WHAT MAKES

A

CRITICAL ENGINE CRITICAL?

(CLASSICAL VERSION)

Part 1 of 14 CFR (the FAR's) defines the term "critical engine" in these terms: "*Critical* engine means the engine whose failure would most adversely affect the performance and handling qualities of an aircraft." Naturally, the aircraft mentioned in this definition is understood to be a *multiengine* airplane. Although no further explanation is provided in Part 1, applicants for Airplane Multiengine ratings are required to provide details of critical engine dynamics in the oral portion of the practical test, as indicated in the following excerpt from the Private Pilot and Commercial Pilot Practical Test Standard:

I. AREA OF OPERATION: PREFLIGHT PREPARATION

H. TASK: PRINCIPLES OF FLIGHT—ENGINE INOPERATIVE
(AMEL and AMES)
REFERENCES: FAA-H-8083-3, AC 61-23/FAA-H-8083-25; POH/AFM.
Objective. To determine that the applicant exhibits knowledge of the elements related to engine inoperative principles of flight by explaining the:

1. meaning of the term "critical engine."
2. effects of density altitude on the V_{MC} demonstration.
3. effects of airplane weight and center of gravity on control.
4. effects of angle of bank on V_{MC}.
5. relationship of V_{MC} to stall speed.
6. reasons for loss of directional control.
7. indications of loss of directional control.
8. importance of maintaining the proper pitch and bank attitude, and the proper coordination of controls.
9. loss of directional control recovery procedure.
10. engine failure during takeoff including planning, decisions, and single-engine operations.

Effective discussion of elements 1 and 6 (author's bold print) above requires a complete working knowledge of the dynamics involved.

Commercially-available texts offer coverage of this subject that is disorganized, incomplete, or (in some cases) erroneous. The goal of this article is to provide multiengine students with a properly-organized, accurate, and easily-understood discussion of critical engine dynamics that will enable them to quickly and correctly deal with this subject on the practical test.

Offered here is the *conventional* explanation of critical engine dynamics. While it contains some disturbing inconsistencies, discussion in these terms will satisfy the elements in the practical test standard.

Additionally, the explanation presented here is valid to a "conventional" multiengine airplane, where both propellers rotate in a clockwise direction (as viewed from the rear).

The elements involved a discussion of critical engine mechanics are commonly committed to memory using the mnemonic acronym **PAST**: **P**-factor, **A**ccelerated slipstream, **S**piraling slipstream, and **T**orque.

P-FACTOR, more properly called asymmetrical disc loading, is a phenomenon that occurs when an airplane is flown a high angle of attack, as would be the case of a multiengine attempting to maintain altitude or climb when being flown single-engine. As every student pilot knows (or SHOULD know), the descending blade of the propeller is operating at a much higher angle of attack than the ascending blade. This shifts the **center of thrust** to the right of the propeller hub, as illustrated in **Figure 1**.

