Instrumentation

Much of the following will be review. What is different from the private certification is the detail regarding instrumentation rather than basic concepts. Please be patient regarding redundent training. It's a good review.

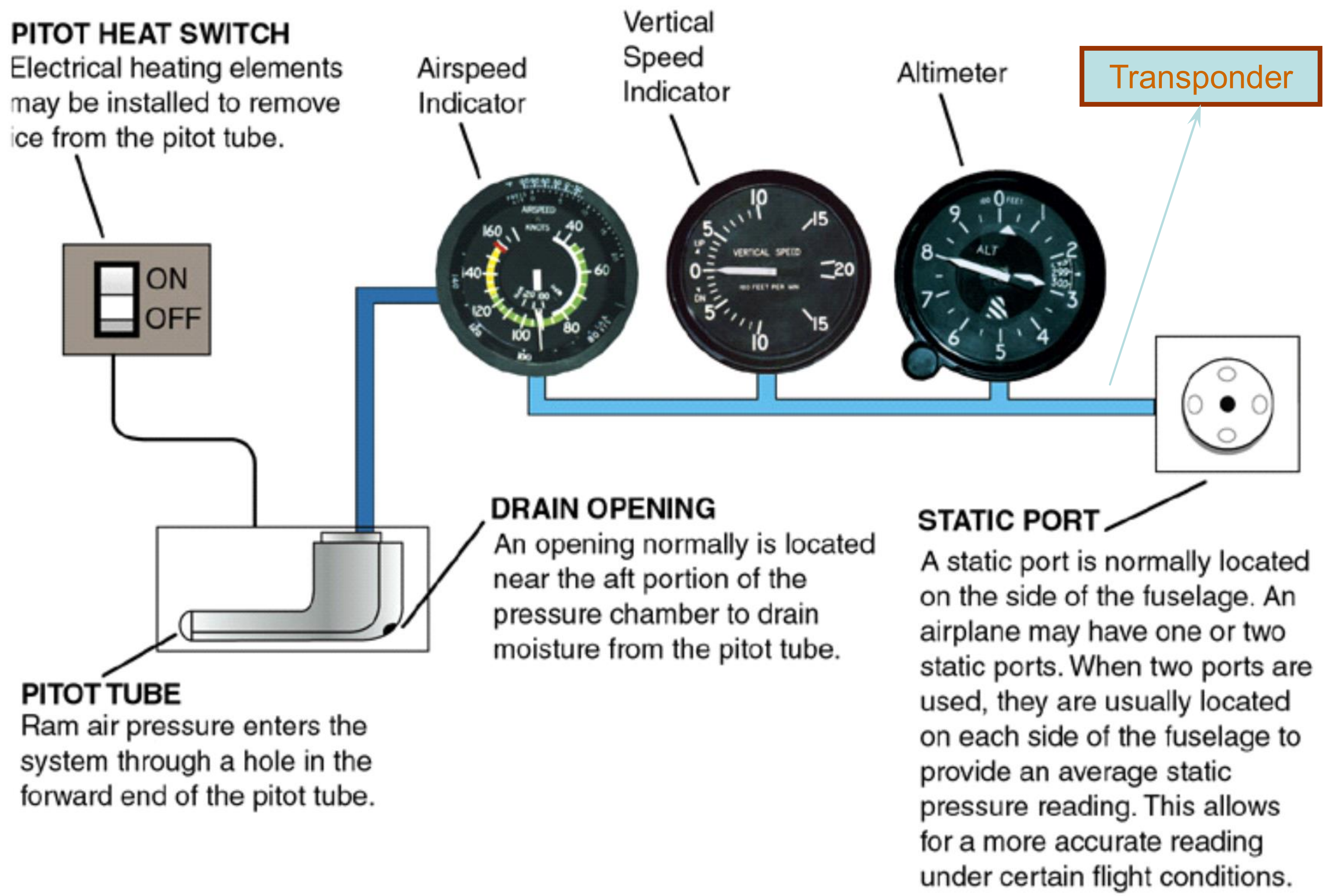
Created by Steve Reisser

FLIGHT INSTRUMENTS

TRANSITIONING: *Important to reorient and KNOW where all are before departure*. Transitioning can be tricky even if flying in a different aircraft of the same. Every aircraft is different. Know *before* you go.

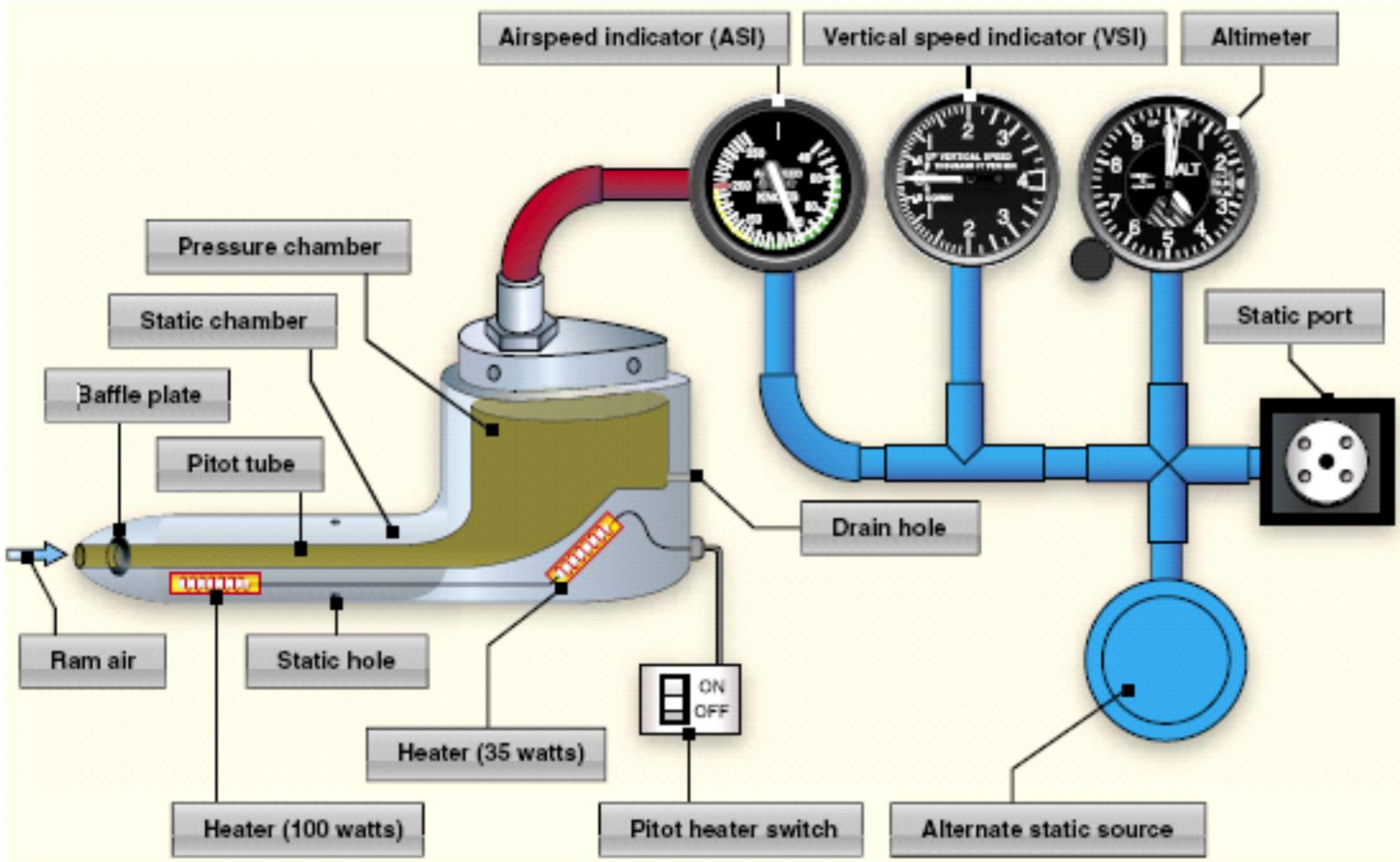
Transitioning from a “6-pack” to “digital” also requires careful ground training before flight. Your brain must adapt to looking and interpreting the instrumentation differently. It is similary to learning a new language. It is HIGHLY recommended this be performed on the ground and not trying to learn while airborne

Flight Instruments: Pitot-Static



Created by Steve Reisser

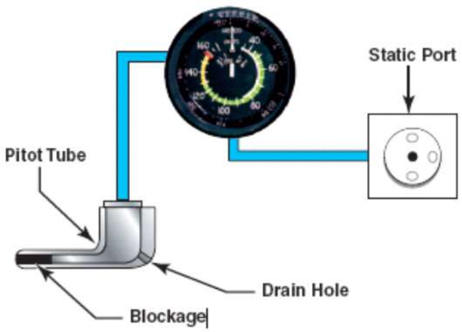
The one instrument that utilizes the pitot tube is the ASI. The total pressure is transmitted to the ASI from the pitot tube's pressure chamber via a small tube. The static pressure is also delivered to the opposite side of the ASI which serves to cancel out the two static pressures, thereby leaving the dynamic pressure to be indicated on the instrument. The two remaining instruments (altimeter and VSI) utilize only the static pressure which is derived from the static port.

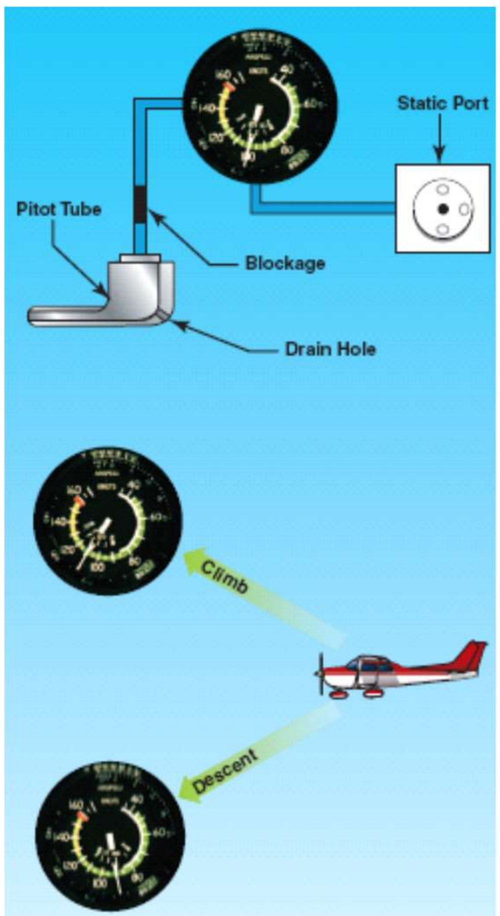


When the alternate static source pressure is used, the following instrument indications are observed:

1. The altimeter indicates a slightly higher altitude than actual.
2. The ASI indicates an airspeed greater than the actual airspeed.
3. The VSI shows a momentary climb and then stabilizes if the altitude is held constant.

