Introduction

Attitude instrument flying is defined as the control of an aircraft’s spatial position by using instruments rather than outside visual references. Today’s aircraft come equipped with analog and/or digital instruments. Analog instrument systems are mechanical and operate with numbers representing directly measurable quantities, such as a watch with a sweep second hand. In contrast, digital instrument systems are electronic and operate with numbers expressed in digits. Although more manufacturers are providing aircraft with digital instrumentation, analog instruments remain more prevalent. This section acquaints the pilot with the use of analog flight instruments.
Any flight, regardless of the aircraft used or route flown, consists of basic maneuvers. In visual flight, aircraft attitude is controlled by using certain reference points on the aircraft with relation to the natural horizon. In instrument flight, the aircraft attitude is controlled by reference to the flight instruments. Proper interpretation of the flight instruments provides essentially the same information that outside references do in visual flight. Once the role of each instrument in establishing and maintaining a desired aircraft attitude is learned, a pilot is better equipped to control the aircraft in emergency situations involving failure of one or more key instruments.

**Learning Methods**

The two basic methods used for learning attitude instrument flying are “control and performance” and “primary and supporting.” Both methods utilize the same instruments and responses for attitude control. They differ in their reliance on the attitude indicator and interpretation of other instruments.

**Attitude Instrument Flying Using the Control and Performance Method**

Aircraft performance is achieved by controlling the aircraft attitude and power. Aircraft attitude is the relationship of both the aircraft’s pitch and roll axes in relation to the Earth’s horizon. An aircraft is flown in instrument flight by controlling the attitude and power, as necessary, to produce both controlled and stabilized flight without reference to a visible horizon. This overall process is known as the control and performance method of attitude instrument flying. Starting with basic instrument maneuvers, this process can be applied through the use of control, performance, and navigation instruments resulting in a smooth flight from takeoff to landing.

**Control Instruments**

The control instruments display immediate attitude and power indications and are calibrated to permit those respective adjustments in precise increments. In this discussion, the term “power” is used in place of the more technically correct term “thrust or drag relationship.” Control is determined by reference to the attitude and power indicators. Power indicators vary with aircraft and may include manifold pressure, tachometers, fuel flow, etc. [Figure 6-1]

**Performance Instruments**

The performance instruments indicate the aircraft’s actual performance. Performance is determined by reference to the altimeter, airspeed, or vertical speed indicator (VSI). [Figure 6-2]

**Navigation Instruments**

The navigation instruments indicate the position of the aircraft in relation to a selected navigation facility or fix. This group of instruments includes various types of course indicators, range indicators, glideslope indicators, and bearing pointers. [Figure 6-3] Newer aircraft with more technologically advanced instrumentation provide blended information, giving the pilot more accurate positional information.

**Procedural Steps in Using Control and Performance**

1. Establish an attitude and power setting on the control instruments that results in the desired performance. Known or computed attitude changes and approximated power settings helps to reduce the pilot’s workload.

2. Trim (fine tune the control forces) until control pressures are neutralized. Trimming for hands-off flight is essential for smooth, precise aircraft control.
It allows a pilot to attend to other flight deck duties with minimum deviation from the desired attitude.

3. Cross-check the performance instruments to determine if the established attitude or power setting is providing the desired performance. The cross-check involves both seeing and interpreting. If a deviation is noted, determine the magnitude and direction of adjustment required to achieve the desired performance.

4. Adjust the attitude and/or power setting on the control instruments as necessary.

**Aircraft Control During Instrument Flight**

**Attitude Control**

Proper control of aircraft attitude is the result of proper use of the attitude indicator, knowledge of when to change the
attitude, and then smoothly changing the attitude a precise amount. The attitude reference provides an immediate, direct, and corresponding indication of any change in aircraft pitch or bank attitude.

Pitch Control
Changing the “pitch attitude” of the miniature aircraft or fuselage dot by precise amounts in relation to the horizon makes pitch changes. These changes are measured in degrees, or fractions thereof, or bar widths depending upon the type of attitude reference. The amount of deviation from the desired performance determines the magnitude of the correction.

Bank Control
Bank changes are made by changing the “bank attitude” or bank pointers by precise amounts in relation to the bank scale. The bank scale is normally graduated at 0°, 10°, 20°, 30°, 60°, and 90° and is located at the top or bottom of the attitude reference. Bank angle use normally approximates the degrees to turn, not to exceed 30°.

Power Control
Proper power control results from the ability to smoothly establish or maintain desired airspeeds in coordination with attitude changes. Power changes are made by throttle adjustments and reference to the power indicators. Power indicators are not affected by such factors as turbulence, improper trim, or inadvertent control pressures. Therefore, in most aircraft little attention is required to ensure the power setting remains constant.

Experience in an aircraft teaches a pilot approximately how far to move the throttle to change the power a given amount. Power changes are made primarily by throttle movement, followed by an indicator cross-check to establish a more precise setting. The key is to avoid fixating on the indicators while setting the power. Knowledge of approximate power settings for various flight configurations helps the pilot avoid overcontrolling power.

Attitude Instrument Flying Using the Primary and Supporting Method
Another basic method for teaching attitude instrument flying classifies the instruments as they relate to control function, as well as aircraft performance. All maneuvers involve some degree of motion about the lateral (pitch), longitudinal (bank/roll), and vertical (yaw) axes. Attitude control is stressed in this handbook in terms of pitch control, bank control, power control, and trim control. Instruments are grouped as they relate to control function and aircraft performance as pitch control, bank control, power control, and trim.

Pitch Control
Pitch control is controlling the rotation of the aircraft about the lateral axis by movement of the elevators. After interpreting the pitch attitude from the proper flight instruments, exert control pressures to effect the desired pitch attitude with reference to the horizon. These instruments include the attitude indicator, altimeter, VSI, and airspeed indicator. [Figure 6-4] The attitude indicator displays a direct indication of the aircraft’s pitch attitude while the other pitch attitude control instruments indirectly indicate the pitch attitude of the aircraft.