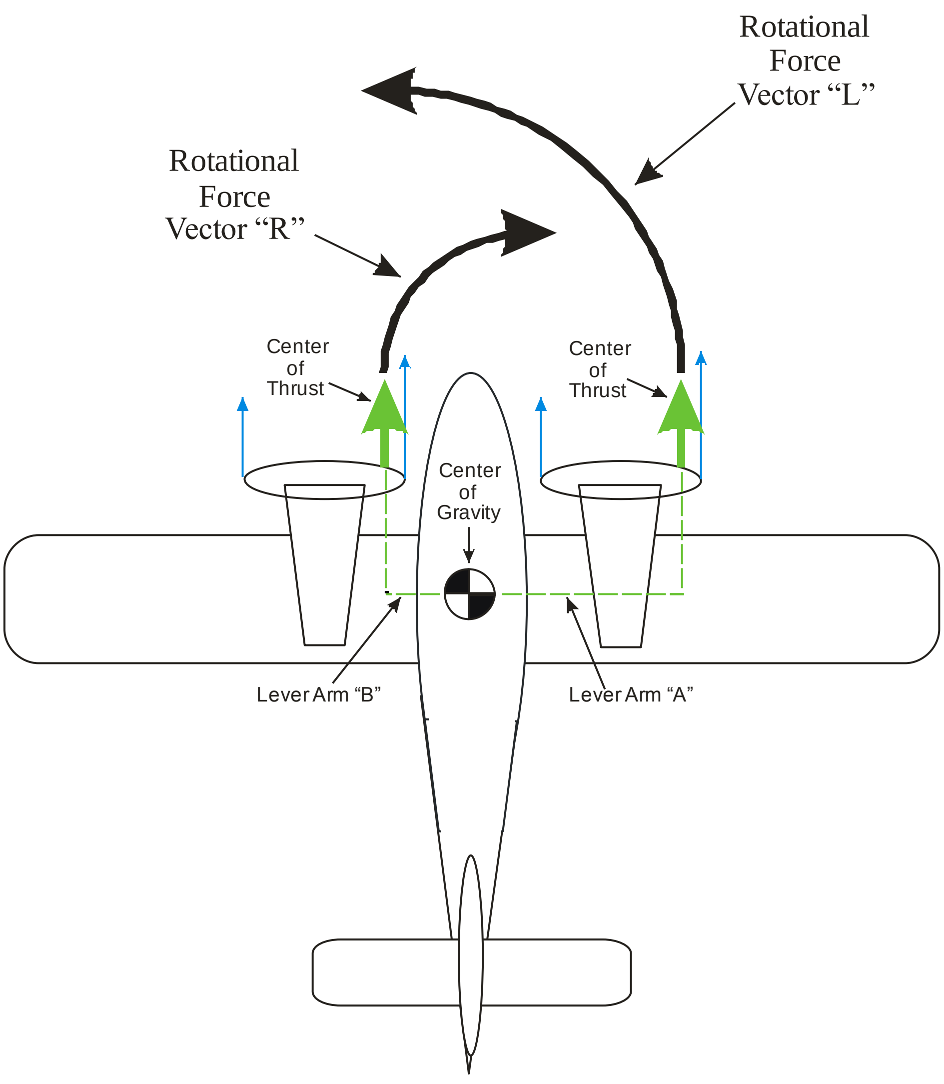

Figure 1

In this figure, the relative amounts of thrust generated by the propellers operating at a high angle of attack are represented by the blue vector arrows. When these force vectors are averaged, the result is the centers of thrust, depicted by the green vector arrows. The dashed green lines demonstrate the lever arms from the center of gravity to the centers of thrust. The same amount of thrust is generated by each engine, but, since Lever Arm “A” is longer that Lever Arm “B”, then the yawing force to the left provided by the right propeller (Rotational Force Vector “L”) is greater than the yawing force to the right (Rotational Force Vector “R”. The conclusion is: the pilot’s ability to generate enough rudder effectiveness to control yaw is diminished with the loss of the thrust from the left engine compared to the opposite condition.

Flight characteristics of the airplane that are associated with P-factor directly impact **YAW control** in single-engine operations.

ACCELERATED SLIPSTREAM is an adverse *rolling* phenomenon that is the result of P-factor. As shown in **Figure 2**, when the center of thrust shifts right as angle of attack is increased, the accelerated air behind the propeller shifts in a similar fashion.

