Chapter 5, Section II

Airplane Basic Flight Maneuvers

Using an Electronic Flight Display

Introduction

The previous chapters have laid the foundation for instrument flying. The pilot's ability to use and interpret the information displayed and apply corrective action is required to maneuver the aircraft and maintain safe flight. A pilot must recognize that each aircraft make and model flown may require a different technique. Aircraft weight, speed, and configuration changes require the pilot to vary his or her technique in order to perform successful attitude instrument flying. A pilot must become familiar with all sections of the Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) prior to performing any flight maneuver.

Chapter 5–II describes basic attitude instrument flight maneuvers and explains how to perform each one by interpreting the indications presented on the electronic flight display (EFD). In addition to normal flight maneuvers, "partial panel" flight will be addressed. With the exception of the instrument takeoff, all flight maneuvers can be performed on "partial panel" with the Attitude Heading Reference System (AHRS) unit simulated or rendered inoperative.

Straight-and-Level Flight

Pitch Control

The pitch attitude of an airplane is the angle between the longitudinal axis of the airplane and the actual horizon. In level flight, the pitch attitude varies with airspeed and load. For training purposes, the latter factor can normally be disregarded in small airplanes. At a constant airspeed, there is only one specific pitch attitude for level flight. At slow cruise speeds, the level flight attitude is nose-high with indications as in *Figure 5-47*; at fast cruise speeds, the level flight attitude is nose-low. *[Figure 5-48] Figure 5-49* shows the indications for the attitude at normal cruise speeds.

Figure 5-47. *Pitch Attitude and Airspeed in Level Flight, Slow Cruise Speed.*

The instruments that directly or indirectly indicate pitch on the Primary Flight Display (PFD) are the attitude indicator, altimeter, vertical speed indicator (VSI), airspeed indicator (ASI), and both airspeed and altitude trend indicators.

Attitude Indicator

The attitude indicator gives the pilot a direct indication of the pitch attitude. The increased size of the attitude display on the EFD system greatly increases situational awareness for the pilot. Most attitude indicators span the entire width of the PFD screen.

The aircraft pitch attitude is controlled by changing the deflection of the elevator. As the pilot pulls back on the control yoke causing the elevator to rise, the yellow chevron will begin to show a displacement up from the artificial horizon line. This is caused by the AHRS unit sensing the changing angle between the longitudinal plane of the earth and the longitudinal axis of the aircraft.

The attitude indicator displayed on the PFD screen is a representation of outside visual cues. Rather than rely on the natural horizon visible during visual flight rules (VFR) flight, the pilot must rely on the artificial horizon of the PFD screen.

During normal cruise airspeed, the point of the yellow chevron (aircraft symbol) will be positioned on the artificial horizon. Unlike conventional attitude indicators, the EFD attitude indicator does not allow for manipulating the position of the chevron in relationship to the artificial horizon. The position is fixed and therefore will always display the pitch angle as calculated by the AHRS unit.

Figure 5-48. *Pitch Attitude Decreasing and Airspeed Increasing—Indicates Need to Increase Pitch.*

Figure 5-49. *Various Pitch Attitudes (Right), Aircraft Shown in Level Flight.*

The attitude indicator only shows pitch attitude and does not indicate altitude. A pilot should not attempt to maintain level flight using the attitude indicator alone. It is important for the pilot to understand how small displacements both up and down can affect the altitude of the aircraft. To achieve this, the pilot should practice increasing the pitch attitude incrementally to become familiar with how each degree of pitch changes the altitude. *[Figures 5-50* and *5-51]* In both cases, the aircraft will slow and gain altitude.

The full height of the chevron is approximately 5° and provides an accurate reference for pitch adjustment. It is imperative that the pilot make the desired changes to pitch by referencing the attitude indicator and then trimming off any excess control pressures. Relieving these pressures will allow for a more stabilized flight and will reduce pilot work load. Once the aircraft is trimmed for level flight, the pilot must smoothly and precisely manipulate the elevator control forces in order to change the pitch attitude.

To master the ability to smoothly control the elevator, a pilot must develop a very light touch on the control yoke. The thumb and two fingers are normally sufficient to move the control yoke. The pilot should avoid griping the yoke with a full fist. When a pilot grips the yoke with a full fist, there is a tendency to apply excess pressures, thus changing the aircraft attitude.

Practice making smooth, small pitch changes both up and down until precise corrections can be made. With practice a pilot will be able to make pitch changes in 1° increments, smoothly controlling the attitude of the aircraft.

The last step in mastering elevator control is trim. Trimming the aircraft to relieve any control pressures is essential for smooth attitude instrument flight. To accomplish this, momentarily release the control yoke. Note which way the aircraft pitch attitude wants to move. Grasp the control yoke again and then reapply the pressure to return the attitude to the previous position. Apply trim in the direction of the control pressure. Small applications of trim will make large changes in the pitch attitude. Be patient and make multiple changes to trim, if necessary.

Once the aircraft is in trim, relax on the control yoke as much as practicable. When pressure is held on the yoke, unconscious pressures are applied to the elevator and ailerons which displaces the aircraft from its desired flight path. If the aircraft is in trim, in calm, non-turbulent air, a pilot should be able to release the control yoke and maintain level flight for extended periods of time. This is one of the hardest skills to learn prior to successfully flying in instrument meteorological conditions (IMC).

Figure 5-50. *Pitch Indications for Various Attitudes (1° through 5°).*

Figure 5-51. *Pitch Illustrated at 10°.*

Altimeter

At constant power, any deviation from level flight (except in turbulent air) must be the result of a pitch change. If the power is constant, the altimeter gives an indirect indication of the pitch attitude in level flight. Since the altitude should remain constant when the airplane is in level flight, any deviation from the desired altitude signals the need for a pitch change. For example, if the aircraft is gaining altitude, the nose must be lowered.

In the PFD, as the pitch starts to change, the altitude trend indicator on the altitude tape will begin to show a change in the direction of displacement. The rate at which the trend indicator grows and the altimeter numbers change aids the pilot in determining how much of a pitch change is necessary to stop the trend.

As a pilot becomes familiar with a specific aircraft's instruments, he or she learns to correlate pitch changes, altimeter tapes, and altitude trend indicators. By adding the altitude tape display and the altitude trend indicator into the scan along with the attitude indicator, a pilot starts to develop the instrument cross-check.

Partial Panel Flight

One important skill to practice is partial panel flight by referencing the altimeter as the primary pitch indicator. Practice controlling the pitch by referencing the altitude tape and trend indicator alone without the use of the attitude indicator. Pilots need to learn to make corrections to altitude deviations by referencing the rate of change of the altitude tape and trend indicator. When operating in IMC and in a partial panel configuration, the pilot should avoid abrupt changes to the control yoke. Reacting abruptly to altitude changes can lead to large pitch changes and thus a larger divergence from the initial altitude.

When a pilot is controlling pitch by the altitude tape and altitude trend indicators alone, it is possible to overcontrol the aircraft by making a larger than necessary pitch correction. Overcontrolling will cause the pilot to move from a nose-high attitude to a nose-low attitude and vice versa. Small changes to pitch are required to insure prompt corrective actions are taken to return the aircraft to its original altitude with less confusion.

When an altitude deviation occurs, two actions need to be accomplished. First, make a smooth control input to stop the needle movement. Once the altitude tape has stopped moving, make a change to the pitch attitude to start back to the entry altitude.

During instrument flight with limited instrumentation, it is imperative that only small and precise control inputs are made. Once a needle movement is indicated denoting a deviation in altitude, the pilot needs to make small control inputs to stop the deviation. Rapid control movements will only compound the deviation by causing an oscillation effect. This type of oscillation can quickly cause the pilot to become disoriented and begin to fixate on the altitude. Fixation on the altimeter can lead to a loss of directional control as well as airspeed control.

As a general rule of thumb, for altitude deviations less than 100 feet, utilize a pitch change of 1°, which equates to 1/5 of the thickness of the chevron. Small incremental pitch changes will allow the performance to be evaluated and will eliminate overcontrolling of the aircraft.

Instrumentation needs to be utilized collectively, but failures will occur which leave the pilot with only limited instrumentation. That is why partial panel flying training is important. If the pilot understands how to utilize each instrument independently, no significant change is encountered in carrying out the flight when other instruments fail.

VSI Tape

The VSI tape provides for an indirect indication of pitch attitude and gives the pilot a more immediate indication of a pending altitude deviation. In addition to trend information, the vertical speed also gives a rate indication. By using the VSI tape in conjunction with the altitude trend tape, a pilot will have a better understanding of how much of a correction needs to be made. With practice, the pilot will learn the performance of a particular aircraft and know how much pitch change is required in order to correct for a specific rate indication.

Unlike older analog VSIs, new glass panel displays have instantaneous VSIs. Older units had a lag designed into the system that was utilized to indicate rate information. The new glass panel displays utilize a digital air data computer that does not indicate a lag. Altitude changes are shown immediately and can be corrected for quickly.

The VSI tape should be used to assist in determining what pitch changes are necessary to return to the desired altitude. A good rule of thumb is to use a vertical speed rate of change that is double the altitude deviation. However, at no time should the rate of change be more than the optimum rate of climb or descent for the specific aircraft being flown. For example, if the altitude is off by 200 feet from the desired altitude, then a 400 feet per minute (fpm) rate of change would be sufficient to get the aircraft back to the original altitude. If the altitude has changed by 700 feet, then doubling that would necessitate a 1,400 fpm change. Most aircraft are not capable of that, so restrict changes to no more than optimum climb and descent. An optimum rate of change would vary between 500 and 1,000 fpm.

One error the instrument pilot encounters is overcontrolling. Overcontrolling occurs when a deviation of more than 200 fpm is indicated over the optimum rate of change. For example, an altitude deviation of 200 feet is indicated on the altimeter, a vertical speed rate of 400 feet should be indicated on the gauge. If the vertical speed rate showed 600 fpm (200 more than optimum), the pilot would be overcontrolling the aircraft.

When returning to altitude, the primary pitch instrument is the VSI tape. If any deviation from the desired vertical speed is indicated, make the appropriate pitch change using the attitude indicator.

As the aircraft approaches the target altitude, the vertical speed rate can be slowed in order to capture the altitude in a more stabilized fashion. Normally within 10 percent of the rate of climb or descent from the target altitude, begin to slow the vertical speed rate in order to level off at the target altitude. This will allow the pilot to level at the desired altitude without rapid control inputs or experiencing discomfort due to G-load.

Airspeed Indicator (ASI)

The ASI presents an indirect indication of the pitch attitude. At a constant power setting and pitch attitude, airspeed remains constant. As the pitch attitude lowers, airspeed increases, and the nose should be raised.