Blocked Static System

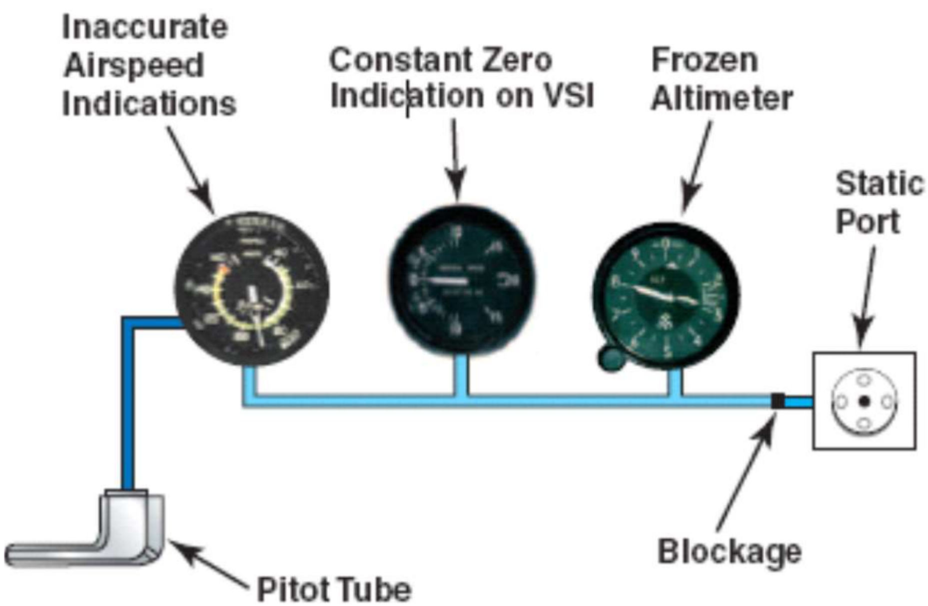




The pitot system can become blocked completely or only partially if the pitot tube drain hole remains open. If the pitot tube becomes blocked and its associated drain hole remains clear, ram air no longer is able to enter the pitot system. Air already in the system will vent through the drain hole, and the remaining pressure will drop to ambient (outside) air pressure. Under these circumstances, the <u>airspeed indicator reading decreases to zero</u>, because the airspeed indicator senses no difference between ram and static air pressure.

If the pitot tube, drain hole, and static system all become blocked in flight, changes in airspeed will not be indicated, due to the trapped pressures. However, if the static system remains clear, the <u>airspeed indicator acts as an altimeter</u>.

Blocked Static System

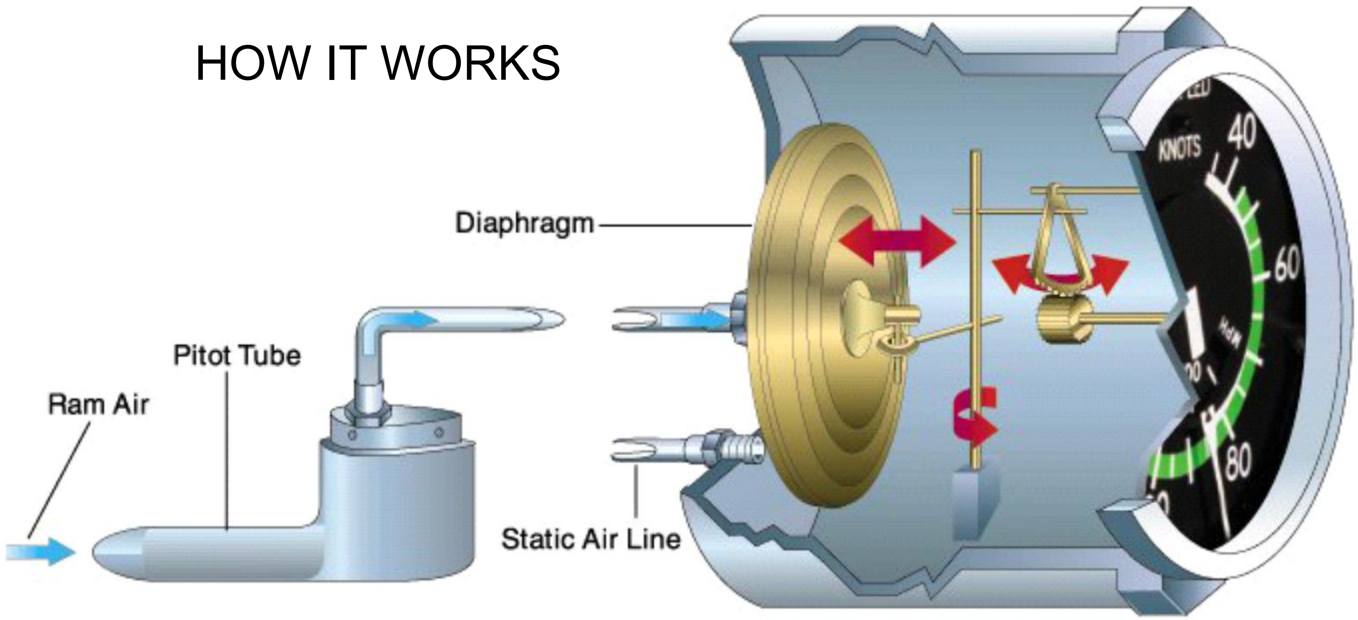


If the static system becomes blocked but the pitot tube remains clear, the airspeed indicator continues to operate; however, it is inaccurate. Airspeed indications are <u>slower</u> than the actual speed when the airplane is operated <u>above the altitude where the static ports became blocked</u>, because the trapped static pressure is higher than normal for that altitude. When operating at a <u>lower altitude</u>, a <u>faster than actual airspeed is displayed</u> due to the relatively low static pressure trapped in the system.

A blockage of the static system also affects the *altimeter and VSI*. Trapped static pressure causes the altimeter to freeze at the altitude where the blockage occurred. In the case of the VSI, a blocked static system produces a continuous zero indication.

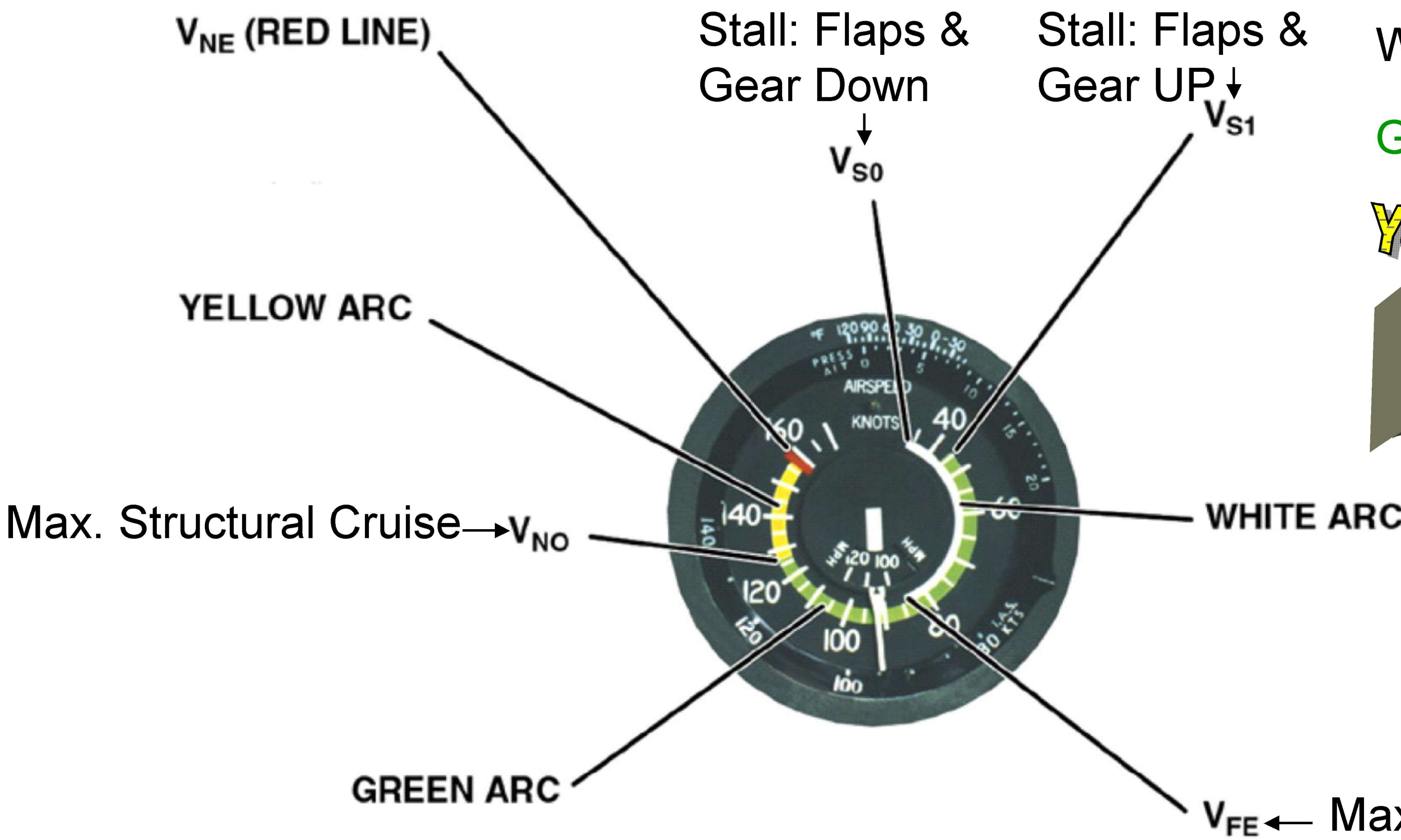
Flight Instruments: Pitot-Static System – Airspeed Indicator

HOW IT WORKS



AIRSPEED INDICATOR IS <u>ONLY INSTRUMENT</u> TO USE “RAM AIR” FROM THE PITOT TUBE.

Flight Instruments: Pitot-Static System – Airspeed Indicator



White-Flaps

Green-Cruise

Yellow-Caution

RED EXTREME DANGER

NOT marked on airspeed indicator: V_A Maneuvering Speed

Important Single-Engine V-Speeds

V_A- Maneuvering speed, the maximum speed at which application of full available aerodynamic control will not overstress the airplane; usually decreases as gross weight decreases. More on next slide.

V_{FE} - Maximum flap-extended speed, the highest speed permissible with wing flaps in a prescribed extended position; top of white arc.

V_{NE}-Never-exceed speed, the speed that may not be exceeded at any time; redline.

V_{NO} - Maximum structural cruising speed, the speed that should not be exceeded except in smooth air and then only with caution; top of green arc.

V_{REF} — Reference speed for final approach, usually 1.3 times VSO.

V_{S1} — Stall speed or minimum steady flight speed obtained in a specific configuration; bottom of the green arc.

V_{SO} — Stall speed or minimum steady flight speed at which the airplane is controllable in the landing configuration; bottom of white arc.

V_X — Best angle-of-climb speed, the airspeed that delivers the greatest gain of altitude in the *shortest possible horizontal distance*. [short field TO]

V_Y — Best rate-of-climb speed, the airspeed that delivers the *greatest gain in altitude* in the shortest possible time.

Maneuvering Speed (Va)

Maneuvering speed is the highest speed at which full deflection of the controls about any one axis are guaranteed not to overstress the airframe.

