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.

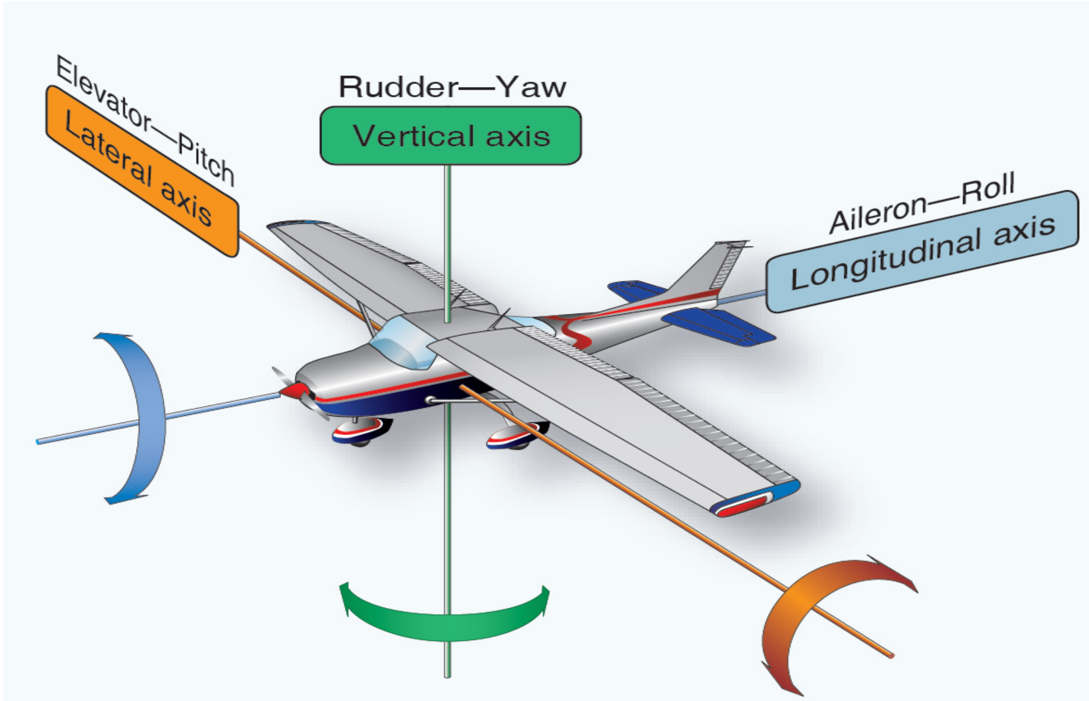
Consider the following: a takeoff is a combination of a ground roll, which may transition to a brief period of straight-and-level flight, and a climb. After-departure includes the climb and turns toward the first navigation fix and is followed by straight-and-level flight. The preparation for landing 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.*



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.*

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 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; 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.

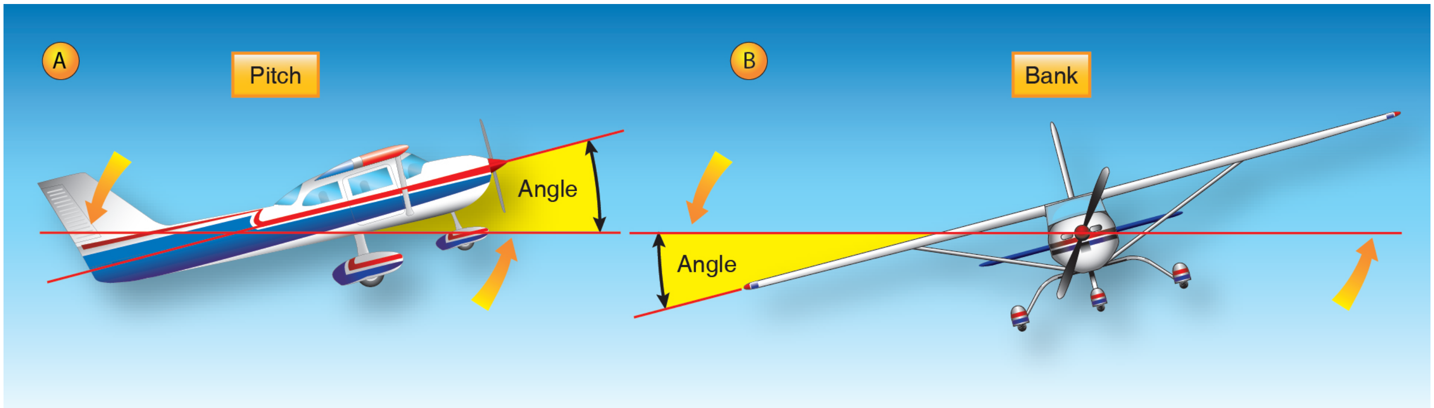


Figure 3-3. *(A) Pitch attitude is the angle formed between the airplane's longitudinal axis, which extends from the nose to tail of the airplane, and the natural horizon. (B) Bank attitude is the angle formed by the airplane's lateral axis, which extends from wingtip to wingtip, and the natural horizon.*

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.