Attitude Indicator
The pitch attitude control of an aircraft controls the angular relationship between the longitudinal axis of the aircraft and the actual horizon. The attitude indicator gives a direct and immediate indication of the pitch attitude of the aircraft. The aircraft controls are used to position the miniature aircraft in relation to the horizon bar or horizon line for any pitch attitude required. [Figure 6-5]
Altimeter

If the aircraft is maintaining level flight, the altimeter needles maintain a constant indication of altitude. If the altimeter indicates a loss of altitude, the pitch attitude must be adjusted upward to stop the descent. If the altimeter indicates a gain in altitude, the pitch attitude must be adjusted downward to stop the climb. [Figure 6-7] The altimeter can also indicate the pitch attitude in a climb or descent by how rapidly the needles move. A minor adjustment in pitch attitude may be made to control the rate at which altitude is gained or lost. Pitch attitude is used only to correct small altitude changes caused by external forces, such as turbulence or up and down drafts.

Vertical Speed Indicator (VSI)

In flight at a constant altitude, the VSI (sometimes referred to as vertical velocity indicator or rate-of-climb indicator) remains at zero. If the needle moves above zero, the pitch attitude must be adjusted downward to stop the climb and return to level flight. Prompt adjustments to the changes in the indications of the VSI can prevent any significant change in altitude. [Figure 6-8] Turbulent air causes the needle to fluctuate near zero. In such conditions, the average of the
fluctuations should be considered as the correct reading. Reference to the altimeter helps in turbulent air because it is not as sensitive as the VSI.

Vertical speed is represented in feet per minute (fpm). [Figure 6-8] The face of the instrument is graduated with numbers such as 1, 2, 3, etc. These represent thousands of feet up or down in a minute. For instance, if the pointer is aligned with .5 (½ of a thousand or 500 fpm), the aircraft climbs 500 feet in one minute. The instrument is divided into two regions: one for climbing (up) and one for descending (down).

During turbulence, it is not uncommon to see large fluctuations on the VSI. It is important to remember that small corrections should be employed to avoid further exacerbating a potentially divergent situation.

Overcorrecting causes the aircraft to overshoot the desired altitude; however, corrections should not be so small that the return to altitude is unnecessarily prolonged. As a guide, the pitch attitude should produce a rate of change on the VSI about twice the size of the altitude deviation. For example, if the aircraft is 100 feet off the desired altitude, a 200 fpm rate of correction would be used.

During climbs or descents, the VSI is used to change the altitude at a desired rate. Pitch attitude and power adjustments are made to maintain the desired rate of climb or descent on the VSI.

When pressure is applied to the controls and the VSI shows an excess of 200 fpm from that desired, overcontrolling is indicated. For example, if attempting to regain lost altitude at the rate of 500 fpm, a reading of more than 700 fpm would indicate overcontrolling. Initial movement of the needle indicates the trend of vertical movement. The time for the VSI to reach its maximum point of deflection after a correction is called lag. The lag is proportional to speed and magnitude of pitch change. In an airplane, overcontrolling may be reduced by relaxing pressure on the controls, allowing the pitch attitude to neutralize. In some helicopters with servo-assisted controls, no control pressures are apparent. In this case, overcontrolling can be reduced by reference to the attitude indicator.

Some aircraft are equipped with an instantaneous vertical speed indicator (IVSI). The letters “IVSI” appear on the face of the indicator. This instrument assists in interpretation by instantaneously indicating the rate of climb or descent at a given moment with little or no lag as displayed in a VSI.

Occasionally, the VSI is slightly out of calibration and indicates a gradual climb or descent when the aircraft is in level flight. If readjustments cannot be accomplished, the error in the indicator should be considered when the instrument is used for pitch control. For example, an improperly set VSI may indicate a descent of 100 fpm when the aircraft is in level flight. Any deviation from this reading would indicate a change in pitch attitude.

Airspeed Indicator

The airspeed indicator gives an indirect reading of the pitch attitude. With a constant power setting and a constant altitude, the aircraft is in level flight and airspeed remains constant. If the airspeed increases, the pitch attitude has lowered and should be raised. [Figure 6-9] If the airspeed decreases, the pitch attitude has moved higher and should be lowered. [Figure 6-10] A rapid change in airspeed indicates a large change in pitch; a slow change in airspeed indicates a small change in pitch. Although the airspeed indicator is used as a pitch instrument, it may be used in level flight for power control. Changes in pitch are reflected immediately by a change in airspeed. There is very little lag in the airspeed indicator.
Pitch Attitude Instrument Cross-Check
The altimeter is an important instrument for indicating pitch attitude in level flight except when used in conditions of exceptionally strong vertical currents, such as thunderstorms. With proper power settings, any of the pitch attitude instruments can be used to hold reasonably level flight attitude. However, only the altimeter gives the exact altitude information. Regardless of which pitch attitude control instrument indicates a need for a pitch attitude adjustment, the attitude indicator, if available, should be used to make the adjustment. Common errors in pitch attitude control are:

- Overcontrolling;
- Improperly using power; and
- Failing to adequately cross-check the pitch attitude instruments and take corrective action when pitch attitude change is needed.

Bank Control
Bank control is controlling the angle made by the wing and the horizon. After interpreting the bank attitude from the appropriate instruments, exert the necessary pressures to move the ailerons and roll the aircraft about the longitudinal axis. As illustrated in Figure 6-11, these instruments include:

- Attitude indicator
- Heading indicator
- Magnetic compass
- Turn coordinator/turn-and-slip indicator

Attitude Indicator
As previously discussed, the attitude indicator is the only instrument that portrays both instantly and directly the actual flight attitude and is the basic attitude reference.

Heading Indicator
The heading indicator supplies the pertinent bank and heading information and is considered a primary instrument for bank.