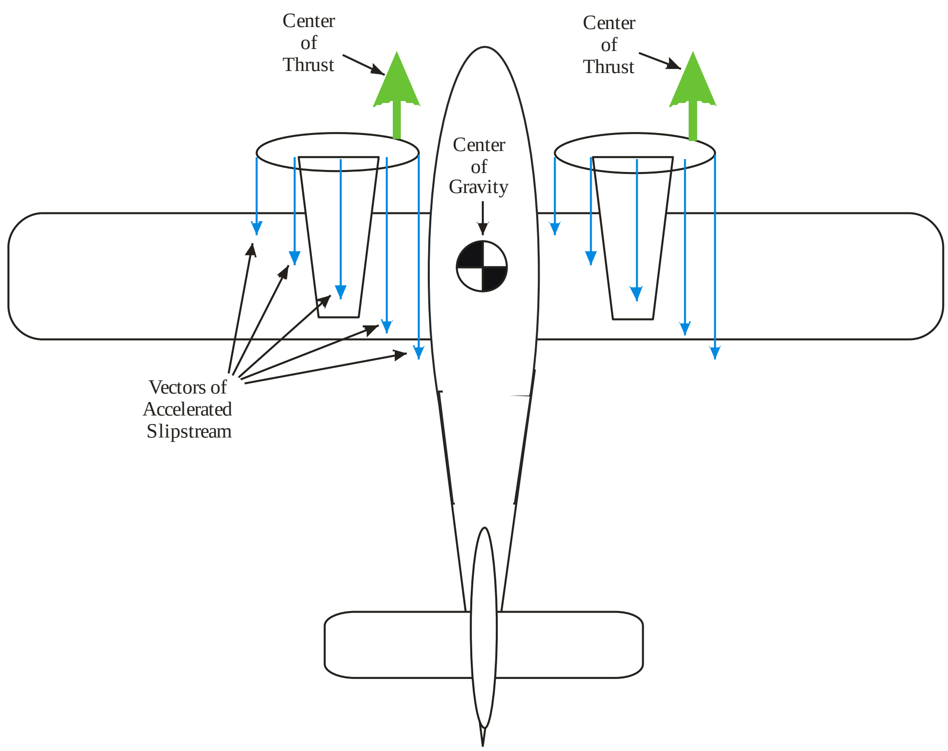

Figure 2

Since Bernoullian lift is airspeed-dependent, the center of lift shifts in the direction of the greater accelerated slipstream, as illustrated in **Figure 3**, as viewed from the rear of the airplane.

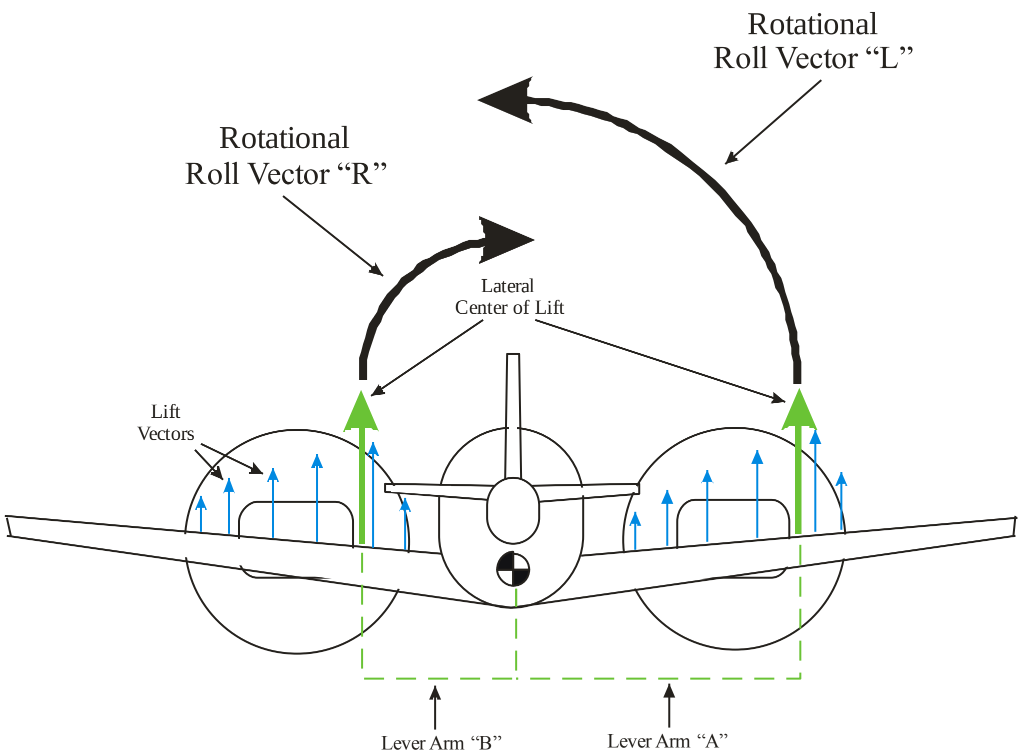

Figure 3

The lateral centers of lift produce rolling moments around the center of gravity. Since the right center of lift acts at a longer lever arm, "A", its rotational force vector, "L", is greater than rotational force vector "R" generated by the left engine/propeller. Therefore, the left engine meets the definition of *critical* because its loss would result in an airplane whose control around its roll axis would be limited to the greatest degree.

Flight characteristics of the airplane that are associated with accelerated slipstream directly impact **ROLL control** in single-engine operations.

