

Airplane Flying Handbook (FAA-H-8083-3C)

Chapter 3: Basic Flight Maneuvers

Introduction

Airplanes operate in an environment that is unlike an automobile. Drivers tend to drive with a fairly narrow field of view and focus primarily on forward motion. Beginning pilots tend to practice the same. Flight instructors face the challenge of teaching beginning pilots about attitude awareness; which requires understanding the motions of flight. An airplane rotates in bank, pitch, and yaw while also moving horizontally, vertically, and laterally. The four fundamentals (straight-and-level flight, turns, climbs, and descents) are the principal maneuvers that control the airplane through the six motions of flight.

The Four Fundamentals

To master any subject, one should first master the fundamentals. For flying, this includes straight-and-level flight, turns, climbs, and descents. All flying tasks are based on these maneuvers, and an attempt to move on to advanced maneuvers prior to mastering the four fundamentals hinders the learning process.

Consider the following: a takeoff is a combination of a ground roll, which may transition to a brief period of straight-and-level flight, and a climb. After-departure includes the climb and turns toward the first navigation fix and is followed by straight-and-level flight. The preparation for landing at the destination may include combinations of descents, turns, and straight-and-level flight. In a typical general aviation (GA) airplane, the final approach ends with a transition from descent to straight-and-level while slowing for the touchdown and ground roll.

The flight instructor needs to impart competent knowledge of these basic flight maneuvers so that the beginning pilot is able to combine them at a performance level that at least meets the Federal Aviation Administration (FAA) Airman Certification Standards (ACS) or Practical Test Standards (PTS). As the beginning pilot progresses to more complex flight maneuvers, any deficiencies in the mastery of the four fundamentals are likely to become barriers to effective and efficient learning.

Effect and Use of Flight Controls

The airplane flies in an environment that allows it to travel up and down as well as left and right. Note that movement *up or down* depends on the flight conditions. If the airplane is right-side up relative to the horizon, forward control stick or wheel (elevator control) movement will result in a loss of altitude. If the same airplane is upside-down relative to the horizon that same forward control movement will result in a gain of altitude. [Figure 3-1] The following discussion considers the pilot's frame of reference with respect to the flight controls. [Figure 3-2]

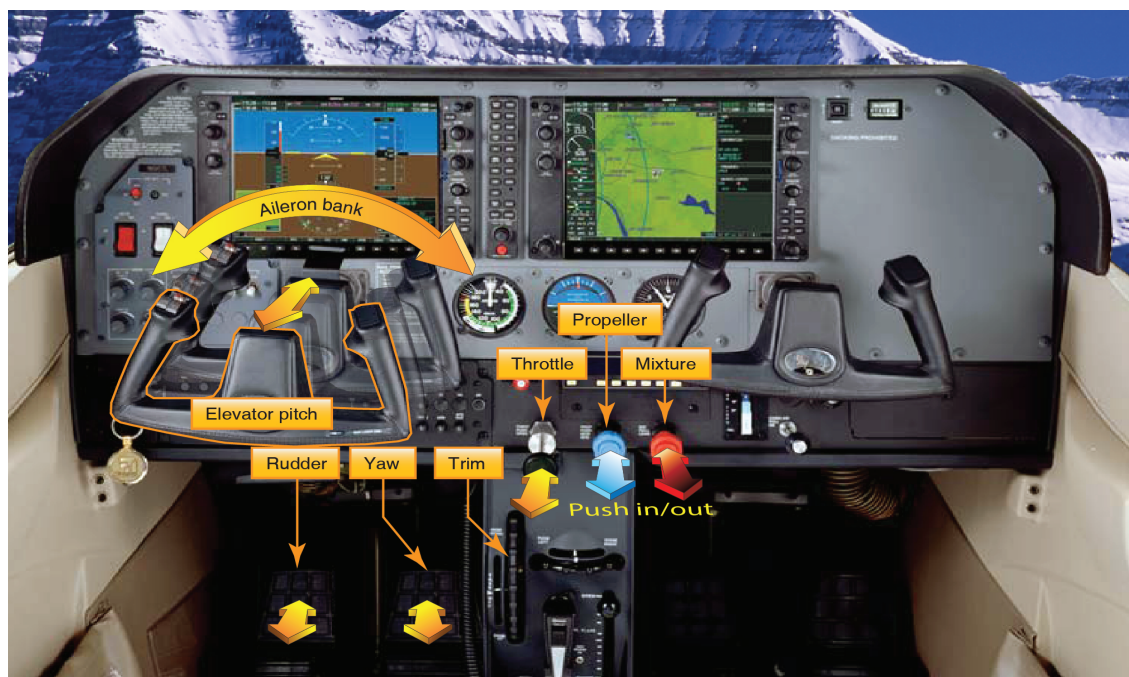


Figure 3-1. Basic flight controls and instrument panel.