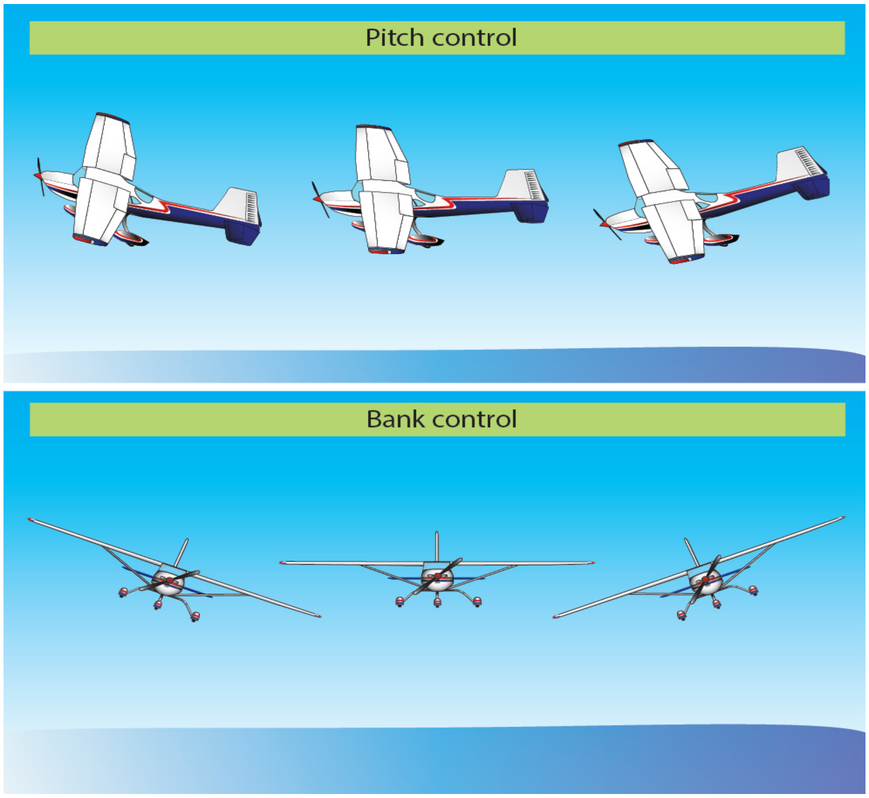


Figure 3-4. *Airplane attitude is based on relative positions of the nose and wings on the natural horizon.*

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).

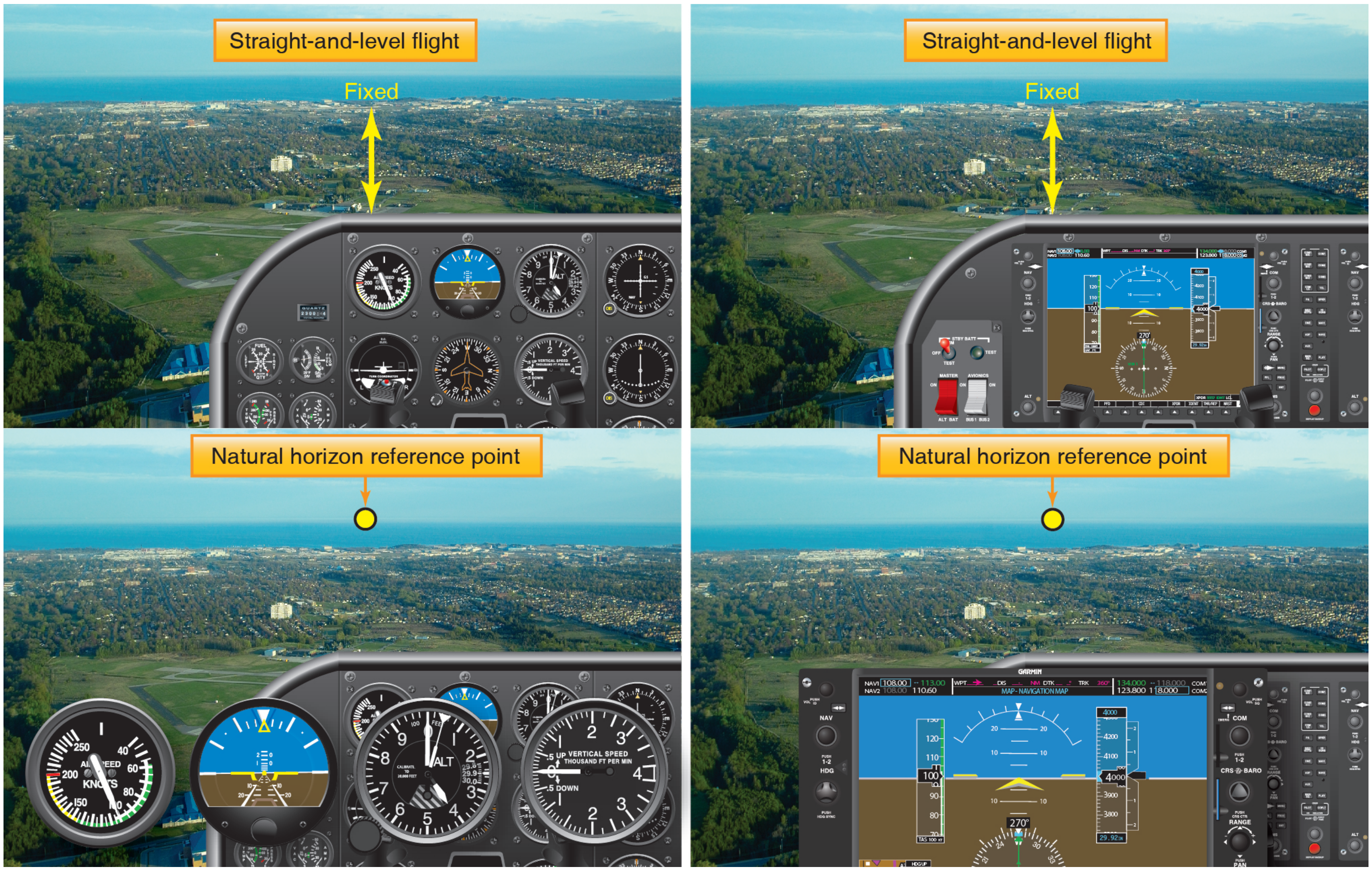


Figure 3-6. *Nose reference for straight-and-level flight.*

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