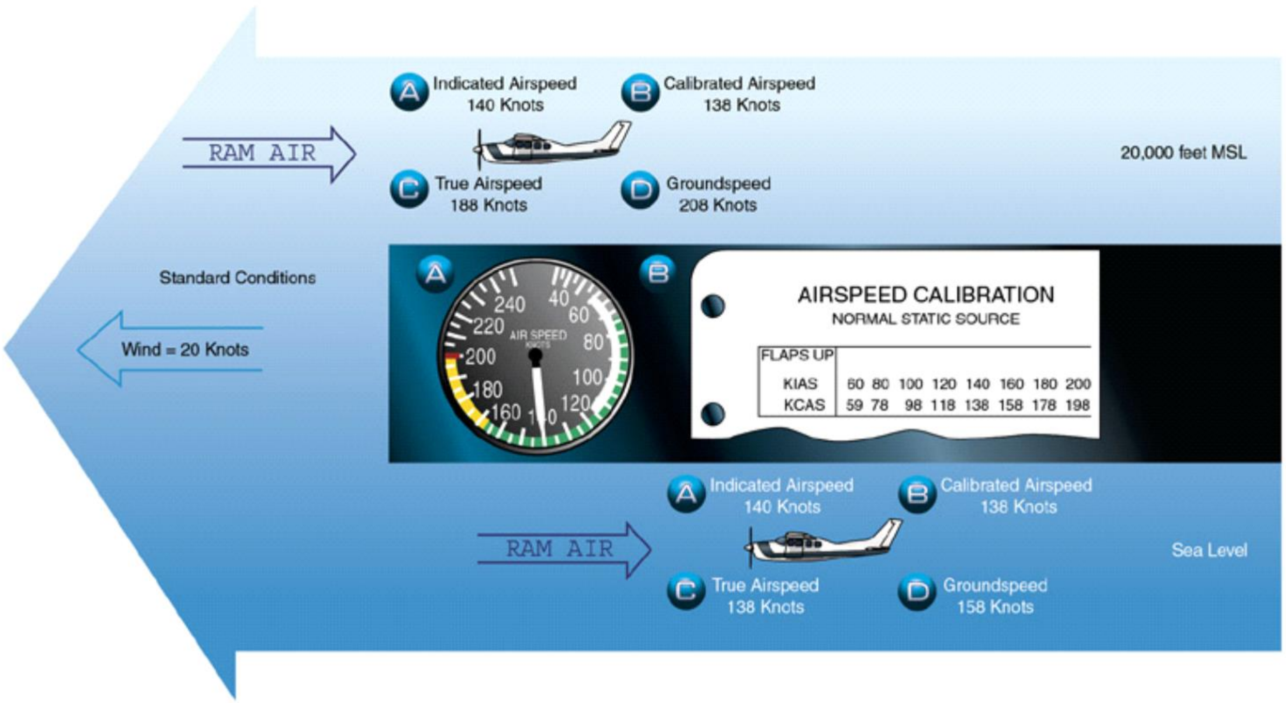
Maneuvering speed is stall <u>speed multiplied by the square root of the limit load factor</u>. Normal category limit is 3.8 Gs, the square root of which is 1.95. If, for example, the flaps-up stalling speed is 70, the maneuvering speed would be 70 * 1.95 = 136.5.

The maneuvering speed decreases as the aircraft's weight decreases from maximum takeoff weight because the effects of the aerodynamic forces become more pronounced as its weight decreases. That is because flying at a lower weight decreases the angle of attack and if the higher speed were maintained, excessive lift forces could cause structural damage at full deflection of the elevator.

The flight manuals for some aircraft (such as the Piper Cherokee) specify the design maneuvering speeds for weights below the maximum takeoff weight but sometimes it is left to the pilot to calculate. Using a "Rule of Thumb", the reduction in Va will be half the percentage reduction in aircraft weight.

- A 10% reduction of weight would result in a 5% decrease in Va
- A 30% reduction of weight would result in a 15% decrease in Va

Flight Instruments: Pitot-Static System – Types of Airspeed



<u>INDICATED</u> (IAS) = What you read on the AS Indicator

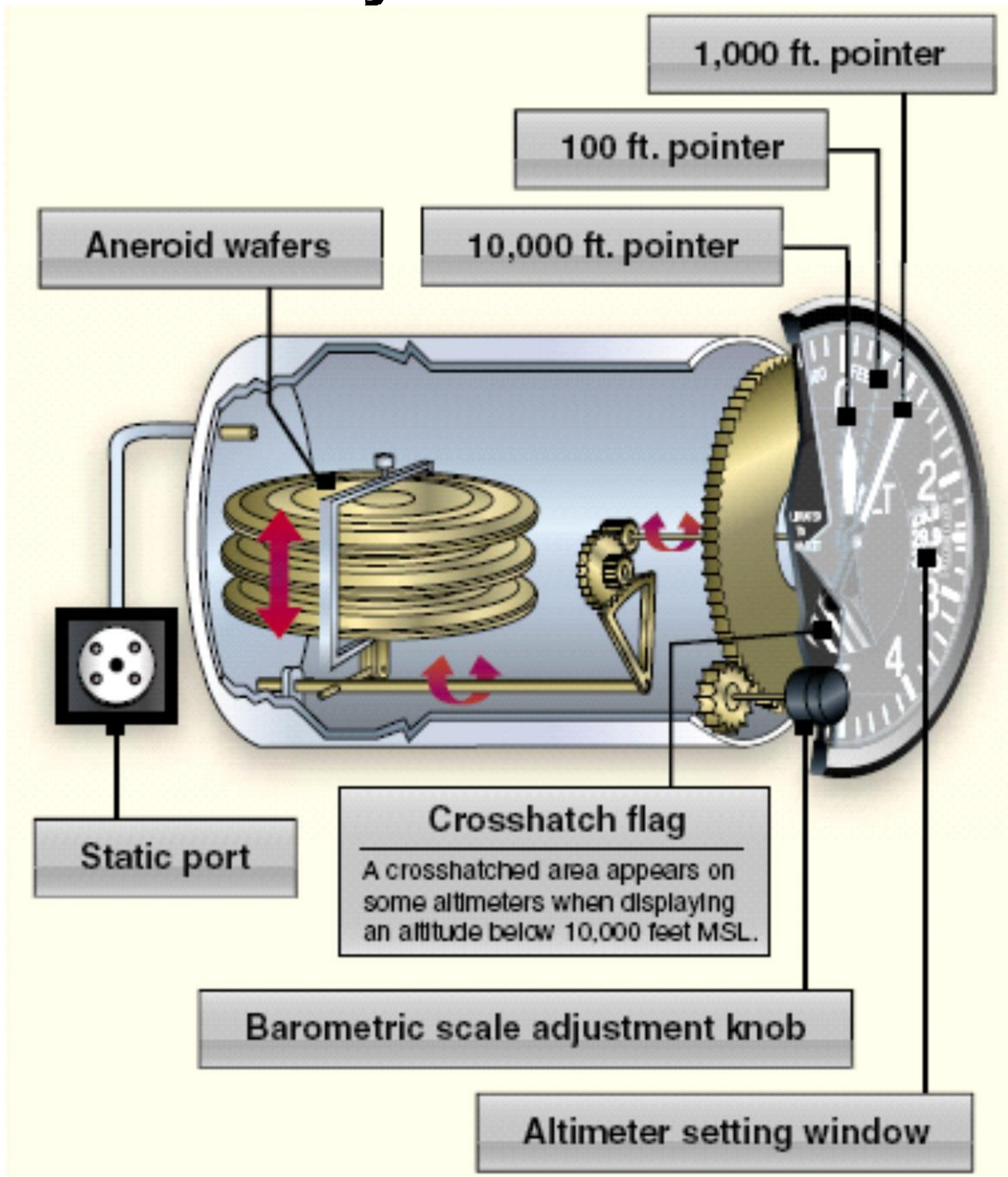
<u>CALIBRATED</u> (CAS) = INDICATED AS adjusted for installation errors.

<u>TRUE</u> (TAS) = CALIBRATED AS corrected for altitude and non-std temperature

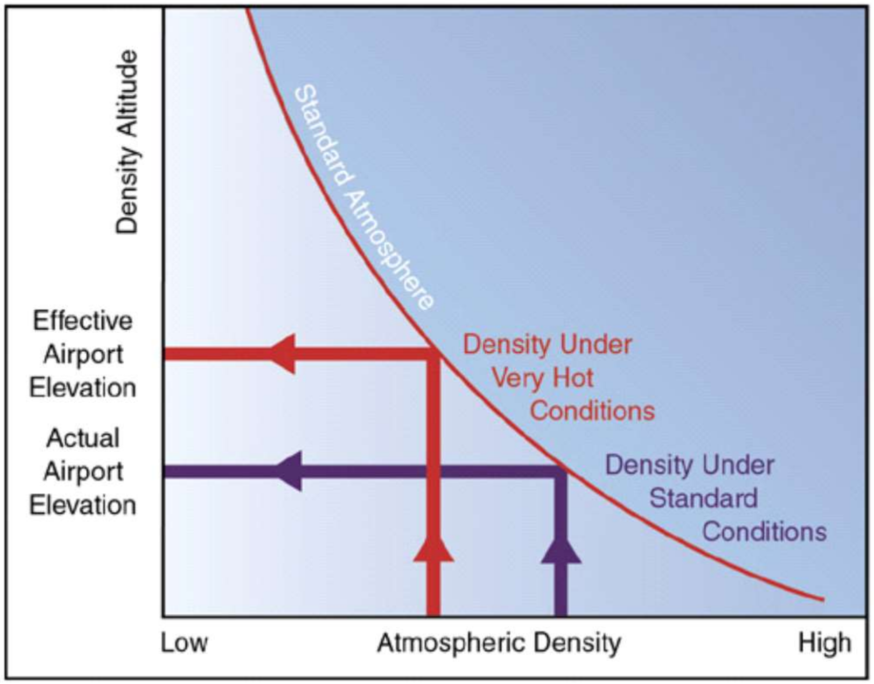
<u>GROUND SPEED</u> – TRUE AS corrected for wind (actual speed moving across ground)

HOW DO YOU FIND EACH OF THESE AIRSPEEDS?

Pitot-Static System – ALTIMETER



Flight Instruments: Pitot-Static System – 6 types of altitude



1. Indicated Altitude: Showing on altimeter

2. Pressure Altitude: Showing when set to standard pressure of 29.92” Formal definition is “the height above a standard datum plane (SDP),

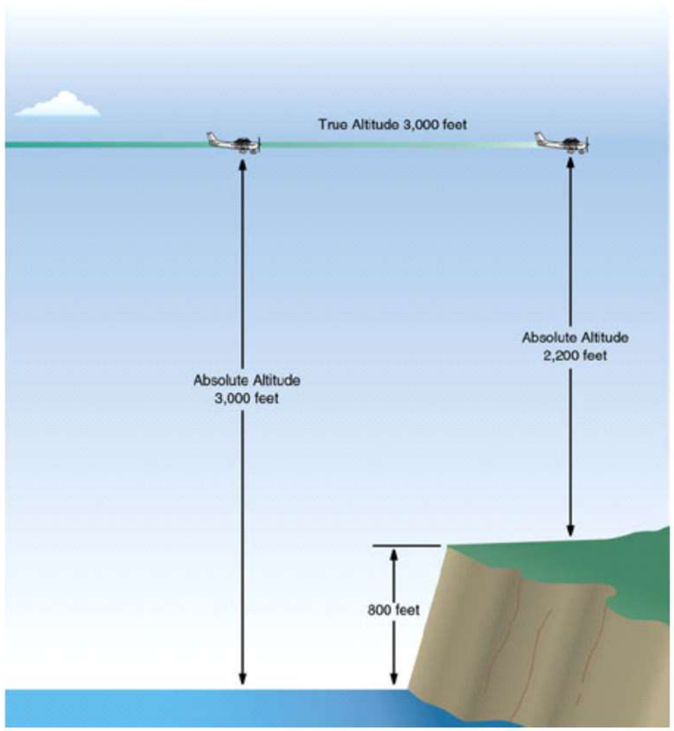
3. Density Altitude is altitude adjusted for non-standard temperature. Less efficient in warmer whereas more efficient in cooler conditions.

Flight Instruments: Pitot-Static System – TYPES of altitude

- Calibrated Altitude – correction to compensate for instrument error for your specific aircraft (see POH).

5. True Altitude – "MSL" (Measure Sea Level) "Height above seal level."

6. Absolute Altitude – above ground level (AGL)



Limitations of Pressure Altitude

PRESSURE

Higher than standard pressure: Altimeter indicates *lower than actual*.

Lower than standard pressure: Altimeter indicates *higher than actual*.