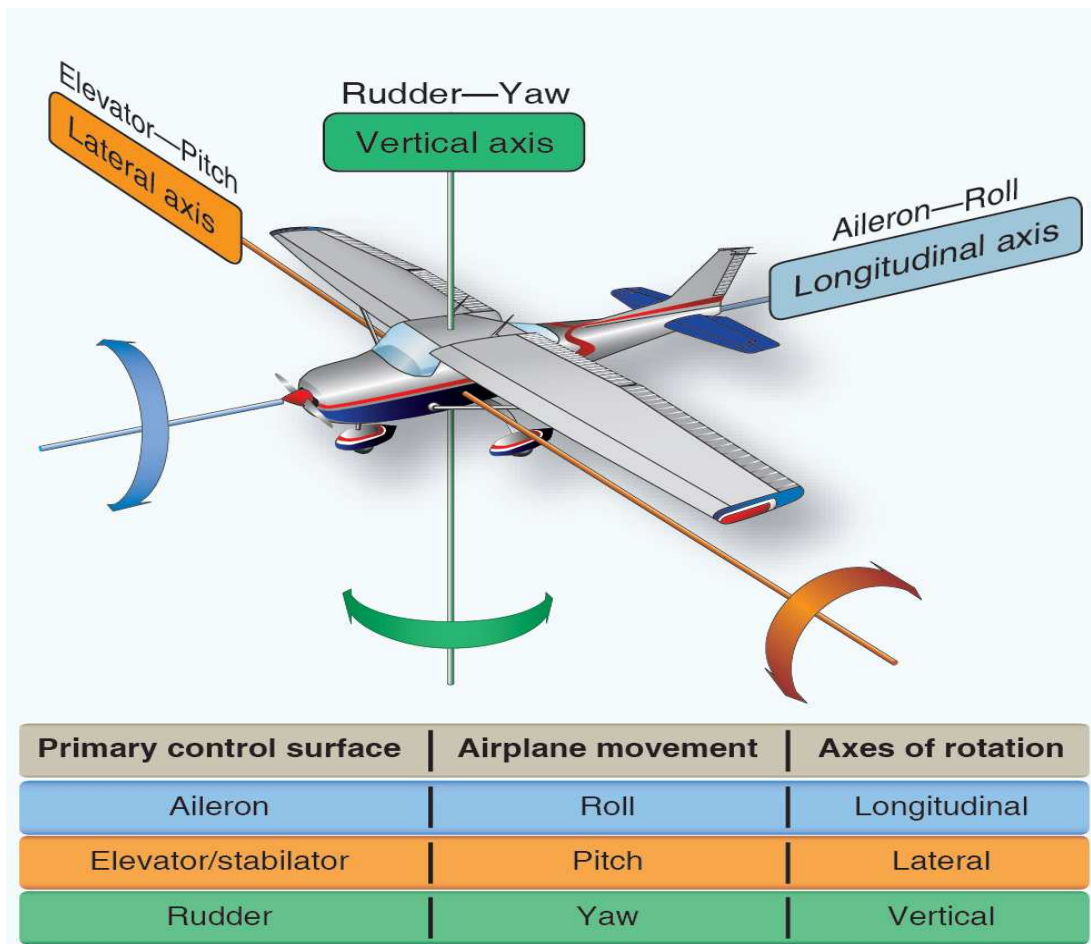


Figure 3-2. *The pilot is always considered the referenced center of effect as the flight controls are used.*

With the pilot's hand:

- When pulling the elevator pitch control toward the pilot, which is an aft movement of the control wheel, yoke, control stick, or side stick controller (referred to as adding back pressure), the airplane's nose will rotate backwards relative to the pilot around the pitch (lateral) axis of the airplane. Think of this movement from the pilot's feet to the pilot's head.
- When pushing elevator pitch control toward the instrument panel, (referred to as increasing forward pressure), the airplane rotates the nose forward relative to the pilot around the pitch axis of the airplane. Think of this movement from the pilot's head to the pilot's feet.
- When right pressure is applied to the aileron control, which rotates the control wheel or yoke clockwise, or deflects the control stick or side stick to the right, the airplane's right wing banks (rolls) lower in relation to the pilot. Think of this movement from the pilot's head to the pilot's right hip.
- When left pressure is applied to the aileron control, which rotates the control wheel or yoke counterclockwise, or deflects the control stick or side stick to the left, the airplane's left wing banks (rolls) lower in relation to the pilot. Think of this movement from the pilot's head to the pilot's left hip.

With the pilot's feet:

- When forward pressure is applied to the right rudder pedal, the airplane's nose moves (yaws) to the right in relation to the pilot. Think of this movement from the pilot's left shoulder to the pilot's right shoulder.
- When forward pressure is applied to the left rudder pedal, the airplane's nose moves (yaws) to the left in relation to the pilot. Think of this movement from the pilot's right shoulder to the pilot's left shoulder.

While in flight, the control surfaces remain in a fixed position as long as all forces acting upon them remain balanced. Resistance to movement increases as airspeed increases and decreases as airspeed decreases. Resistance also increases as the controls move away from a streamlined position. While maneuvering the airplane, it is not the amount of control surface displacement the pilot needs to consider, but rather the application of flight control pressures that give the desired result.

The pilot should hold the pitch and roll flight controls (aileron and elevator controls, yoke, stick, or side-stick control) lightly with the fingers and not grab or squeeze them with the entire hand. When flight control pressure is applied to change a control surface position, the pilot should exert pressure on the aileron and elevator controls with the fingers only. This is an important concept and habit to learn. A common error with beginning pilots is that they grab the aileron and elevator controls with a closed palm with such force that sensitive feeling is lost. Pilots may wish to consider this error at the onset of training as it prevents the development of “feel,” which is an important aspect of airplane control.

So that slight rudder pressure changes can be felt, both heels should support the weight of the pilot's feet on the floor with the ball of each foot touching the individual rudder pedals. The legs and feet should be relaxed. When using the rudder pedals, pressure should be applied smoothly and evenly by pressing with the ball of one foot. Since the rudder pedals are interconnected through springs or a direct mechanical linkage and act in opposite directions, when pressure is applied to one rudder pedal, foot pressure on the opposite rudder pedal should be relaxed proportionately.

In summary, during flight, the pressure the pilot exerts on the aileron and elevator controls and rudder pedals causes the airplane to move about the roll (longitudinal), pitch (lateral), and yaw (vertical) axes. When a control surface moves out of its streamlined position (even slightly), moving air exerts a force against that surface. It is this force that the pilot feels on the controls.

Feel of the Airplane

The ability to sense a flight condition, such as straight-and-level flight or a dive, without relying on instrumentation is often called “feeling the airplane.” Examples of this “feel” may be sounds of the airflow across the airframe, vibrations felt through the controls, engine and propeller sounds and vibrations at various flight attitudes, and the sensations felt by the pilot through physical accelerations.

Humans sense “feel” through kinesthesia (the ability to sense movement through the body) and proprioception (unconscious perception of movement and spatial orientation). These stimuli are detected by nerves and by the semicircular canals of the inner ear. When properly developed, kinesthesia can provide the pilot with critical information about changes in the airplane's direction and speed; however, there are limits in kinesthetic sense when relied upon solely without visual information, as when flying in instrument meteorological conditions (IMC). Sole reliance on the kinesthetic sense ultimately leads to disorientation and loss of aircraft control.