As the pitch attitude is increased, the nose of the aircraft will raise, which will result in an increase in the angle of attack as well as an increase in induced drag. The increased drag will begin to slow the momentum of the aircraft which will be indicated on the ASI. The airspeed trend indicator will show a trend as to where the airspeed will be in 6 seconds. Conversely, if the nose of the aircraft should begin to fall, the angle of attack as well as induced drag will decrease.

There is a lag associated with the ASI when using it as a pitch instrument. It is not a lag associated with the construction of the ASI, but a lag associated with momentum change. Depending on the rate of momentum change, the ASI may not indicate a pitch change in a timely fashion. If the ASI is being used as the sole reference for pitch change, it may not allow for a prompt correction. However, if smooth pitch changes are executed, modern glass panel displays are capable of indicating 1 knot changes in airspeed and also capable of projecting airspeed trends.

When flying by reference to flight instruments alone, it is imperative that all of the flight instruments be cross-checked for pitch control. By cross-checking all pitch related instruments, the pilot can better visualize the aircraft attitude at all times.

As previously stated, the primary instrument for pitch is the instrument that gives the pilot the most pertinent information for a specific parameter. When in level flight and maintaining a constant altitude, what instrument shows a direct indication of altitude? The only instrument that is capable of showing altitude is the altimeter. The other instruments are supporting instruments that are capable of showing a trend away from altitude, but do not directly indicate an altitude.

The supporting instruments forewarn of an impending altitude deviation. With an efficient cross-check, a proficient pilot will be better able to maintain altitude.

Bank Control

This discussion assumes the aircraft is being flown in coordinated flight which means the longitudinal axis of the aircraft is aligned with the relative wind. On the PFD, the attitude indicator shows if the wings are level. The turn rate indicator, slip/skid indicator, and the heading indicator also indicate whether or not the aircraft is maintaining a straight (zero bank) flight path.

Attitude Indicator

The attitude indicator is the only instrument on the PFD that has the capability of displaying the precise bank angle of the aircraft. This is made possible by the display of the roll scale depicted as part of the attitude indicator.

Figure 5-52 identifies the components that make up the attitude indicator display. Note that the top of the display is blue, representing sky, the bottom is brown, depicting dirt, and the white line separating them is the horizon. The lines parallel to the horizon line are the pitch scale which is marked in 5° increments and labeled every 10°. The pitch scale always remains parallel to the horizon.

The curved line in the blue area is the roll scale. The triangle on the top of the scale is the zero index. The hash marks on the scale represent the degree of bank. *[Figure 5-53]* The roll scale always remains in the same position relative to the horizon line.

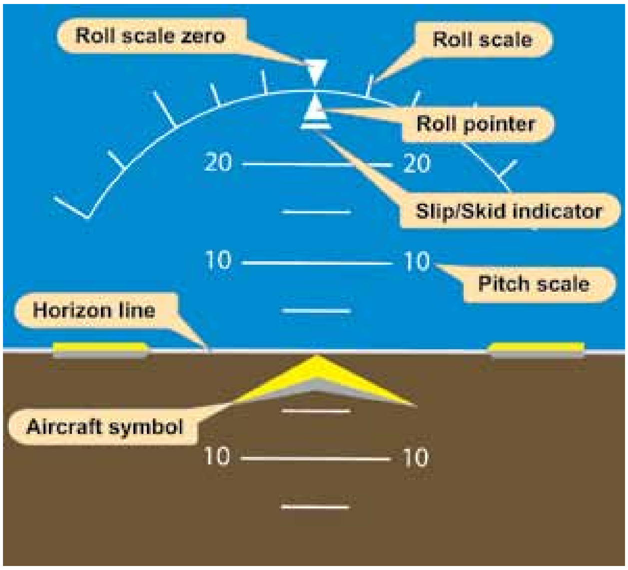

Figure 5-52. *Attitude Indicator.*

The roll pointer indicates the direction and degree of bank. *[Figure 5-53]* The roll pointer is aligned with the aircraft symbol. The roll pointer indicates the angle of the lateral axis of the aircraft compared to the natural horizon. The slip/skid indicator will show if the longitudinal axis of the aircraft is aligned with the relative wind, which is coordinated flight. With the roll index and the slip/skid indicator aligned, any deflection, either right or left of the roll index will cause the aircraft to turn in that direction. With the small graduations on the roll scale, it is easy to determine the bank angle within approximately 1°. In coordinated flight, if the roll index is aligned with the roll pointer, the aircraft is achieving straight flight.

An advantage of EFDs is the elimination of the precession error. Precession error in analog gauges is caused by forces being applied to a spinning gyro. With the new solid state instruments, precession error has been eliminated.

Since the attitude indicator is capable of showing precise pitch and bank angles, the only time that the attitude indicator will be a primary instrument is when attempting to fly at a specific bank angle or pitch angle. Other times, the attitude instrument can be thought of as a control instrument.

Horizontal Situation Indicator (HSI)

The HSI is a rotating 360° compass card that indicates magnetic heading. The HSI is the only instrument that is capable of showing exact headings. The magnetic compass can be used as a backup instrument in case of an HSI failure; however, due to erratic, unstable movements, it is more likely to be used a supporting instrument.

In order for the pilot to achieve the desired rate of change, it is important for him or her to understand the relationship

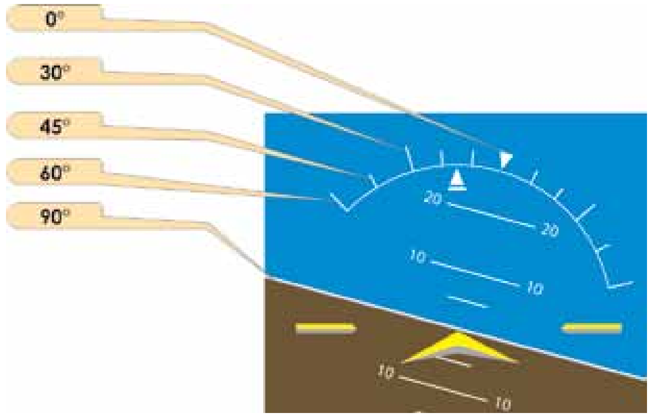

Figure 5-53. *Attitude Indicator Showing a 15° left bank.*

between the rate at which the HSI changes heading displays and the amount of bank angle required to meet that rate of change. A very small rate of heading change means the bank angle is small, and it will take more time to deviate from the desired straight flight path. A larger rate of heading change means a greater bank angle will happen at a faster rate.

Heading Indicator

The heading indicator is the large black box with a white number that indicates the magnetic heading of the aircraft. *[Figure 5-54]* The aircraft heading is displayed to the nearest degree. When this number begins to change, the pilot should be aware that straight flight is no longer being achieved.

Turn Rate Indicator

The turn rate indicator gives an indirect indication of bank. It is a magenta trend indicator capable of displaying half-standard as well as standard rate turns to both the left and right. *[Figure 5-54]* The turn indicator is capable of indicating turns up to 4° per second by extending the magenta line outward from the standard rate mark. If the rate of turn has

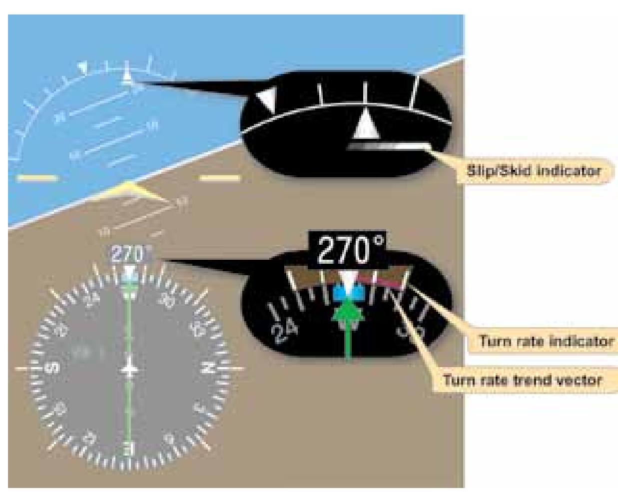

Figure 5-54. *Slip/Skid and Turn Rate Indicator.*

exceeded 4° per second, the magenta line can not precisely indicate where the heading will be in the next 6 seconds, the magenta line freezes and an arrowhead will be displayed. This alerts the pilot to the fact that the normal range of operation has been exceeded.

Slip/Skid Indicator

The slip/skid indicator is the small portion of the lower segmented triangle displayed on the attitude indicator. This instrument depicts whether the aircraft's longitudinal axis is aligned with the relative wind. *[Figure 5-54]*

The pilot must always remember to cross-check the roll index to the roll pointer when attempting to maintain straight flight. Any time the heading remains constant and the roll pointer and the roll index are not aligned, the aircraft is in uncoordinated flight. To make a correction, the pilot should apply rudder pressure to bring the aircraft back to coordinated flight.

Power Control

Power produces thrust which, with the appropriate angle of attack of the wing, overcomes the forces of gravity, drag, and inertia to determine airplane performance.

Power control must be related to its effect on altitude and airspeed, since any change in power setting results in a change in the airspeed or the altitude of the airplane. At any given airspeed, the power setting determines whether the airplane is in level flight, in a climb, or in a descent. If the power is increased in straight-and-level flight and the airspeed held constant, the airplane will climb; if power is decreased while the airspeed is held constant, the airplane will descend. On the other hand, if altitude is held constant, the power applied will determine the airspeed.

The relationship between altitude and airspeed determines the need for a change in pitch or power. If the airspeed is off the desired value, always check the altimeter before deciding that a power change is necessary. Think of altitude and airspeed as interchangeable; altitude can be traded for airspeed by lowering the nose, or convert airspeed to altitude by raising the nose. If altitude is higher than desired and airspeed is low, or vice versa, a change in pitch alone may return the airplane to the desired altitude and airspeed. *[Figure 5-55]* If both airspeed and altitude are high or if both are low, then a change in both pitch and power is necessary in order to return to the desired airspeed and altitude. *[Figure 5-56]*

For changes in airspeed in straight-and-level flight, pitch, bank, and power must be coordinated in order to maintain constant altitude and heading. When power is changed to vary airspeed in straight-and-level flight, a single-engine, propeller-driven airplane tends to change attitude around all axes of movement. Therefore, to maintain constant altitude and heading, apply various control pressures in proportion to the change in power. When power is added to increase airspeed, the pitch instruments indicate a climb unless forward-elevator control pressure is applied as the airspeed changes. With an increase in power, the airplane tends to yaw and roll to the left unless counteracting aileron and rudder pressures are applied. Keeping ahead of these changes requires increasing cross-check speed, which varies with the type of airplane and its torque characteristics, the extent of power and speed change involved.

Power Settings

Power control and airspeed changes are much easier when approximate power settings necessary to maintain various airspeeds in straight-and-level flight are known in advance. However, to change airspeed by any appreciable amount, the common procedure is to underpower or overpower on initial power changes to accelerate the rate of airspeed change. (For small speed changes, or in airplanes that decelerate or accelerate rapidly, overpowering or underpowering is not necessary.)