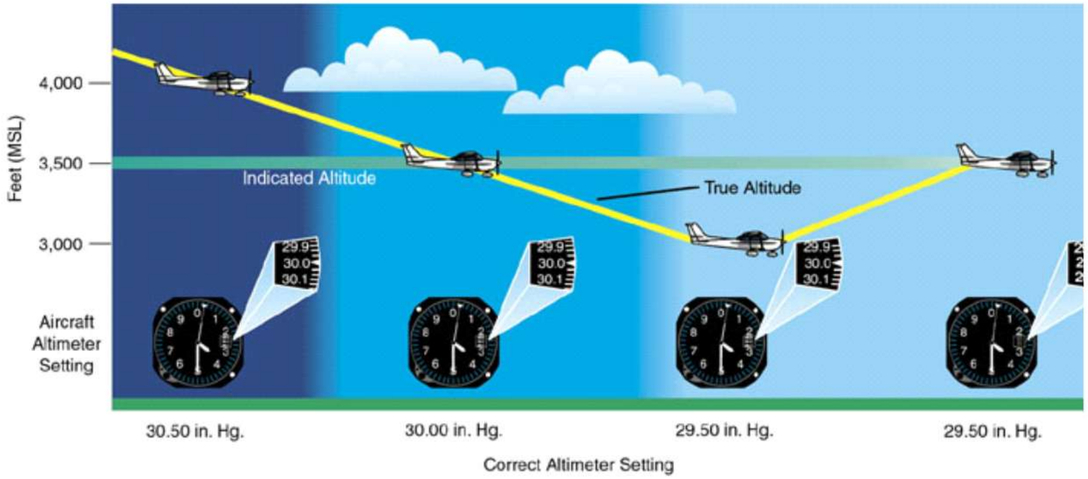
TEMPERATURE

On a Cold day: Temperature is lower than on standard day – altimeter indicates higher *than actual*. You are LOWER than you think! Critical to instrument approaches!

On a Warm day: Temperature is higher than on a standard day – altimeter indicates *lower than actual*. You are HIGHER than you think!

Pitot-Static System

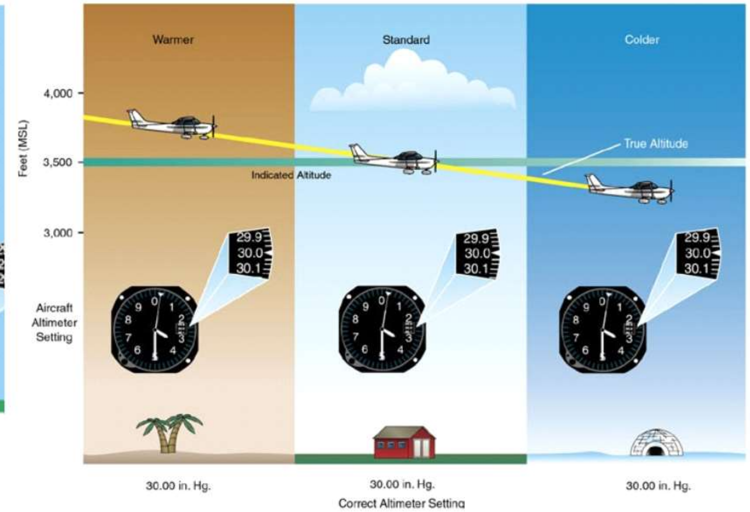
PRESSURE



If correct pressure not adjusted on altimeter, the indicated altitude will be I N C O R R E C T.

“High to low – Look out below”
“Low to high – Look to the sky”

TEMPERATURE



Flying from warm to cooler the altimeter will indicate lower indicated altitude than true altitude.

“FROM HOT TO COLD, LOOK OUT BELOW.”
“FROM COLD TO HOT LOOK TO THE TOP.”

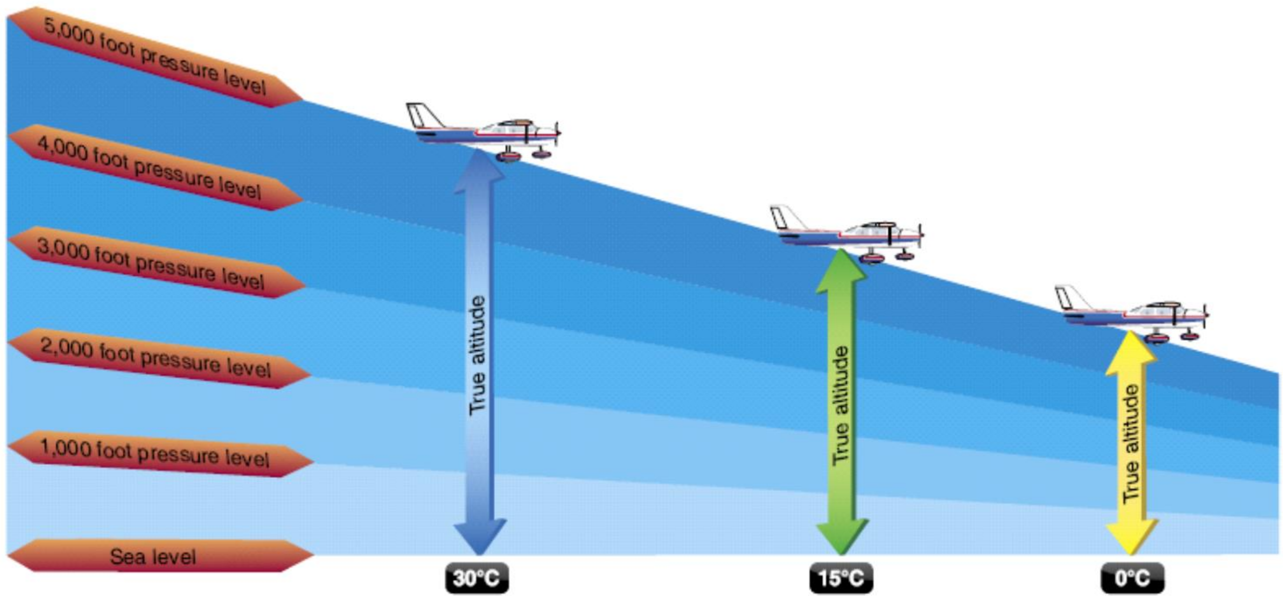


Figure 7-3. *Effects of nonstandard temperature on an altimeter.*

Altimeter Check

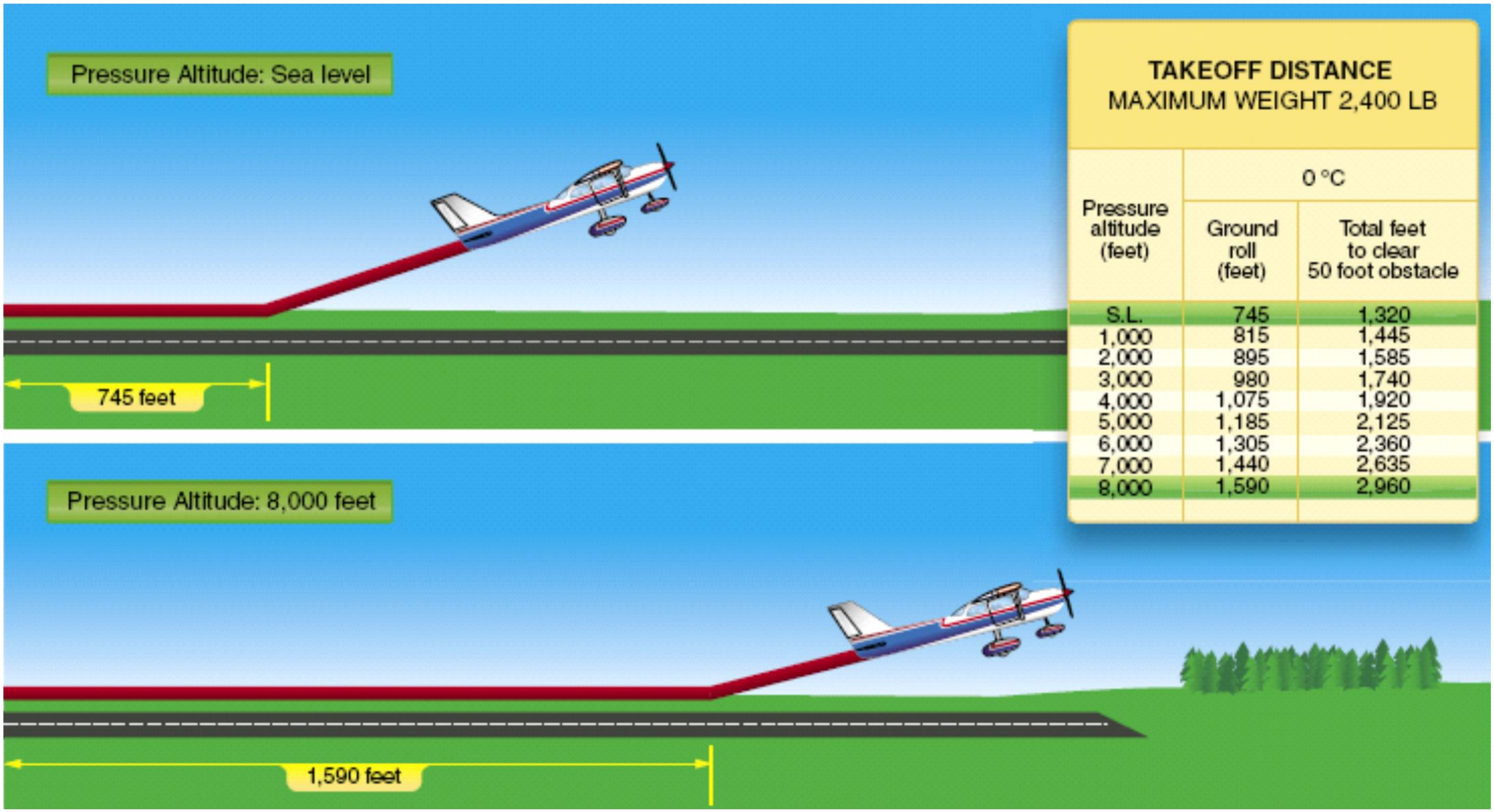
Prior to each flight, a pilot should examine the altimeter for proper indications in order to verify its accuracy. To determine the condition of an altimeter, set the barometric scale to the current reported altimeter setting transmitted by the local automated flight service station (AFSS) or any other reliable source, such as ATIS, AWOS, or ASOS. The altimeter pointers should indicate the surveyed field elevation of the airport.

<u>If the indication is off more than 75 feet from the surveyed field elevation, the instrument should be referred to a certificated instrument repair station for recalibration</u>.

Altitude and Flight

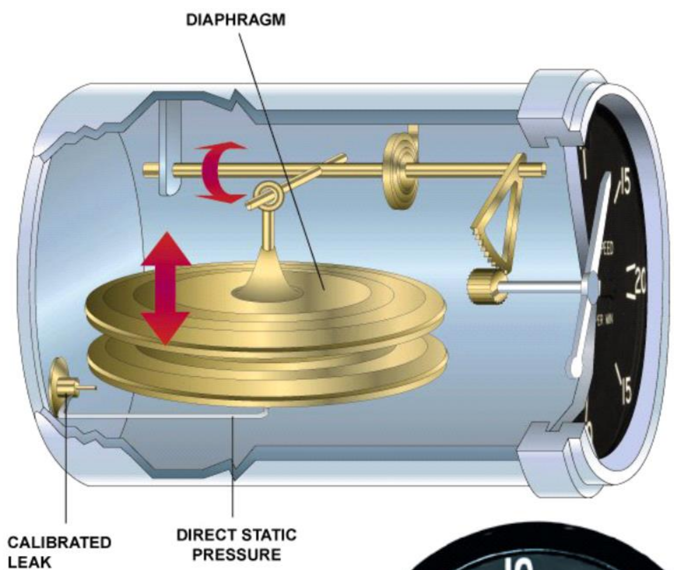
Altitude affects every aspect of flight from aircraft performance to human performance. At higher altitudes, with a decreased atmospheric pressure, takeoff and landing distances are increased, as are climb rates.