The traditional view of the subject of **SPIRALLING SLIPSTREAM** maintains that, as a spinning propeller creates thrust, it imparts a spin to the airflow behind it. The coriolis effect causes this spiralling slipstream to be displaced laterally. In conventional multiengine airplanes with engines rotating clockwise (when viewed from the rear), that displacement is to the left, as illustrated in **Figure 4** below:

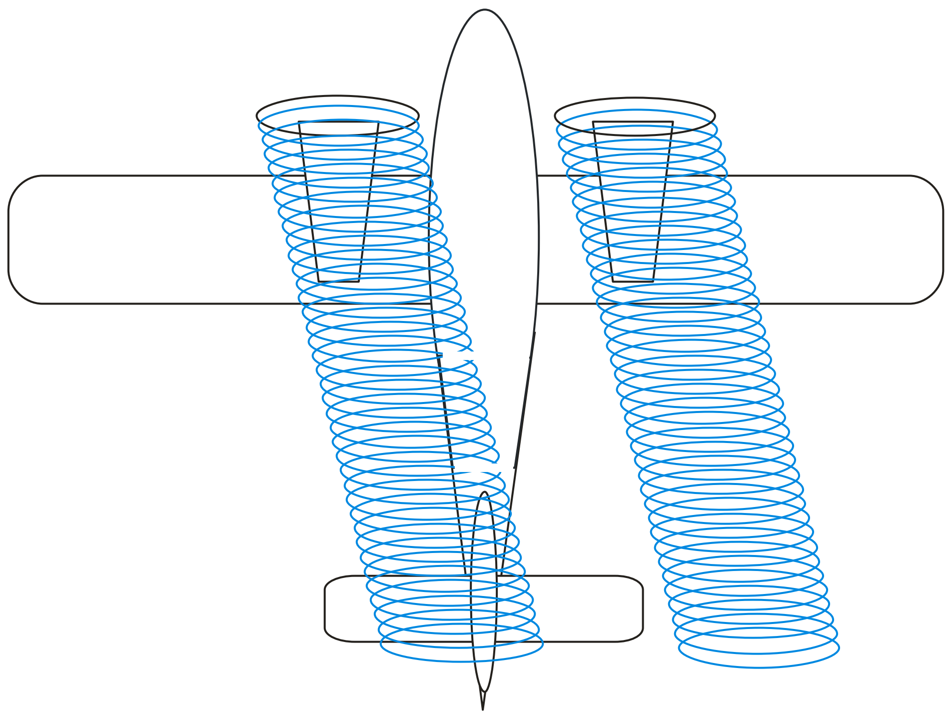

Figure 4

The slipstream from the left propeller is displaced inboard. The resulting increased airflow over the vertical fin enhances longitudinal stability. Increased airflow across the rudder provides greater control around the yaw axis. The slipstream from the right propeller angles away from the aircraft centerline, providing no advantage in terms of stability and rudder control. Therefore, loss of thrust from the left engine/propeller renders control more problematic, meeting the definition of *critical*.

Flight characteristics of the airplane that are associated with spiralling slipstream directly impact **YAW control** in single-engine operations.

TORQUE in an aircraft engine is a physical demonstration of Newton's third law of motion, which states (simply) that each action produces an equal and opposite reaction. In a conventional airplane having a propeller that rotates clockwise when viewed from behind, the torque generated by the engine will impart a left-rolling moment to the airframe. In a conventional twin-engine airplane, the torque from each engine is produced around axes defined by the engine crankshaft, and are equidistant from the aircraft centerline, as shown in **Figure 5**.

