Attitude Instrument Flying

- Fundamental Skills
- Basic Flight Maneuvers
- Instrument Failures
- Unusual Attitude Recovery
- Stall Recovery

Instruments Used for IFR Aircraft Control

3 Fundamental Skills...

Cross-check

Interpretation

Aircraft control

In their proper order!

Instrument Cross-check (Scan) Errors

Fixation

Why wouldn't the attitude indicator work *by itself* for maintaining <u>altitude</u> in S&L?

Omission

Emphasis

Pitch attitude for level flight is dependent on airspeed, air density, and aircraft weight.

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 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

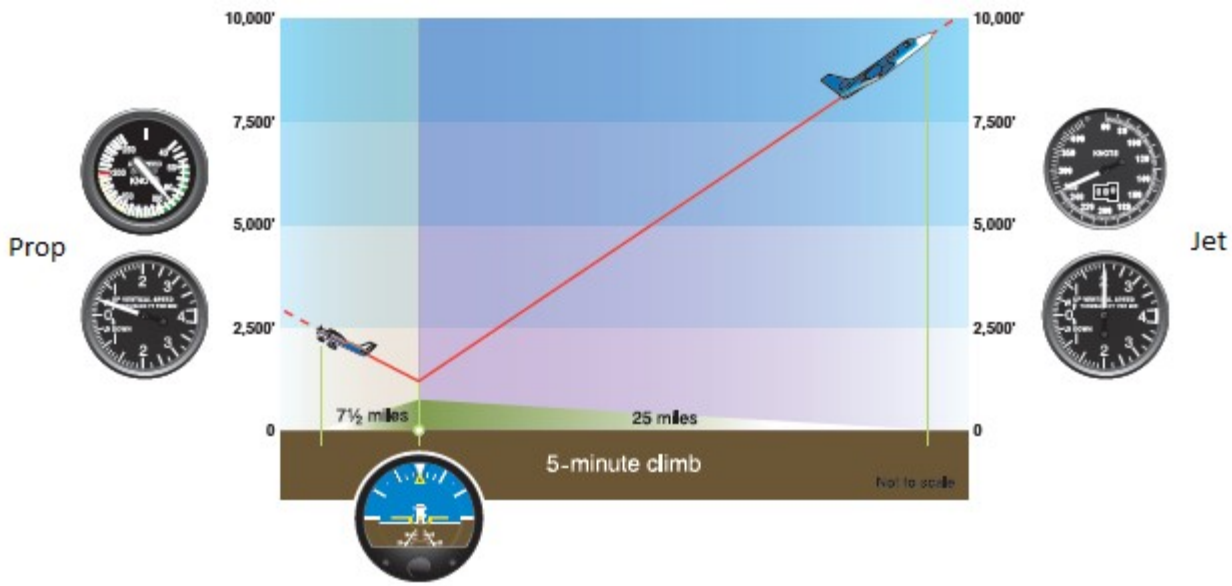
Omitting instruments from a cross-check is another likely fault. It may be caused by failure to anticipate significant instrument indications following attitude changes. For example, in a roll-out from a 180° steep turn, straight-and-level flight is established with reference only to the attitude indicator, 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

Focusing 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. 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.



There are 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.

Figure 6-1. *Control instruments.*

Figure 6-2. *Performance instruments.*

Figure 6-3. *Navigation instruments.*

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. In most aircraft little attention is required to ensure the power setting remains constant.

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 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**. 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.

Figure 6-4. *Pitch instruments.*

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.

The miniature aircraft should be placed in the proper position in relation to the horizon bar or horizon line **before takeoff**. The aircraft operator's manual explains this position. As soon as practicable in level flight and at desired cruise airspeed, the miniature aircraft should be moved to a position that aligns its wings in front of the horizon bar or horizon line.

When using the attitude indicator in applying pitch attitude corrections, control pressure should be extremely light. Movement of the horizon bar above or below the miniature aircraft of the attitude indicator in an airplane should not exceed one-half the bar width, If further change is required, an additional correction of not more than one-half horizon bar wide normally counteracts any deviation from normal flight.