When an aircraft takes off, lift must be developed by the flow of air around the wings. If the air is thin, more speed is required to obtain enough lift for takeoff; therefore, the ground run is longer. An aircraft that requires 745 feet of ground run at sea level requires more than double that at a pressure altitude of 8,000 feet. [Figure 11-9]. It is also true that at higher altitudes, due to the decreased density of the air, aircraft engines and propellers are less efficient. This leads to reduced rates of climb and a greater ground run for obstacle clearance.



Pressure altitude (feet)	0 °C	
	Ground roll (feet)	Total feet to clear 50 foot obstacle
S.L.	745	1,320
1,000	815	1,445
2,000	895	1,585
3,000	980	1,740
4,000	1,075	1,920
5,000	1,185	2,125
6,000	1,305	2,360
7,000	1,440	2,635
8,000	1,590	2,960

Flight Instruments: Pitot-Static System – Vertical Speed Indicator (VSI)



TREND INFORMATION ON CHANGE IN VERTICAL SPEED (rate of descent or climb in hundreds of feet per minute). Indicator not accurate until aircraft stabilized. There is a 6-9 second lag for stable pressure to give accurate reading. DON'T CHASE IT…

Created by Steve Reisser

Flight Instruments: Gyroscopic

Attitude indicator
shows a right turn

ATTITUDE
INDICATOR

HEADING
INDICATOR (DG)

TURN
COORDINATOR

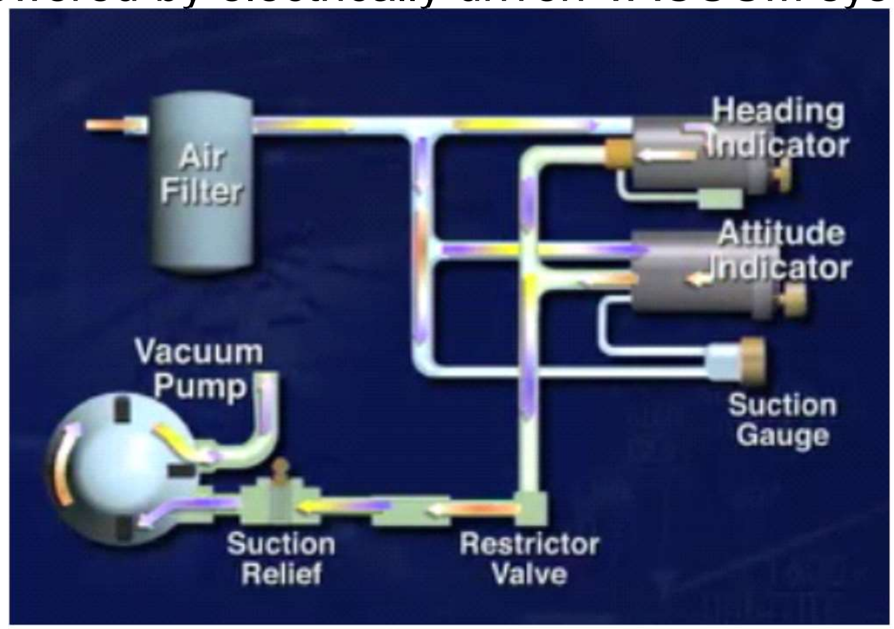
Turn coordinator
indicates a right turn

Heading moves from
northerly to easterly direction
indicating a right turn

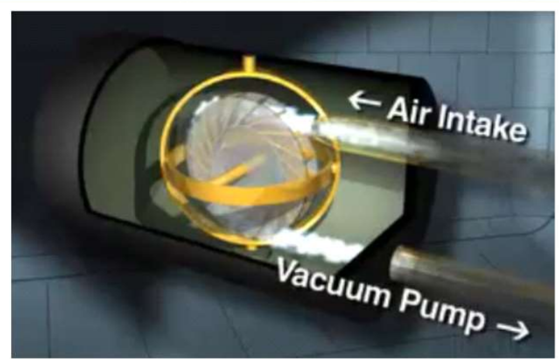
Flight Instruments: Gyroscopic Principles – Rigidity in Space and Precession

Rigidity: Tendency to remain in a constant position no mater what the orientation.

Powered by electrically driven VACUUM system



Precession: Small forces applied to a gyro will cause a resultant 90 degree force that is inversely proportional to the speed of the rotor and proportional to the deflective force.



Vacuum System Failure?

DISCUSSION

1. What are the chances of a vacuum system failure in your lifetime of flight?

   Almost certain

2. IFR pilots are fly in conditions that require use of vacuum system instruments. You should avoid being in IMC unless you are instrument rated. What do you is the survival rate of pilots getting into IMC with a loss of the vacuum system?

   Only 13%

3. The key to surviving such an event is TRAINING. We react in emergencies in the manner of which we are trained. YOU MUST GET TRAINING TO HANDLE PARTIAL PANEL even if not IFR rated.

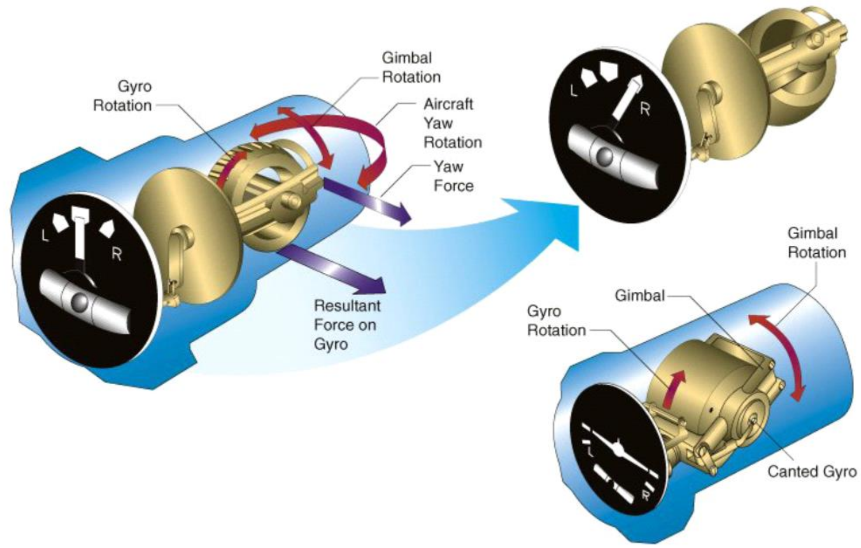
   INSIST you be taught use of Power Setting for controlled descents and airspeeds, and use of compass as only directional control.

4. Add ICING to that and without 2 items your toast! What might they be?

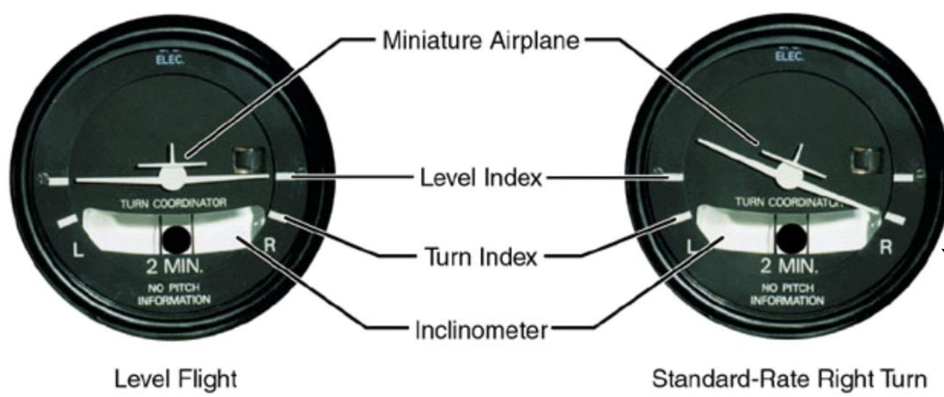
   Instrument covers to prevent MISSINFORMATION, and consider a single-axis autopilot to keep wings level!

WHAT WOULD BE YOUR ACTION IF YOUR AIRCRAFT LAST THE VACUUM SYSTEM?

Flight Instruments: Gyroscopic
TURN COORDINATOR



Gyro driven by electrical or vacuum (pressure)

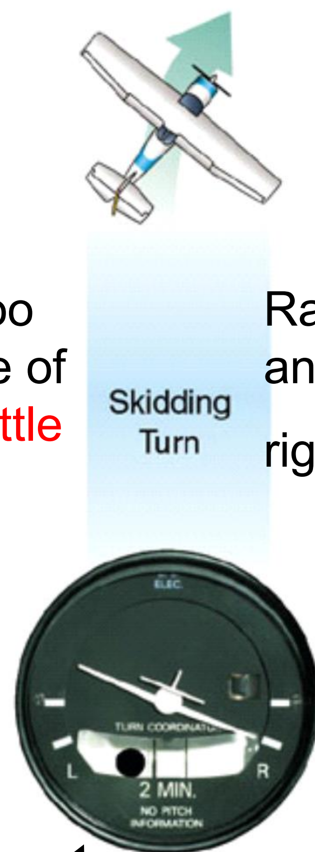


Standard rate turn-2 minutes

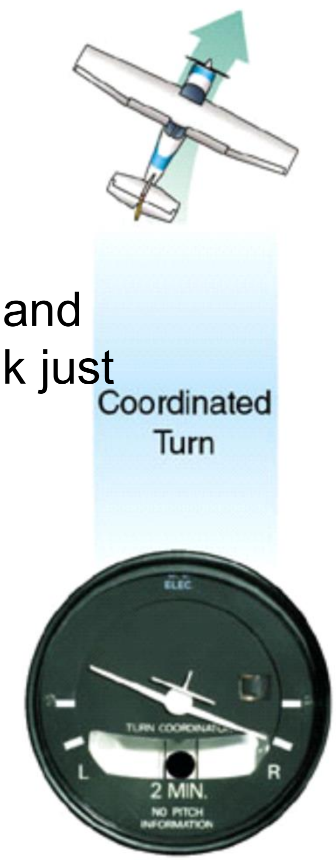
Flight Instruments: Gyroscopic
TURN COORDINATOR

Rate of turn too slow for angle of bank. ☹ Too much bank (roll)

Rate of turn too great for angle of bank. ☹ Too little bank (roll)