Figure 5-55. *An aircraft decreasing in airspeed while gaining altitude. In this case, the pilot has decreased pitch.*

Figure 5-56. *Figure shows both an increase in speed and altitude where pitch adjustment alone is insufficient. In this situation, a reduction of power is also necessary.*

Consider the example of an airplane that requires 23" of manifold pressure (Hg) to maintain a normal cruising airspeed of 120 knots, and 18" Hg to maintain an airspeed of 100 knots. The reduction in airspeed from 120 knots to 100 knots while maintaining straight-and-level flight is discussed below and illustrated in *Figures 5-57, 5-58,* and *5-59*.

Instrument indications, prior to the power reduction, are shown in *Figure 5-57*. The basic attitude is established and maintained on the attitude indicator. The specific pitch, bank, and power control requirements are detected on these primary instruments:

Altimeter—Primary Pitch
Heading Indicator—Primary Bank
Airspeed Indicator—Primary Power

Supporting pitch and bank instruments are shown in *Figure 5-57*. Note that the supporting power instrument is the manifold pressure gauge (or tachometer if the propeller is fixed pitch). However, when a smooth power reduction to approximately 15" Hg (underpower) is made, the manifold pressure gauge becomes the primary power instrument. *[Figure 5-58]* With practice, power setting can be changed with only a brief glance at the power instrument, by sensing the movement of the throttle, the change in sound, and the changes in the feel of control pressures.

As the thrust decreases, increase the speed of the cross-check and be ready to apply left rudder, back-elevator, and aileron control pressure the instant the pitch-and-bank instruments show a deviation from altitude and heading. As proficiency is obtained, a pilot will learn to cross-check, interpret, and control the changes with no deviation of heading and altitude. Assuming smooth air and ideal control technique, as airspeed decreases, a proportionate increase in airplane pitch attitude is required to maintain altitude. Similarly, effective torque control means counteracting yaw with rudder pressure.

As the power is reduced, the altimeter is primary for pitch, the heading indicator is primary for bank, and the manifold pressure gauge is momentarily primary for power (at 15" Hg in *Figure 5-58*). Control pressures should be trimmed off as the airplane decelerates. As the airspeed approaches the desired airspeed of 100 knots, the manifold pressure is adjusted to approximately 18" Hg and becomes the supporting power instrument. The ASI again becomes primary for power. *[Figure 5-58]*

Airspeed Changes in Straight-and-Level Flight

Practice of airspeed changes in straight-and-level flight provides an excellent means of developing increased proficiency in all three basic instrument skills, and brings out some common errors to be expected during training in straight-and-level flight. Having learned to control the airplane in a clean configuration (minimum drag conditions), increase proficiency in cross-check and control by practicing speed changes while extending or retracting the flaps and landing gear. While practicing, be sure to comply with the airspeed limitations specified in the POH/AFM for gear and flap operation.

Figure 5-57. *Straight-and-Level Flight (Normal Cruising Speed).*

Figure 5-58. *Straight-and-Level Flight (Airspeed Decreasing).*

Figure 5-59. *Straight-and-Level Flight (Reduced Airspeed Stabilized).*

Sudden and exaggerated attitude changes may be necessary in order to maintain straight-and-level flight as the landing gear is extended and the flaps are lowered in some airplanes. The nose tends to pitch down with gear extension, and when flaps are lowered, lift increases momentarily (at partial flap settings) followed by a marked increase in drag as the flaps near maximum extension.

Control technique varies according to the lift and drag characteristics of each airplane. Accordingly, knowledge of the power settings and trim changes associated with different combinations of airspeed, gear, and flap configurations will reduce instrument cross-check and interpretation problems. *[Figure 5-60]*

For example, assume that in straight-and-level flight instruments indicate 120 knots with power at 23" Hg manifold pressure/2,300 revolutions per minute (rpm), gear and flaps up. After reduction in airspeed, with gear and flaps fully extended, straight-and-level flight at the same altitude requires 25" Hg manifold pressure/2,500 rpm. Maximum gear extension speed is 115 knots; maximum flap extension speed is 105 knots. Airspeed reduction to 95 knots, gear and flaps down, can be made in the following manner:

1. Maintain rpm at 2,500, since a high power setting will be used in full drag configuration.
2. Reduce manifold pressure to 10" Hg. As the airspeed decreases, increase cross-check speed.
3. Make trim adjustments for an increased angle of attack and decrease in torque.
4. Lower the gear at 115 knots. The nose may tend to pitch down and the rate of deceleration increases. Increase pitch attitude to maintain constant altitude, and trim off some of the back-elevator pressures. If full flaps are lowered at 105 knots, cross-check, interpretation, and control must be very rapid. A simpler technique is to stabilize attitude with gear down before lowering the flaps.
5. Since 18" Hg manifold pressure will hold level flight at 100 knots with the gear down, increase power smoothly to that setting as the ASI shows approximately 105 knots, and retrim. The attitude indicator now shows approximately two-and-a-half bar width nose-high in straight-and-level flight.
6. Actuate the flap control and simultaneously increase power to the predetermined setting (25" Hg) for the desired airspeed, and trim off the pressures necessary to hold constant altitude and heading. The attitude indicator now shows a bar width nose-low in straight-and-level flight at 95 knots.

Figure 5-60. *Cross-check Supporting Instruments.*

Trim Technique

Trim control is one of the most important flight habits to cultivate. Trimming refers to relieving any control pressures that need to be applied by the pilot to the control surfaces to maintain a desired flight attitude. The desired result is for the pilot to be able to take his or her hands off the control surfaces and have the aircraft remain in the current attitude. Once the aircraft is trimmed for hands-off flight, the pilot is able to devote more time to monitoring the flight instruments and other aircraft systems.

In order to trim the aircraft, apply pressure to the control surface that needs trimming and roll the trim wheel in the direction pressure is being held. Relax the pressure that is being applied to the control surface and monitor the primary instrument for that attitude. If the desired performance is achieved, fly hands off. If additional trimming is required, redo the trimming steps.

An aircraft is trimmed for a specific airspeed, not pitch attitude or altitude. Any time an aircraft changes airspeed there is a need to re-trim. For example, an aircraft is flying at 100 knots straight-and-level. An increase of 50 rpm will cause the airspeed to increase. As the airspeed increases, additional lift will be generated and the aircraft will climb. Once the additional thrust has stabilized at some higher altitude, the airspeed will again stabilize at 100 knots.

This demonstrates how trim is associated with airspeed and not altitude. If the initial altitude is to be maintained, forward pressure would need to be applied to the control wheel while the trim wheel needs to be rolled forward to eliminate any control pressures. Rolling forward on the trim wheel is equal to increasing for a trimmed airspeed. Any time the airspeed is changed, re-trimming will be required. Trimming can be accomplished during any transitional period; however, prior to final trimming, the airspeed must be held constant. If the airspeed is allowed to change, the trim will not be adjusted properly and the altitude will vary until the airspeed for which the aircraft is trimmed is achieved.

Common Errors in Straight-and-Level Flight

Pitch

Pitch errors usually result from the following errors:

1. Improper adjustment of the yellow chevron (aircraft symbol) on the attitude indicator.

   Corrective Action: Once the aircraft has leveled off and the airspeed has stabilized, make small corrections to the pitch attitude to achieve the desired performance. Cross-check the supporting instruments for validation.

2. Insufficient cross-check and interpretation of pitch instruments. *[Figure 5-61]*

Figure 5-61. *Insufficient cross-check. The problem is power and not nose-high. In this case, the pilot decreased pitch inappropriately.*

Example: The airspeed indication is low. The pilot, believing a nose-high pitch attitude exists, applies forward pressure without noting that a low power setting is the cause of the airspeed discrepancy.

Corrective Action: Increase the rate of cross-check of all the supporting flight instruments. Airspeed and altitude should be stabilized before making a control input.

3. Acceptance of deviations.

   Example: A pilot has an altitude range of ±100 feet according to the practical test standards for straight-and level-flight. When the pilot notices that the altitude has deviated by 60 feet, no correction is made because the altitude is holding steady and is within the standards.

   Corrective Action: The pilot should cross-check the instruments and, when a deviation is noted, prompt corrective actions should be taken in order to bring the aircraft back to the desired altitude. Deviations from altitude should be expected but not accepted.

4. Overcontrolling—Excessive Pitch Changes.

   Example: A pilot notices a deviation in altitude. In an attempt to quickly return to altitude, the pilot makes a large pitch change. The large pitch change destabilizes the attitude and compounds the error.

   Corrective Action: Small, smooth corrections should be made in order to recover to the desired altitude (0.5° to 2° depending on the severity of the deviation). Instrument flying is comprised of small corrections to maintain the aircraft attitude. When flying in IMC, a pilot should avoid making large attitude changes in order to avoid loss of aircraft control and spatial disorientation.

5. Failure to Maintain Pitch Corrections.

   Pitch changes need to be made promptly and held for validation. Many times pilots will make corrections and allow the pitch attitude to change due to not trimming the aircraft. It is imperative that any time a pitch change is made; the trim is readjusted in order to eliminate any control pressures that are being held. A rapid cross-check will aid in avoiding any deviations from the desired pitch attitude.

   Example: A pilot notices a deviation in altitude. A change in the pitch attitude is accomplished but no adjustment to the trim is made. Distractions cause the pilot to slow the cross-check and an inadvertent reduction in the pressure to the control column commences. The pitch attitude then changes, thus complicating recovery to the desired altitude.

   Corrective Action: The pilot should initiate a pitch change and then immediately trim the aircraft to relieve any control pressures. A rapid cross-check should be established in order to validate the desired performance is being achieved.

6. Fixation During Cross-Check.

   Devoting an unequal amount of time to one instrument either for interpretation or assigning too much importance to an instrument. Equal amounts of time should be spent during the cross-check to avoid an unnoticed deviation in one of the aircraft attitudes.

   Example: A pilot makes a correction to the pitch attitude and then devotes all of the attention to the altimeter to determine if the pitch correction is valid. During this time, no attention is paid to the heading indicator which shows a turn to the left. *[Figure 5-62]*

   Corrective Action: The pilot should monitor all instrumentation during the cross-check. Do not fixate on one instrument waiting for validation. Continue to scan all instruments to avoid allowing the aircraft to begin a deviation in another attitude.

Heading

Heading errors usually result from but are not limited to the following errors:

1. Failure to cross-check the heading indicator, especially during changes in power or pitch attitude.
2. Misinterpretation of changes in heading, with resulting corrections in the wrong direction.
3. Failure to note and remember a preselected heading.
4. Failure to observe the rate of heading change and its relation to bank attitude.
5. Overcontrolling in response to heading changes, especially during changes in power settings.
6. Anticipating heading changes with premature application of rudder pressure.
7. Failure to correct small heading deviations. Unless zero error in heading is the goal, a pilot will tolerate larger and larger deviations. Correction of a 1° error takes far less time and concentration than correction of a 20° error.
8. Correcting with improper bank attitude. If correcting a 10° heading error with a 20° bank correction, the aircraft will roll past the desired heading before the bank is established, requiring another correction in the opposite direction. Do not multiply existing errors with errors in corrective technique.