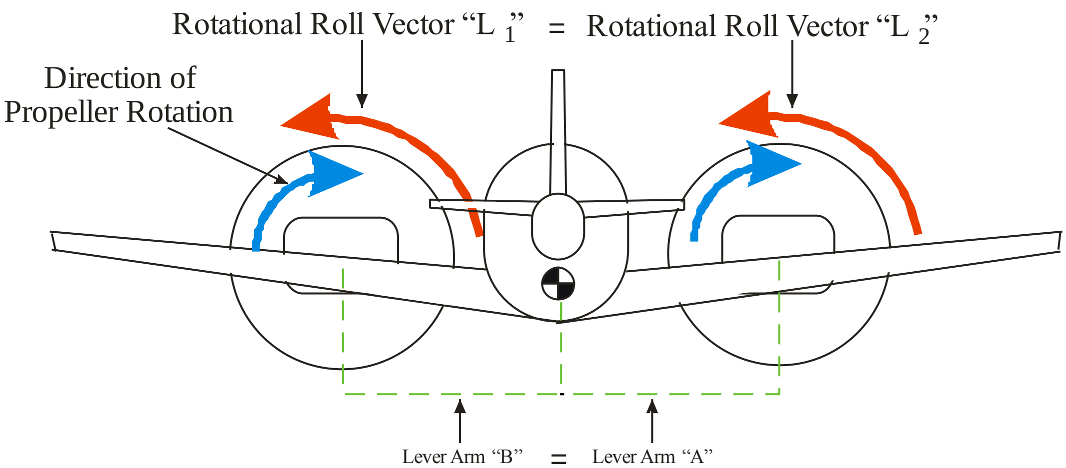

Figure 5

When torque alone is considered, neither engine meets the definition of *critical*, since each engine creates the same amount of torque in the same direction. But when torque is considered in combination with asymmetrical thrust resulting from power loss on one engine, the concept becomes clear. **Figure 6** illustrates these forces when the right engine is inoperative.

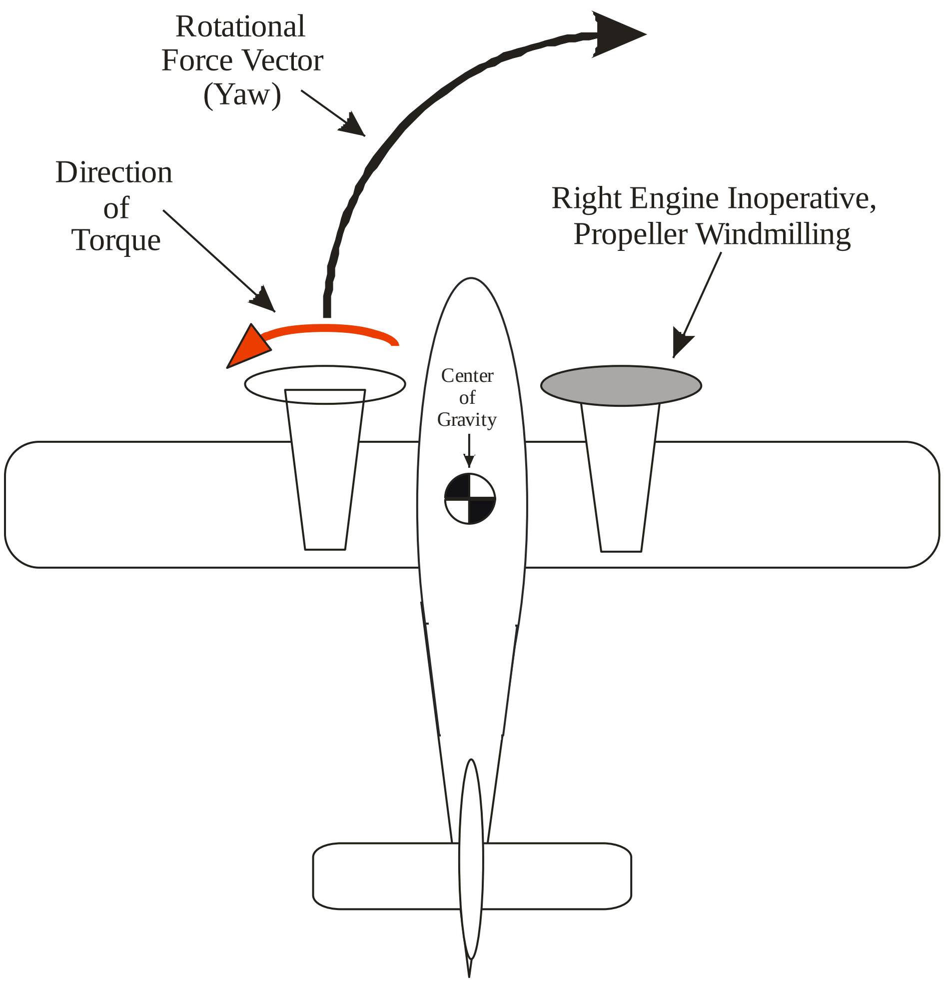

Figure 6

In this condition, the right engine is inoperative with the propeller windmilling, The asymmetrical thrust of the left engine yaws the aircraft to the right. The torque of the left engine generates a rolling moment to the left, partially offsetting the effect of the yaw. This condition preserves some degree of control authority, enhancing the pilot's ability to maintain directional control.