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.*

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. 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.

Airspeed Indicator

The airspeed indicator gives an <u>indirect reading of the pitch attitude</u>. 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*.

If the airspeed decreases, the pitch attitude has moved higher and should be lowered. **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. 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. The turn coordinator provides both bank rate and then turn rate once stabilized. The turn-and-slip indicator provides only turn rate.

Trim Control

Proper trim technique is essential for smooth and accurate instrument flying and utilizes instrumentation. 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 aircraft at a certain attitude. This allows more time to devote to the navigation instruments and additional flight deck duties.

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.

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.

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.

Inverted-V Cross-Check

In the inverted-V cross-check, the *<u>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.</u>*

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).

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.

Primary/Supporting Concept

<u>Primary instruments</u>

Provide *most essential information* during a phase of flight

<u>Supporting Instruments</u>

Help you to maintain the desired indications on primary instruments.

Pitch, Bank, and Power Instruments Review

Attitude Instrument Flying (KNOW THIS!)

During **any** ***change*** **in** **<u>pitch, bank, or both</u>, the ATTITUDE INDICATOR becomes the primary instrument for pitch, bank, or both.**

During **any** ***change*** **in** **<u>airspeed</u>, the POWER INSTRUMENT(s) become primary for power.**

The above conditions will be indicated by words such as ***transitioning***, **and** ***establishing***.

Once established **in a standard rate turn**, **the turn coordinator becomes the primary bank.** (Attitude Indicator is primary when you want to maintain a specific *angle* of bank.)

Once **a pitch change is** ***established*****, the ASI,VSI, or ALT is primary.**

Attitude Instrument Flying

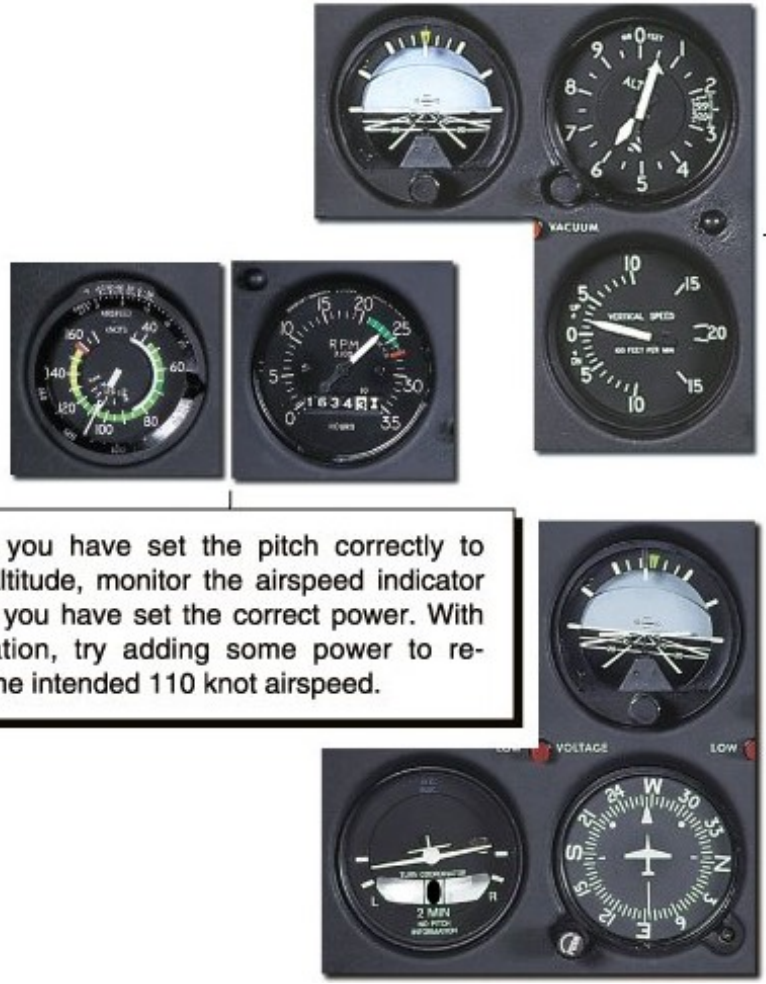
Straight-and-level, constant airspeed flight

Primary

Altimeter

Heading Indicator

Airspeed



Monitor the altimeter, along with the VSI, to confirm you have set the correct pitch. These instruments suggest pitching down 1/2 bar width on the attitude indicator.