Figure 5-62. *The pilot has fixated on pitch and altitude, leaving bank indications unattended. Note the trend line to the left.*

9. Failure to note the cause of a previous heading error and thus repeating the same error. For example, the airplane is out of trim, with a left wing low tendency. Repeated corrections for a slight left turn are made, yet trim is ignored.

Power

Power errors usually result from but are not limited to the following errors:

1. Failure to become familiar with the aircraft's specific power settings and pitch attitudes.
2. Abrupt use of throttle.
3. Failure to lead the airspeed when making power changes, climbs or descents.

   Example: When leveling off from a descent, increase the power in order to avoid the airspeed from bleeding off due to the decrease in momentum of the aircraft. If the pilot waits to bring in the power until after the aircraft is established in the level pitch attitude, the aircraft will have already decreased below the speed desired which will require additional adjustment in the power setting.
4. Fixation on airspeed tape or manifold pressure indications during airspeed changes, resulting in erratic control of airspeed, power, as well as pitch and bank attitudes.

Trim

Trim errors usually result from the following faults:

1. Improper adjustment of seat or rudder pedals for comfortable position of legs and feet. Tension in the ankles makes it difficult to relax rudder pressures.
2. Confusion about the operation of trim devices, which differ among various airplane types. Some trim wheels are aligned appropriately with the airplane's axes; others are not. Some rotate in a direction contrary to expectations.
3. Failure to understand the principles of trim and that the aircraft is being trimmed for airspeed, not a pitch attitude.
4. Faulty sequence in trim techniques. Trim should be utilized to relieve control pressures, not to change pitch attitudes. The proper trim technique has the pilot holding the control wheel first and then trimming to relieve any control pressures. Continuous trim changes will be required as the power setting is changed. Utilize the trim continuously, but in small amounts.

Straight Climbs and Descents

Each aircraft will have a specific pitch attitude and airspeed that corresponds to the most efficient climb rate for a specified weight. The POH/AFM contains the speeds that will produce the desired climb. These numbers are based on maximum gross weight. Pilots must be familiar with how the speeds will vary with weight so they can compensate during flight.

Entry

Constant Airspeed Climb From Cruise Airspeed

To enter a constant airspeed climb from cruise airspeed, slowly and smoothly apply aft elevator pressure in order to raise the yellow chevron (aircraft symbol) until the tip points to the desired degree of pitch. *[Figure 5-63]* Hold the aft control pressure and smoothly increase the power to the climb power setting. This increase in power may be initiated either prior to initiating the pitch change or after having established the desired pitch setting. Consult the POH/AFM for specific climb power settings if anything other than a full power climb is desired. Pitch attitudes will vary depending on the type of aircraft being flown. As airspeed decreases, control forces will need to be increased in order to compensate for the additional elevator deflection required to maintain attitude. Utilize trim to eliminate any control pressures. By effectively using trim, the pilot will be better able to maintain the desired pitch without constant attention. The pilot is thus able to devote more time to maintaining an effective scan of all instrumentation.

The VSI should be utilized to monitor the performance of the aircraft. With a smooth pitch transition, the VSI tape should begin to show an immediate trend upward and stabilize on a

Figure 5-63. *Constant Airspeed Climb From Cruise Airspeed.*

rate of climb equivalent to the pitch and power setting being utilized. Depending on current weight and atmospheric conditions, this rate will be different. This will require the pilot to be knowledgeable of how weight and atmospheric conditions affect aircraft performance.

Once the aircraft is stabilized at a constant airspeed and pitch attitude, the primary flight instrument for pitch will be the ASI and the primary bank instrument will be the heading indicator. The primary power instrument will be the tachometer or the manifold pressure gauge depending on the aircraft type. If the pitch attitude is correct, the airspeed should slowly decrease to the desired speed. If there is any variation in airspeed, make small pitch changes until the aircraft is stabilized at the desired speed. Any change in airspeed will require a trim adjustment.

Constant Airspeed Climb from Established Airspeed

In order to enter a constant airspeed climb, first complete the airspeed reduction from cruise airspeed to climb airspeed. Maintain straight-and-level flight as the airspeed is reduced. The entry to the climb is similar to the entry from cruise airspeed with the exception that the power must be increased when the pitch attitude is raised. *[Figure 5-64]* Power added after the pitch change will show a decrease in airspeed due to the increased drag encountered. Power added prior to a pitch change will cause the airspeed to increase due to the excess thrust.

Constant Rate Climbs

Constant rate climbs are very similar to the constant airspeed climbs in the way the entry is made. As power is added,

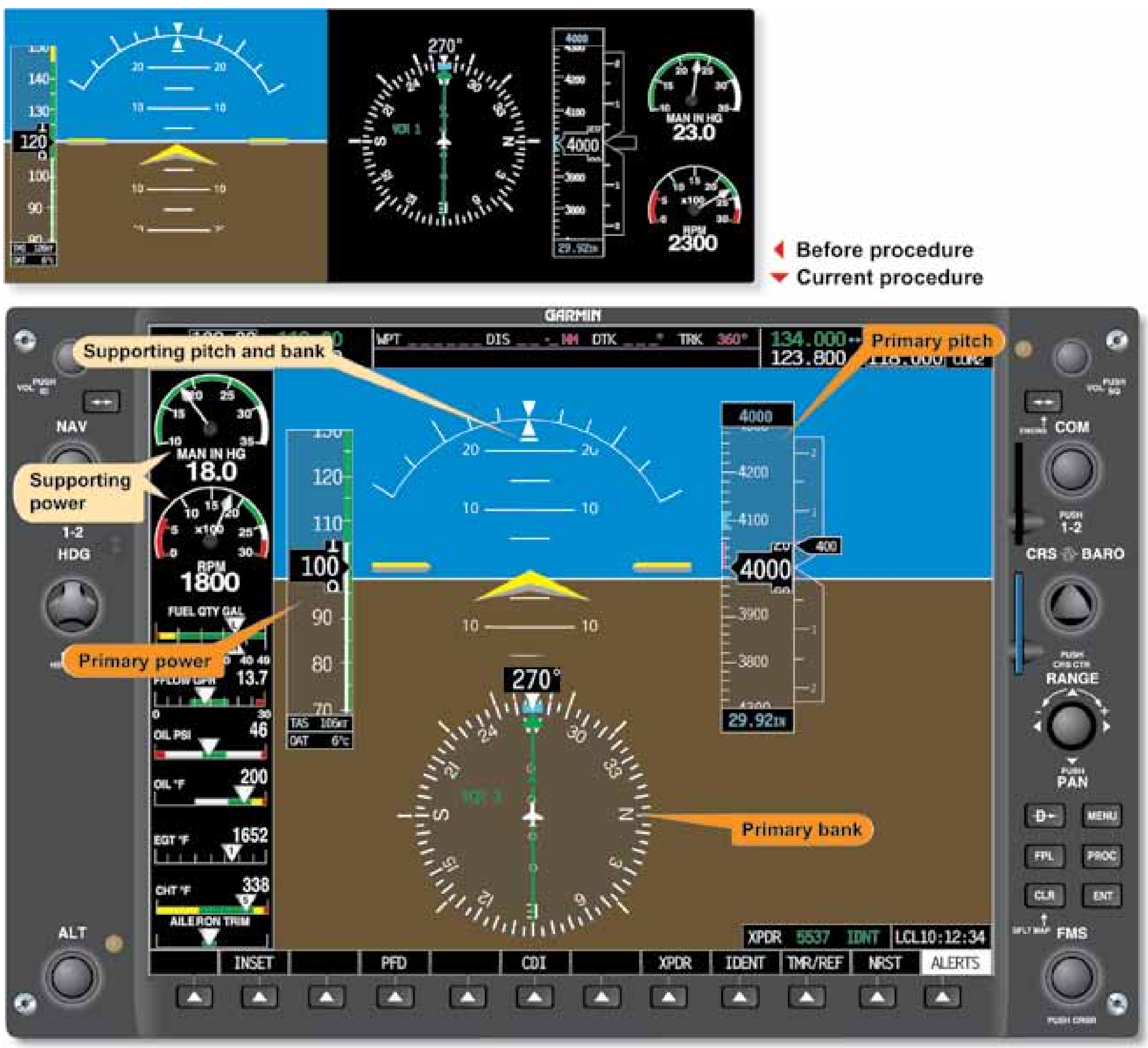

Figure 5-64. *Constant-Airspeed Climb From Established Airspeed.*

smoothly apply elevator pressure to raise the yellow chevron to the desired pitch attitude that equates to the desired vertical speed rate. The primary instrument for pitch during the initial portion of the maneuver is the ASI until the vertical speed rate stabilizes and then the VSI tape becomes primary. The ASI then becomes the primary instrument for power. If any deviation from the desired vertical speed is noted, small pitch changes will be required in order to achieve the desired vertical speed. *[Figure 5-65]*

When making changes to compensate for deviations in performance, pitch, and power, pilot inputs need to be coordinated to maintain a stable flight attitude. For instance, if the vertical speed is lower than desired but the airspeed is correct, an increase in pitch will momentarily increase the vertical speed. However, the increased drag will quickly start to degrade the airspeed if no increase in power is made. A change to any one variable will mandate a coordinated change in the other.

Conversely, if the airspeed is low and the pitch is high, a reduction in the pitch attitude alone may solve the problem. Lower the nose of the aircraft very slightly to see if a power reduction is necessary. Being familiar with the pitch and power settings for the aircraft aids in achieving precise attitude instrument flying.

Leveling Off

Leveling off from a climb requires a reduction in the pitch prior to reaching the desired altitude. If no change in pitch is made until reaching the desired altitude, the momentum of the aircraft causes the aircraft to continue past the desired altitude throughout the transition to a level pitch attitude. The amount of lead to be applied depends on the vertical speed rate. A higher vertical speed requires a larger lead for level off. A good rule of thumb to utilize is to lead the level off by 10 percent of the vertical speed rate (1,000 fpm ÷ 10 = 100 feet lead).

To level off at the desired altitude, refer to the attitude display and apply smooth forward elevator pressure toward the desired level pitch attitude while monitoring the VSI and altimeter tapes. The rates should start to slow and airspeed should begin to increase. Maintain the climb power setting until the airspeed approaches the desired cruise airspeed. Continue to monitor the altimeter to maintain the desired altitude as the airspeed increases. Prior to reaching the cruise airspeed, the power must be reduced to avoid overshooting the desired speed. The amount of lead time that is required depends on the speed at which the aircraft accelerates. Utilization of the airspeed trend indicator can assist by showing how quickly the aircraft will arrive at the desired speed.

