field elevation if the pilot has recency and proficiency. This becomes the decision point easily determined on the altimeter for continued flight regardless of gear position. Consider 1000 ft AGL added to the field elevation for pilots who do not have recency of engine out training as a decision point for continued flight vs landing relatively straight ahead. In mountainous terrain or high density altitude, the decision to return to the airport may require a few thousand feet and careful pre-flight planning.

Comments on Maneuvering on engine In-operative. Many multi instructors tell pilots, “never turn into a dead engine”. This is fear driven bad advice as pilots are afraid of maneuvering the aircraft and may elect to only make turns away from the dead engine despite traffic or rising terrain. Once the propellor is feathered, Vmc is usually far below stall speed. You are now flying a relatively normal single engine aircraft with a stall speed. We make turns in both directions in single engine trainers.

Emphasis should be placed on getting the propellor feathered, maintain altitude and at least blue line airspeed before making any turns. Once these three things are accomplished, the pilot should be confident in making turns any direction. Altitude is required because banks of more than about 20 degrees either direction may result in altitude loss. The internet is filled with videos of multi-engine aircraft near pattern altitude with an engine failure. In a panic, the pilot makes a turn into an un-feathered prop with the expected Vmc roll and spin into the ground. As long as the pilot has altitude, airspeed and a feathered prop, they can turn either direction with as much bank as required to achieve the objective.

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En Route Engine Failure, Maneuvering With One Engine Inoperative

Description: This lesson is to prepare the multiengine pilot for a situation where power has been lost in one engine or the engine has been shut down for an emerging problem. Once the engine is secured, the pilot needs to be able to maneuver the aircraft to a safe place for landing. This lesson will involve simulated engine inoperative procedures which may include actual feathering of the critical engine or setting "zero thrust" to the simulated engine out.
Objective: Determine that the student understands the elements related to maneuvering with one engine inoperative and becomes familiar with the techniques and capability of the aircraft in single engine flight to the extent the pilot can maneuver the aircraft to a safe landing area. in a safe manner
Note: The feathering of one propeller shall be demonstrated in any multiengine airplane equipped with propellers which can be safely feathered and un-feathered in flight. Feathering for pilot test purposes should be performed only under such conditions –
No lower than 5,000 (POH specific) feet above the surface and positions where safe landings on established airports (runway minimum of 100' x 5000") can be readily accomplished in the event of difficulty for the un-feathering procedure.
At altitudes lower than 5,000 feet AGL, simulated engine failure shall be performed setting to zero thrust per POH recommendations (BE55 MP=12 inches, Prop/RPM reduced to detent just before feather).
In the event a propeller cannot be un-feathered it should be treated as an emergency.
Elements:

Clear the Area
Maintain 5000 ft AGL
Maintain proximity to airport with suitable runway in case unable to restart OEI
When engine becomes Inoperative:

1. **Airspeed and directional control**
    a. Cram – call out prop, throttle, Mixture. Control Aircraft same time.
    b. Control Aircraft: Maintain Heading and Altitude (or Blue line)
    c. Zero side slip (yaw string)
        i. 2 degrees bank toward op engine + rudder for directional control (1/2 ball out toward OPERATIVE engine)
2. **Use of Memory Items on check list for inoperative engine**
    a. Identify –Dead Foot Dead Engine
    b. Verify - retard Throttle
    c. check lists – (Fuel, fuel, fuel, mags, alternate air)
3. **Use of prescribed emergency checklists to verify accomplishment of procedures:**
    a. En route engine Failure
    b. Trouble shooting in operative engine (fuel, fuel, fuel, mags, alt air)
    c. Securing inoperative engine (fuel, fuel, fuel, mags, alt air)

4. **After Prop feathered, sufficient Altitude and airspeed at or above Blue line.** Performance of straight-and-level flight, 40 degree turns in both directions, descents, and climbs.
    a. Air Restart/Unfeathering (fuel, fuel, fuel, mags, alt air- adv prop, throttle, restart)
    b. Trim as needed
5. **Flight characteristics and controllability associated with maneuvering with one engine inoperative**