Developing this “feel” takes time and exposure in a particular airplane. It only comes with dedicated practice at the various flight conditions so that a pilot's senses are trained by the sounds, vibrations, and forces produced by the airplane. The following are some important examples:

- Rushing air creates a distinctive noise pattern and as the level of sound increases, it likely indicates that the airplane's airspeed is increasing and that the pitch attitude is decreasing. As the noise decreases, the airplane's pitch attitude is likely increasing and its airspeed decreasing.
- The sound of the engine in cruise flight is different from that in a climb and different again when in a dive. In fixed-pitch propeller airplanes, when the airplane's pitch attitude increases, the engine sound decreases and as pitch attitude decreases, the engine sound increases.
- In a banked turn, the pilot is forced downward into the seat due to the resultant load factor. The increased G force of a turn feels the same as the pull up from a dive, and the decreased G force from leveling out feels the same as lowering the nose out of a climb.

Sources of actual “feel” are very important to the pilot. This actual feel is the result of acceleration, which is simply how fast velocity is changing. Acceleration describes the rate of change in both the magnitude and the direction of velocity. These accelerations impart forces on the airplane and its occupants during flight. The pilot can sense vertical forces through pressure changes into the seat or horizontal forces while being pushed from side to side in the seat if the airplane slips or skids. These forces need not be strong, only perceptible by the pilot, to be useful. An accomplished pilot who has excellent “feel” for the airplane is able to detect even the smallest accelerations.

The flight instructor should teach the difference between perceiving and reacting to sound, vibrations, and forces versus merely noticing them. It is this increased understanding that contributes to developing a “feel” for the airplane. A pilot who develops a “feel” for the airplane early in flight training is likely to have less difficulty during more advanced training.

Attitude Flying

An airplane's attitude is determined by the angular difference between a specific axis and the natural horizon. A false horizon can occur when the natural horizon is obscured or not readily apparent. This is an important concept because it requires the pilot to develop a pictorial sense of this natural horizon. Pitch attitude is the angle formed between the airplane's longitudinal axis, which extends from the nose to the tail of the airplane, and the natural horizon. Bank attitude is the angle formed by the airplane's lateral axis, which extends from wingtip to wingtip, and the natural horizon. [Figures 3-3A and 3-3B] Angular difference about the airplane's vertical axis (yaw) is an attitude relative to the airplane's direction of flight but not relative to the natural horizon.

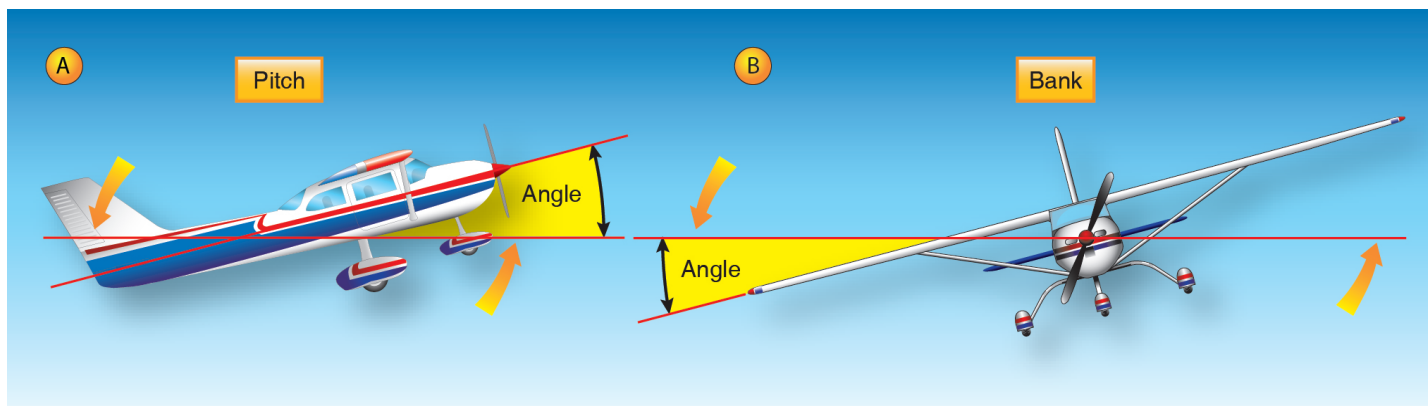


Figure 3-3. (A) Pitch attitude is the angle formed between the airplane's longitudinal axis, which extends from the nose to tail of the airplane, and the natural horizon. (B) Bank attitude is the angle formed by the airplane's lateral axis, which extends from wingtip to wingtip, and the natural horizon.

Controlling an airplane requires one of two methods to determine the airplane's attitude in reference to the horizon. When flying "visually" in visual meteorological conditions (VMC), a pilot uses their eyes and visually references the airplane's wings and cowling to establish the airplane's attitude to the natural horizon (a visible horizon). If no visible horizon can be seen due to clouds, whiteouts, haze over the ocean, night over a dark ocean, etc., it is IMC for practical and safety purposes. [Figure 3-4] When flying in IMC or when cross-checking the visual references, the airplane's attitude is controlled by the pilot referencing the airplane's mechanical or electronically-generated instruments to determine the airplane's attitude in relation to the natural horizon.