Figure 5-65. *Constant Rate Climbs.*

To level off at climbing airspeed, lower the nose to the appropriate pitch attitude for level flight with a simultaneous reduction in power to a setting that will maintain the desired speed. With a coordinated reduction in pitch and power there should be no change in the airspeed.

Descents

Descending flight can be accomplished at various airspeeds and pitch attitudes by reducing power, lowering the nose to a pitch attitude lower than the level flight attitude, or adding drag. Once any of these changes have been made, the airspeed will eventually stabilize. During this transitional phase, the only instrument that will display an accurate indication of pitch is the attitude indicator. Without the use of the attitude indicator (such as in partial panel flight), the ASI tape, the VSI tape, and the altimeter tape will show changing values until the aircraft stabilizes at a constant airspeed and constant rate of descent. The altimeter tape continues to show a descent. Hold pitch constant and allow the aircraft to stabilize. During any change in attitude or airspeed, continuous application of trim is required to eliminate any control pressures that need to be applied to the control yoke. An increase in the scan rate during the transition is important since changes are being made to the aircraft flight path and speed. *[Figure 5-66]*

Entry

Descents can be accomplished with a constant rate, constant airspeed or a combination. The following method can accomplish any of these with or without an attitude indicator. Reduce the power to allow the aircraft to decelerate to the desired airspeed while maintaining straight-and-level flight. As the aircraft approaches the desired airspeed, reduce the

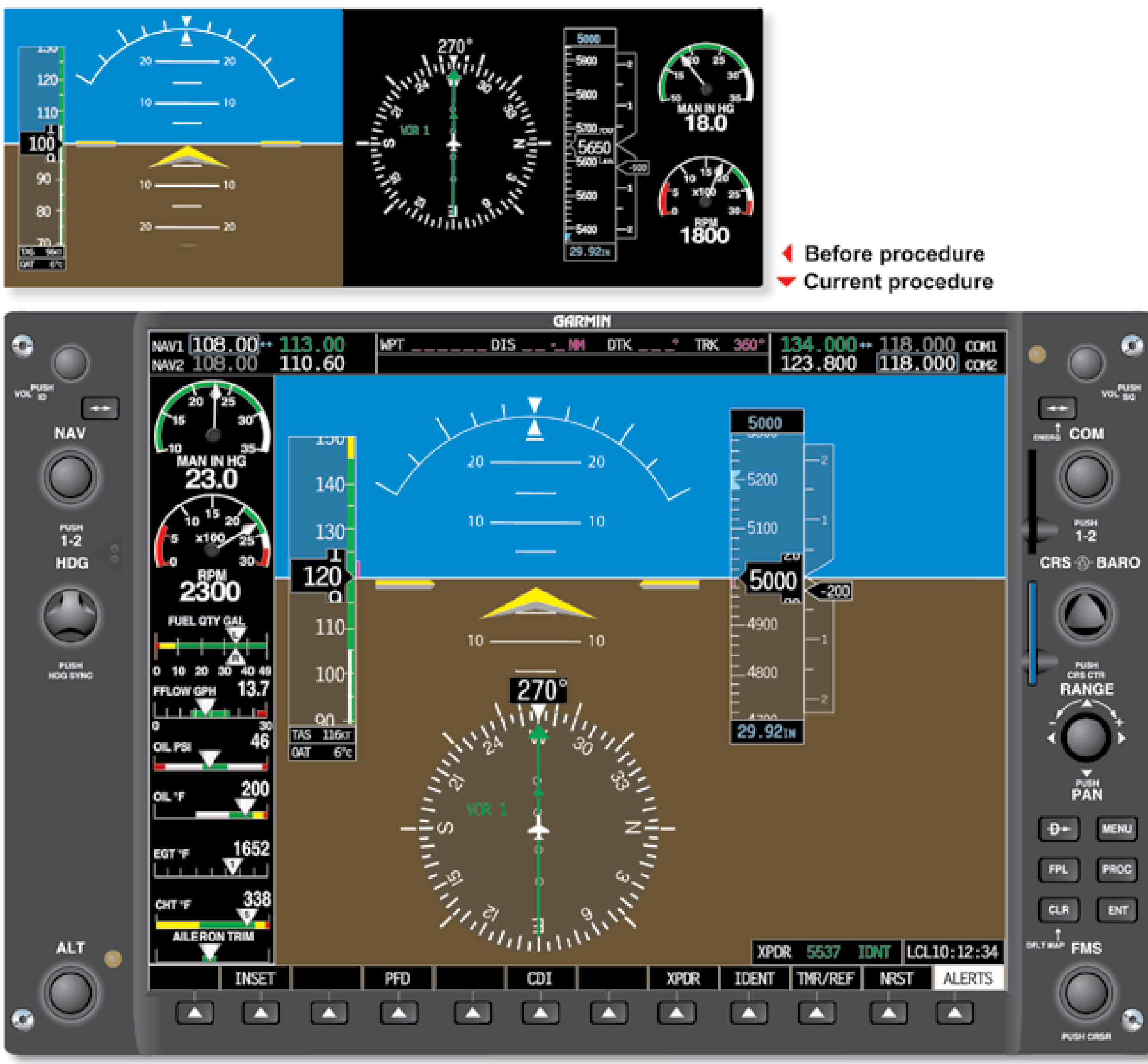

Figure 5-66. *The top image illustrates a reduction of power and descending at 500 fpm to an altitude of 5,000 feet. The bottom image illustrates an increase in power and the initiation of leveling off.*

power to a predetermined value. The airspeed continues to decrease below the desired airspeed unless a simultaneous reduction in pitch is performed. The primary instrument for pitch is the ASI tape. If any deviation from the desired speed is noted, make small pitch corrections by referencing the attitude indicator and validate the changes made with the airspeed tape. Utilize the airspeed trend indicator to judge if the airspeed will be increasing and at what rate. Remember to trim off any control pressures.

The entry procedure for a constant rate descent is the same except the primary instrument for pitch is the VSI tape. The primary instrument for power will be the ASI. When performing a constant rate descent while maintaining a specific airspeed, coordinated use of pitch and power will be required. Any change in pitch directly affects the airspeed. Conversely, any change in airspeed will have a direct impact on vertical speed as long as the pitch is being held constant.

Leveling Off

When leveling off from a descent with the intention of returning to cruise airspeed, first start by increasing the power to cruise prior to increasing the pitch back toward the level flight attitude. A technique used to determine how soon to start the level off is to lead the level off by an altitude corresponding to 10 percent of the rate of descent. For example, if the aircraft is descending at 1,000 fpm, start the level off 100 feet above the level off altitude. If the pitch attitude change is started late, there is a tendency to overshoot the desired altitude unless the pitch change is made with a rapid movement. Avoid making any rapid changes that could lead to control issues or spatial disorientation. Once in level pitch attitude, allow the aircraft to accelerate to the desired speed. Monitor the performance on the airspeed and altitude tapes. Make adjustments to the power in order to correct any deviations in the airspeed. Verify that the aircraft is maintaining level flight by cross-checking the altimeter tape. If deviations are noticed, make an appropriate smooth pitch change in order to arrive back at desired altitude. Any change in pitch requires a smooth coordinated change to the power setting. Monitor the airspeed in order to maintain the desired cruise airspeed.

To level off at a constant airspeed, the pilot must again determine when to start to increase the pitch attitude toward the level attitude. If pitch is the only item that is changing, airspeed varies due to the increase in drag as the aircraft's pitch increases. A smooth coordinated increase in power will need to be made to a predetermined value in order to maintain speed. Trim the aircraft to relieve any control pressure that may have to be applied.

Common Errors in Straight Climbs and Descents

Climbing and descending errors usually result from but are not limited to the following errors:

1. Overcontrolling pitch on beginning the climb. Aircraft familiarization is the key to achieving precise attitude instrument flying. Until the pilot becomes familiar with the pitch attitudes associated with specific airspeeds, the pilot must make corrections to the initial pitch settings. Changes do not produce instantaneous and stabilized results; patience must be maintained while the new speeds and vertical speed rates stabilize. Avoid the temptations to make a change and then rush into making another change until the first one is validated. Small changes will produce more expeditious results and allow for a more stabilized flight path. Large changes to pitch and power are more difficult to control and can further complicate the recovery process.
2. Failure to increase the rate of instrument cross-check. Any time a pitch or power change is made, an increase in the rate a pilot cross-checks the instrument is required. A slow cross-check can lead to deviations in other flight attitudes.
3. Failure to maintain new pitch attitudes. Once a pitch change is made to correct for a deviation, that pitch attitude must be maintained until the change is validated. Utilize trim to assist in maintaining the new pitch attitude. If the pitch is allowed to change, it is impossible to validate whether the initial pitch change was sufficient to correct the deviation. The continuous changing of the pitch attitude delays the recovery process.
4. Failure to utilize effective trim techniques. If control pressures have to be held by the pilot, validation of the initial correction will be impossible if the pitch is allowed to vary. Pilots have the tendency to either apply or relax additional control pressures when manually holding pitch attitudes. Trim allows the pilot to fly without holding pressure on the control yoke.
5. Failure to learn and utilize proper power settings. Any time a pilot is not familiar with an aircraft's specific pitch and power settings, or does not utilize them, a change in flight paths will take longer. Learn pitch and power settings in order to expedite changing the flight path.
6. Failure to cross-check both airspeed and vertical speed prior to making adjustments to pitch and or power. It is possible that a change in one may correct a deviation in the other.

7. Uncoordinated use of pitch and power during level offs. During level offs, both pitch and power settings need to be made in unison in order to achieve the desired results. If pitch is increased before adding power, additional drag will be generated thereby reducing airspeed below the desired value.
8. Failure to utilize supporting pitch instruments which will lead to chasing the VSI. Always utilize the attitude indicator as the control instrument on which to change the pitch.
9. Failure to determine a proper lead time for level off from a climb or descent. Waiting too long can lead to overshooting the altitude.
10. Ballooning—Failure to maintain forward control pressure during level off as power is increased. Additional lift is generated causing the nose of the aircraft to pitch up.

Turns

Standard Rate Turns

The previous sections have addressed flying straight-and-level as well as climbs and descents. However, attitude instrument flying is not accomplished solely by flying in a straight line. At some point, the aircraft will need to be turned to maneuver along victor airways, global positioning system (GPS) courses, and instrument approaches. The key to instrument flying is smooth, controlled changes to pitch and bank. Instrument flying should be a slow but deliberate process that takes the pilot from departure airport to destination airport without any radical flight maneuvers.

A turn to specific heading should be made at standard rate. Standard rate is defined as a turning rate of 3° per second which will yield a complete 360° turn in 2 minutes. A turning rate of 3° per second will allow for a timely heading change, as well as allowing the pilot sufficient time to cross-check the flight instruments and avoid drastic changes to the aerodynamic forces being exerted on the aircraft. At no time should the aircraft be maneuvered faster than the pilot is comfortable cross-checking the flight instruments. Most autopilots are programmed to turn at standard rate.