6. **Importance of establishing a heading toward the nearest suitable airport or landing area**
    a. declare emergency if needed, 121.5, and squawk 7700

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Instructor: Reviews and demonstrates inoperative engine procedures, checklist usage, and aircraft maneuvers
Student: practices and performs inoperative engine procedures, checklist usage and aircraft maneuvers
Common errors

Failure to follow prescribed emergency checklists
Rushing through check list- missing items
Fails to call out and verify correct controls- LEFt mag, LEFT fuel valve, LEFT mixture, LEFT fuel pump etc.
Failure to POWER up and then trouble ID of failed engine
Securing or feathering wrong engine
Failure to recognize an inoperative engine
Failure to properly adjust engine controls and reduce drag
Failure to establish and maintain the best engine inoperative airspeed
Failure to unfeather prop, may need to use starter and dive for airspeed
Failure to establish and maintain proper bank for best performance
Failure to maintain positive control while maneuvering
Hazards of attempting flight contrary to the airplane's operating limitations

Completion standards: Determining that the student understands the elements related to maneuvering with one engine inoperative, maintains aircraft directional control, airspeed, memory items, follows check lists and maneuvers aircraft safely to landing area or airport
References: FAR/AIM 14 CFR 23.149, FAA-H-8083-3B Airplane Flying Handbook, Chapt 12-27
Tips and tricks for managing engine in operative emergencies:
First, make a personal decision at what altitude (considering terrain, obstacles, VMC vs IMC, aircraft performance) will you decide to "fix or feather" by running a check list vs immediately feathering. This altitude will help you choose the correct procedure. Trouble shoot vs immediate feather.
Enroute (or altitude above XXXX)

__NOTE: ZERO SIDESLIP__ can be approximated by slight bank toward operative engine and LOTS of rudder to control and maintain heading. The "ball" should be where it needs to be and you can fly looking out window or at instruments if IMC.

1) **Control** aircraft- hold heading and altitude (or blue line for minimum sink)
2) **Cram** controls- but call out "Throttles, Props, Mixtures" (above 5000 ft mixture "adjust")
    a. *Increasing power maintains altitude and helps Ident dead engine easier*
    b. *If at low power settings you may have great difficulty identifying dead engine without cramming all the controls forward*

…..breath, relax a second, don't rush….then…..

3) **Identify**: dead foot, dead engine. Call it out loud "right engine in op"
4) **Verify:** place hand on correct throttle and call it out "verify right engine", retard throttle partially
   Check heading and altitude, heading and altitude (or blue line for minimum sink).
5) **Check list:** Trouble shoot Engine (or flow and check list): **Fuel, Fuel, Mags!!**
    a. Fuel valve on or best tank,
    b. Fuel Emergency pump
    c. Fuel- check mixture
    d. Mags- L, R, Both
    e. Alternate Air- or carb heat

Check heading and altitude, heading and altitude (or blue line for minimum sink).

6) **Secure Engine**: use check list:
   a. **Retard correct throttle :**Say out loud : “right engine out, retard right throttle”
   b. **Feather Correct Prop:** Say out loud: “right (or left) engine out, feather right prop”
   c. **Pull correct Mixture:** say out loud “left (or right) engine out, pull left mixture”
   d. **Then use flow/check list for fuel valve, mags, fuel pumps etc**
      i. **Fuel, fuel, fuel, mags (see above)**

7) **Unfeather Prop: use check list to reverse the secure engine procedure**
      i. **Fuel, fuel, fuel, mags**
      ii. **Prop fwd, throttle cracked, starter and dive if needed**

Check heading and altitude, heading and altitude (or blue line for minimum sink).

