The Pilot's Manual

Multi-Engine Flying

All the aeronautical knowledge required to earn a multi-engine rating on your pilot certificate

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The Pilot's Manual: Multi-Engine Flying
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Foreword

Congratulations! You are entering the world of multi-engine flying, which will open up new opportunities for you to utilize an airplane for personal or professional transportation. A multi-engine airplane allows you to cruise faster, carry more passengers or cargo, and in most cases, fly higher. Since most are larger and more capable, you and your passengers can fly in greater comfort as well.

With this greater capability comes a greater complexity of the aircraft systems, their operation, aircraft performance, and their effect on your decision-making. A multi-engine airplane with two or more engines adds to the performance and redundancy of the aircraft, so it imposes more duties upon you as the pilot when one of those engines fail.

For these reasons, it is essential that you have a thorough understanding of the aircraft's systems and performance in both normal and abnormal situations so that you make proper decisions to ensure safety of flight. Proper aeronautical decision making is driven in part by a full understanding of how each system operates, what factors are affected in aircraft controllability and performance when an engine fails, and proper performance planning.

Section I of this book provides a thorough investigation of the aircraft systems of multi-engine airplanes. The systems found in cabin-class, pressurized multi-engine aircraft covered here are those of the typical light-twin trainer. Yet this solid foundation also touches on some advanced systems, in order to give you a boost toward future preparations for the more complex multi-engine aircraft that you'll encounter later on.

Sections II and III cover the aerodynamics knowledge, aircraft controllability, and proper performance planning that will be necessary for operating and making proper decisions when flying multi-engine airplanes.

The Pilot's Manual: Multi-Engine Flying is written to give you the insight into all these aspects in order to lay a strong foundation in your preparation to become a multi-engine pilot. The chapters include scenarios and questions so you can apply your understanding.

If you want to better prepare yourself through in-depth learning about multi-engine flying, *The Pilot's Manual: Multi-Engine Flying* is definitely for you.

Kent Lovelace
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Introduction

Multi-engine aircraft fly faster and farther, and are capable of reaching higher altitudes and carrying more payload—all very desirable characteristics for pilots and owners alike. Along with these characteristics, however, comes an increase in systems complexity and a demand for decision making, problem solving, and flight planning skills. If you are a pilot accustomed to lower speeds, lower altitudes, and the more simplistic systems of single-engine aircraft, adding a multi-engine class rating to your pilot certificate can present a steep learning curve. This book is one tool available to you that will help with that learning curve—being introduced to the concepts and practice of flying multi-engine aircraft.

It doesn't take long to become comfortable with the flight characteristics of multi-engine aircraft, as they fly much the same as their single-engine counterparts. The biggest challenge in becoming a multi-engine pilot is in learning the complexity of the systems, and leveraging that knowledge to maximize aircraft performance and effectively handle abnormalities.

A multi-engine pilot must be prepared for an engine failure at any given point in the flight and have a list of possible alternatives. Preflight planning—performance calculations and airport planning—requires more attention to detail. The pilot of a single-engine aircraft does not have to decide what to do if the engine fails; gravity will limit the options available. The pilot of a multi-engine aircraft is faced with a much more complicated decision if an engine fails in flight—a decision that will vary widely depending on many factors such as aircraft performance, surrounding terrain, and weather conditions.

Section I of this book describes the systems of multi-engine aircraft, focusing on the items that present unique challenges. Multi-engine aircraft aerodynamics and related concerns are covered in Section II. Section III combines the concepts from the first two sections to provide you with a scenario-based example of the problems and challenges that multi-engine pilots must handle. This section provides you with skills to understand and mitigate the risks associated with multi-engine flying, and discusses the regulatory aspects. Multi-engine aircraft are expensive and their owners often want to gain a quick return on their investments. Multi-engine pilots must be aware of the unique regulatory concerns, and the limitations on what they can and cannot do.

It is essential for the multi-engine pilot to be prepared for the challenge of flying these aircraft. This book will provide the foundational knowledge necessary to become a safe and effective multi-engine pilot. By tying together a systems knowledge, checklist protocol, and aeronautical decision making, a multi-engine pilot can be confident of achieving mastery of the aircraft.