Magnetic Compass
The magnetic compass provides heading information and is considered a bank instrument when used with the heading indicator. Care should be exercised when using the magnetic compass as it is affected by acceleration, deceleration in flight caused by turbulence, climbing, descending, power changes, and airspeed adjustments. Additionally, the magnetic compass indication will lead and lag in its reading depending upon the direction of turn. As a result, acceptance of its indication should be considered with other instruments that indicate turn information. These include the already mentioned attitude and heading indicators, as well as the turn-and-slip indicator and turn coordinator.
Turn Coordinator/Turn-and-Slip Indicator
Both of these instruments provide turn information. [Figure 6-12] The turn coordinator provides both bank rate and then turn rate once stabilized. The turn-and-slip indicator provides only turn rate.

Figure 6-12. Turn coordinator and turn-and-slip indicator.

Power Control
A power change to adjust airspeed may cause movement around some or all of the aircraft axes. The amount and direction of movement depends on how much or how rapidly the power is changed, whether single-engine or multiengine airplane or helicopter. The effect on pitch attitude and airspeed caused by power changes during level flight is illustrated in Figures 6-13 and 6-14. During or immediately after adjusting the power control(s), the power instruments should be cross-checked to see if the power adjustment is as desired. Whether or not the need for a power adjustment is indicated by another instrument(s), adjustment is made by cross-checking the power instruments. Aircraft are powered by a variety of powerplants, each powerplant having certain instruments that indicate the amount of power being applied to operate the aircraft. During instrument flight, these instruments must be used to make the required power adjustments.

As illustrated in Figure 6-15, power indicator instruments include:
- Airspeed indicator
- Engine instruments

Airspeed Indicator
The airspeed indicator provides an indication of power best observed initially in level flight where the aircraft is in balance and trim. If in level flight the airspeed is increasing, it can generally be assumed that the power has increased, necessitating the need to adjust power or re-trim the aircraft.

Engine Instruments
Engine instruments, such as the manifold pressure (MP) indicator, provide an indication of aircraft performance for a given setting under stable conditions. If the power conditions are changed, as reflected in the respective engine instrument readings, there is an affect upon the aircraft performance, either an increase or decrease of airspeed. When the propeller rotational speed (revolutions per minute (RPM) as viewed on a tachometer) is increased or decreased on fixed-pitch propellers, the performance of the aircraft reflects a gain or loss of airspeed as well.

Trim Control
Proper trim technique is essential for smooth and accurate instrument flying and utilizes instrumentation illustrated in Figure 6-16. The aircraft should be properly trimmed while executing a maneuver. The degree of flying skill, which ultimately develops, depends largely upon how well the aviator learns to keep the aircraft trimmed.

Airplane Trim
An airplane is correctly trimmed when it is maintaining a desired attitude with all control pressures neutralized. By relieving all control pressures, it is much easier to maintain the

Figure 6-13. An increase in power—increasing airspeed accordingly in level flight.
Figure 6-14. Pitch control and power adjustment required to bring aircraft to level flight.

Figure 6-15. Power instruments.

Figure 6-16. Trim instruments.
An aircraft is placed in trim by:

- Applying control pressure(s) to establish a desired attitude. Then, the trim is adjusted so that the aircraft maintains that attitude when flight controls are released. The aircraft is trimmed for coordinated flight by centering the ball of the turn-and-slip indicator.
- Moving the rudder trim in the direction where the ball is displaced from center. Aileron trim may then be adjusted to maintain a wings-level attitude.
- Using balanced power or thrust when possible to aid in maintaining coordinated flight. Changes in attitude, power, or configuration may require trim adjustments. Use of trim alone to establish a change in aircraft attitude usually results in erratic aircraft control. Smooth and precise attitude changes are best attained by a combination of control pressures and subsequent trim adjustments. The trim controls are aids to smooth aircraft control.

**Helicopter Trim**

A helicopter is placed in trim by continually cross-checking the instruments and performing the following:

- Using the cyclic-centering button. If the helicopter is so equipped, this relieves all possible cyclic pressures.
- Using the pedal adjustment to center the ball of the turn indicator. Pedal trim is required during all power changes and is used to relieve all control pressures held after a desired attitude has been attained.

An improperly trimmed helicopter requires constant control pressures, produces tension, distracts attention from cross-checking, and contributes to abrupt and erratic attitude control. The pressures felt on the controls should be only those applied while controlling the helicopter.

Adjust the pitch attitude, as airspeed changes, to maintain desired attitude for the maneuver being executed. The bank must be adjusted to maintain a desired rate of turn, and the pedals must be used to maintain coordinated flight. Trim must be adjusted as control pressures indicate a change is needed.

**Example of Primary and Support Instruments**

Straight-and-level flight at a constant airspeed means that an exact altitude is to be maintained with zero bank (constant heading). The primary pitch, bank, and power instruments used to maintain this flight condition are:

- **Altimeter**—supplies the most pertinent altitude information and is primary for pitch.
- **Heading Indicator**—supplies the most pertinent bank or heading information and is primary for bank.
- **Airspeed Indicator**—supplies the most pertinent information concerning performance in level flight in terms of power output and is primary for power.

Although the attitude indicator is the basic attitude reference, the concept of primary and supporting instruments does not devalue any particular flight instrument, when available, in establishing and maintaining pitch-and-bank attitudes. It is the only instrument that instantly and directly portrays the actual flight attitude. It should always be used, when available, in establishing and maintaining pitch-and-bank attitudes. The specific use of primary and supporting instruments during basic instrument maneuvers is presented in more detail in Chapter 7, Airplane Basic Flight Maneuvers.

**Fundamental Skills**

During attitude instrument training, two fundamental flight skills must be developed. They are instrument cross-check and instrument interpretation, both resulting in positive aircraft control. Although these skills are learned separately and in deliberate sequence, a measure of proficiency in precision flying is the ability to integrate these skills into unified, smooth, positive control responses to maintain any prescribed flightpath.

