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 principle maneuvers that control the airplane through the six motions of flight.

The Four Fundamentals

To master any subject, one must first master the fundamentals. An attempt to move on to advanced maneuvers prior to mastering the four fundamentals hinders the learning process. To be a competent pilot first requires that the pilot is skilled in the basics of fundamental airmanship. This requires mastery of the four basic flight maneuvers upon which all flying tasks are based: straight-and-level flight, turns, climbs, and descents.

Consider the following: a takeoff is a combination of straight-and-level and a climb, turning on course to the first navigation fix after departure is a climb and a turn, and the landing at the destination is a combination of airplane ground handling, acceleration, pitch and a climb.

The flight instructor must 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) Practical Test Standards (PTS) or Airman Certification Standards (ACS), as appropriate. The importance of this phase of flight training cannot be overstated. 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. Many beginning pilot difficulties in advanced maneuvers are likely caused by a lack of understanding, training, or practice in the four fundamentals.

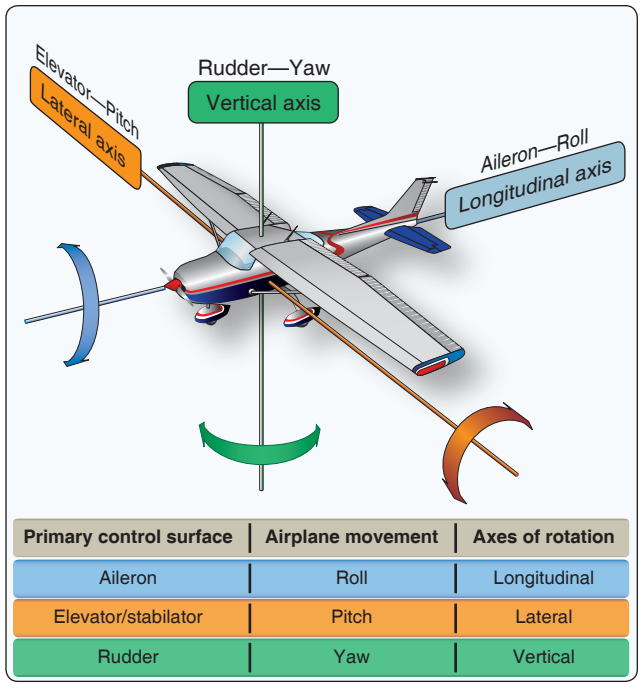
Effect and Use of the Flight Controls

The airplane flies in an environment that allows it to travel up and down as well as left and right. That up or down can be relative to 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. In any regard, that forward movement of the elevator control will always move the airplane in the same direction relative to the pilot's perspective. Therefore, the airplane controls always function the same relative to the pilot. Depending on the airplane's orientation to the Earth, the same control actions may result in different movements of the airplane. *[Figure 3-1]* The pilot is always considered the referenced center of effect as the flight controls are used. *[Figure 3-2]* The following is always true, regardless of the airplane's attitude in relation to the Earth's horizon.

With the pilot's hand:

- When pulling the elevator pitch control toward the pilot, which is an aft movement of the aileron and elevator controls, 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.

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



Primary control surface	Airplane movement	Axes of rotation
Aileron	Roll	Longitudinal
Elevator/stabilator	Pitch	Lateral
Rudder	Yaw	Vertical

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

- When pushing the elevator pitch control toward the instrument panel, which is the forward movement of the aileron and elevator controls, control stick, or side stick controller (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 is a clockwise rotation of aileron and elevator controls or the right deflection of the control stick or side stick controller, 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 is a counterclockwise rotation of aileron and elevator controls or the left deflection of the control stick or side stick controller, 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 flight controls have a resistance to a pilot's movement due to the airflow over the airplane's control surfaces, and the control surfaces remain in a fixed position as long as all forces acting upon them remain balanced. The amount of force that the passing airflow exerts on a control surface is governed by the airspeed and the degree that the surface is moved out of its streamlined position. This resistance increases as airspeed increases and decreases as airspeed decreases. While the airflow over the control surfaces changes during various flight maneuvers, it is not the amount of control surface movement that is important. What is important, is that the pilot maneuvers the airplane by applying sufficient flight control pressures to obtain the desired result.