Establishing A Standard Rate Turn

In order to initiate a standard rate turn, approximate the bank angle and then establish that bank angle on the attitude indicator. A rule of thumb to determine the approximate angle of bank is to use 15 percent of the true airspeed. A simple way to determine this amount is to divide the airspeed by 10 and add one-half the result. For example, at 100 knots, approximately 15° of bank is required (100/10 = 10 + 5 = 15); at 120 knots, approximately 18° of bank is needed for a standard-rate turn. Cross-check the turn rate indicator, located on the HSI, to determine if that bank angle is sufficient to deliver a standard rate turn. Slight modifications may need to be made to the bank angle in order to achieve the desired performance. The primary bank instrument in this case is the turn rate indicator since the goal is to achieve a standard rate turn. The turn rate indicator is the only instrument that can specifically indicate a standard rate turn. The attitude indicator is used only to establish a bank angle (control instrument) but can be utilized as a supporting instrument by cross-checking the bank angle to determine if the bank is greater or less than what was calculated.

As the aircraft rolls into the bank, the vertical component of lift will begin to decrease. *[Figure 5-67]* As this happens, additional lift must be generated to maintain level flight. Apply aft control pressure on the yoke sufficient to stop any altitude loss trend. With the increase in lift that needs to be generated, additional induced drag will also be generated. This additional drag will cause the aircraft to start to decelerate. To counteract this, apply additional thrust by adding power to the power lever. Once altitude and airspeed is being maintained, utilize the trim wheel to eliminate any control forces that need to be held on the control column.

When rolling out from a standard rate turn, the pilot needs to utilize coordinated aileron and rudder and roll-out to a wings level attitude utilizing smooth control inputs. The roll-out rate should be the same as the roll-in rate in order to estimate the lead necessary to arrive at the desired heading without over- or undershooting.

During the transition from the turn back to straight flight, the attitude indicator becomes the primary instrument for bank. Once the wings are level, the heading indicator becomes the primary instrument for bank. As bank decreases, the vertical component increases if the pitch attitude is not decreased sufficiently to maintain level flight. An aggressive cross-check keeps the altimeter stationary if forward control pressure is applied to the control column. As the bank angle is decreased, the pitch attitude should be decreased accordingly in order to arrive at the level pitch attitude when the aircraft reaches zero bank. Remember to utilize the trim wheel to eliminate any excess control forces that would otherwise need to be held.

Common Errors

1. One common error associated with standard rate turns is due to pilot inability to hold the appropriate bank angle that equates to a standard rate. The primary bank instrument during the turn is the turn rate indicator; however the bank angle varies slightly. With an

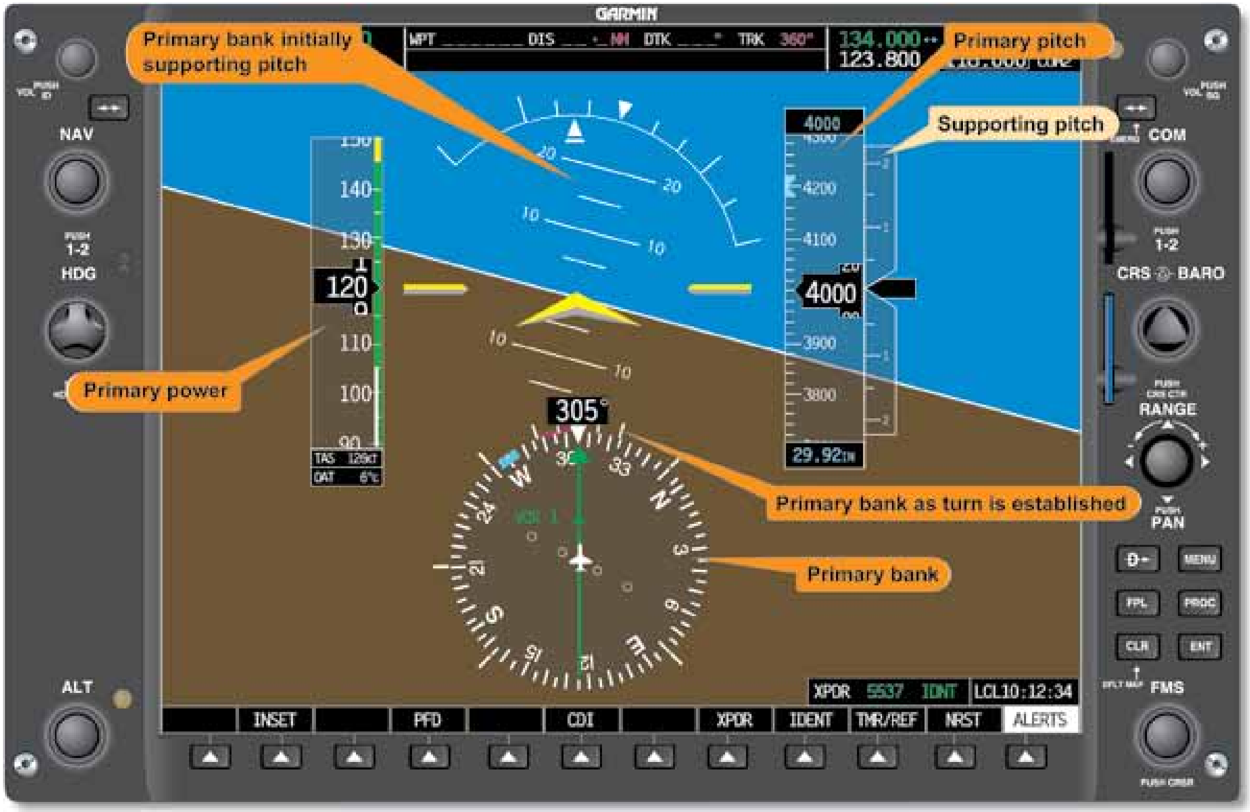

Figure 5-67. *Standard Rate Turn—Constant Airspeed.*

aggressive cross-check, a pilot should be able to minimize errors arising from over- or underbanking.

2. Another error normally encountered during standard rate turns is inefficient or lack of adequate cross-checking. Pilots need to establish an aggressive cross-check in order to detect and eliminate all deviations from altitude, airspeed, and bank angle during a maneuver.
3. Fixation is a major error associated with attitude instrument flying in general. Pilots training for their instrument rating tend to focus on what they perceive to be the most important task at hand and abandon their cross-check by applying all of their attention to the turn rate indicator. A modified radial scan works well to provide the pilot with adequate scanning of all instrumentation during the maneuver.

Turns to Predetermined Headings

Turning the aircraft is one of the most basic maneuvers that a pilot learns during initial flight training. Learning to control the aircraft, maintaining coordination, and smoothly rolling out on a desired heading are all keys to proficient attitude instrument flying.

EFDs allow the pilot to better utilize all instrumentation during all phases of attitude instrument flying by consolidating all traditional instrumentation onto the PFD. The increased size of the attitude indicator, which stretches the entire width of the PFD, allows the pilot to maintain better pitch control while the introduction of the turn rate indicator positioned directly on the compass rose aids the pilot in determining when to begin a roll-out for the desired heading.

When determining what bank angle to utilize when making a heading change, a general rule states that for a small heading change, do not use a bank angle that is greater than the total number of degrees of change needed. For instance, if a heading change of 20° is needed, a bank angle of not more than 20° is required. Another rule of thumb that better defines the bank angle is half the total number of degrees of heading change required, but never greater than standard rate. The exact bank angle that equates to a standard rate turn varies due to true airspeed.

With this in mind and the angle of bank calculated, the next step is determining when to start the roll-out process. For example:

An aircraft begins a turn from a heading of 030° to a heading of 120°. With the given airspeed, a standard rate turn has yielded a 15° bank. The pilot wants to begin a smooth coordinated roll-out to the desired heading when the heading indicator displays approximately 112°. The necessary calculations are:

15° bank (standard rate) ÷ 2 = 7.5°
120° – 7.5° = 112.5°

By utilizing this technique the pilot is better able to judge if any modifications need to be made to the amount of lead once the amount of over- or undershooting is established.

Timed Turns

Timed turns to headings are performed in the same fashion with an EFD as with an analog equipped aircraft. The instrumentation used to perform this maneuver is the turn rate indicator as well as the clock. The purpose of this maneuver is to allow the pilot to gain proficiency in scanning as well as to further develop the pilot's ability to control the aircraft without standard instrumentation.

Timed turns become essential when controlling the aircraft with a loss of the heading indicator. This may become necessary due to a loss of the AHRS unit or the magnetometer. In any case, the magnetic compass will still be available for navigation. The reason for timed turns instead of magnetic compass turns is the simplicity of the maneuver. Magnetic compass turns require the pilot to take into account various errors associated with the compass; timed turns do not.

Prior to initiating a turn, determine if the standard rate indication on the turn rate indicator will actually deliver a 3° per second turn. To accomplish this, a calibration must be made. Establish a turn in either direction at the indicated standard rate. Start the digital timer as the compass rolls past a cardinal heading. Stop the timer once the compass card rolls through another cardinal heading. Roll wings level and compute the rate of turn. If the turn rate indicator is calibrated and indicating correctly, 90° of heading change should take 30 seconds. If the time taken to change heading by 90° is more or less than 30 seconds, then a deflection above or below the standard rate line needs to be made to compensate for the difference. Once the calibration has been completed in one direction, proceed to the opposite direction. When both directions have been calibrated, apply the calibrated calculations to all timed turns.

In order to accomplish a timed turn, the amount of heading change needs to be established. For a change in heading from 120° to a heading of 360°, the pilot calculates the difference and divides that number by 3. In this case, 120° divided by 3° per second equals 40 seconds. This means that it would take 40 seconds for an aircraft to change heading 120° if that aircraft were held in a perfect standard rate turn. Timing for the maneuver should start as the aircraft begins rolling into the standard rate turn. Monitor all flight instruments during this maneuver. The primary pitch instrument is the altimeter. The primary power instrument is the ASI and the primary bank instrument is the turn rate indicator.

Once the calculated time expires, start a smooth coordinated roll-out. As long as the pilot utilizes the same rate of roll-in as roll-out, the time it takes for both will not need to be included in the calculations. With practice the pilot should level the wings on the desired heading. If any deviation has occurred, make small corrections to establish the correct heading.

Compass Turns

The magnetic compass is the only instrument that requires no other source of power for operation. In the event of an AHRS or magnetometer failure, the magnetic compass is the instrument the pilot uses to determine aircraft heading. For a more detailed explanation on the use of the magnetic compass, see page 5-21.