Assuming you have set the pitch correctly to maintain altitude, monitor the airspeed indicator to confirm you have set the correct power. With this indication, try adding some power to re-establish the intended 110 knot airspeed.

Monitor the heading indicator, along with the turn coordinator, to make sure you have set the correct bank. This deviation suggests a momentary 5° bank to the right to re-establish the intended 270° heading.

Attitude Instrument Flying

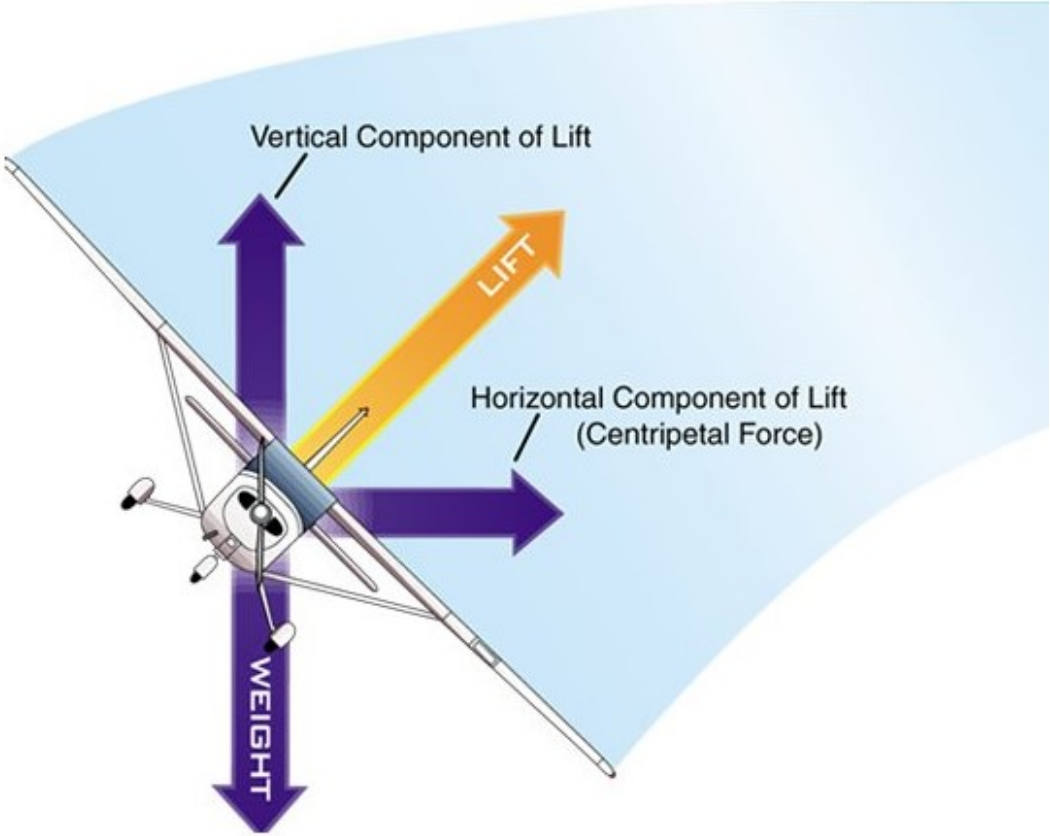
Straight-and-level, constant airspeed flight

- Pitch control
  - Altimeter provides most pertinent info for pitch in *level* flight
  - Altitude corrections
    - < 100 ft.; use 1/2 bar width correction on attitude indicator
    - ≥ 100 ft.; VSI = 2 * altitude deviation (Ex: 100 ft. dev, VSI = 200 fpm)
- Bank control
  - Heading Indicator provides most pertinent info for bank in *straight* flight
- Power control
  - The airspeed indicator is primary in *unaccelerated* flight since it is the only instrument that can tell you if you have the right power to maintain a given airspeed.