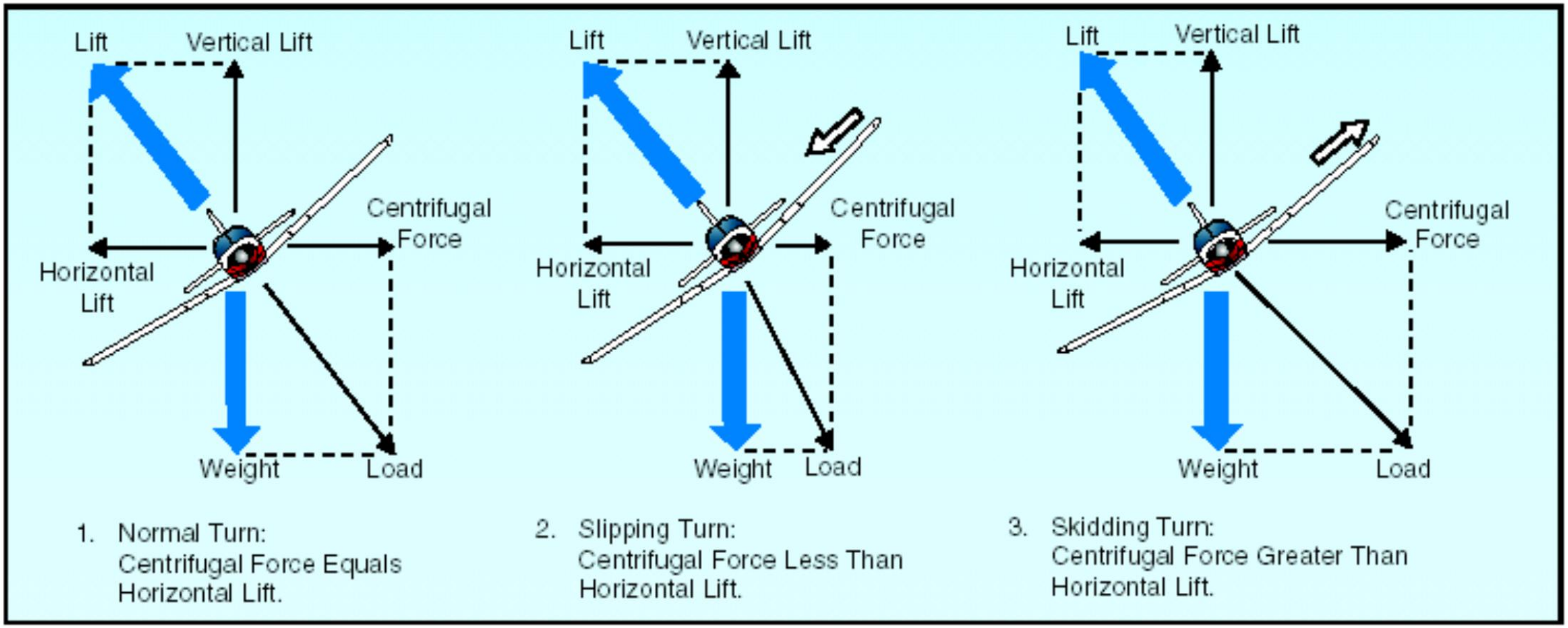
Rate of turn and angle of bank just right ☺



Vary rate of turn or "Step On the Ball"

Created by Steve Reisser

AERODYNAMICS OF SLIPS AND SKID



Don't let this confuse you...
The turn and bank indicators
Show what the pilot observes →
Slip (slipping down to right)
Skid (skipping out to left)

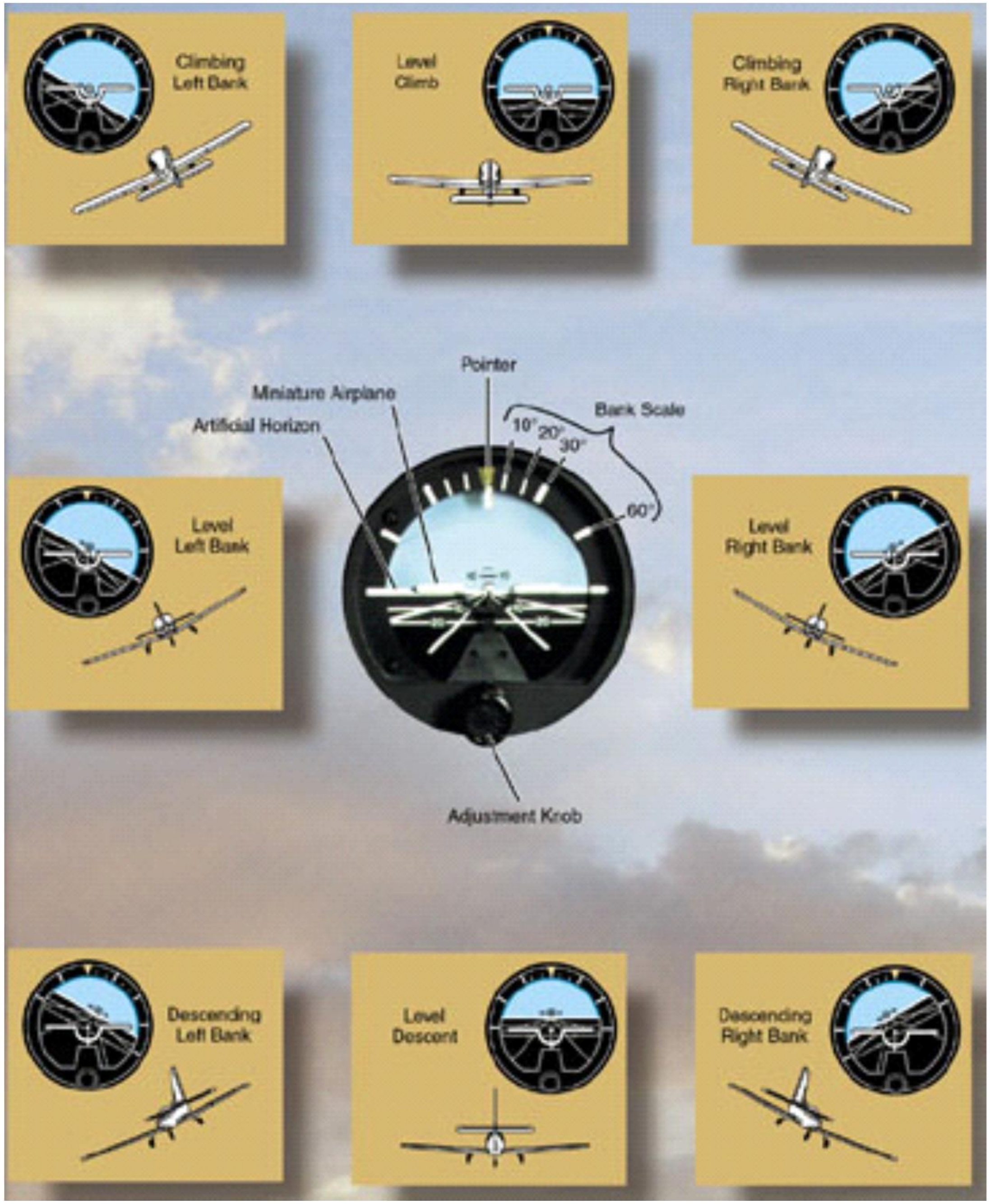
Standard Rate Turns

- Two Minute Turn (3 degrees per second)
- Always use Turn and Bank Indicator as your "primary" reference for standard rate turns !!
- You can determine the angle on the "Attitude Indicator" by a mental calculation of

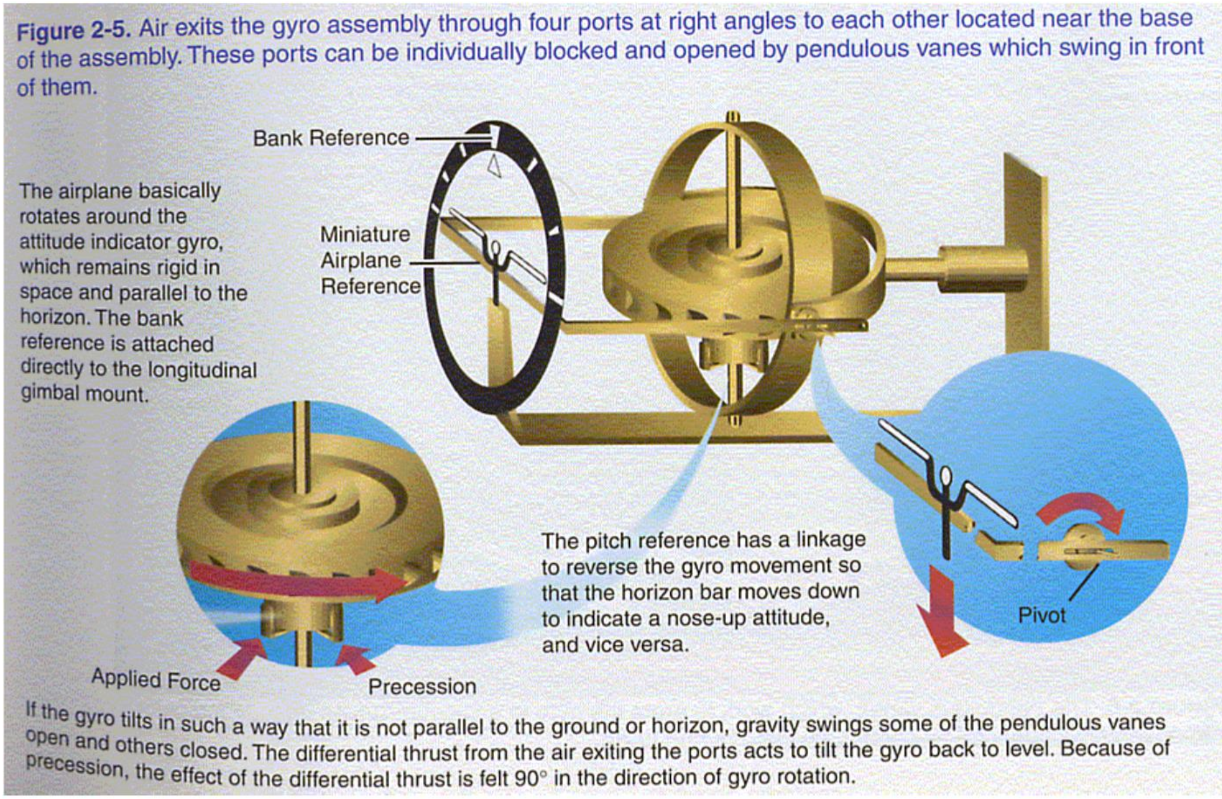
<u>Airspeed / 10 * 1.5</u>

TAS 80/10 = 8*1.5= 12 degrees
TAS 100 /10 = 10*1.5= 15 degrees
TAS 120 /10 = 12*1.5= 18 degrees
TAS 160 /10 = 16*1.5= 24 degrees

ATTITUDE INDICATOR also referred to as the Artificial Horizon



Flight Instruments: *Mechanical* Gyroscopic Attitude Indicator



LIMITS:

- Roll = 60-70 degrees and Pitch = 100-110 degrees after which the gyro will become *caged* and require service to unseat the gyros.
- Might be a "slight" nose-up indication in rapid acceleration or nose-down indication on rapid deceleration.
- There is a slight chance of a small bank or pitch error following a 180 degree turn that will correct itself after about a minute of straight and level flight.

Attitude Determination

<u>Mechanical attitude reference</u> (shown on the previous page)

Heavy & big

Expensive to maintain

Dependent on vacuum system

Susceptible to mechanical failure (caging)

<u>Non-mechanical attitude reference</u>

GPS derived and 3-axis inferrometer gyroscopes, accelerometers, and magnetometers. Senses of position, speed, G-Forces

Inexpensive

Generally accurate

Much lighter than mechanical

Mobile: iPhone, iPad and integrated Apps

AHRS: Attitude Heading Reference System (3-axis laser inferrometer)