Maneuvering on engine In-operative. Many multi instructors tell pilots, “never turn into a dead engine”. This is fear driven bad advice as pilots are afraid of maneuvering the aircraft and may elect to only make turns away from the dead engine despite traffic or rising terrain. Once the propellor is feathered, Vmc is usually far below stall speed. You are now flying a relatively normal single engine aircraft with a stall speed. We make turns in both directions in single engine trainers. Emphasis should be placed on getting the propellor feathered, maintain altitude and at least blue line airspeed before making any turns. Once these three things are accomplished, the pilot should be confident in making turns any direction. Altitude is required because banks of more than about 20 degrees either direction may result in altitude loss. The internet is filled with videos of multi-engine aircraft near pattern altitude but in a panic, the pilot makes a turn into an un-feathered prop with the expected Vmc roll and spin into the ground. As long the pilot has altitude, airspeed and a feathered prop, they can turn either direction and as much as required to achieve the objective

One Engine Inoperative approach and landing

Attention/Motivation: Approach and landing with one engine inoperative may be a likely event a pilot will face. It requires an understanding of the aerodynamics involved and practice of the procedures to safely perform in the event such a landing is required.

Objective

Teaching techniques necessary for a inoperative engine approach and landing

***NOTE**: inoperative engine procedures below 3000 ft are to be simulated with neutral thrust. Approach and landing with simulated engine inoperative are to be done on runways of minimum 100 ft wide and 5000 ft in length.*

***NOTE**: when operative engine is producing power, Rudder and Bank toward the operative engine is required for direction/roll control. As power in the operative engine is reduced to idle in the round out and landing, bank and rudder change to the inoperative engine. The wind milling propeller on the operative engine produces significant drag compared to the neutral thrust/feathered inoperative engine. Anticipate for significant float and longer runway requirement with inoperative engine landings because of the significant reduction in drag of the feathered prop. Strict adherence to airspeeds is critical to safe performance of this procedure.*

Elements

- **Airspeed and directional control**
- **Use of Memory Items on check list for inoperative engine**
- **Use of prescribed emergency checklists for inoperative engine procedures:**
    - **Enroute or take off as appropriate**
    - **Troubleshooting/securing as appropriate**
- **Remove Rudder trim** prior to traffic pattern for change in rudder authority required at landing
- **Enter downwind**, maintaining traffic pattern altitude (typically 1000' AGL)
- **Configure aircraft for approach:** Check list + GUMPS check:
- **Abeam touchdown point, Gear down, approach flaps if needed** (15 degrees)
- **Coordinated turn to base** when reference point is 45° behind the wing
- **Reduce power for descent (___mmHg, ____KIAS)**
- **Clear area, then turn to final**
- **On final: remaining flaps if needed** *(30º)* when runway is assured, **GUMPS** check
- **Select "aiming point"** (e.g. runway numbers, marker)
- **Adjust pitch and power to maintain Vyse (Blue line) approach speed and descent angle** *(____KIAS) till short final transition to POH recommended approach*
- **Elevator Trim** to relieve control pressures
- **Make sure feet are not on brakes**
- **10-20' off ground: reduce throttle on operative engine to idle**
- **Leave in-operative engine at ZERO thrust till after touch down**
- **Gradually apply back pressure to pitch for landing attitude**, attempting to fly just above runway (fly in ground effect) straight-and-level until passing aim point, then continue adjusting pitch for climb attitude just above horizon
- **Touchdown on main gear** just above stalling speed

- **Maintain pitch attitude for aerodynamic braking**
- **Gradually relax back pressure** to lower nose wheel
- **braking** as required

Instructor: Discuss power and flap configuration, airspeed in various parts of the approach
Describe and demonstrate landing technique with emphasis on check list and stabilized approach
.

Student: Describe and demonstrate landing technique with utilization of check list

Discussion: Pilots tend to fear emergencies and increase speed to increase their comfort level. Or considering a possible go around the pilot may try a no flap landing. Given there is half the drag from a feathered propellor, no flap landing and adding airspeed can lead to dramatic increase in runway required. Excess airspeed increases risk of ballooning, porpoising, flat landings with loss of directional control and runway over runs. Single engine go arounds or balked approaches are high risk maneuvers that most GA light twins are not capable of. On final approach in a light twin with an in operative engine, the pilot is committed to the landing. An over run off runway at low speed is preferable to a high speed Vmc roll over or stall spin accident. Recommendation is to approach no faster than 1.3 Vso or as recommended by POH.