The pitch and roll flight controls (aileron and elevator controls, stick, or side-stick control) should be held lightly with the fingers and not grabbed or squeezed by the hand. When flight control pressure is applied to change a control surface position, pressure should only be exerted on the aileron and elevator controls with the fingers. This is an important concept and habit to learn which benefits the pilot as they progress to greater challenges such as instrument flying. A common error with beginning pilots is that they grab the aileron and elevator controls with a closed palm with such force that the sensitive feeling is lost. This must be avoided as it prevents the development of "feel," which is an important aspect of airplane control.

The pilot's feet should rest comfortably against the rudder pedals. Both heels should support the weight of the feet on the cockpit 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 must be relaxed proportionately. Remember, the ball of each foot must rest comfortably on the rudder pedals so that even slight pressure changes can be felt.

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

Feel of the Airplane

The ability to sense a flight condition, such as straight-and-level flight or a dive, without relying on cockpit 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 kinesthesis (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, kinesthesis can provide the pilot with critical information about changes in the airplane's direction and speed of motion; however, there are limits in kinesthetic sense and when relied upon solely without visual information, as when flying in instrument meteorological conditions (IMC), ultimately leads to disorientation and loss of aircraft control.

Developing this "feel" takes time and exposure in a particular airplane and 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 past a cockpit 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 noise 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 these forces through pressures into or out of the seat; or shift the pilot from side to side in their seat as 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.

A flight instructor should direct the beginner pilot to be aware of these senses and teach an awareness of their meaning and their relationship to the various conditions of flight. To do this effectively, the flight instructor must fully understand the difference between perceiving and reacting to sound, vibrations, and forces versus merely noticing them. A pilot who develops a "feel" for the airplane early in flight training is likely to have less difficulty advancing in their flight training.

Attitude Flying

An airplane's attitude is determined by the angular difference between a specific airplane's 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

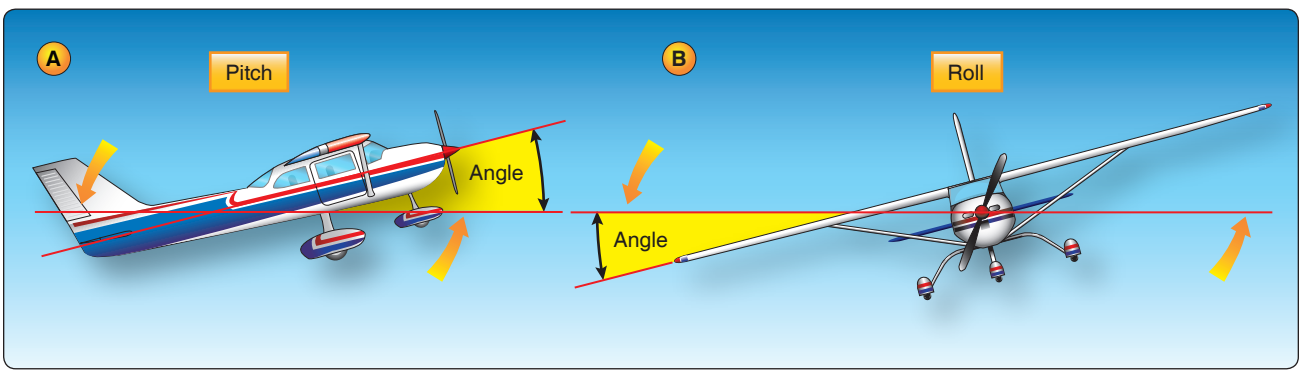


Figure 3-3. *(A) Pitch attitude is the angle formed between the airplane's longitudinal axis. (B) Bank attitude is the angle formed by the airplane's lateral axis.*

the airplane's vertical axis (yaw) is an attitude relative to the airplane's direction of flight but not relative to 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 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 relationship to 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.