**Instrument Cross-Check**

The first fundamental skill is cross-checking (also called “scanning” or “instrument coverage”). Cross-checking is the continuous and logical observation of instruments for attitude and performance information. In attitude instrument flying, the pilot maintains an attitude by reference to instruments, producing the desired result in performance. Observing and interpreting two or more instruments to determine attitude and performance of an aircraft is called cross-checking. Although no specific method of cross-checking is recommended, those instruments that give the best information for controlling the aircraft in any given maneuver should be used. The important instruments are the ones that give the most pertinent information for any particular phase of the maneuver. These are usually the instruments that should be held at a constant indication. The remaining instruments should help maintain the important instruments at the desired indications, which is also true in using the emergency panel.

Cross-checking is mandatory in instrument flying. In visual flight, a level attitude can be maintained by outside references. However, even then the altimeter must be checked to determine if altitude is being maintained. Due to human error, instrument error, and airplane performance differences in various atmospheric and loading conditions, it is impossible to establish an attitude and have performance remain constant...
for a long period of time. These variables make it necessary for the pilot to constantly check the instruments and make appropriate changes in airplane attitude using cross-checking of instruments. Examples of cross-checking are explained in the following paragraphs.

Selected Radial Cross-Check
When the selected radial cross-check is used, a pilot spends 80 to 90 percent of flight time looking at the attitude indicator, taking only quick glances at the other flight instruments (for this discussion, the five instruments surrounding the attitude indicator are called the flight instruments). With this method, the pilot’s eyes never travel directly between the flight instruments but move by way of the attitude indicator. The maneuver being performed determines which instruments to look at in the pattern. [Figure 6-17]

Inverted-V Cross-Check
In the inverted-V cross-check, the pilot scans from the attitude indicator down to the turn coordinator, up to the attitude indicator, down to the VSI, and back up to the attitude indicator. [Figure 6-18]

Rectangular Cross-Check
In the rectangular cross-check, the pilot scans across the top three instruments (airspeed indicator, attitude indicator, and altimeter), and then drops down to scan the bottom three instruments (VSI, heading indicator, and turn instrument). This scan follows a rectangular path (clockwise or counterclockwise rotation is a personal choice). [Figure 6-19]

This cross-checking method gives equal weight to the information from each instrument, regardless of its importance to the maneuver being performed. However, this method lengthens the time it takes to return to an instrument critical to the successful completion of the maneuver.

Common Cross-Check Errors
A beginner might cross-check rapidly, looking at the instruments without knowing exactly what to look for. With increasing experience in basic instrument maneuvers and familiarity with the instrument indications associated with them, a pilot learns what to look for, when to look for it, and what response to make. As proficiency increases, a pilot cross-checks primarily from habit, suiting scanning rate and sequence to the demands of the flight situation. Failure to maintain basic instrument proficiency through practice can result in many of the following common scanning errors, both during training and at any subsequent time.

Fixation, or staring at a single instrument, usually occurs for a reason, but has poor results. For example, a pilot may stare...
Figure 6-18. *Inverted-V cross-check.*

Figure 6-19. *Rectangular cross-check.*
at the altimeter reading 200 feet below the assigned altitude, and wonder how the needle got there. While fixated on the instrument, increasing tension may be unconsciously exerted on the controls, which leads to an unnoticed heading change that leads to more errors. Another common fixation is likely when initiating an attitude change. For example, a shallow bank is established for a 90° turn and, instead of maintaining a cross-check of other pertinent instruments, the pilot stares at the heading indicator throughout the turn. Since the aircraft is turning, there is no need to recheck the heading indicator for approximately 25 seconds after turn entry. The problem here may not be entirely due to cross-check error. It may be related to difficulties with instrument interpretation. Uncertainty about reading the heading indicator (interpretation) or uncertainty because of inconsistency in rolling out of turns (control) may cause the fixation.

Omission of an instrument from a cross-check is another likely fault. It may be caused by failure to anticipate significant instrument indications following attitude changes. For example, in a roll-out from a 180° steep turn, straight-and-level flight is established with reference only to the attitude indicator, and the pilot neglects to check the heading indicator for constant heading information. Because of precession error, the attitude indicator temporarily shows a slight error, correctable by quick reference to the other flight instruments.

Emphasis on a single instrument, instead of on the combination of instruments necessary for attitude information, is an understandable fault during the initial stages of training. It is a natural tendency to rely on the instrument that is most readily understood, even when it provides erroneous or inadequate information. Reliance on a single instrument is poor technique. For example, a pilot can maintain reasonably close altitude control with the attitude indicator, but cannot hold altitude with precision without including the altimeter in the cross-check.

**Instrument Interpretation**

The second fundamental skill, instrument interpretation, requires more thorough study and analysis. It begins by understanding each instrument’s construction and operating principles. Then, this knowledge must be applied to the performance of the aircraft being flown, the particular maneuvers to be executed, the cross-check and control techniques applicable to that aircraft, and the flight conditions.

For example, a pilot uses full power in a small airplane for a 5-minute climb from near sea level, and the attitude indicator shows the miniature aircraft two bar widths (twice the thickness of the miniature aircraft wings) above the artificial horizon. [Figure 6-20] The airplane is climbing at 500 fpm as shown on the VSI, and at airspeed of 90 knots, as shown on the airspeed indicator. With the power available in this particular airplane and the attitude selected by the pilot, the performance is shown on the instruments. Now, set up the identical picture on the attitude indicator in a jet airplane. With the same airplane attitude as shown in the first example, the VSI in the jet reads 2,000 fpm and the airspeed indicator reads 250 knots.