Completion Standards: Student is able identify inoperative engine, establish appropriate bank and rudder inputs, demonstrate appropriate checklist usage with proper configuration of aircraft, dividing attention to traffic pattern, checking for traffic, apply power and control inputs smoothly with positive aircraft control with a stabilized approach. Lands in first one third of runway and maintains directional control landing aligned with and over the runway center/landing path.

Common Errors

failure to follow prescribed emergency checklist.
failure to properly identify and verify the inoperative engine.
failure to properly adjust engine controls and reduce drag.
failure to establish and maintain recommended airspeed (usually too fast).
On round out, reducing both throttles to idle (simulated feathered engine is to stay at zero thrust till after touch down)
failure to establish proper approach and landing configuration at appropriate time/sequence.
improper directional control after touchdown (excess speed and flat touch down attitude)
excessive float (no flaps, high approach speed)
improper use of brakes

References

FAA-H-8083-3B Airplane Flying Handbook p. 8-1, POH

Vmc Demonstration

Attention/Motivation: One of the unique characteristics of multi-engine aircraft is potential loss of control when an engine becomes in-operative. An engine inoperative produces both lateral (yaw) and rolling moments toward the inoperative engine, which if not addressed rapidly could deteriorate into loss of control of the aircraft to an inverted spin. The danger is significantly higher at lower airspeeds near the aircraft's Vmc such as engine failure right after take off or while flyig the airport traffic pattern to land with one engine in-operative. Multi-engine aircraft are notorious for their inability to recover from spins. The Vmc demonstration is used to demonstrate the loss of lateral control of the aircraft at reduced airspeed. Additionally, this maneuver is to emphasize the converse, that increased airspeed produces a margin of safety with single engine operation of the multi-engine aircraft.
Objective: To determine that the applicant exhibits knowledge related to the elements of Vmc and common problems associated.
NOTE: Performing this maneuver by increasing pitch attitude to a higher angle with both engines operating and then reducing power on the critical engine should be avoided. This technique is hazardous and may result in loss of aircraft control.
Recommended procedure for DEMO at or above 5000 ft AGL and instructor blocks rudder pedal to simulate loss of directional control (stall and VMC converge at altitude) approximately Vs + 20 kias. Alternately, Vmc Demo with wings level. Loss of lateral control occurs before stall.
Schedule: 1:00 hour Equipment: Aircraft
Elements:

VMC definition
Causes of loss of control (review of aerodynamics lesson)
Factors affecting Vmc (review of aerodynamics lesson)
Setting up the aircraft and performance of Vmc Demo
Recovery Technique from Vmc Demo

Instructor Actions/Notes:

1. **VMC:** Lowest airspeed able to maintain directional control with critical engine suddenly inoperative, thereafter maintain straight flight (<20 degree heading change), bank angle $\leq$ 5 degrees with the most unfavorable weight and CG. At VMC rudder pedal force < 150 lbs. Determined at **Sea Level** for certification and marked as **REDLINE** on airspeed indicator**.**
   - **a.** Max power
   - **b.** Trim for take off
   - **c.** Flaps in take-off position
   - **d.** Landing gear retracted
   - **e.** Props in take-off position

2. **Causes of loss of directional control at airspeeds less than Vmc**
   - **I.** Below minimum control speed, the rudder is no longer able to provide directional control due to the decreased amount of airflow over the control surfaces
3. **Factors affecting Vmc (not always redline) and safe recovery procedures**
   - **I.** Determinants of VMC
     - **a.** Power –High power, High VMC, low power, low VMC
     - **b.** Props- fine pitch, wind milling more drag, increase VMC
     - **c.** Altitude- high density altitude, lower power, lower VMC
     - **d.** Weight- increase weight offsets side slip toward in op engine, decrease VMC
     - **e.** Center of gravity- Aft CG decreases rudder authority, increase VMC
     - **f.** Bank angle-

i. Vmc increases > 3 kts for each degree of bank below 5 degrees into operative engine. When wings level, Vmc typically is close to Blue line.
ii. Vmc decreases with bank into operative engine more than 5 degrees but decreases climb from increased increase side slip and drag.