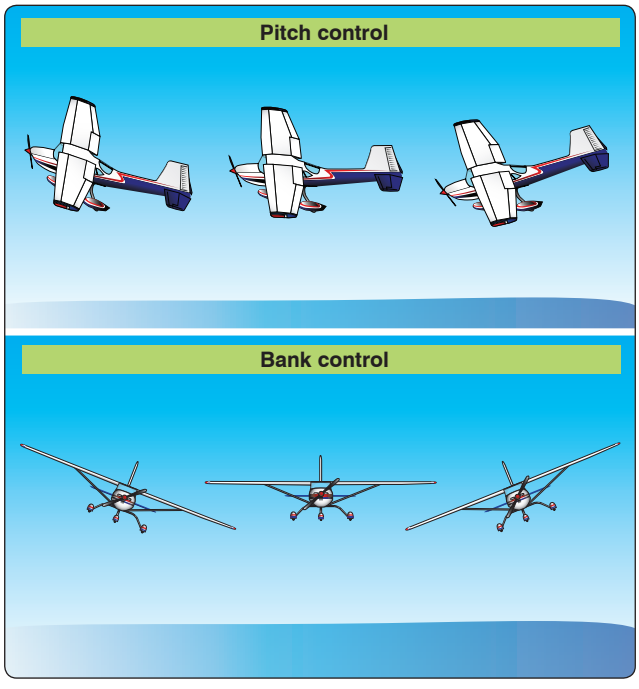


Figure 3-4. *Airplane attitude is based on relative positions of the nose and wings on the natural horizon.*

- Power control—in most general aviation (GA) airplanes is controlled by the throttle 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. *[Figure 3-5]* 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 must make a determined effort to master the technique.

As the beginner pilot develops a competent skill in visual reference flying, the flight instructor should further develop the beginner pilot's effectiveness through the use of integrated flight instruction; however, it is important that the beginner pilot's visual skills be sufficiently developed for long-term, safe, and effective aircraft control. *[Figure 3-5]*

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. At least 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 is nearly an imperceptible continuous stream of attitude information. If the attitude is found to be 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 must be determined and then precisely,

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

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 making quick snap-shots of the flight instruments. No more than 10 percent of the pilot's attention should be inside the cockpit. The pilot must develop the skill to quickly focus on 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 the cockpit. 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 use of integrated flight instruction does not, and is not intended to prepare pilots for flight in instrument weather conditions. The most common error made by the beginning student is to make pitch or bank corrections while still looking inside the cockpit. Control pressure is applied, but 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, is immediate in its indications, accurate, and presented many times larger than any instrument could be. Also, the beginning pilot must be made aware that anytime, for whatever reason, airplane attitude by reference to the natural horizon cannot be established and/or maintained, the situation should be considered a bona fide emergency.

Straight-and-Level Flight

Straight-and-level flight is flight in which heading and altitude are constantly maintained. The four fundamentals are in essence a derivation of straight-and-level flight. As such, the need to form proper and effective skills in flying straight and level should not be understated. Precise mastery of straight-and-level flight is the result of repetition and effective practice. Perfection in straight-and-level flight comes only as a result of

the pilot understanding the effect and use of the flight controls, properly using the visual outside references, and the utilization of snap-shots from the flight instruments in a continuous loop of information gathering. A pilot must make effective, timely, and proportional corrections for deviations in the airplane's direction and altitude from unintentional slight turns, descents, and climbs to master straight-and-level flight.

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 reference points should be initiated on the ground as the reference points depends on the pilot's seating position, height, and manner of sitting. It is important that the pilot sit in a normal manner with the seat position adjusted, which allows for the pilot to see adequately over the instrument panel while being able to fully depress the rudder pedals to their maximum forward position without straining or reaching.