**Figure 6-20. Power and attitude equal performance.**
As the performance capabilities of the aircraft are learned, a pilot interprets the instrument indications appropriately in terms of the attitude of the aircraft. If the pitch attitude is to be determined, the airspeed indicator, altimeter, VSI, and attitude indicator provide the necessary information. If the bank attitude is to be determined, the heading indicator, turn coordinator, and attitude indicator must be interpreted. For each maneuver, learn what performance to expect and the combination of instruments to be interpreted in order to control aircraft attitude during the maneuver. It is the two fundamental flight skills, instrument cross-check and instrument interpretation, that provide the smooth and seamless control necessary for basic instrument flight as discussed at the beginning of the chapter.
Introduction

Attitude instrument flying is defined as the control of an aircraft’s spatial position by using instruments rather than outside visual references. As noted in Section I, today’s aircraft come equipped with analog and/or digital instruments. Section II acquaints the pilot with the use of digital instruments known as an electronic flight display (EFD).

The improvements in avionics coupled with the introduction of EFDs to general aviation aircraft offer today’s pilot an unprecedented array of accurate instrumentation to use in the support of instrument flying.
Until recently, most general aviation aircraft were equipped with individual instruments utilized collectively to safely maneuver the aircraft by instrument reference alone. With the release of the EFD system, the conventional instruments have been replaced by multiple liquid crystal display (LCD) screens. The first screen is installed in front of the left seat pilot position and is referred to as the primary flight display (PFD). [Figure 6-21] The second screen is positioned in approximately the center of the instrument panel and is referred to as the multifunction display (MFD). [Figure 6-22] The pilot can use the MFD to display navigation information (moving maps), aircraft systems information (engine monitoring), or should the need arise, a PFD. [Figure 6-23] With just these two screens, aircraft designers have been able to declutter instrument panels while increasing safety. This has been accomplished through the utilization of solid-state instruments that have a failure rate far lower than those of conventional analog instrumentation.

However, in the event of electrical failure, the pilot still has emergency instruments as a backup. These instruments either do not require electrical power, or as in the case of many attitude indicators, they are battery equipped. [Figure 6-24]

Pilots flying under visual flight rules (VFR) maneuver their aircraft by reference to the natural horizon, utilizing specific reference points on the aircraft. In order to operate the aircraft in other than VFR weather, with no visual reference to the natural horizon, pilots need to develop additional skills. These skills come from the ability to maneuver the aircraft by reference to flight instruments alone. These flight instruments replicate all the same key elements that a VFR pilot utilizes during a normal flight. The natural horizon is replicated on the attitude indicator by the artificial horizon.

Understanding how each flight instrument operates and what role it plays in controlling the attitude of the aircraft is fundamental in learning attitude instrument flying. When the pilot understands how all the instruments are used in establishing and maintaining a desired aircraft attitude, the pilot is better prepared to control the aircraft should one or more key instruments fail or if the pilot should enter instrument flight conditions.

Learning Methods

There are two basic methods utilized for learning attitude instrument flying. They are “control and performance” and “primary and supporting.” These methods rely on the same flight instruments and require the pilot to make the same adjustments to the flight and power controls to control aircraft attitude. The main difference between the two methods is the importance that is placed on the attitude indicator and the interpretation of the other flight instruments.
Figure 6-22. Multifunction display (MFD).

Figure 6-23. Reversionary displays.
Control and Performance Method

Aircraft performance is accomplished by controlling the aircraft attitude and power output. Aircraft attitude is the relationship of its longitudinal and lateral axes to the Earth’s horizon. When flying in instrument flight conditions, the pilot controls the attitude of the aircraft by referencing the flight instruments and manipulating the power output of the engine to achieve the performance desired. This method can be used to achieve a specific performance level enabling a pilot to perform any basic instrument maneuver.

The instrumentation can be broken up into three different categories: control, performance, and navigation.

Control Instruments

The control instruments depict immediate attitude and power changes. The instrument for attitude display is the attitude indicator. Power changes are directly reflected on the manifold pressure gauge and the tachometer. [Figure 6-25] All three of these instruments can reflect small adjustments, allowing for precise control of aircraft attitude.

Figure 6-24. Emergency back-up of the airspeed indicator, attitude indicator, and altitude indicator.

Figure 6-25. Control instruments.
In addition, the configuration of the power indicators installed in each aircraft may vary to include the following types of power indicators: tachometers, manifold pressure indicator, engine pressure ratio indicator, fuel flow gauges, etc.

The control instruments do not indicate how fast the aircraft is flying or at what altitude it is flying. In order to determine these variables and others, a pilot needs to refer to the performance instruments.

**Performance Instruments**

The performance instruments directly reflect the performance the aircraft is achieving. The speed of the aircraft can be referenced on the airspeed indicator. The altitude can be referenced on the altimeter. The aircraft’s climb performance can be determined by referencing the vertical speed indicator (VSI). [Figure 6-26] Other performance instruments available are the heading indicator, pitch attitude indicator, and the slip/skid indicator.

The performance instruments most directly reflect a change in acceleration, which is defined as change in velocity or direction. Therefore, these instruments indicate if the aircraft is changing airspeed, altitude, or heading, which are horizontal, vertical, or lateral vectors.

**Navigation Instruments**

The navigation instruments are comprised of global positioning system (GPS) displays and indicators, very high frequency omnidirectional range/nondirectional radio beacon (VOR/NDB) indicators, moving map displays, localizer, and glideslope (GS) indicators. [Figure 6-27] The instruments indicate the position of the aircraft relative to a selected navigation facility or fix. Navigation instruments allow the pilot to maneuver the aircraft along a predetermined path of ground-based or spaced-based navigation signals without reference to any external visual cues. The navigation instruments can support both lateral and visual inputs.

**The Four-Step Process Used to Change Attitude**

In order to change the attitude of the aircraft, the pilot must make the proper changes to the pitch, bank, or power settings of the aircraft. Four steps (establish, trim, cross-check, and adjust) have been developed in order to aid in the process.

**Establish**

Any time the attitude of the aircraft requires changing, the pilot must adjust the pitch and/or bank in conjunction with power to establish the desired performance. The changes in pitch and bank require the pilot to reference the attitude indicator in order to make precise changes. Power changes should be verified on the tachometer, manifold pressure gauge, etc. To ease the workload, the pilot should become

![Figure 6-26. Performance instruments.](image-url)
familiar with the approximate pitch and power changes necessary to establish a specified attitude.