Enjoy your journey into the flight levels!

How This Book is Organized

The sections of this book are broken down into multiple parts to aid your comprehension of the material and help you reach mastery of each topic. Key components of each chapter include **objectives**, defining what you need to learn; **key terms** used in the chapter; **detailed descriptions** and discussion of the concepts to provide you with a thorough understanding; and **review questions** designed to deepen your understanding and apply the material.

In addition, the chapters on systems in Section I cover **operation and handling** considerations, providing an overview of how pilots interact with the systems during aircraft operations, as well as possible **emergencies** that pilots may face related to each system.

We recommend that you first read the objective to gain a sense of the desired outcome of each chapter. Next, read through and become familiar with the key terms, referencing the glossary in Appendix 1 for definitions as needed. If you need help identifying the most important concepts, examine the review questions at the end of the chapter before reading or rereading the chapter content. As do the other volumes in "The Pilot's Manual Series," the margins contain notes and sidebars about key terms and concepts to aid you in retention of the material.

Section I

Multi-Engine Systems

In years past, a pilot moving from a high-performance single-engine airplane to a multi-engine airplane would benefit from not only another engine, but also redundancy in aircraft systems. Today's multi-engine aircraft share many similarities with their single-engine counterparts: the systems on multi-engine aircraft function in the same manner but with the added complexity of the interaction and management of multiple, redundant systems operating simultaneously.

In multi-engine flying, you as the pilot need to understand how best to interact with the system and how to appropriately respond to a malfunction of that system. Therefore, a particular challenge lies in the decision-making process as it ties in with the intricacies of the systems—thus, the principles of aeronautical decision making (ADM) are worked into the discussion for each systems chapter in this section.

In each chapter, you will first review system basics and then cover the limited differences between multi-engine and single-engine airplanes, and how to operate within those differences accordingly. At the end of each systems chapter, the discussion will be on examining emergencies and the appropriate pilot response when systems fail or degrade in performance.

For the multi-engine pilot, effectively tying together knowledge of the aircraft's systems with checklist protocol and ADM leads to mastery of the aircraft.

Flight Controls

1

Chapter Focus for Multi-Engine Flight Control Systems

Flight controls on multi-engine aircraft are nearly identical to those used on single-engine aircraft with two exceptions: multi-engine aircraft tend to have larger control surfaces (sometimes requiring powered deflection), and universally require larger rudders and vertical stabilizer surfaces. The reasons for these differences are covered in this chapter.

You will also learn to identify and describe the primary and secondary flight controls found on multi-engine aircraft, and apply that knowledge to the operation and handling of the aircraft. Following that you will learn to apply the appropriate emergency action for the various abnormal and emergency events involving flight controls.

Aircraft flight control systems might seem like an elementary concept, but as aircraft weight and complexity increases so does the complexity of the flight control system. Each multi-engine type's basic flight control system will have its own unique characteristics, so pilots must always review the Pilot's Operating Handbook (POH) and receive competent flight instruction on that aircraft type prior to operating the aircraft.

Key Terms

(in the order they appear in this chapter)

primary flight controls
ailerons
single-engine operations
elevator
rudder
stabilator
spoiler
anti-servo tab
differential ailerons
Frise ailerons
deep stall
secondary flight controls
plain flap
split flap
Fowler flap
slotted flap

Primary Flight Controls

The *primary flight controls* are the ailerons, elevator, and rudder. These controls are used to maneuver the aircraft about the vertical, longitudinal, and lateral axis (pitch, roll, and yaw). *See* Figure 1-1.

Ailerons

There are three main types of *aileron*: plain, differential, and Frise. Some aircraft use a combination of these. The purpose of ailerons is simply to roll the aircraft. Most aircraft—both single- and multi-engine—use ailerons for roll; one exception to this is the Mitsubishi MU-2, which uses flight spoilers on the wings to reduce lift asymmetrically, causing the aircraft to roll. More commonly, multi-engine aircraft use flight spoilers and ailerons working together to create more responsive roll authority through all phases of flight. These unique systems utilize an interconnect system to tie-in flight spoiler movement with aileron movement.