Attitude Instrument Flying

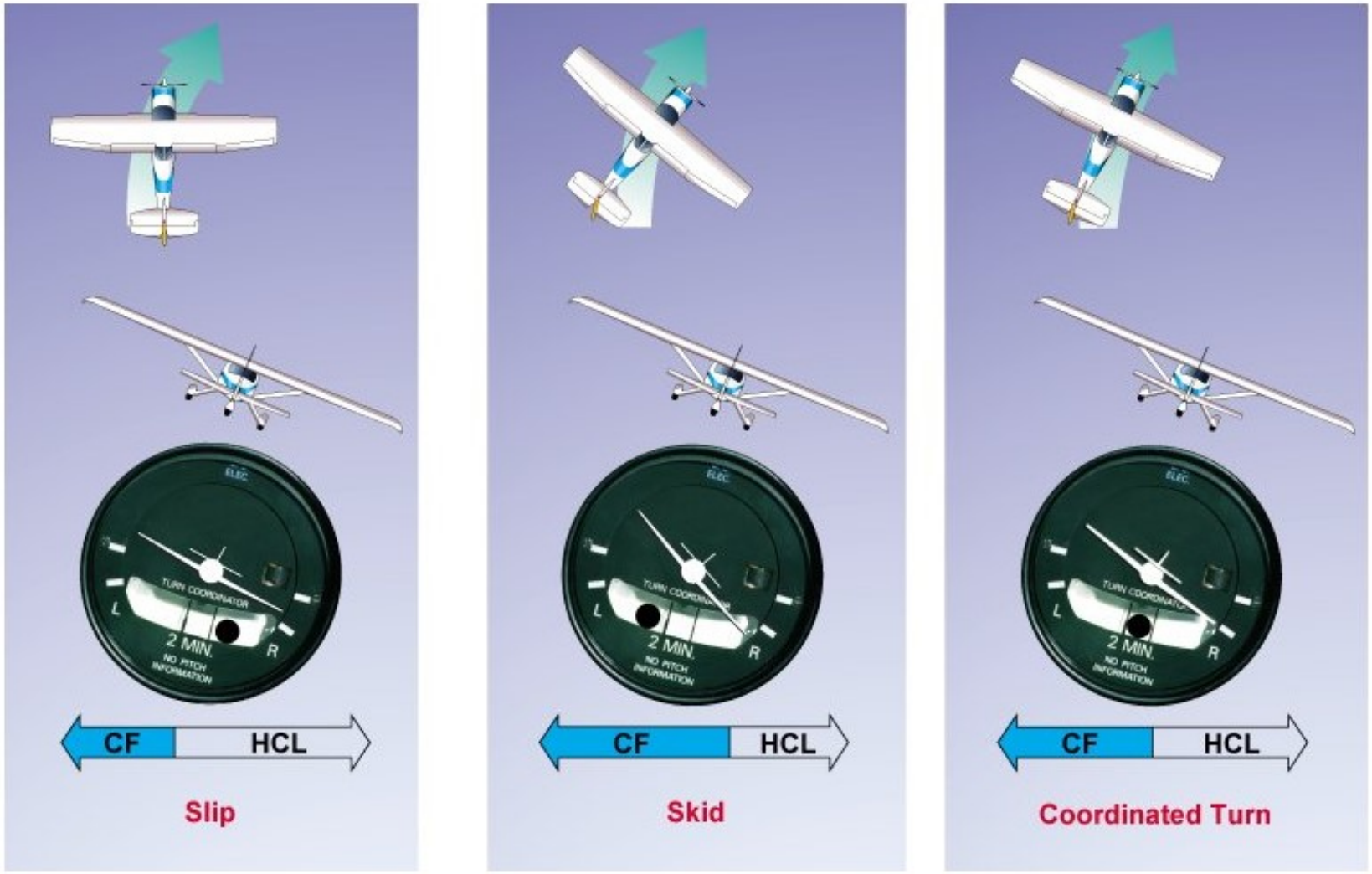
Remember: *Rate of turn at any airspeed is dependent upon the horizontal component of lift.*