**Trim**

Another important step in attitude instrument flying is trimming the aircraft. Trim is utilized to eliminate the need to apply force to the control yoke in order to maintain the desired attitude. When the aircraft is trimmed appropriately, the pilot is able to relax pressure on the control yoke and momentarily divert attention to another task at hand without deviating from the desired attitude. Trimming the aircraft is very important, and poor trim is one of the most common errors instructors note in instrument students.

**Cross-Check**

Once the initial attitude changes have been made, the pilot should verify the performance of the aircraft. Cross-checking the control and performance instruments requires the pilot to visually scan the instruments, as well as interpret the indications. All the instruments must be utilized collectively in order to develop a full understanding of the aircraft attitude. During the cross-check, the pilot needs to determine the magnitude of any deviations and determine how much of a change is required. All changes are then made based on the control instrument indications.

**Adjust**

The final step in the process is adjusting for any deviations that have been noted during the cross-check. Adjustments should be made in small increments. The attitude indicator and the power instruments are graduated in small increments to allow for precise changes to be made. The pitch should be made in reference to bar widths on the miniature airplane. The bank angle can be changed in reference to the roll scale and the power can be adjusted in reference to the tachometer, manifold pressure gauge, etc.

By utilizing these four steps, pilots can better manage the attitude of their aircraft. One common error associated with this process is making a larger than necessary change when a deviation is noted. Pilots need to become familiar with the aircraft and learn how great a change in attitude is needed to produce the desired performance.

**Applying the Four-Step Process**

In attitude instrument flight, the four-step process is used to control pitch attitude, bank attitude, and power application of the aircraft. The EFD displays indications precisely enough that a pilot can apply control more accurately.

**Pitch Control**

The pitch control is indicated on the attitude indicator, which spans the full width of the PFD. Due to the increased size of the display, minute changes in pitch can be made and corrected. The pitch scale on the attitude indicator is graduated in 5-degree increments that allow the pilot to make corrections with precision to approximately \( \frac{1}{2} \) degree. The miniature airplane utilized to represent the aircraft in conventional attitude indicators is replaced in glass panel displays by a yellow chevron. [Figure 6-28] Representing the nose of the aircraft, the point of the chevron affords the pilot a much more precise indication of the degree of pitch and allows the pilot to make small, precise changes should the desired aircraft performance change. When the desired performance is not being achieved, precise pitch changes should be made by referencing the point of the yellow chevron.

**Bank Control**

Precise bank control can be developed utilizing the roll pointer in conjunction with the roll index displayed on the attitude indicator. The roll index is sectioned by hash marks at \( 0^\circ, 10^\circ, 20^\circ, 30^\circ, 45^\circ, 60^\circ \) and the horizon line, which depicts \( 90^\circ \) of bank. [Figure 6-29] The addition of the \( 45^\circ \) hash mark is an improvement over conventional attitude indicators.
In addition to the roll index, the instrument pilot utilizes the turn rate indicator to maintain the aircraft in a standard rate turn (3° per second). Most instrument maneuvers can be done comfortably, safely, and efficiently by utilizing a standard rate turn.

**Power Control**

The power instruments indicate how much power is being generated by the engine. They are not affected by turbulence, improper trim, or control pressures. All changes in power should be made with reference to power instruments and cross-checked on performance instruments.

Power control needs to be learned from the beginning of flight training. Attitude instrument flying demands increased precision when it comes to power control. As experience increases, pilots begin to know approximately how much change in throttle position is required to produce the desired change in airspeed. Different aircraft demand differing amounts of throttle change to produce specific performance. It is imperative that the pilot make the specific changes on the power instruments and allow the performance to stabilize. Avoid the tendency to overcontrol.

One common error encountered with glass panel displays is associated with the precision of the digital readouts. This precision causes pilots to focus too much attention on establishing the exact power setting.

Control and power instruments are the foundation for precise attitude instrument flying. The keys to attitude instrument flying are establishing the desired aircraft attitude on the attitude indicator and selecting the desired engine output on the power instruments. Cross-checking is the vital ingredient in maintaining precise attitude instrument flight.

**Attitude Instrument Flying—Primary and Supporting Method**

The second method for performing attitude instrument flight is a direct extension of the control/power method. By utilizing the primary and supporting flight instruments in conjunction with the control and power instruments, the pilot can precisely maintain aircraft attitude. This method utilizes the same instruments as the control/power method; however, it focuses more on the instruments that depict the most accurate indication for the aspect of the aircraft attitude being controlled. The four key elements (pitch, bank, roll, and trim) are discussed in detail.

Similar to the control/power method, all changes to aircraft attitude need to be made using the attitude indicator and the power instruments (tachometer, manifold pressure gauge, etc.). The following explains how each component of the aircraft attitude is monitored for performance.
**Pitch Control**

The pitch of the aircraft refers to the angle between the longitudinal axis of the aircraft and the natural horizon. When flying in instrument meteorological conditions (IMC), the natural horizon is unavailable for reference and an artificial horizon is utilized in its place. [Figure 6-30] The only instrument capable of depicting the aircraft attitude is the attitude indicator displayed on the PFD. The attitude and heading reference system (AHRS) is the engine that drives the attitude display. The AHRS unit is capable of precisely tracking minute changes in the pitch, bank, and yaw axes, thereby making the PFD very accurate and reliable. The AHRS unit determines the angle between the aircraft’s longitudinal axis and the horizon line on initialization. There is no need or means for the pilot to adjust the position of the yellow chevron, which represents the nose of the aircraft.

**Straight-and-Level Flight**

In straight-and-level flight, the pilot maintains a constant altitude, airspeed and, for the most part, heading for extended periods of time. To achieve this, the three primary instruments that need to be referenced in order to maintain these three variables are the altitude, airspeed, and heading indicators.