g. Flaps- improves directional control with greater loss of climb ability
h. Gear- improves directional control with greater loss of climb ability

II. VMC decreases with higher density altitude, danger is stall may occur before loss of directional control: Inverted spin crash burn. (Block rudder at minimum safe altitude, 5000 ft AGL)
III. Recovery: Reduce power on operative engine, decrease angle of attack, resume power on operative engine ONLY and maintain altitude when at or above blue line airspeed.
IV. Note: best rate of climb occurs at Zero side slip (least drag) usually at much lower than 5 degrees of bank. (typically 2-3 Degrees)

4. **Establishment of airplane configuration, adjustment of power controls, and trim prior to the demonstration**
   - ❑ Minimum maintain 3000 ft agl, recommended 5000 ft AGL or per POH.
   - ❑ Clearing turn
   - ❑ Landing gear – up
   - ❑ Flaps – up
   - ❑ Airspeed – Vyse (Vsse) +10
   - ❑ Trimmed for take off
   - ❑ Propeller controls – high RPM
   - ❑ Throttle (Left engine) – idle
   - ❑ Throttle (right engine) – max allowable
   - ❑ Bank angle ≤ 5 degrees, rudder as required
   - ❑ Airspeed – Slowly pitch up to reduce airspeed 1 knot per second
   - ❑ Initiate Recovery upon reaching the first sign of ***ANY*** of the following:
     - loss of directional control from entry heading
     - stall horn (keep in mind that Vmc decreases with altitude)
     - Buffet of impending stall
   - ❑ Recovery with minimum loss of altitude, maintain entry heading:
     - reducing power to idle on the operating engine
     - lower the nose to regain Vsse/Vsye. (Blue Line)
     - Increase power on operating engine ONLY and hold blue line.
     - Re trim as necessary

VMC demonstration should not be attempted from high pitch attitude with both engines operating and then reducing power on one engine. Level flight at or above Vsye/Vsse should be established prior to reducing power on one engine.

Student:
State definition of Vmc
Discuss Cause of loss of control and factors affecting Vmc
Properly sets up aircraft and performs Vmc Demo with appropriate recovery technique.

Common errors relate to Vmc

Inadequate knowledge of the causes of loss of directional control at airspeeds less than Vmc, factors affecting Vmc, and safe recovery procedures
Improper entry procedures, including pitch attitude, bank attitude, and airspeed
Failure to recognize imminent loss of directional control
Failure to use proper recovery procedures

Completion standards: Determine that the student demonstrates and explains engine inoperative loss of directional control and analyzes and corrects the common errors related to engine inoperative loss of directional control.
Commercial pilot: Recovery within 20 degrees of heading, advance power smoothly on operating engine and accelerated to Vxse/Vyse +- 5 knots.

References: FAR/AIM 14 CFR 23.149, FAA-H-8083-3B Airplane Flying Handbook, Chapt 12-27

Drag Demonstration Multiengine Aircraft

Motivation/Attention: Multiengine aircraft performance with one engine inoperative is highly dependent on density altitude and aircraft configuration. Flaps, Gear and Wind milling prop reduce aircraft performance to various degrees depending on make and model. Understanding how these various configurations affect the performance or ability of the aircraft to maintain altitude during single engine operations is paramount to critical decision making in the event of an engine failure, especially close to the ground or at high density altitude. Determining density altitude, reference to aircraft performance charts, and taking note of surrounding terrain or landing areas will help the pilot anticipate the best course of action in the event of an engine failure.

Objective: to demonstrate comparative drag effect of various combinations of aircraft configurations during engine inoperative procedures.