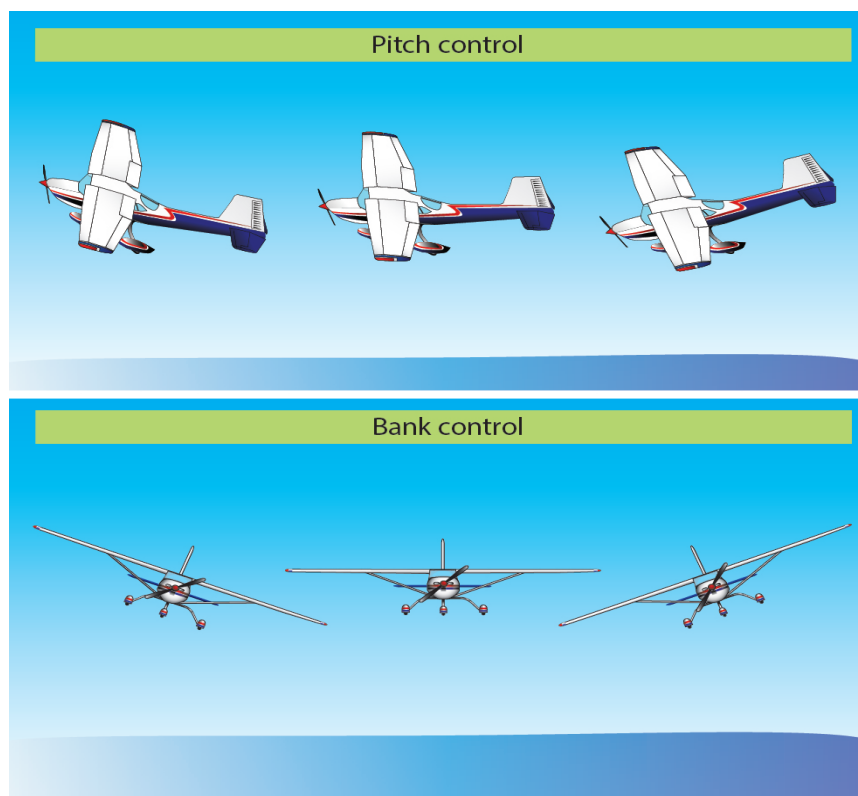


Figure 3-4. Airplane attitude is based on relative positions of the nose and wings on the natural horizon.

Airplane attitude control is composed of four components: pitch control, bank (roll) control, power control, and trim.

- Pitch control—controlling of the airplane’s pitch attitude about the lateral axis by using the elevator to raise and lower the nose in relation to the natural horizon or to the airplane’s flight instrumentation.
- Bank control—controlling of the airplane about the airplane’s longitudinal axis by use of the ailerons to attain a desired bank angle in relation to the natural horizon or to the airplane’s instrumentation.
- Power control—controlled by the throttle in most general aviation (GA) airplanes and is used when the flight situation requires a specific thrust setting or for a change in thrust to meet a specific objective.
- Trim control—used to relieve the control pressures held by the pilot on the flight controls after a desired attitude has been attained.

Note: Yaw control is used to cancel out the effects of yaw-induced changes, such as adverse yaw and effects of the propeller.

Integrated Flight Instruction

When introducing basic flight maneuvers to a beginning pilot, it is recommended that the “integrated” or “composite” method of flight instruction be used. This means the use of outside references and flight instruments to establish and maintain desired flight attitudes and airplane performance. When beginning pilots use this technique, they achieve a more precise and competent overall piloting ability. Although this method of airplane control may become second nature with experience, the beginning pilot needs to make a determined effort to master the technique. In all cases, a pilot’s visual skills need to be sufficiently developed for long-term, safe, and effective aircraft control. [Figure 3-5]



Figure 3-5. Integrated flight instruction teaches pilots to use both external and instrument attitude references.

The basic elements of integrated flight instruction are as follows:

- The pilot visually controls the airplane’s attitude in reference outside to the natural horizon. Approximately 90 percent of the pilot’s attention should be devoted to outside visual references and scanning for airborne traffic. The process of visually evaluating pitch and bank attitude comes from a continuous stream of attitude information. When the pilot perceives that the attitude is other than desired, the pilot should make precise, smooth, and accurate flight control corrections to return the airplane to the desired attitude. Continuous visual checks of the outside references and immediate corrections made by the pilot minimize the chance for the airplane to deviate from the desired heading, altitude, and flightpath.

- The airplane's attitude is validated by referring to flight instruments and confirming performance. If the flight instruments display that the airplane's performance is in need of correction, the required correction needs to be determined and then precisely, smoothly, and accurately applied with reference to the natural horizon. The airplane's attitude and performance are then rechecked by referring to flight instruments. The pilot then maintains the corrected attitude by reference to the natural horizon.
- The pilot should monitor the airplane's performance by briefly checking the flight instruments. No more than about 10 percent of the pilot's attention should be inside the flight deck. The pilot should develop the skill to quickly analyze the appropriate flight instruments and then immediately return to the visual outside references to control the airplane's attitude.

The pilot should become familiar with the relationship between outside visual references to the natural horizon and the corresponding flight instrument indications. For example, a pitch attitude adjustment may require a movement of the pilot's reference point of several inches in relation to the natural horizon but correspond to a seemingly insignificant movement of the reference bar on the airplane's attitude indicator. Similarly, a deviation from a desired bank angle, which is obvious when referencing the airplane's wingtips or cowling relative to the natural horizon, may be imperceptible on the airplane's attitude indicator to the beginner pilot.

The most common error made by the beginner pilot is to make pitch or bank corrections while still looking inside. It is also common for beginner pilots to fixate on the flight instruments—a conscious effort is required by them to return to outside visual references. For the first several hours of instruction, flight instructors may choose to use flight instrument covers to develop a beginning pilot's skill or to correct a pilot's poor habit of fixating on instruments by forcing them to use outside visual references for aircraft control.

The beginning pilot, not being familiar with the intricacies of flight by references to instruments, including such things as instrument lag and gyroscopic precession, will invariably make excessive attitude corrections and end up “chasing the instruments.” Airplane attitude by reference to the natural horizon, however, presents immediate and accurate indications many times larger than on any instrument. The beginning pilot should understand that anytime airplane attitude by reference to the natural horizon cannot be established or maintained, the situation has become a genuine emergency and that the use of integrated flight instruction does not prepare pilots for flight in IMC.

Straight-and-Level Flight

Straight-and-level flight is flight in which heading and altitude are maintained. The other fundamentals are derived as variations from straight-and-level flight, and the need to form proper and effective skills in flying straight and level should be understood. The ability to perform straight-and-level flight results from repetition and practice. A high level of skill results when the pilot perceives outside references, takes mental snap shots of the flight instruments, and makes effective, timely, and proportional corrections from unintentional slight turns, descents, and climbs.