Angle of attack must be increased to maintain altitude in a turn because the vertical component of lift has decreased.



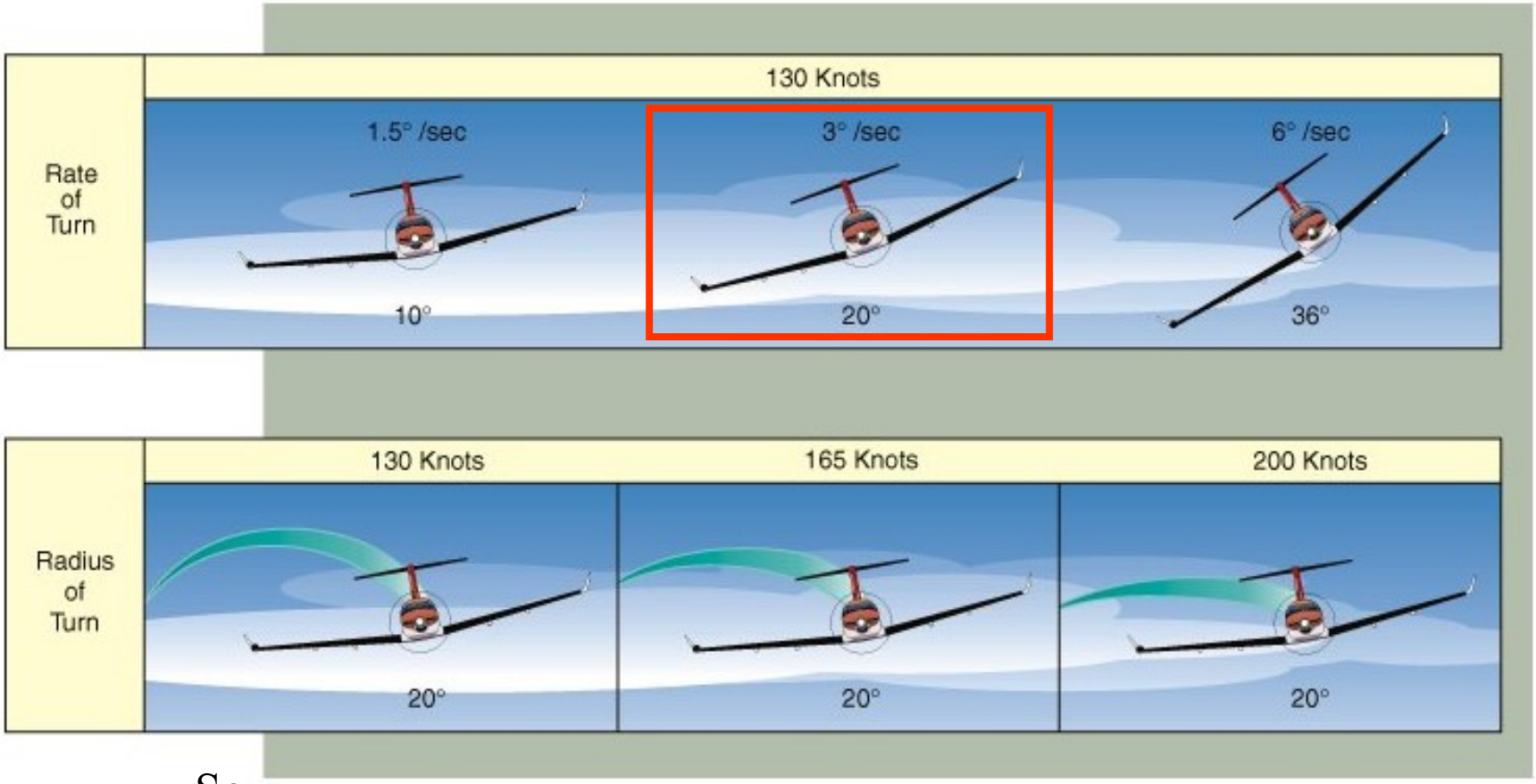
If you increase airspeed in a turn, what must be done to maintain level flight?