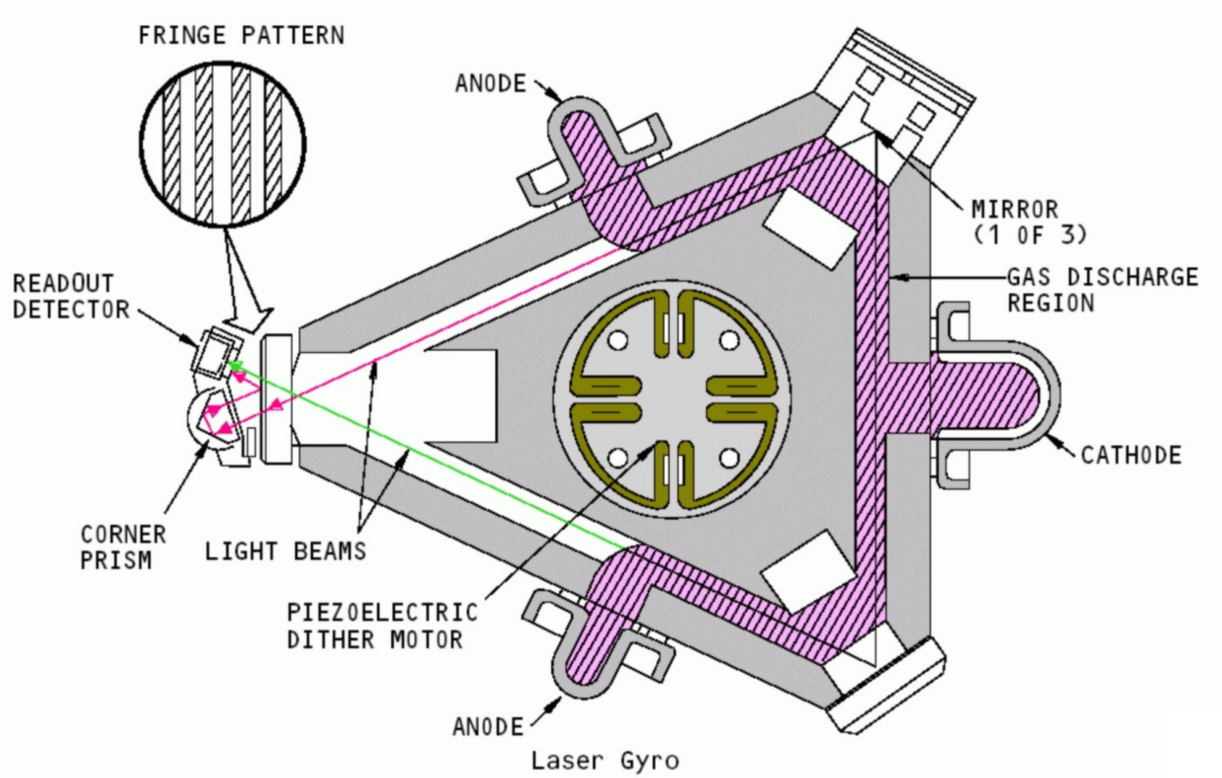
Inexpensive

Lightweight & Small

VERY accurate

Attitude Heading Reference System: AHRS

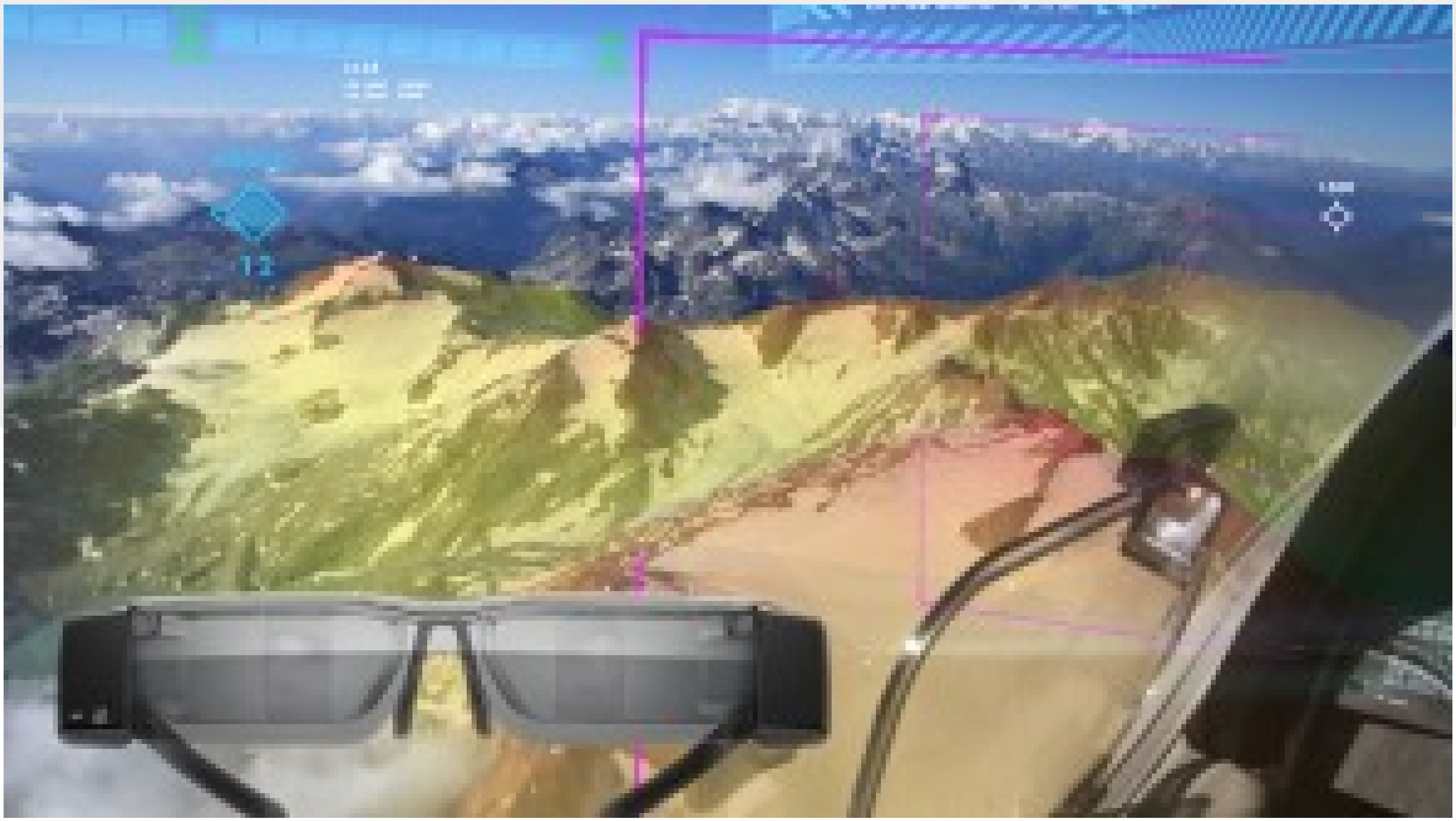
Video. iLevel http://youtu.be/1BVY7k3yeJc



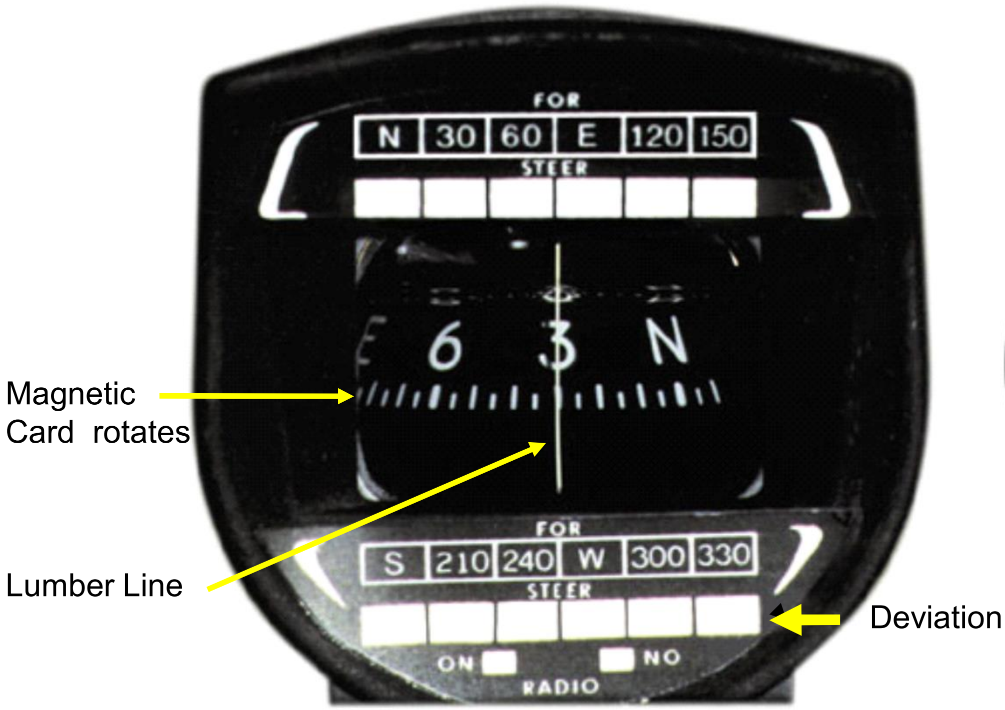
Stratus 2: http://youtu.be/Ijf8rOMq_nE

Augmented reality glasses for pilots!

Aero Glass showcased Augmented reality glasses for pilots using Epson's Moverio technology and Google Glass. The glasses display a virtual reality, in 360 degrees of view, showing victor airways, flight instrumentation, approaches and 3D airspace. When connected to an iLevil receiver, the glasses portray ADS-B information (traffic and weather) and uses the remote AHRS to display the attitude of your aircraft as a HUD! https://glass.aero/



Flight Instruments: HEADING INDICATORS



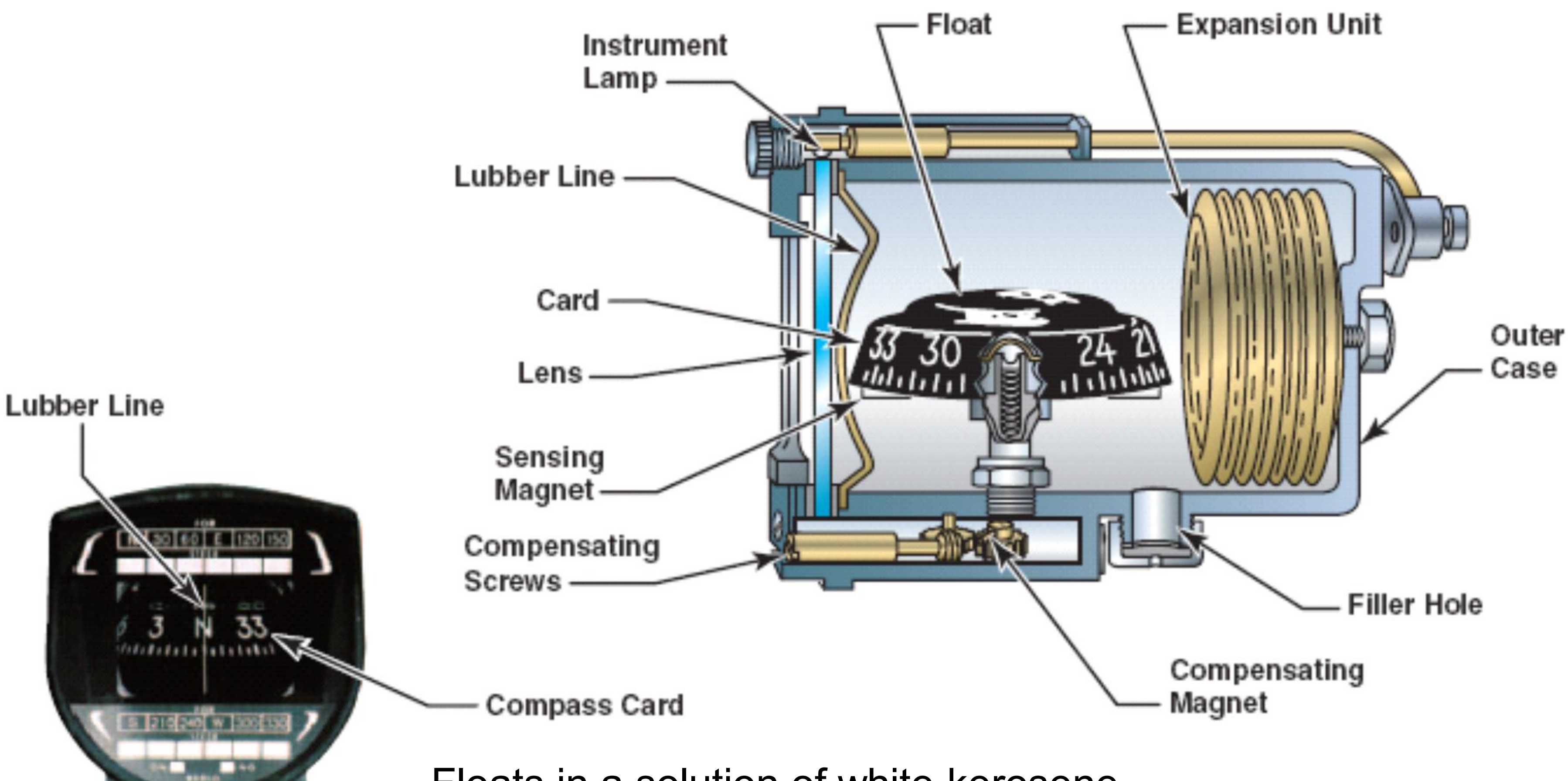
NON-GYROSCOPIC: Magnetic Compass. Accurate in straight and level, non-accelerated flight.