Straight-and-level flight is a matter of consciously fixing the relationship of a reference point on the airplane in relation to the natural horizon. [Figure 3-6] The establishment of these reference points should be initiated on the ground as they depend on the pilot's seating position, height, and posture. The pilot should sit in a normal manner with the seat position adjusted, such that the pilot sees adequately over the instrument panel while being able to fully depress the rudder pedals without straining or reaching.

A flight instructor may use a dry erase marker or removable tape to make reference lines on the windshield or cowling to help the beginner pilot establish visual reference points. Vertical reference lines are best established on the ground, such as when the airplane is placed on a marked centerline, with the beginner pilot seated in proper position. Horizontal reference lines are best established with the airplane in flight, such as during slow flight and cruise configurations. The horizon reference point is always the same, no matter what altitude, since the point is always on the horizon, although the distance to the horizon will be further as altitude increases. There are multiple horizontal reference lines due to varying pitch attitude requirements; however, these teaching aids are generally needed for only a short period until the beginning pilot understands where and when to look while maneuvering the airplane.

Straight Flight

Maintaining a constant direction or heading is accomplished by visually checking the relationship of the airplane's wingtips to the natural horizon. Depending on whether the airplane is a high wing or low wing, both wingtips should be level and equally above or below the natural horizon. Any necessary bank corrections are made with the pilot's coordinated use of ailerons and rudder. [Figure 3-7] The pilot should understand that anytime the wings are banked, the airplane turns. The objective of straight flight is to detect and correct small deviations, necessitating minor flight control corrections. The bank attitude information can also be obtained from a quick scan of the attitude indicator (which shows the position of the airplane's wings relative to the horizon) and the heading indicator (which indicates if the airplane is off the desired heading).

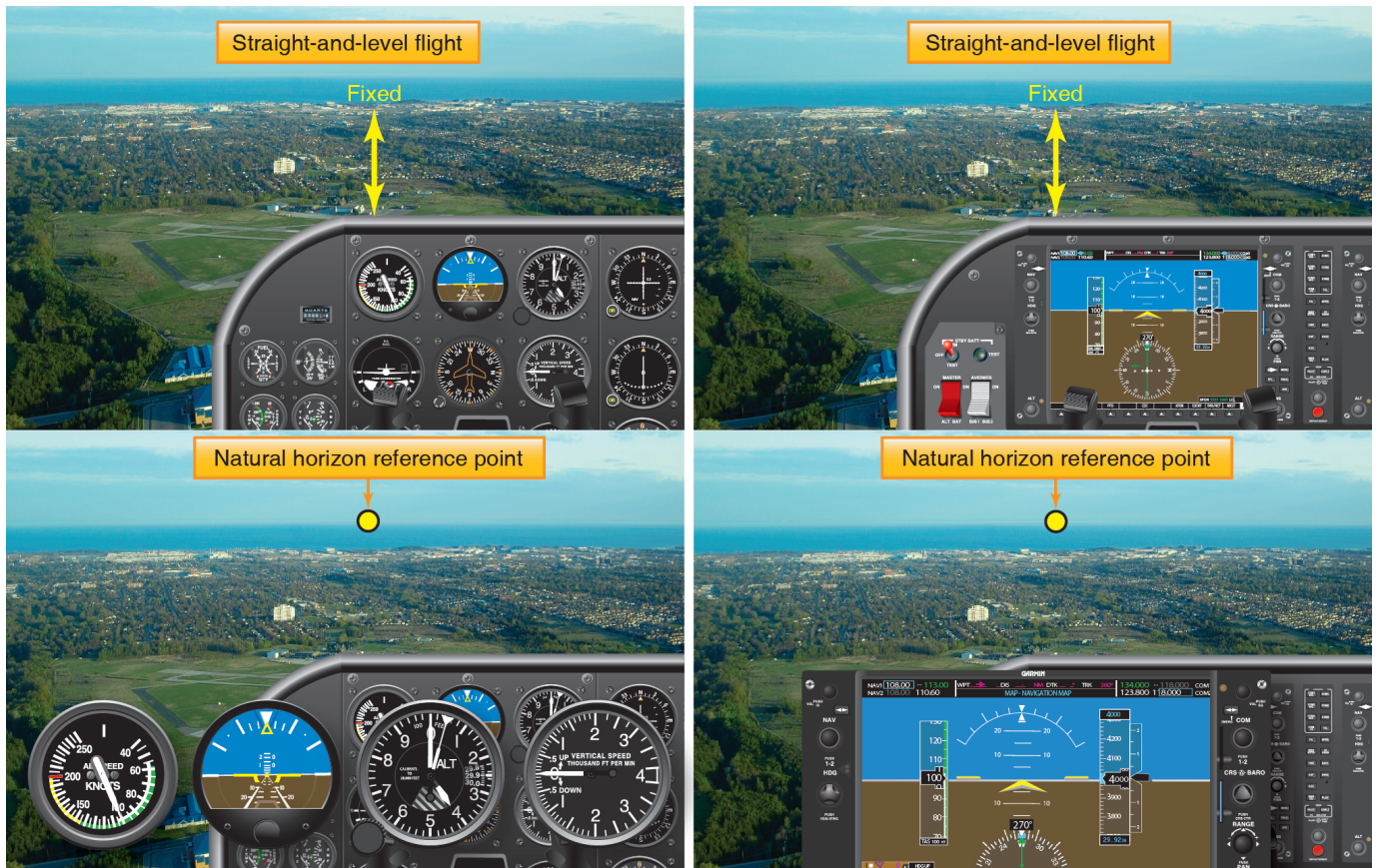


Figure 3-6. Nose reference for straight-and-level flight.



Figure 3-7. Wingtip reference for straight-and-level flight.

It is possible to maintain straight flight by simply exerting the necessary pressure with the ailerons or rudder independently in the desired direction of correction. However, the practice of using the ailerons and rudder independently is not correct and makes precise control of the airplane difficult. The correct bank flight control movement requires the coordinated use of ailerons and rudder. Straight-and-level flight requires almost no application of flight control pressures if the airplane is properly trimmed and the air is smooth. For that reason, the pilot should not form the habit of unnecessarily moving the flight controls. The pilot needs to learn to recognize when corrections are necessary and then to make a measured flight control response precisely, smoothly, and accurately.