Steep Turns

For the purpose of instrument flight training, a steep turn is defined as any turn in excess of standard rate. A standard rate turn is defined as 3° per second. The bank angle that equates to a turn rate of 3° per second varies according to airspeed. As airspeed increases, the bank angle must be increased. The exact bank angle that equates to a standard rate turn is unimportant. Normal standard rate turn bank angles range from 10° to 20°. The goal of training in steep turn maneuvers is pilot proficiency in controlling the aircraft with excessive bank angles.

Training in excessive bank angles will challenge the pilot in honing cross-checking skills and improve altitude control throughout a wider range of flight attitudes. Although the current instrument flight check practical test standards (PTS) do not call for a demonstration of steep turns on the certification check flight, this does not eliminate the need for the instrument pilot-in-training to demonstrate proficiency to an instructor.

Training in steep turns teaches the pilot to recognize and to adapt to rapidly changing aerodynamic forces that necessitate an increase in the rate of cross-checking all flight instruments. The procedures for entering, maintaining and exiting a steep turn are the same as for shallower turns. Proficiency in instrument cross-check and interpretation is increased due to the higher aerodynamic forces and increased speed at which the forces are changing.

Performing the Maneuver

To enter a steep turn to the left, roll into a coordinated 45° bank turn to the left. An advantage that glass panel displays have over analog instrumentation is a 45° bank indication on the roll scale. This additional index on the roll scale allows the pilot to precisely roll into the desired bank angle instead of having to approximate it as is necessary with analog instrumentation. *[Figure 5-68]*

Figure 5-68. *Steep Left Turn.*

As soon as the bank angle increases from level flight, the vertical component of lift begins to decrease. If the vertical component of lift is allowed to continue to decrease, a pronounced loss of altitude is indicated on the altimeter along with the VSI tape, as well as the altitude trend indicator. Additionally, the airspeed will begin to increase due to the lowered pitch attitude. It is very important to have a comprehensive scan developed prior to training in steep turns. Utilization of all of the trend indicators, as well the VSI, altimeter, and ASI, is essential in learning to fly steep turns by reference to instruments alone.

In order to avoid a loss of altitude, the pilot begins to slowly increase back pressure on the control yoke in order to increase the pitch attitude. The pitch change required is usually no more than 3° to 5°, depending on the type of aircraft. As the pilot increases back pressure, the angle of attack increases, thus increasing the vertical component of lift. When a deviation in altitude is indicated, proper control force corrections need to be made. During initial training of steep turns, pilots have a tendency to overbank. Over banking is when the bank angle exceeds 50°. As the outboard wing begins to travel faster through the air it will begin to generate a greater and greater differential in lift compared to the inboard wing. As the bank angle continues to progress more and more steeply past 45°, the two components of lift (vertical and horizontal) become inversely proportionate.

Once the angle has exceeded 45°, the horizontal component of lift is now the greater force. If altitude should continue to decrease and the pilot only applies back yoke pressure, the aircraft's turn radius begins to tighten due to the increased horizontal force. If aft control pressure continues to increase, there will come a point where the loss of the vertical component of lift and aerodynamic wing loading prohibits the nose of the aircraft from being raised. Any increase in pitch only tightens the turning radius.

The key to successfully performing a steep turn by reference to instruments alone is the thorough understanding of the aerodynamics involved, as well as a quick and reliable cross-check. The pilot should utilize the trim to avoid holding control forces for any period of time. With time and practice, a flight instructor can demonstrate how to successfully fly steep turns with and without the use of trim. Once the aircraft is trimmed for the maneuver, accomplishing the maneuver will be virtually a hands-off effort. This allows additional time for cross-checking and interpreting the instruments.

It is imperative when correcting for a deviation in altitude, that the pilot modify the bank angle ±5° in order to vary the vertical component of lift, not just adjust back pressure. These two actions should be accomplished simultaneously.

During the recovery from steep turns to straight-and-level flight, aft control forces must be varied with the power control to arrive back at entry altitude, heading and airspeed.

Steps:

1. Perform clearing turns.
2. Roll left into a 45° bank turn and immediately begin to increase the pitch attitude by approximately 3° to 5°.
3. As the bank rolls past 30°, increase power to maintain the entry airspeed.
4. Apply trim to eliminate any aft control wheel forces.
5. Begin rolling out of the steep turn approximately 20° prior to the desired heading.
6. Apply forward control pressure and place the pitch attitude in the level cruise pitch attitude.
7. Reduce power to the entry power setting to maintain the desired airspeed.
8. Re-trim the aircraft as soon as practical or continue into a right hand steep turn and continue from step 3.

9. Once the maneuver is complete, establish cruise flight and accomplish all appropriate checklist items.

Unusual Attitude Recovery Protection

Unusual attitudes are some of the most hazardous situations for a pilot to be in. Without proper recovery training on instrument interpretation and aircraft control, a pilot can quickly aggravate an abnormal flight attitude into a potentially fatal accident.

Analog gauges require the pilot to scan between instruments to deduce the aircraft attitude. Individually, these gauges lack the necessary information needed for a successful recovery.

EFDs have additional features to aid in recognition and recovery from unusual flight attitudes. The PFD displays all the flight instruments on one screen. Each instrument is superimposed over a full-screen representation of the attitude indicator. With this configuration, the pilot no longer needs to transition from one instrument to another.

The new unusual attitude recovery protection allows the pilot to be able to quickly determine the aircraft's attitude and make a safe, proper and prompt recovery. Situational awareness is increased by the introduction of the large full-width artificial horizon depicted on the PFD. This now allows for the attitude indicator to be in view during all portions of the scan.

One problem with analog gauges is that the attitude indicator displays a complete blue or brown segment when the pitch attitude is increased toward 90° nose-up or nose-down.

With the EFDs, the attitude indicator is designed to retain a portion of both sky and land representation at all times. This improvement allows the pilot to always know the quickest way to return to the horizon. Situational awareness is greatly increased.

NOTE: The horizon line starts moving downward at approximately 47° pitch up. From this point on, the brown segment will remain visible to show the pilot the quickest way to return to the level pitch attitude. *[Figure 5-69]*

NOTE: The horizon line starts moving upward at approximately 27° pitch down. From this point on, the blue segment will remain visible to show the pilot the quickest way to return to the level pitch attitude. *[Figure 5-70]*

It is imperative to understand that the white line on the attitude indicator is the horizon line. The break between the blue and brown symbols is only a reference and should not be thought of as the artificial horizon.

Another important advancement is the development of the unusual attitude recovery protection that is built into the PFD software and made capable by the AHRS. In the case of a nose-high unusual attitude, the unusual attitude recovery protection displays red chevrons which point back to the horizon line.

Figure 5-69. *Unusual Attitude Recovery Protection. Note the brown horizon line is visible at the bottom.*

Figure 5-70. *Horizon line starts moving upward at 27°. Note that the blue sky remains visible at 17° nose-down.*

These chevrons are positioned at 50° up on the attitude indicator. The chevrons appear when the aircraft approaches a nose-high attitude of 30°. The software automatically de-clutters the PFD leaving only airspeed, heading, attitude, altimeter, VSI tape, and the trend vectors. The de-cluttered information reappears when the pitch attitude falls below 25°.

For nose-low unusual attitudes, the chevrons are displayed when the pitch exceeds 15° nose-down. If the pitch continues to decrease, the unusual attitude recovery protection de-clutters the screen at 20° nose-down. The de-cluttered information reappears when the pitch increases above 15°.

Additionally, there are bank limits that trigger the unusual attitude protection. If the aircraft's bank increases beyond 60°, a continuation of the roll index occurs to indicate the shortest direction to roll the wings back to level. At 65°, the PFD de-clutters. All information reappears when the bank decreases below 60°.

In *Figure 5-71*, the aircraft has rolled past 60°. Observe the white line that continues from the end of the bank index. This line appears to indicate the shortest distance back to wings level.

When experiencing a failure of the AHRS unit, all unusual attitude protection is lost. The failure of the AHRS results in the loss of all heading and attitude indications on the PFD. In addition, all modes of the autopilot, except for roll and altitude hold, are lost.

The following picture series represents how important this technology is in increasing situational awareness, and how critical it is in improving safety.

Figure 5-72 shows the unusual attitude protection with valid AHRS and air data computer (ADC) inputs. The bright red chevrons pointing down to the horizon indicate a nose-high unusual attitude that can be easily recognized and corrected.

NOTE: The red chevrons point back to the level pitch attitude. The trend indicators show where the airspeed and altitude will be in 6 seconds. The trend indicator on the heading indicator shows which direction the aircraft is turning. The slip/skid indicator clearly shows if the aircraft is coordinated. This information helps the pilot determine which type of unusual attitude the aircraft has taken.

Now look at *Figure 5-73*. The display shows the same airspeed as the picture above; however, the AHRS unit has failed. The altimeter and the VSI tape are the only clear indications that the aircraft is in a nose-high attitude. The one key instrument that is no longer present is the slip/skid indicator. There is not a standby turn coordinator installed in the aircraft for the pilot to reference.

The magnetic compass indicates a heading is being maintained; however, it is not as useful as a turn coordinator or slip/skid indicator.

Figure 5-71. *Aircraft Rolled Past 60°.*

Figure 5-72. *Unusual Attitude Protection With Valid AHRS.*

Figure 5-73. *AHRS Unit Failed.*

Figure 5-74 depicts an AHRS and ADC failure. In this failure scenario, there are no indications of the aircraft's attitude. The manufacturer recommends turning on the autopilot which is simply a wing leveler.

With a failure of the primary instrumentation on the PFD, the only references available are the stand-by instruments. The standby instrumentation consists of an analog ASI, attitude indicator, altimeter, and magnetic compass. There is no standby turn coordinator installed.

In extreme nose-high or nose-low pitch attitudes, as well as high bank angles, the analog attitude indicator has the potential to tumble, rendering it unusable.

Autopilot Usage

The autopilot is equipped with inputs from a turn coordinator installed behind the MFD screen. This turn coordinator is installed solely for the use of the autopilot to facilitate the roll mode. Roll mode, which is simply a wing leveler. This protection will always be available, barring a failure of the turn coordinator (to aid the pilot if the aircraft attains an unusual attitude).

NOTE: The pilot is not able to gain access to the turn coordinator. This instrument is installed behind the MFD panel. *[Figure 5-75]*

Most EFD equipped aircraft are coming from the factory with autopilots installed. However, the purchaser of the aircraft can specify if an autopilot is to be installed. Extreme caution should be utilized when flying an EFD equipped aircraft without an autopilot in IMC with an AHRS and ADC failure.

The autopilot should be utilized to reduce workload, which affords the pilot more time to monitor the flight. Utilization of the autopilot also decreases the chances of entry into an unusual attitude.

Flying an EFD equipped aircraft without the use of an autopilot has been shown to increase workload and decrease situational awareness for pilots first learning to flying the new system.