On most light multi-engine aircraft, the basic flight control surfaces are mechanically driven using a series of cables, rods, and pulleys connected directly to the flight controls in the cockpit. Some multi-engine aircraft incorporate a system called rudder boost, which helps the pilot apply rudder force during one-engine-inoperative (or, single-engine) operations. Of course, flight control systems can vary greatly from aircraft to aircraft and the specifics for each aircraft you fly will be found in the POH and Aircraft Maintenance Manual (AMM).

single-engine operations: operating a multi-engine aircraft with one engine inoperative

Plain ailerons travel the same distance whether deflecting upwards or downwards. They are not designed to compensate for adverse yaw or reduce the likelihood of a wingtip stall at high angles of attack (AOA). Wingtip stalls occur

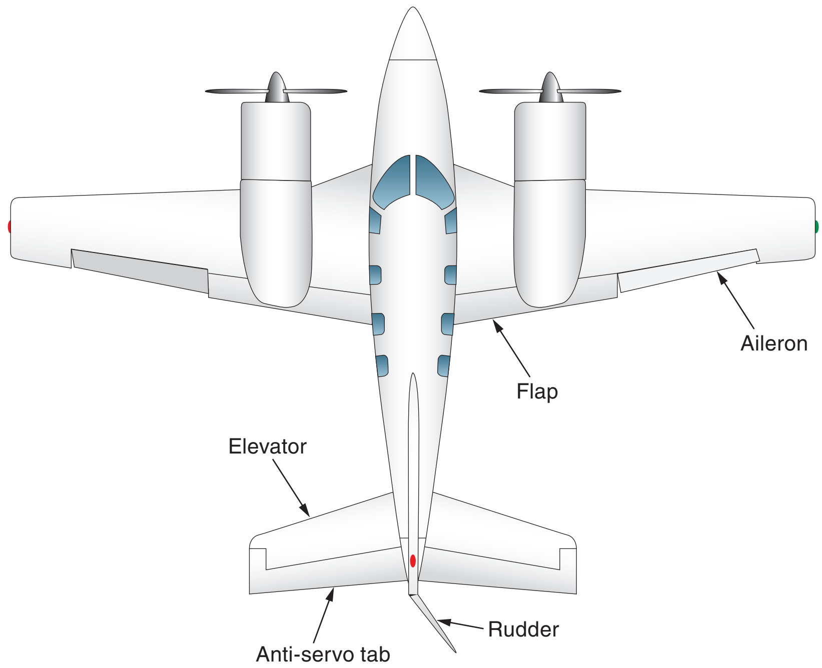


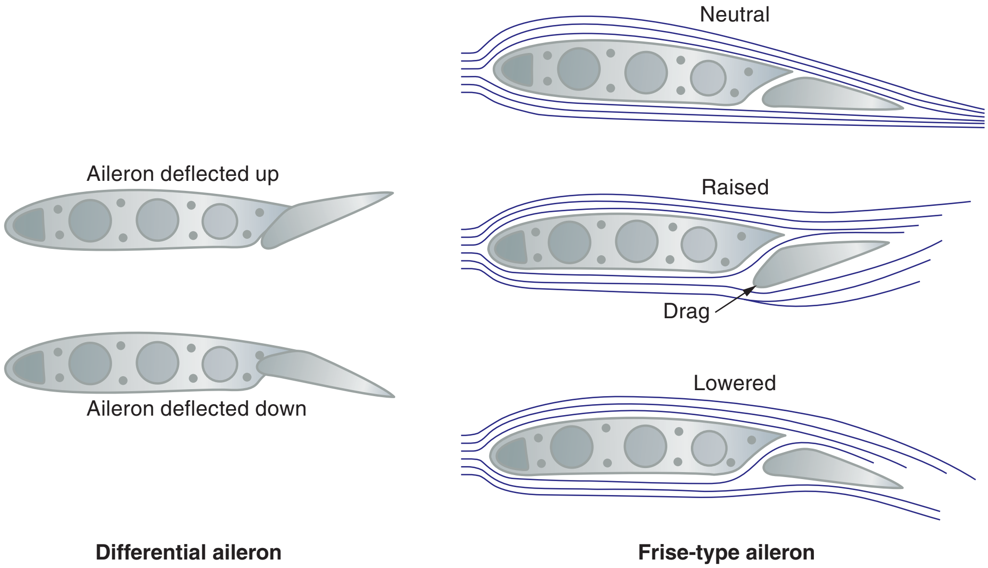
Figure 1-1. Typical flight controls on a multi-engine aircraft.