Figure 7 illustrates the opposite engine-out possibility, with the left engine inoperative and the left propeller windmilling:

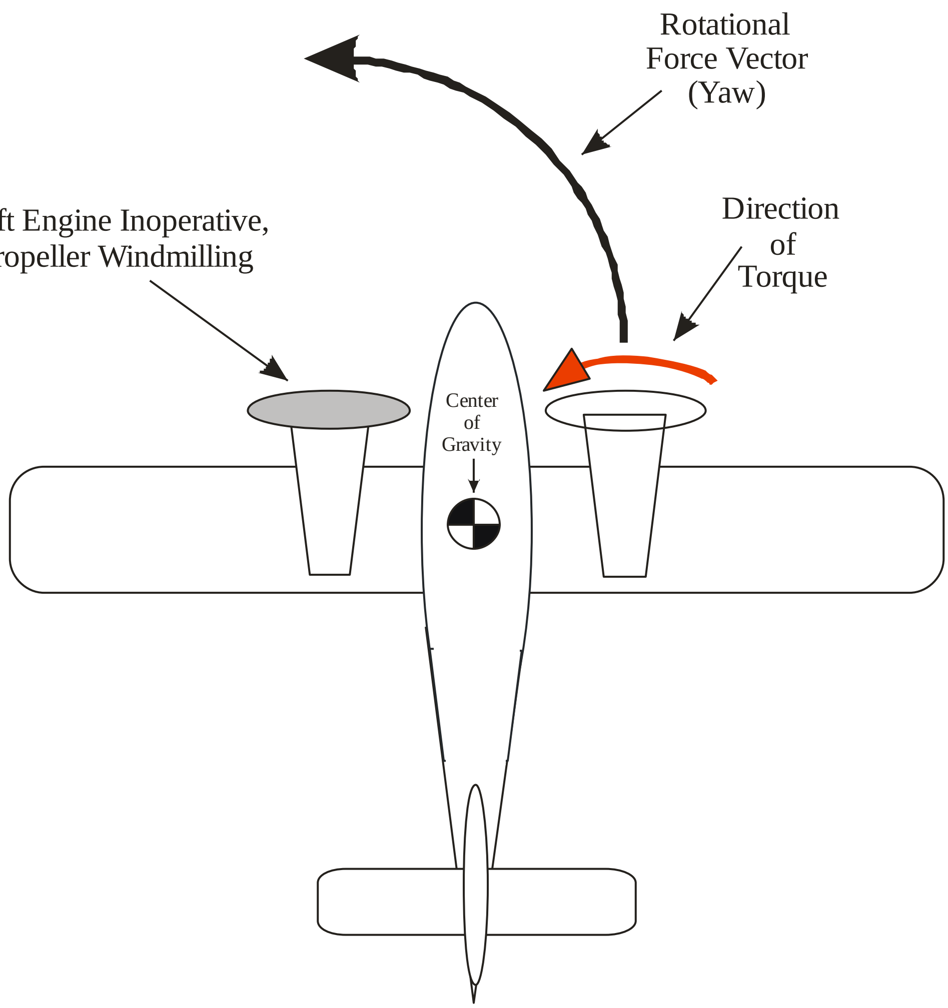

Figure 7

In this condition, the effects of yaw and roll are ***additive***, maximizing directional displacement toward the inoperative engine and presenting the pilot with a substantial challenge in the quest for directional control. The additive nature this combination of effects causes the left engine to meet the definition of *critical* with regard to roll.

Flight characteristics of the airplane that are associated with torque directly impact **ROLL control** in single-engine operations.

The preceding information is valid only conventional multiengine airplanes. Twin engine airplanes with counter-rotating propellers, such as the Beechcraft Duchess, the Piper Seminole, and some of the Piper Seneca series, are considered to have no critical engine. Airplanes such as the Piper PA-31P Navajo have propellers that rotate counterclockwise, and all the physical processes mentioned here reversed, making the *right* engine critical.

The **PAST** explanation of the nature critical engines has some troubling inconsistencies. Nonetheless, demonstration of this aeronautical knowledge will satisfy the requirements of Area of Operation I on the airman practical test.