Slip/Skid Indicators (Inclinometer)



Quality of a turn is indicated by inclinometer (ball)

Attitude Instrument Flying - Turns



So…

1. If the angle of bank increases, the turn rate increases.
2. If the velocity increases, the turn rate decreases.

Attitude Instrument Flying

Constant airspeed climbs/descents

Transition to climb by increasing attitude for climb and letting airspeed indicator reach climb airspeed before increasing power

Transition to descent by simultaneously reducing power and adjust pitch to maintain desired airspeed

During the pitch transition to a straight climb, the attitude indicator is the primary pitch instrument. Once you are established in a climb, the airspeed indicator becomes the primary pitch instrument with support from the attitude indicator. Throughout the climb, the attitude indicator acts as a supporting bank instrument.

Supporting Bank Primary Bank Supporting Pitch

Primary Power

Attitude Instrument Flying

Constant rate climbs/descents

What's the only instrument that will tell you if you are climbing/descending at a given rate?

Vertical Speed Indicator; therefore this is primary for pitch

Which instrument is primary for power?

Airspeed Indicator; (when AS is only pitch requirement, ASI is primary for *pitch*; when AS is 1 of 2 pitch requirements, ASI is primary for *power*.)

When 2 pitch requirements exist, use pitch to control the rate of climb/descent and power to control the airspeed.

How do we lead the level off from a climb/descent?

Instrument Failures & Partial Panel Flying

Vacuum System Failure
(You are in S&L flight)

Attitude Indicator Failure
You are in a climbing turn

To identify a failed instrument cross-check other instruments and accept the indications of those that <u>agree with each other</u>.

Turns Using the Magnetic Compass

- When the heading indicator fails, what is primary for bank?

  MC (since it is the only instrument that can tell you if your heading is correct)

- Compass turns
  - Turns to specific headings - use known errors of the magnetic compass (UNOS or “North lags, South leads”)
  - Once you decide to roll out of a turn, DO NOT fixate on the magnetic compas - use the airspeed indicatior-AI, or turn coordinator during AI failure)
- Timed turns
  - Most accurate way to turn without a Heading Indicator
  - Roll-in and roll-out time will cancel each other

Unusual Attitude Recovery - *Nose High*

1. If the airspeed is decreasing or below the desired airspeed, add power. Use the attitude indicator to lower the nose and level the wings.

2. If you suspect the attitude indicator is inoperative, apply just enough forward pressure to reverse the movement of the airspeed indicator and altimeter and to start the VSI moving toward zero.

1. Add power

2. Lower the nose.

3. Level the wings

3. If you suspect the attitude indicator is inoperative, use the turn coordinator to level the wings.

Unusual Attitude Recovery - *Nose Low*

1. If the airspeed is increasing, or above the desired airspeed, reduce power to prevent excessive airspeed. Use the attitude indicator to first level the wings and then gently raise the nose to a level pitch attitude.