because the down aileron increases the AOA on the outboard section of the wing, which can cause the tips to stall before the root. This is an undesirable characteristic that is overcome by incorporating a different aileron in aircraft design.

Differential ailerons are designed to reduce the chances of wingtip stalls as well as adverse yaw. This is done by restricting travel of the downward-moving aileron in comparison to the upward moving aileron. The name "differential" refers to the difference in travel distance of upward and downward moving ailerons. This technique is achieved through the rigging of the cable and pulley system used to move the ailerons.

Frise-type ailerons are designed to counteract adverse yaw. With a plain aileron, the downward moving aileron produces more lift as a result of the higher angle of attack. Due to the increase in lift there is an increase in induced drag. In a roll to the left, the right aileron produces more lift than the left; this also produces more drag, yawing the aircraft to the right away from the desired direction of travel. Frise ailerons deflect the upward moving aileron into the slipstream below the wing surface, causing more parasite drag on the descending wing. This will compensate for the induced drag caused by the down-going aileron (Figure 1-2).

Frise-type and differential ailerons do not completely eliminate adverse yaw, they only reduce it. In order to counteract adverse yaw, the pilot must apply rudder in the direction of the turn to maintain coordination. Some multi-engine aircraft utilize a combination of Frise and differential ailerons to maximize the benefits and minimize adverse yaw and wingtip stalling characteristics.



Down aileron deflects less than up aileron, reducing adverse yaw. On Frise-type ailerons, the upward moving aileron protrudes into the airflow below the wing, increasing drag and reducing adverse yaw.

Figure 1-2. Typical Frise-type and differential ailerons.

Elevator and Rudder

The *rudder* and *elevator* are part of the empennage and are included to provide lateral and longitudinal control and stability. The rudder is hinged off of the vertical tail surface. Some light multi-engine aircraft—including the Piper Seminole (a common multi-engine training aircraft)—have a stabilator instead of an elevator (Figure 1-3).

stabilator: a single-piece, horizontal tail surface on an airplane that serves as both a horizontal stabilizer and an elevator.

The rudder on multi-engine aircraft tends to be much larger (heavier and harder to move) than on single-engine aircraft. This is because of the directional control requirements of operating a multi-engine aircraft with one engine failed.

There are four methods of increasing the force that the rudder creates: increase the surface area, increase the deflection, increase the airflow around the rudder, and increase the distance from the rudder to the center of gravity, which affects maximum available rudder force. This will impact the rudder effectiveness when operating a multi-engine airplane with one engine inoperative.

Light twins also incorporate rudder trim. The trim tab is located on the back of the rudder and may also serve as an anti-servo tab. Using the rudder trim wheel in the cockpit, the pilot can relieve rudder pressure. During single-engine operations, the pilot will have to remove any rudder trim applied in cruise before landing. This is to prevent directional control problems when power on the operative engine is reduced to idle.

The rudder's *anti-servo tab* moves with the rudder but travels farther in the same direction, adding control force resistance when the pilot pushes the rudder pedals. This feature is designed to prevent the pilot from overstressing the rudder by making it more difficult to make full and abrupt rudder applications. Alternatively, the pilot can move the anti-servo tab manually using the rudder trim wheel in the cockpit in order to relieve control pressures. In essence, the same surface is used for two completely different purposes, which can cause confusion about the system's function and operation, yet reduces the complexity of the aircraft system. Ultimately, aircraft manufacturers attempt to achieve the most efficient and effective design possible.