Pilots may tend to look out to one side continually, generally to the left due to the pilot's left seat position and consequently focus attention in that direction. This not only gives a restricted angle from which the pilot is to observe but also causes the pilot to exert unconscious pressure on the flight controls in that direction. It is also important that the pilot not fixate in any one direction and continually scan outside the airplane, not only to ensure that the airplane's attitude is correct, but also to ensure that the pilot is considering other factors for safe flight. Continually observing both wingtips has advantages other than being the only positive check for leveling the wings. This includes looking for aircraft traffic, terrain and weather influences, and maintaining overall situational awareness.

Straight flight allows flying along a line. For outside references, the pilot selects a point on the horizon aligned with another point ahead. If those two points stay in alignment, the airplane will track the line formed by the two points. A pilot can also hold a course in VFR by tracking to a point in front of a compass or magnetic direction indicator, with only glances at the instrument or indicator to ensure being on course. The reliance on a surface point does not work when flying over water or flat snow covered surfaces. In these conditions, the pilot should rely on the magnetic heading indication.

Level Flight

In learning to control the airplane in level flight, it is important that the pilot be taught to maintain a light touch on the flight controls using fingers rather than the common problem of a tight-fisted palm wrapped around the flight controls. The pilot should exert only enough pressure on the flight controls to produce the desired result. The pilot should learn to associate the apparent movement of the references with the control pressures which produce attitude movement. As a result, the pilot can develop the ability to adjust the change desired in the airplane's attitude by the amount and direction of pressures applied to the flight controls without the pilot excessively referring to instrument or outside references for each minor correction.

The pitch attitude for level flight is first obtained by the pilot being properly seated, selecting a point toward the airplane's nose as a reference, and then keeping that reference point in a fixed position relative to the natural horizon. [Figure 3-8] The principles of attitude flying require that the reference point to the natural horizon position should be cross-checked against the flight instruments to determine if the pitch attitude is correct. If trending away from the desired altitude, the pitch attitude should be readjusted in relation to the natural horizon and then the flight instruments crosschecked to determine if altitude is now being corrected or maintained. In level flight maneuvers, the terms "increase the back pressure" or "increase pitch attitude" implies raising the airplane's nose in relation to the natural horizon and the terms "decreasing the pitch attitude" or "decrease pitch attitude" means lowering the nose in relation to the natural horizon. The pilot's primary reference is the natural horizon.

For all practical purposes, the airplane's airspeed remains constant in straight-and-level flight if the power setting is also constant. Intentional airspeed changes, by increasing or decreasing the engine power, provide proficiency in maintaining straight-and-level flight as the airplane's airspeed is changing. Pitching moments may also be generated by extension and retraction of flaps, landing gear, and other drag producing devices, such as spoilers. Exposure to the effect of the various configurations should be covered in any specific airplane checkout.

Common Errors

A common error of a beginner pilot is attempting to hold the wings level by only observing the airplane's nose. Using this method, the nose's short horizontal reference line can cause slight deviations to go unnoticed. However, deviations from level flight are easily recognizable when the pilot references the wingtips and, as a result, the wingtips should be the pilot's primary reference for maintaining level bank attitude. This technique also helps eliminate the potential for flying the airplane with one wing low and correcting heading errors with the pilot holding opposite rudder pressure. A pilot with a bad habit of dragging one wing low and compensating with opposite rudder pressure will have difficulty mastering other flight maneuvers.

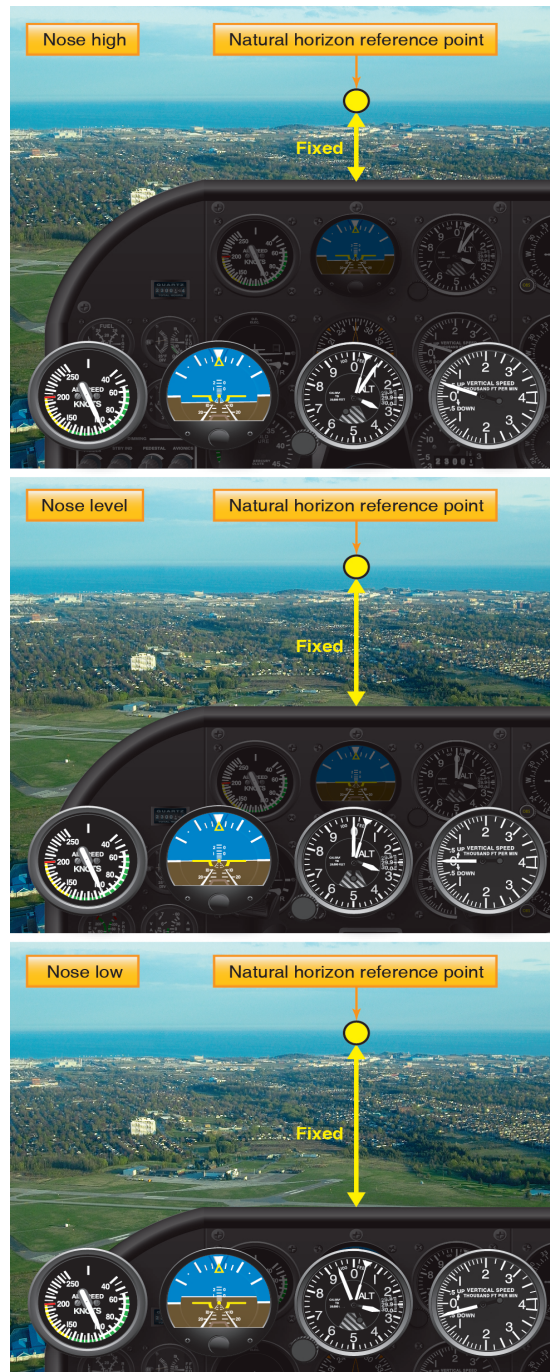


Figure 3-8. *Nose reference for level flight.*

Common errors include:

1. Attempting to use improper pitch and bank reference points.
2. Forgetting the location of preselected reference points on subsequent flights.
3. Attempting to establish or correct airplane attitude using flight instruments rather than the natural horizon.
4. "Chasing" the flight instruments rather than adhering to the principles of attitude flying.
5. Mechanically pushing or pulling on the flight controls rather than exerting accurate and smooth pressure.
6. Not scanning outside the aircraft for other traffic and weather and terrain influences.
7. A tight palm grip on the flight controls resulting in a desensitized feeling of the hand and fingers.
8. Overcontrolling the airplane.
9. Habitually flying with one wing low or maintaining directional control using only the rudder control.
10. Failure to make timely and measured control inputs after a deviation from straight-and-level.
11. Inadequate attention to sensory inputs in developing feel for reference points on the airplane to establish attitude.