2. If you suspect the attitude indicator is inoperative, use the turn coordinator to level the wings.

1. Reduce power.
2. Level the wings.
3. Raise the nose.

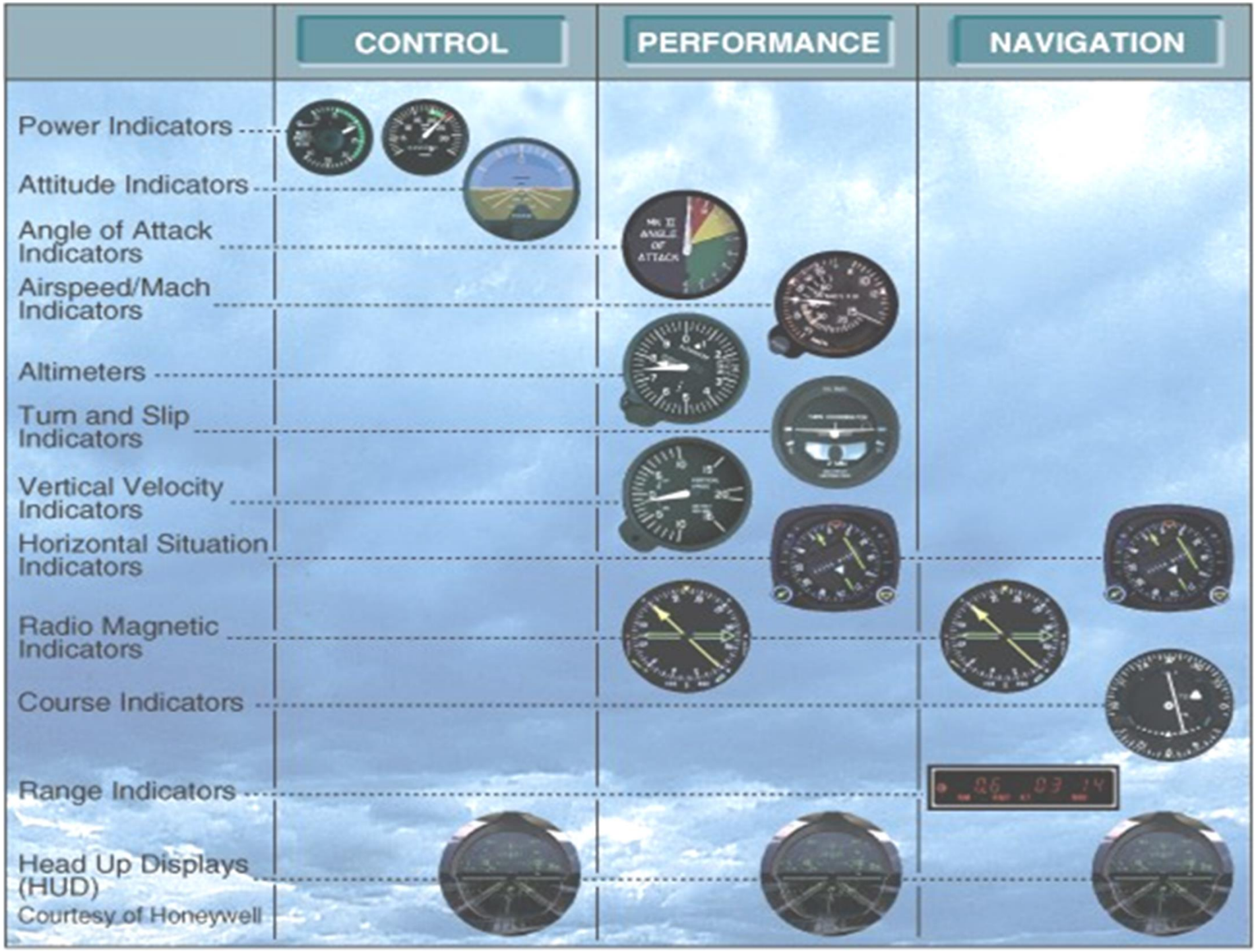
3. If you suspect the attitude indicator is inoperative, use the altimeter and VSI to recover from the dive after leveling the wings. Apply just enough back pressure to reverse the movement of the airspeed indicator and altimeter and start the VSI moving toward zero.

Stall Recovery

- Recovery from stalls using instruments is the same as it is in visual flight.
  - Reduce angle of attack
  - Increase power
  - Level the wings
    - Use your *feet* as well as your head!
    - Keep the BALL CENTERED to avoid a spin!
    - STEP ON THE BALL!