The anti-servo tab moves farther in the same direction as control deflection. The pilot can also manually move the anti-servo tab in the opposite direction, relieving control pressure.

A traditional elevator's trim tab is hinged from the trailing edge of the horizontal stabilizer, and moves independently; a traditional trim tab only relieves control pressure.

Figure 1-3. Stabilator (left) with anti-servo tab compared with a traditional elevator (right).

Stabilator

The Piper Seminole uses a *stabilator* in place of a horizontal stabilizer and elevator system. A stabilator is simply a fully moveable horizontal flight surface in contrast to the fixed horizontal stabilizer and moveable elevator used on other aircraft. The stabilator design provides more maneuverability for aircraft that are longitudinally stable.

Like the rudder, the stabilator includes an anti-servo and trim tab. The anti-servo tab is designed to prevent the pilot from overstressing the aircraft by increasing control pressure progressively as control surface deflection is increased. The anti-servo tab moves in the same direction as the stabilator, but slightly farther. For example, if the stabilator is at +10°, the anti-servo tab would be at +12°. The anti-servo tab on the stabilator can also be moved manually by the pilot (using the trim wheel or electric trim) to relieve control pressures much the same as an elevator trim tab (Figure 1-4).

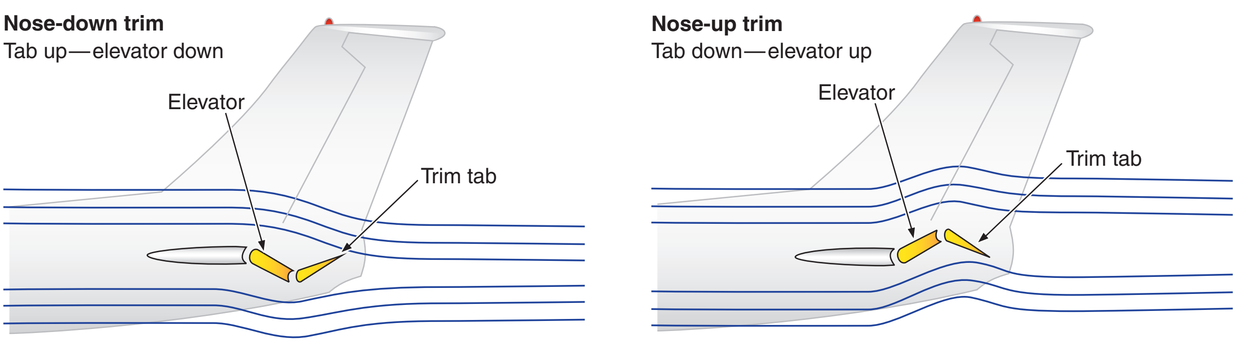


Figure 1-4. Trim operation for an anti-servo tab and a traditional elevator work the same—the pilot moves the tab in the opposite direction of deflection, to relieve control pressure.

Tail Design

Some multi-engine aircraft incorporate a T-tail design, while others use a conventional tail design. Each design has its own benefits and drawbacks.

One benefit of a T-tail design is that in cruise flight the stabilator is located in undisturbed airflow above the effects of the wing downwash. A T-tail aircraft will be less pitch-sensitive during power changes and while adding flaps.

The drawbacks of a T-tail are found at low airspeeds and in a *deep stall* condition. At low airspeeds, the T-tail requires larger control deflection to create a pitch change. The deep stall condition is usually caused by an aft center of gravity (CG) position and a high AOA, and can result in an unrecoverable stall. At a high AOA, the wings and fuselage blanket the horizontal tail surface, reducing the amount of laminar airflow over the elevator or stabilator. This reduces its effectiveness and in extreme cases can make stall recovery impossible (Figure 1-5).

In an attempt to prevent an aircraft from reaching the deep stall condition, aircraft manufacturers have included an elevator/stabilator down spring to the mechanical linkage that controls the elevator/stabilator. When airflow over the tail surface is reduced to the point at which the control surface cannot maintain balance, the down spring drives the stabilator to a nose-down position.