**Primary Pitch**

When the pilot is maintaining a constant altitude, the primary instrument for pitch is the altimeter. As long as the aircraft maintains a constant airspeed and pitch attitude, the altitude should remain constant.

Two factors that cause the altitude to deviate are turbulence and momentary distractions. When a deviation occurs, a change in the pitch needs to be made on the attitude indicator. Small deviations require small corrections, while large deviations require larger corrections. Pilots should avoid making large corrections that result in rapid attitude changes, for this may lead to spatial disorientation. Smooth, timely corrections should be made to bring the aircraft back to the desired attitude.

Pay close attention to indications on the PFD. An increase in pitch of 2.5° produces a climb rate of 450 feet per minute (fpm). Small deviations do not require large attitude changes. A rule of thumb for correcting altitude deviations is to establish a change rate of twice the altitude deviation, not to exceed 500 fpm. For example, if the aircraft is off altitude by 40 feet, $2 \times 40 = 80$ feet, so a descent of approximately 100 fpm allows the aircraft to return to the desired altitude in a controlled, timely fashion.

In addition to the primary instrument, there are also supporting instruments that assist the pilot in cross-checking the pitch attitude. The supporting instruments indicate trend, but they do not indicate precise attitude indications. Three instruments (vertical speed, airspeed, and altitude trend tape) indicate when the pitch attitude has changed and that the altitude is changing. [Figure 6-31] When the altitude is constant, the VSI and altitude trend tape are not shown on the PFD. When these two trend indicators are displayed, the
regarding the direction and rate of altitude deviations. The pilot is thus able to make corrections to the pitch attitude before a large deviation in altitude occurs. The airspeed indicator depicts an increase if the pitch attitude is lowered. Conversely, when the pitch attitude increases, the pilot should note a decrease in the airspeed.

**Primary Bank**

When flying in IMC, pilots maintain preplanned or assigned headings. With this in mind, the primary instrument for bank angle is the heading indicator. Heading changes are displayed instantaneously. The heading indicator is the only instrument that displays the current magnetic heading, provided that it is matched to the magnetic compass with all deviation adjustments accounted for. [Figure 6-32]

There are supporting instruments associated with bank as well. The turn rate trend indicator shows the pilot when the aircraft is changing heading. The magnetic compass is also useful for maintaining a heading; however, it is influenced by several errors in various phases of flight.

**Primary Yaw**

The slip/skid indicator is the primary instrument for yaw. It is the only instrument that can indicate if the aircraft is

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**Figure 6-31. Supporting instruments.**

The pilot is made aware that the pitch attitude of the aircraft has changed and may need adjustment. Notice in Figure 6-31 that the aircraft is descending at a rate of 500 fpm.

The instrument cross-check necessitates utilizing these supporting instruments to better manage altitude control. The VSI and trend tape provide the pilot with information

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**Figure 6-32. Primary bank.**
moving through the air with the longitudinal axis of the
aircraft aligned with the relative wind.

**Primary Power**
The primary power instrument for straight-and-level flight is
the airspeed indicator. The main focus of power is to maintain
a desired airspeed during level flight. No other instrument
delivers instantaneous indication.

Learning the primary and supporting instruments for
each variable is the key to successfully mastering attitude
instrument flying. At no point does the primary and supporting
method devalue the importance of the attitude indicator or the
power instruments. All instruments (control, performance,
primary, and supporting) must be utilized collectively.

**Fundamental Skills of Attitude Instrument Flying**
When first learning attitude instrument flying, it is very
important that two major skills be mastered. Instrument cross-
check and instrument interpretation comprise the foundation
for safely maneuvering the aircraft by reference to instruments
alone. Without mastering both skills, the pilot is not able to
maintain precise control of aircraft attitude.

**Instrument Cross-Check**
The first fundamental skill is cross-checking (also call
“scanning”). Cross-checking is the continuous observation of
the indications on the control and performance instruments.
It is imperative that the new instrument pilot learn to
observe and interpret the various indications in order to
control the attitude and performance of the aircraft. Due to
the configuration of some glass panel displays, such as the
Garmin G1000, one or more of the performance instruments
may be located on an MFD installed to the right of the pilot’s
direct forward line of sight.

How a pilot gathers the necessary information to control
the aircraft varies by individual pilot. No specific method of
cross-checking (scanning) is recommended; the pilot must
learn to determine which instruments give the most pertinent
information for any particular phase of a maneuver. With
practice, the pilot is able to observe the primary instruments
quickly and cross-check with the supporting instruments
in order to maintain the desired attitude. At no time during
instrument flying should the pilot stop cross-checking
the instrumentation.

**Scanning Techniques**
Since most of the primary and supporting aircraft attitude
information is displayed on the PFD, standard scanning
techniques can be utilized. It is important to remember
to include the stand-by flight instruments as well as the
engine indications in the scan. Due to the size of the
attitude instrument display, scanning techniques have been
simplified because the attitude indicator is never out of
peripheral view.

**Selected Radial Cross-Check**
The radial scan is designed so that your eyes remain on the
attitude indicator 80–90 percent of the time. The remainder
of the time is spent transitioning from the attitude indicator
to the various other flight instruments. [Figure 6-33]

The radial scan pattern works well for scanning the PFD. The
close proximity of the instrument tape displays necessitates
very little eye movement in order to focus in on the desired
instrument. While the eyes move in any direction, the
extended artificial horizon line allows the pilot to keep the
pitch attitude in his or her peripheral vision. This extended
horizon line greatly reduces the tendency to fixate on one
instrument and completely ignore all others. Because of
the size of the attitude display, some portion of the attitude
indicator is always visible while viewing another instrument
display on the PFD.

**Starting the Scan**
Start the scan in the center of the PFD on the yellow chevron.
Note the pitch attitude and then transition the eyes upward to
the slip/skid indicator. Ensure that the aircraft is coordinated
by aligning the split triangle symbol. The top of the split
triangle is referred to as the roll pointer. The lower portion of
the split triangle is the slip/skid indicator. If the lower portion
of the triangle is off to one side, step on the rudder pedal on
the same side to offset it. [Figure 6-34 NOTE: The aircraft
is not changing heading. There is no trend vector on the turn
rate indicator.]