NOTE: *Performing this maneuver by increasing pitch attitude to a higher angle with both engines operating and then reducing power on the critical engine should be avoided. This technique is hazardous and may result in loss of aircraft control.* ***Recommended procedure for DEMO at or above 5000 ft AGL***

Elements:

- **Clear the area**
- **Altitude**: 5000 ft AGL
- **Configure aircraft**: flaps up, gear up, cowl flaps open, power for Va
- **During simulated engine inoperative**, maintain Zero Side Slip and directional control
- **Props, Throttles, Mixtures full forward**
- **Left engine to idle and bleed airspeed with slow pitch up to Vyse**
- **Gear down at Vlo-**
- **Flaps down at Vfe-**
- **Maintain Vyse- check VSI**
- **Gear up – check VSI, record change**
- **Flaps up – Check VSI**
- **2 degrees bank vs 7 degrees bank toward operative engine- check VSI**
- **Left Engine to Zero Thrust – check VSI**
- **Recover by slowly adding power and return to cruise flight**
- **Use Cruise check list**

Drag factors:

- **Full flaps**: -300 to 400fpm vertical speed
- **Windmilling prop**: -400 to –500 fpm vertical speed
- **Gear extended**: -300 400 fpm vertical speed

- **Non- Zero side slip** (vary bank angle and rudder input)**-**200-500 fpm

Instructor: *Discusses relative drag of various aircraft configurations and implications for engine failure close to ground. Performs drag demo*

Student: *Able to identify relative drag (rate of descent) for wind milling prop, flaps, gear. Discusses implications for engine failure near ground. Performs Drag Demo.*

Common Errors:

improper entry procedures, including pitch attitude, bank attitude, and airspeed.
improper airspeed control throughout the demonstration.
rough and/or uncoordinated use of flight controls.
improper procedures during resumption of cruise flight.

References: *FAA-H-8083-3, FAA-S-8081-12, FAA-S-8081-14;POH/AFM.*

Drag Table – start at Vyse, Left engine idle, right engine full, gear, flaps deployed, zero side slip

Drag configuration	VSI reading or change
LEFT Idle + gear + flaps+ zero side slip	
Gear up	
Flaps up	
7-10 degrees bank (non-zero side slip)	
Left engine Zero Thrust	

Emergency Descent

Description
A maximum performance maneuver that requires you to combine spiraling descent with division of attention to emergency procedures. This is a Power off, maximum drag descent. Please note, follow recommended procedure in the POH.

Objective
To develop pilot techniques for airspeed control, planning, orientation, and division of attention, with practical application for emergency landings.

Elements
- **Clear the area**
- **Choose forced landing area** (ideally adjacent to encircling point)
- **Configure aircraft**: straight-and-level at or just below flap speed, altitude sufficient to allow three complete turns and still be ≥1000' AGL, *(5000' AGL minimum)*
- Descent checklist, GUMPS (propeller to full), flaps full
- **Select outside references** (point to encircle, ideally adjacent to a forced landing area)
- **Throttle to idle,** propeller to high RPM
- **Gear (and Flaps per POH) down at appropriate speed**
- **Maximum speed without exceeding the lower of flap (Vfe), gear(Vle)**.
    - **Establish a bank of 30 to 45º**
- **Maintaining maximum safe airspeed by adjusting pitch and bank** as necessary
- **Trim** as necessary
- **Clear the engine when into the wind** (advance throttle to normal cruise momentarily)
- **Recovery after descent is established/stabilized when practicing:** do not descend below 1000' AGL unless the maneuver is to be followed by an emergency landing
- **Maintain coordination**
- **Look for traffic**

Completion Standards
Rapid controlled descent, maintaining maximum airspeed and descent rate without exceeding 45 degrees of bank or maximum safe speed (flap or gear extension) speed.

Common Errors
- Failure to clear area
- Failure to identify the reason for an emergency descent
- Failure to complete emergency check list
- Failure to maintain appropriate airspeed
- Improper procedures for recovering from an emergency descent.
- Failure to scan for other traffic during descent
- Failure to clear engine into wind

References
FAA-H-8083-3B Airplane Flying Handbook p. 16-6, POH