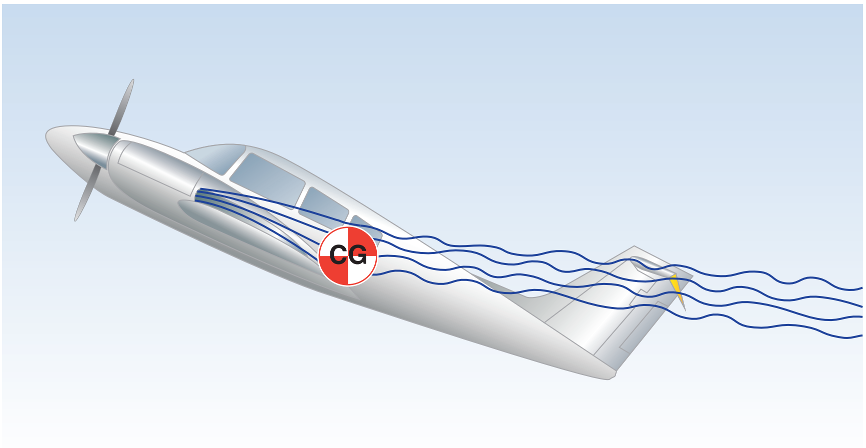


Figure 1-5. T-Tail aircraft with aft CG at a high AOA can lead to a deep stall and make elevators/stabilators less effective control surfaces.

Secondary Flight Controls

Secondary control surfaces allow the pilot to refine control of the aircraft, reduce pilot workload, and maximize aerodynamic effectiveness in slow and high-speed flight. *Secondary flight controls* include flaps, trim, and flight spoilers.

Flaps

The *plain flap* is the simplest of the four types. It increases the airfoil camber, resulting in a significant increase in the coefficient of lift (C_L) at a given angle of attack. The plain flap is a simple hinged portion of the trailing edge. Out of the four types

Coefficient of Lift (C_L) is a numeric measurement of the amount of lift produced by an airfoil at a specific AOA.

of flaps, the plain flap produces the least amount of C_L for a given AOA. Plain flaps are rarely used in multi-engine aircraft.

The most popular flap on aircraft today is the *slotted flap*. Variations of this design are used for both small and large aircraft. Slotted flaps increase the lift coefficient significantly more than plain or split flaps. On small aircraft, the hinge is located below the lower surface of the flap, and when the flap is lowered, a duct forms between the flap well in the wing and the leading edge of the flap. When the slotted flap is lowered, high energy air from the lower surface is ducted to the flap's upper surface. The high energy air from the slot accelerates the upper surface boundary layer and delays airflow separation, providing a higher coefficient of lift.

Multi-engine aircraft built by Cessna commonly use *split flap* systems. In a split flap system, a portion of the underside of the wing "splits" from the upper portion of the wing (Figure 1-6). This results in a change in the coefficient of lift at low angles of deflection and an increase in interference drag at high angles of deflection. When operating split flaps, the pilot will notice a few important differences in aircraft control. At low angles of deflection the split flap will create an increase in lift, but also a considerable increase in drag. At high deflection angles (higher flap settings) the split flap will create negligible lift but a high amount of drag. For this reason, a split flap system at full flap extension is very effective at slowing the aircraft down, or creating high rates of descent. The pilot must be sure to reduce flap settings promptly in the case of a go-around or during single-engine climbs in order to gain the best climb performance available.

Fowler flaps are a type of slotted flap. This flap design not only changes the camber of the wing, it also increases the wing area. Instead of rotating down on a hinge, it slides backwards on tracks. In the first portion of its extension, it increases the drag very little, but increases the lift a great deal as it increases both the area and camber. As the extension continues, the flap deflects downward. During the last portion of its travel, the flap increases the drag with little additional increase in lift.

Some light twins combine flap types; for example, the Seminole has plain slotted flaps. Flaps are usually controlled electrically or mechanically.

Figure 1-6. Cessna split flap system.