While scanning that region, check the roll pointer and assure
that the desired degree of roll is being indicated on the bank
scale. The roll index and the bank scale remain stationary at
the top of the attitude indicator. The index is marked with
angles of 10°, 20°, 30°, 45°, and 60° in both directions. If
the desired bank angle is not indicated, make the appropriate
aileron corrections. Verify the bank angle is correct and
continue scanning back to the yellow chevron.

Scan left to the airspeed tape and verify that the airspeed is
as desired, then return back to the center of the display. Scan
to the altimeter tape. Verify that the desired altitude is being
maintained. If it is not, make the appropriate pitch
change and verify the result. Once the desired altitude has been
verified, return to the center of the display. Transition down to
the heading indicator to verify the desired heading. When the
heading has been confirmed, scan to the center of the display.
Scan pattern should start with left (airspeed indicator), then right (altitude indicator/VSI), then up (slip/skid indicator), then down (heading indicator). The pilot should return attention back to the center (pitch attitude) before proceeding to the next direction. For example: left, center, right, center, up, center, down, center.

Figure 6-33. Selected radial cross-check.

Figure 6-34. Roll pointer and slip/skid indicator.
It is also important to include the engine indications in the scan. Individualized scan methods may require adjustment if engine indications are presented on a separate MFD. A modified radial scan can be performed to incorporate these instruments into the scan pattern. Another critical component to include in the scan is the moving map display located on the MFD. To aid in situational awareness and facilitate a more centralized scan, a smaller inset map can be displayed in the lower left corner of the PFD screen.

**Trend Indicators**

One improvement the glass panel displays brought to the general aviation industry is the trend vector. Trend vectors are colored lines that appear on the airspeed and altitude tapes, as well as on the turn rate indicator. The color of the line may vary depending on the airplane manufacturer. For example, on a Cirrus SR-20, the trend vector lines are magenta and on the B-737 they are green. These colored lines indicate what the associated airspeed, altitude, or heading will be in 6 seconds for the Cirrus SR-20 and 10 seconds for the B-737 if the current rate is maintained. The example shown in Figure 6-35 uses the color and data that represents the trend vector for a Cirrus SR-20. The trend vector is not displayed if there is no change to the associated tape and the value remains constant [Figure 6-36] or if there is a failure in some portion of the system that would preclude the vector from being determined.

Trend vectors are a very good source of information for the new instrument rated pilot(s). Pilots who utilize good scanning techniques can pick up subtle deviations from desired parameters and make small correction to the desired attitude. As soon as a trend is indicated on the PFD, a conscientious pilot can adjust to regain the desired attitude. [Figure 6-37]

Another advancement in attitude instrument flying is the turn rate trend indicator. As in the cases of airspeed, altitude, and vertical speed trend indicators, the turn rate trend indicator depicts what the aircraft’s heading will be in 6 seconds. While examining the top of the heading indicator, notice two white lines on the exterior of the compass rose. [Figure 6-38] These two tick marks located on both sides of the top of the heading indicator show half-standard rate turns as well as standard rate turns.

In Figure 6-39, when the aircraft begins its turn to the left, the magenta trend indicator elongates proportionally with the rate of turn. To initiate a half-standard rate turn, position the
Figure 6-35. HSI Trend Indicator elongates proportionate to the rate of turn.

indicator on the first tick mark. A standard rate turn would be indicated by the trend indicator extending to the second tick mark. A turn rate in excess of standard rate would be indicated by the trend indicator extending past the second tick mark. This trend indicator shows what the aircraft’s heading will be in 6 seconds, but is limited to indicate no more than 24° in front of the aircraft or 4° per second. When the aircraft exceeds a turning rate of 25° in 6 seconds, the trend indicator has an arrowhead attached to it.

Trend indicators are very useful when leveling off at a specific altitude, when rolling out on a heading, or when stabilizing airspeed. One method of determining when to start to level off from a climb or descent is to start leveling at 10 percent of the vertical speed rate prior to the desired altitude.

As the aircraft approaches the desired altitude, adjust the pitch attitude to keep the trend indicator aligned with the target altitude. As the target approaches, the trend indicator gradually shrinks until altitude stabilizes. Trend indicators should be used as a supplement, not as a primary means of determining pitch change.

Common Errors

Fixation

Fixation, or staring at one instrument, is a common error observed in pilots first learning to utilize trend indicators. The pilot may initially fixate on the trend indicator and make adjustments with reference to that alone. Trend indicators are not the only tools to aid the pilot in maintaining the desired
power or attitude; they should be used in conjunction with the primary and supporting instruments in order to better manage the flight. With the introduction of airspeed tapes, the pilot can monitor airspeed to within one knot. Fixation can lead to attempting to keep the airspeed to an unnecessarily tight tolerance. There is no need to hold airspeed to within one knot; the Instrument Rating Practical Test Standards (PTS) allows greater latitude.

**Omission**
Another common error associated with attitude instrument flying is omission of an instrument from the cross-check. Due to the high reliability of the PFD and associated components, pilots tend to omit the stand-by instruments as well as the magnetic compass from their scans. An additional reason for the omission is the position of the stand-by instruments. Pilots should continue to monitor the stand-by instruments in order to detect failures within those systems. One of the most commonly omitted instruments from the scan is the slip/skid indicator.

**Emphasis**
In initial training, placing emphasis on a single instrument is very common and can become a habit if not corrected. When the importance of a single instrument is elevated above another, the pilot begins to rely solely on that instrument for guidance. When rolling out of a 180° turn, the attitude indicator, heading indicator, slip/skid indicator, and altimeter need to be referenced. If a pilot omits the slip/skid indicator, coordination is sacrificed.