With beginner pilots, a flight instructor will likely 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 being 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 the pitch attitude requirements of the maneuver; however, these teaching aids are generally needed for only a short period of time until the beginning pilot understands where and when to look during the various maneuvers.

Straight Flight

Maintaining a constant direction or heading is accomplished by visually checking the lateral level 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 small deviations as soon as they occur, thereby necessitating only 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 whether flight control pressure is necessary to change the bank attitude to return to straight flight).

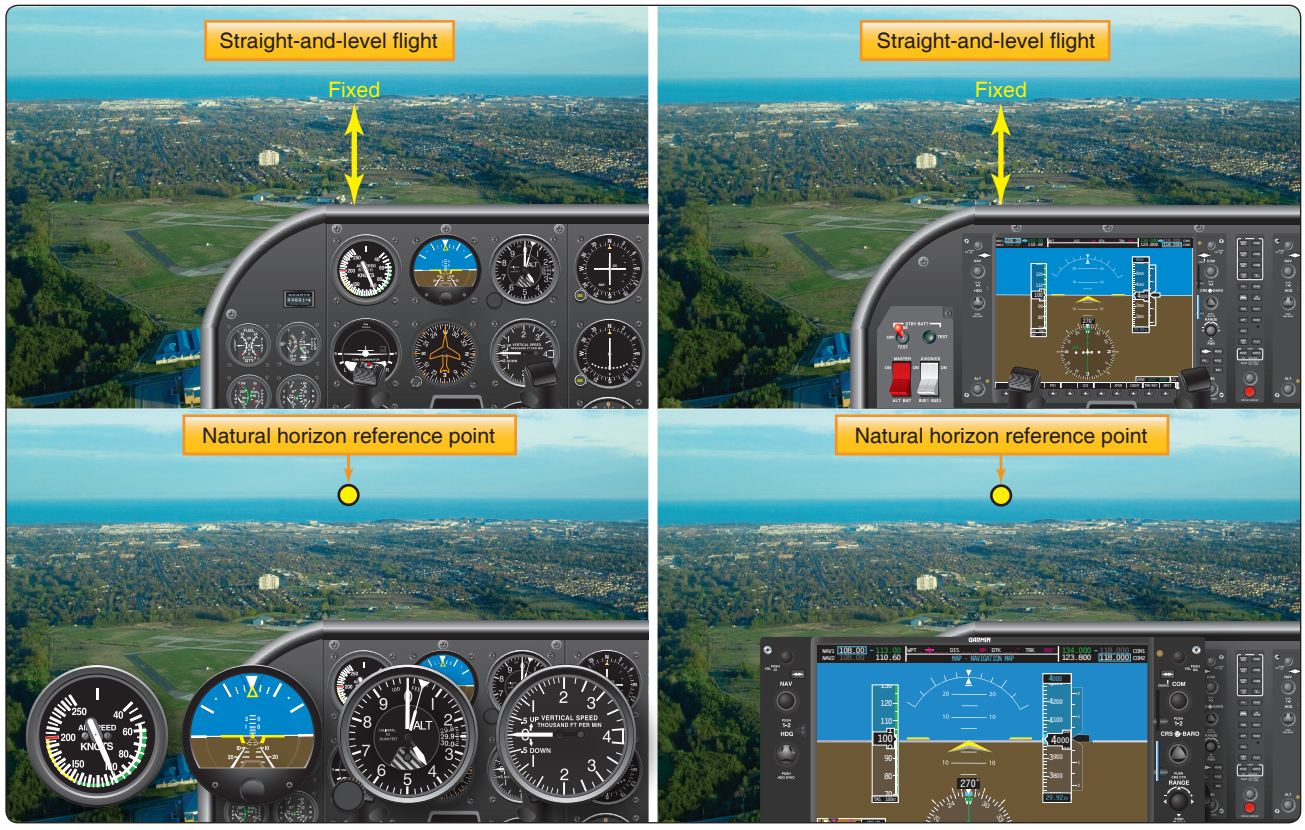


Figure 3-6. *Nose reference for straight-and-level flight.*