Common Errors Leading to Unusual Attitudes

The following errors have the potential to disrupt a pilot's situational awareness and lead to unusual attitudes.

1. Improper trimming techniques. A failure to keep the aircraft trimmed for level flight at all times can turn a momentary distraction into an emergency situation if the pilot stops cross-checking.
2. Poor crew resource management (CRM) skills. Failure to perform all single-pilot resource management duties efficiently. A major cause of CRM related accidents comes from the failure of the pilot to maintain an organized flight deck. Items that are being utilized for the flight portion should be neatly arranged for easy access. A disorganized flight deck

Figure 5-74. *AHRS ADC Failure.*

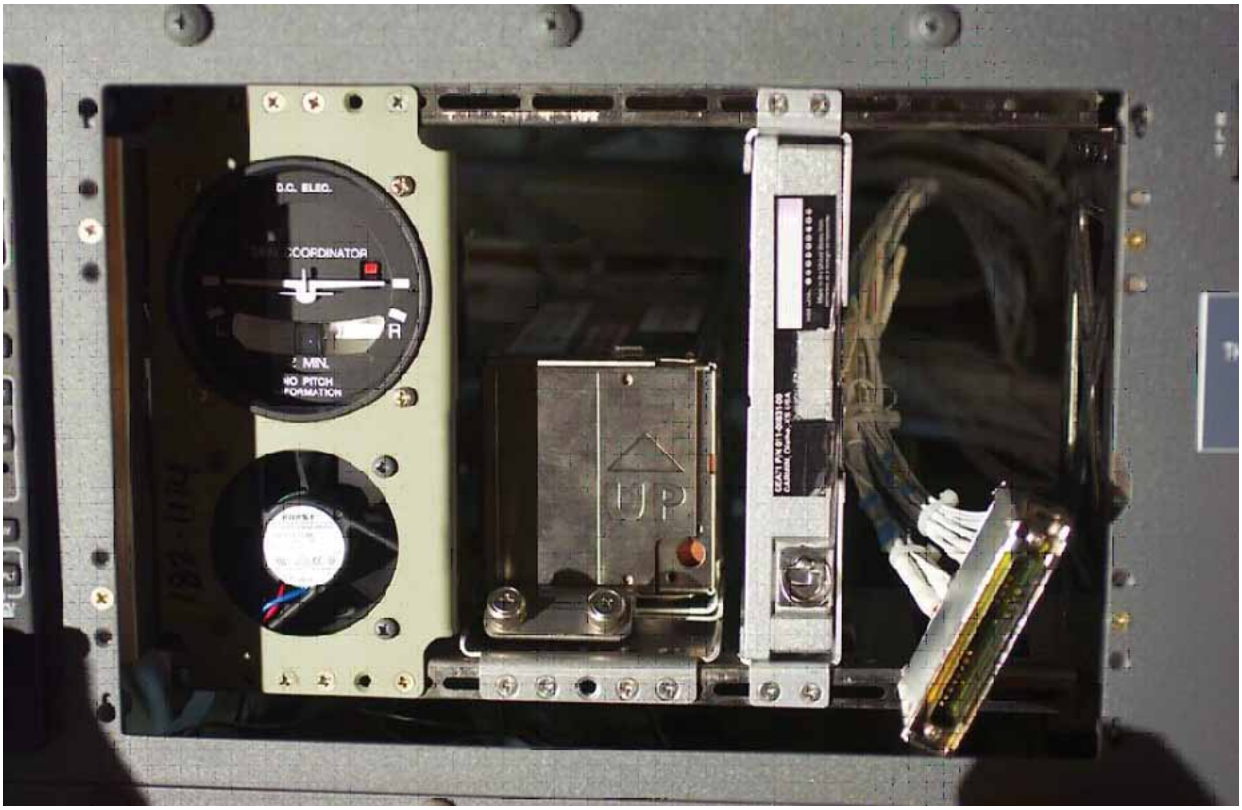

Figure 5-75. *This autopilot requires roll information from a turn coordinator.*

can lead to a distraction that causes the pilot to cease cross-checking the instruments long enough to enter an unusual attitude.

3. Fixation is displayed when a pilot focuses far too much attention on one instrument because he or she perceives something is wrong or a deviation is occurring. It is important for the instrument pilot to remember that a cross-check of several instruments for corroboration is more valuable than checking a single instrument.
4. Attempting to recover by sensory sensations other than sight. Recovery by instinct almost always leads to erroneous corrections due to the illusions that are prevalent during instrument flight.
5. Failure to practice basic attitude instrument flying. When a pilot does not fly instrument approach procedures or even basic attitude instrument flying maneuvers for long periods of time, skill levels diminish. Pilots should avoid flying in IMC if they are not proficient. They should seek a qualified instructor to receive additional instruction prior to entry into IMC.

Instrument Takeoff

The reason for learning to fly by reference to instruments alone is to expand a pilot's abilities to operate an aircraft in visibility less than VFR. Another valuable maneuver to learn is the instrument takeoff. This maneuver requires the pilot to maneuver the aircraft during the takeoff roll by reference to flight instruments alone with no outside visual reference. With practice, this maneuver becomes as routine as a standard rate turn.

The reason behind practicing instrument takeoffs is to reduce the disorientation that can occur during the transitional phase of quickly moving the eyes from the outside references inside to the flight instruments.

One EFD system currently offers what is trademarked as synthetic vision. Synthetic vision is a three-dimensional computer-generated representation of the terrain that lies ahead of the aircraft. The display shows runways as well as a depiction of the terrain features based on a GPS terrain database. Similar to a video game, the display generates a runway the pilot can maneuver down in order to maintain directional control. As long as the pilot tracks down the computer-generated runway, the aircraft will remain aligned with the actual runway.

Not all EFD systems have such an advanced visioning system. With all other systems, the pilot needs to revert to the standard procedures for instrument takeoffs. Each aircraft may require a modification to the maneuver; therefore, always obtain training on any new equipment to be used.

In order to accomplish an instrument takeoff, the aircraft needs to be maneuvered on the centerline of the runway facing the direction of departure with the nose or tail wheel straight. Assistance from the instructor may be necessary if the pilot has been taxiing while wearing a view limiting device. Lock the tail wheel, if so equipped, and hold the brakes firmly to prevent the aircraft from creeping. Cross-check the heading indicator on the PFD with the magnetic compass and adjust for any deviations noted on the compass card. Set the heading to the nearest 5° mark closest to the runway heading. This allows the pilot to quickly detect any deviations from the desired heading and allows prompt corrective actions during the takeoff roll. Using the omnibearing select (OBS) mode on the GPS, rotate the OBS selector until the needle points to the runway heading. This adds additional situational awareness during the takeoff roll. Smoothly apply power to generate sufficient rudder authority for directional control. Release the brakes and continue to advance the power to the takeoff setting.

As soon as the brakes are released, any deviation in heading needs to be corrected immediately. Avoid using brakes to control direction as this increases the takeoff roll, as well as provides the potential of overcontrolling the aircraft.

Continuously cross-check the ASI and the heading indicator as the aircraft accelerates. As the aircraft approaches 15-25 knots below the rotation speed, smoothly apply aft elevator pressure to increase the pitch attitude to the desired takeoff attitude (approximately 7° for most small airplanes). With the pitch attitude held constant, continue to cross-check the flight instruments and allow the aircraft to fly off of the runway. Do not pull the aircraft off of the runway. Pulling the aircraft off of the runway imposes left turning tendencies due to P-Factor, which will yaw the aircraft to the left and destabilize the takeoff.

Maintain the desired pitch and bank attitudes by referencing the attitude indicator and cross-check the VSI tape for an indication of a positive rate of climb. Take note of the magenta 6-second altimeter trend indicator. The trend should show positive. Barring turbulence, all trend indications should be stabilized. The airspeed trend indicator should not be visible at this point if the airspeed is being held constant. An activation of the airspeed trend indicator shows that the pitch attitude is not being held at the desired value and, therefore, the airspeed is changing. The desired performance is to be climbing at a constant airspeed and vertical speed rate. Use the ASI as the primary instrument for the pitch indication.

Once the aircraft has reached a safe altitude (approximately 100 feet for insufficient runway available for landing should an engine failure occur) retract the landing gear and flaps while referencing the ASI and attitude indicator to maintain the desired pitch. As the configuration is changed, an increase in aft control pressure is needed in order to maintain the desired pitch attitude. Smoothly increase the aft control pressure to compensate for the change in configuration. Anticipate the changes and increase the rate of cross-check. The airspeed tape and altitude tape increases while the VSI tape is held constant. Allow the aircraft to accelerate to the desired climb speed. Once the desired climb speed is reached, reduce the power to the climb power setting as printed in the POH/AFM. Trim the aircraft to eliminate any control pressures.

Common Errors in Instrument Takeoffs

Common errors associated with the instrument takeoff include, but are not limited to, the following:

1. Failure to perform an adequate flight deck check before the takeoff. Pilots have attempted instrument takeoff with inoperative airspeed indicators (pitot tube obstructed), controls locked, and numerous other oversights due to haste or carelessness. It is imperative to cross-check the ASI as soon as possible. No airspeed will be indicated until 20 knots of true airspeed is generated in some systems.
2. Improper alignment on the runway. This may result from improper brake applications, allowing the airplane to creep after alignment, or from alignment with the nosewheel or tailwheel cocked. In any case, the result is a built-in directional control problem as the takeoff starts.
3. Improper application of power. Abrupt applications of power complicate directional control. Power should be applied in a smooth and continuous manner to arrive at the takeoff power setting within approximately 3 seconds.
4. Improper use of brakes. Incorrect seat or rudder pedal adjustment, with feet in an uncomfortable position, frequently causes inadvertent application of brakes and excessive heading changes.
5. Overcontrolling rudder pedals. This fault may be caused by late recognition of heading changes, tension on the controls, misinterpretation of the heading indicator (and correcting in the wrong direction), failure to appreciate changing effectiveness of rudder control as the aircraft accelerates, and other factors. If heading changes are observed and corrected instantly with small movement of the rudder pedals, swerving tendencies can be reduced.
6. Failure to maintain attitude after becoming airborne. If the pilot reacts to seat-of-the-pants sensations when the airplane lifts off, pitch control is guesswork. The pilot may either allow excessive pitch or apply excessive forward-elevator pressure, depending on the reaction to trim changes.
7. Inadequate cross-check. Fixations are likely during the trim changes, attitude changes, gear and flap retractions, and power changes. Once an instrument or a control input is applied, continue the cross-check and note the effect control during the next cross-check sequence.
8. Inadequate interpretation of instruments. Failure to understand instrument indications immediately indicates that further study of the maneuver is necessary.

Basic Instrument Flight Patterns

After attaining a reasonable degree of proficiency in basic maneuvers, apply these skills to the various combinations of individual maneuvers. The practice flight patterns, beginning on page 5-30, are directly applicable to operational instrument flying.