Control and Performance Concept

- Attitude + Power = Performance
- More suited for high performance airplanes
  - Precisely calibrated attitude indicators
  - Angle of attack indicators
  - Back-up attitude indicators
- Majority of scan time is spent on the attitude indicator
  - Set the attitude
  - Set the power
  - Get the performance


CONTROL
PERFORMANCE
NAVIGATION
Power Indicators
Attitude Indicators
Angle of Attack Indicators
Airspeed/Mach Indicators
Altimeters
Turn and Slip Indicators
Vertical Velocity Indicators
Horizontal Situation Indicators
Radio Magnetic Indicators
Course Indicators
Range Indicators
Head Up Displays (HUD)
Courtesy of Honeywell

Summary Checklist

- Attitude instrument flying consists of 3 fundamental skills: Instrument cross check, instrument interpretation, and aircraft control.
- Instrument cross-check, or scan, requires logical and systematic observation of the instrument panel. Most common scanning errors are fixation, omission and emphasis.
- Effective instrument interpretation requires a good working knowledge of how each instrument operates.
- Aircraft control is the result of instrument cross-check and interpretation. It requir4es that the airplane be kept properly trimmed so small flight control movements can achieve precise adjustments to pitch, bank, and power.
- *Primary instruments* provide the most pertinent pitch, bank, and power information for a given flight condition. *Supporting instruments* provide additional pitch, bank, and power information to help maintain the desired indication on the primary instruments.
- Supporting instruments are no less important than primary instruments. The altitude indicator, although usually a supporting instrument, is essential and central to your scan.
- The *ATTITUDE INDICATOR is the PRIMARY INSTRUMENT during any CHANGE IN PITCH* and is the *PRIMARY BANK INSTRUMENT during any any CHANGE IN BANK*.
- The *ALTIMETER IS THE PRIMARY PITCH INSTRUMENT* any time your objective is *TO MAINTAIN ALTITUDE*.
- The VERTICAL SPEED INCICATOR (VSI) IS THE *PRIMARY PITCH INSTRUMET any time your objective is to MAINTAIN A SPECIFIC RATE OF CLIMB OR DESCENT*.
- The TURN COORDINATOR IS THE *PRIMARY BANK INSTRUMENT any time your objective is TO MAINTAIN A SPECIFIC RATE OF TURN*.

Summary Checklist

- The AIRSPEED INDICATOR is the *PRIMARY POWER INSTRUMENT any time your OBJECTIVE IS TO MAINTAIN A CONSTANT AIRSPEED DURING LEVEL FLIGHT*. It is the *PRIMARY PITCH INSTRUMENT DURING A CONSTANT AIRSPEED CLIMB OR DESCENT*.
- In a constant airspeed climb, set climb power, pitch up and get a specific airspeed, and accept the resulting rate of climb. In a constant rate of climb, maintain a specific vertical velocity in addition to controlling the airspeed.
- To enter a constant airspeed descent, reduce the power, pitch down to maintain airspeed, and accept the resulting rate of descent. In a constant rate descent, control the rate of descent with pitch and control the airspeed with power.
- Loss of the attitude in IFR is a potential disaster situation. Advise ATC immediately.
- Instrument failures can be subtle. If you suspect instrument failure, look for corresponding indications among various instruments.
- A timed turn is the most accurate way to turn to a specific heading without the heading indicator.
- Use the VSI and airspeed indicator to make changes in pitch when flying with inoperative gyroscopic instruments. Use smooth, gradual control inputs and allow a few moments for the chance to be reflected in the instrumentation.
- When recovering from nose-high unusual attitude, your objective is to avert a stall. In a nose-low unusual attitude, your objective is to avoid overstressing the airplane structure as well as excessive loss of altitude. Recovery from partial panel, use the turn coordinator to stop a turn.
- In the control and performance concept, use the control instruments (ie, manifold pressure gauge and attitude indicator, set up power/attitude combinations for specific maneuvers.