Trim Control

Trim control surfaces are required to offset any constant flight control pressure inputs provided by the pilot. For example, elevator trim is a typical trim in light GA airplanes and is used to null the pressure exerted by the pilot in order to maintain a particular pitch attitude. [Figure 3-9] This provides an opportunity for the pilot to divert attention to other tasks.

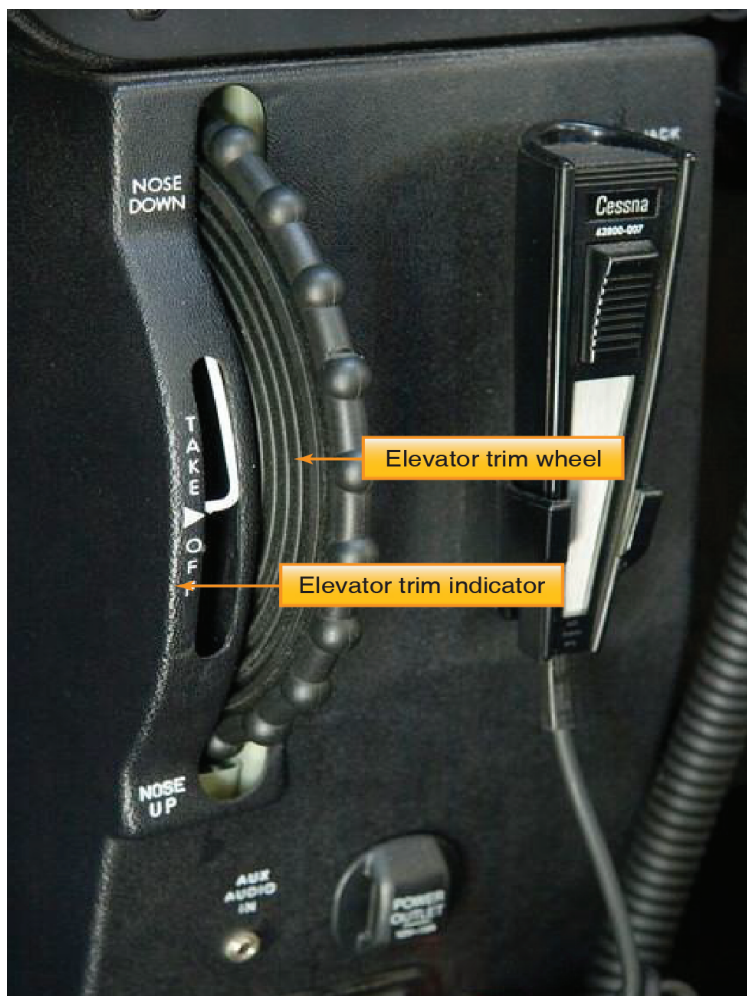


Figure 3-9. Elevator trim is used in airplanes to null the pressure exerted by the pilot on the pitch flight control.

Because of their relatively low power, speed, and cost constraints, not all light airplanes have a complete set (elevator, rudder, and aileron) of trim controls that are adjustable from inside the flight deck. Nearly all light airplanes are equipped with at least adjustable elevator trim. As airplanes increase in power, weight, and complexity, flight deck adjustable trim systems for the rudder and aileron may be available.

In airplanes where multiple trim axes are available, the rudder should be trimmed first. Rudder, elevator, and then aileron should be trimmed next in sequence. However, if the airspeed is varying, continuous attempts to trim the rudder and aileron produce unnecessary pilot workload and distraction. Attempts to trim the rudder at varying airspeeds are impractical in many propeller airplanes because of the built-in compensation for the effect of a propeller's left turning tendencies. The correct procedure is when the pilot has established a constant airspeed and pitch attitude, the pilot should then hold the wings level with aileron flight control pressure while rudder control pressure is trimmed out. Finally, aileron trim should be adjusted to relieve any aileron flight control pressure.

A properly trimmed airplane is an indication of good piloting skills. Any control forces that the pilot feels should be a result of deliberate flight control pressure inputs during a planned change in airplane attitude, not a result of forces being applied by the airplane. A common trim control error is the tendency for the pilot to overcontrol the airplane with trim adjustments. Attempting to fly the airplane with the trim is a common fault in basic flying technique even among experienced pilots. The airplane attitude should be established first and held with the appropriate flight control pressures, and then the flight control pressures trimmed out so that the airplane maintains the desired attitude without the pilot exerting flight control pressure.

Level Turns

A turn is initiated by banking the wings in the desired direction of the turn through the pilot's use of the aileron flight controls. Left aileron flight control pressure causes the left wing to lower in relation to the pilot. Right aileron flight control pressure causes the right wing to lower in relation to the pilot. In other words, to turn left, the pilot lowers the left wing with aileron by left stick. To turn right, the pilot lowers the right wing with right stick. Depending on bank angle and airplane engineering, at many bank angles, the airplane will continue to turn with ailerons neutralized. The sequence could be as follows:

1. Bank the airplane, adding either enough power or pitching up to compensate for the loss of vertical lift.
2. Neutralize controls as necessary to stop bank from increasing and hold desired bank angle.
3. Use the opposite stick (aileron) to return airplane to level.
4. Neutralize the ailerons (along with either power or pitch reduction) for level flight. [Figure 3-10]



Figure 3-10. *Level turn to the left.*

A turn is the result of the following:

- The ailerons bank the wings and determine the rate of turn for a given airspeed. Lift is divided into both vertical and horizontal lift components as a result of the bank. The horizontal component of lift moves the airplane toward the banked direction.
- The elevator pitches the nose of the airplane up or down in relation to the pilot and perpendicular to the wings. If the pilot does not add power, and there is sufficient airspeed margin, the pilot needs to slightly increase the pitch to increase wing lift enough to replace the wing lift being diverted into turning force so as to maintain the current altitude.
- The vertical fin on an airplane does not produce lift. Rather the vertical fin on an airplane is a stabilizing surface and produces no lift if the airplane is flying straight ahead. The vertical fin's purpose is to keep the aft end of the airplane behind the front end.
- The throttle provides thrust, which may be used for airspeed control and to vary the radius of the turn.
- The pilot uses the rudder to offset any adverse yaw developed by wing's differential lift and the engine/propeller. The rudder does not turn the airplane. The rudder is used to maintain coordinated flight.

For purposes of this discussion, turns are divided into three classes: shallow, medium, and steep.

- Shallow turns—bank angle is approximately 20° or less. This shallow bank is such that the inherent lateral stability of the airplane slowly levels the wings unless aileron pressure in the desired direction of bank is held by the pilot to maintain the bank angle.
- Medium turns—result from a degree of bank between approximately 20° and 45° . At medium bank angles, the airplane's inherent lateral stability does not return the wings to level flight. As a result, the airplane tends to remain at a constant bank angle without any flight control pressure held by the pilot. The pilot neutralizes the aileron flight control pressure to maintain the bank.
- Steep turns—result from a degree of bank of approximately 45° or more. The airplane continues in the direction of the bank even with neutral flight controls unless the pilot provides opposite flight control aileron pressure to prevent the airplane from overbanking. The actual amount of opposite flight control pressure used depends on various factors, such as bank angle and airspeed.

When an airplane is flying straight and level, the total lift is acting perpendicular to the wings and to the earth. As the airplane is banked into a turn, total lift is the resultant of two components: vertical and horizontal. [Figure 3-11] The vertical lift component continues to act perpendicular to the earth and opposes gravity. The horizontal lift component acts parallel to the earth's surface opposing centrifugal force. These two lift components act at right angles to each other, causing the resultant total lifting force to act perpendicular to the banked wing of the airplane. It is the horizontal lift component that begins to turn the airplane and not the rudder.

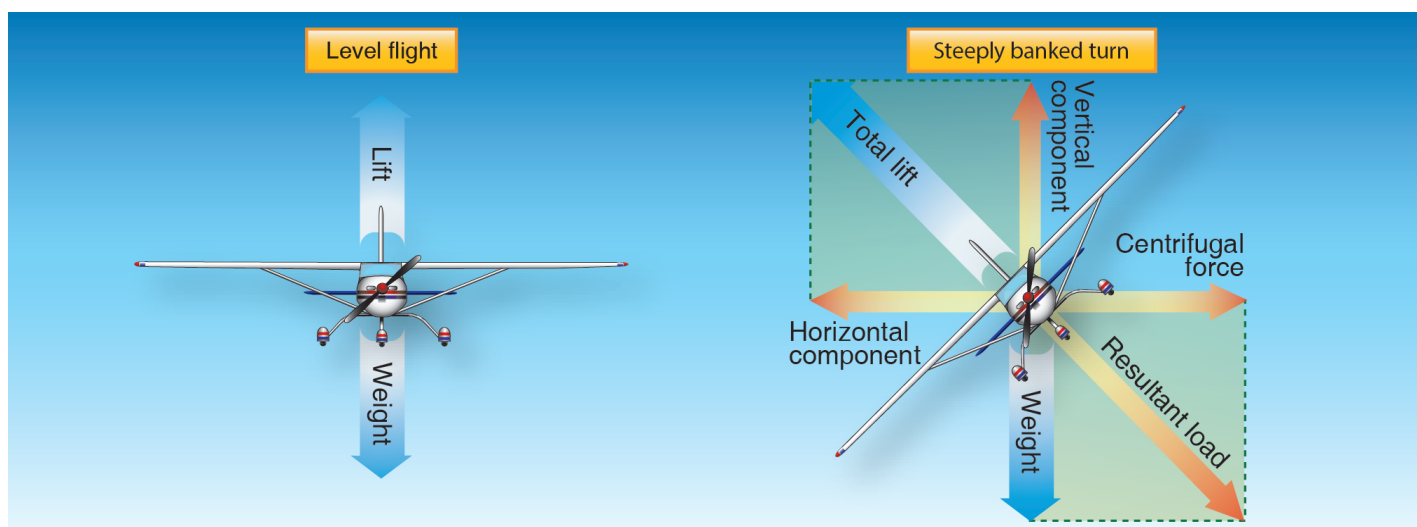


Figure 3-11. When the airplane is banked into a turn, total lift is the resultant of two components: vertical and horizontal.

In constant altitude, constant airspeed turns, it is necessary to increase the AOA of the wing when rolling into the turn by increasing back pressure on the elevator, as well to add power countering the loss of speed due to increased drag. This is required because total lift has divided into vertical and horizontal components of lift. In order to maintain altitude, the total lift (since total lift acts perpendicular to the wing) needs to be increased to meet the vertical component of lift requirements (to balance weight and load factor) for level flight.

The purpose of the rudder in a turn is to coordinate the turn. As lift increases, so does drag. When the pilot deflects the ailerons to bank the airplane, both lift and drag are increased on the rising wing and, simultaneously, lift and drag are decreased on the lowering wing. [Figure 3-12] This increased drag on the rising wing and decreased drag on the lowering wing results in the airplane yawing opposite to the direction of turn. To counteract this adverse yaw, rudder pressure is applied simultaneously with the aileron deflection in the desired direction of turn. This action is required to produce a coordinated turn. Coordinated flight is an important part of airplane control. Situations can develop when a pilot maintains certain uncoordinated flight control deflections, which create the potential for a spin. This is especially hazardous when operating at low altitudes, such as when operating in the airport traffic pattern.