GYROSCOPIC: Heading Indicator also referred to as the Directional Gyro. Adjust with Magnetic Compass every 15 minutes during flight.

Limitations of Gyroscopic Heading Indicator (Directional Gyro)

- On SOME older heading indicators, the limits are approximately 55 degrees of pitch and 55 degrees of bank.
- When exceeded the instrument “tumbles” or “spills” and no longer gives correct indication until reset.
- Many modern DGs will not tumble
- MUST re-align to COMPASS during straight and level flight because precession caused by friction may cause as much as 15 degree error every hour.

Magnetic Compass

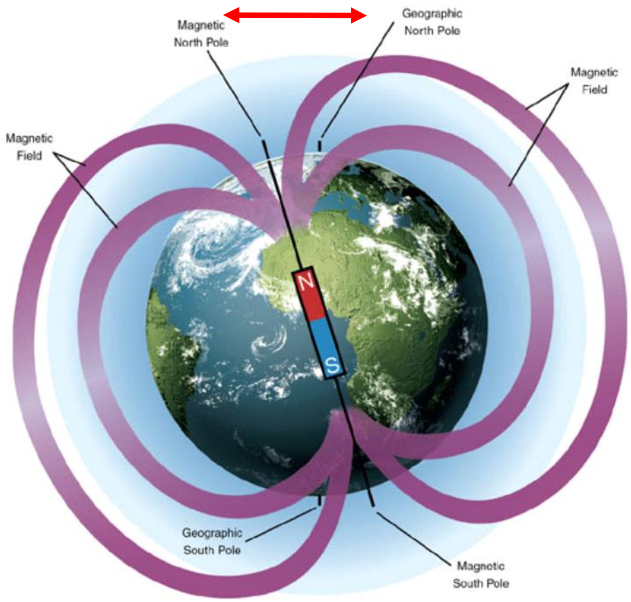


Floats in a solution of white kerosene

Note: Sensing Magnet positioned differently for Northern and Southern Hemisphere
360 Northern 180 Southern

Flight Instruments:
Magnetic Variation & Deviation

Variation: difference in True North and Magnetic North

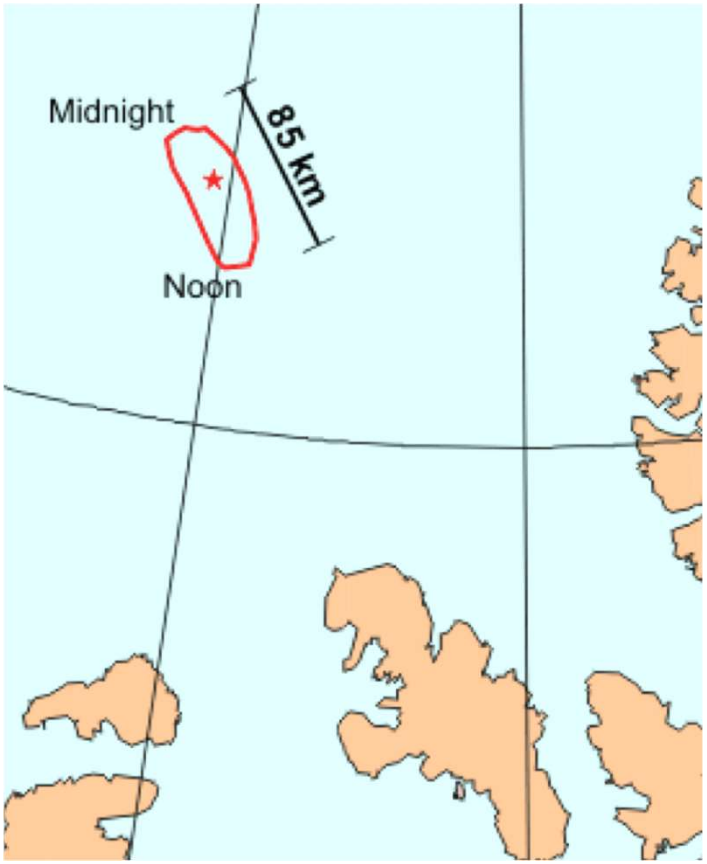


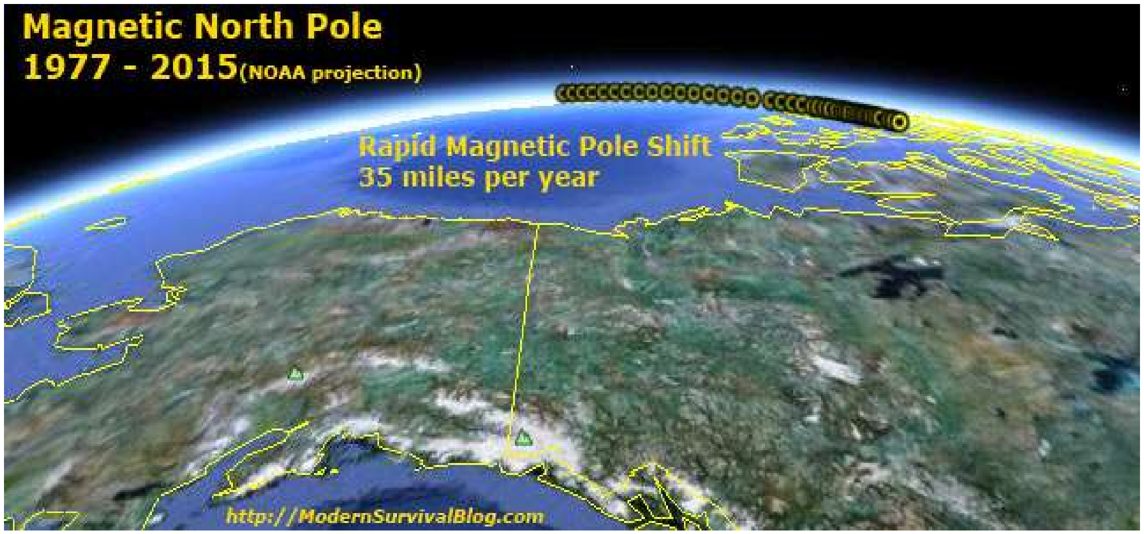
Deviation: Instrument errc displayed on Magnetic Compass and aircraft documents (POH)

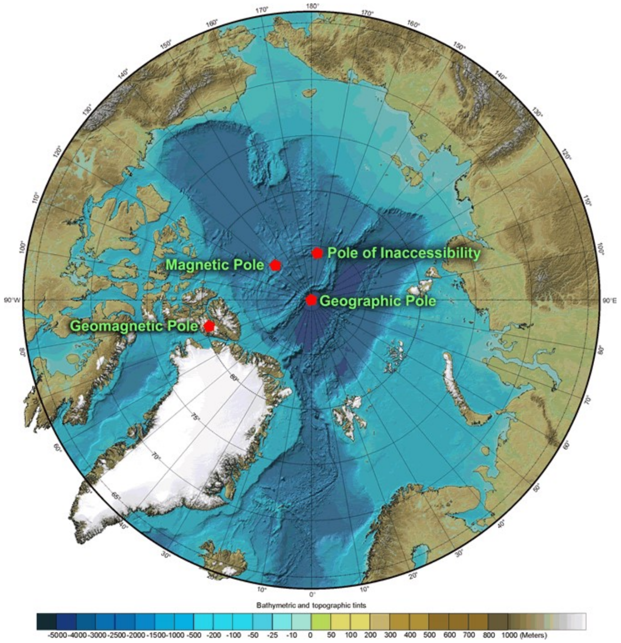
FOR (MH)	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
STEER (CH)	359°	30°	60°	88°	120°	152°	183°	212°	240°	268°	300°	329°
RADIO ON ✓						RADIO OFF ☐						

Where is Magnetic North?

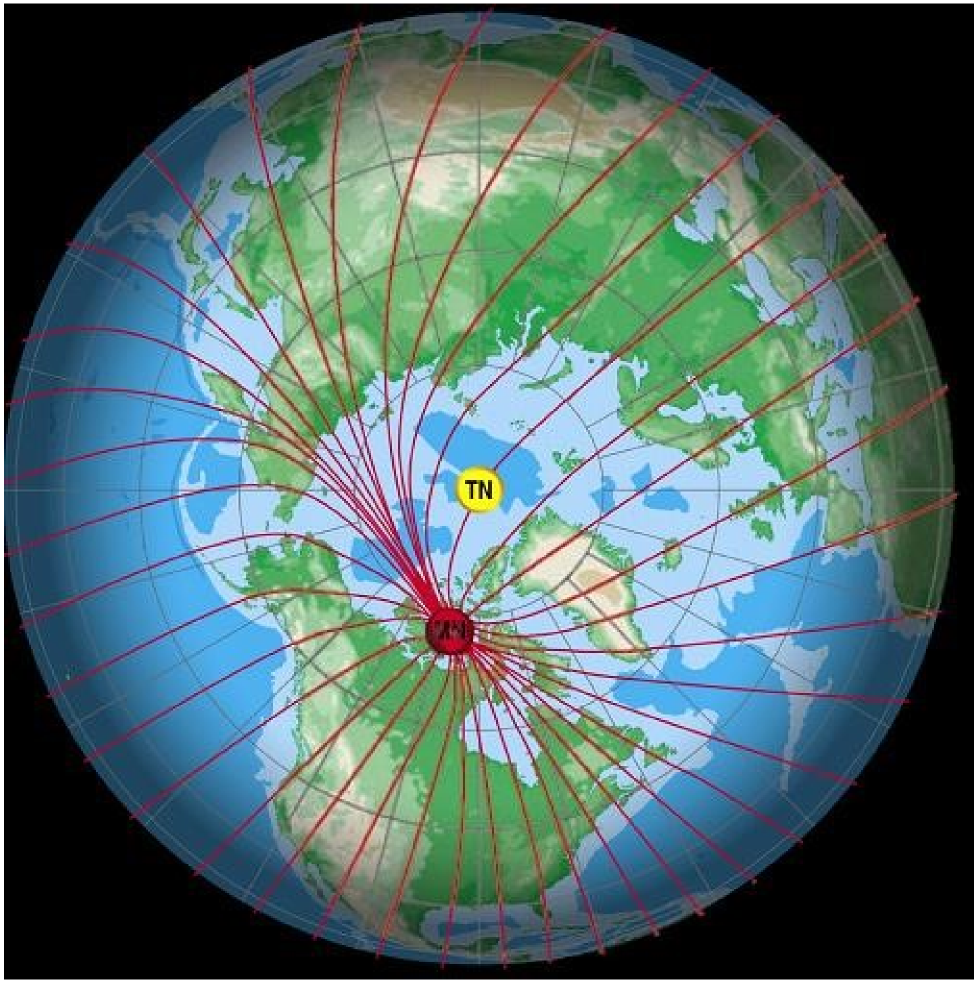
- Variation is the difference is position between True North (The North Pole) and Magnetic North Pole. NOT THE SAME – Moves daily and annually!



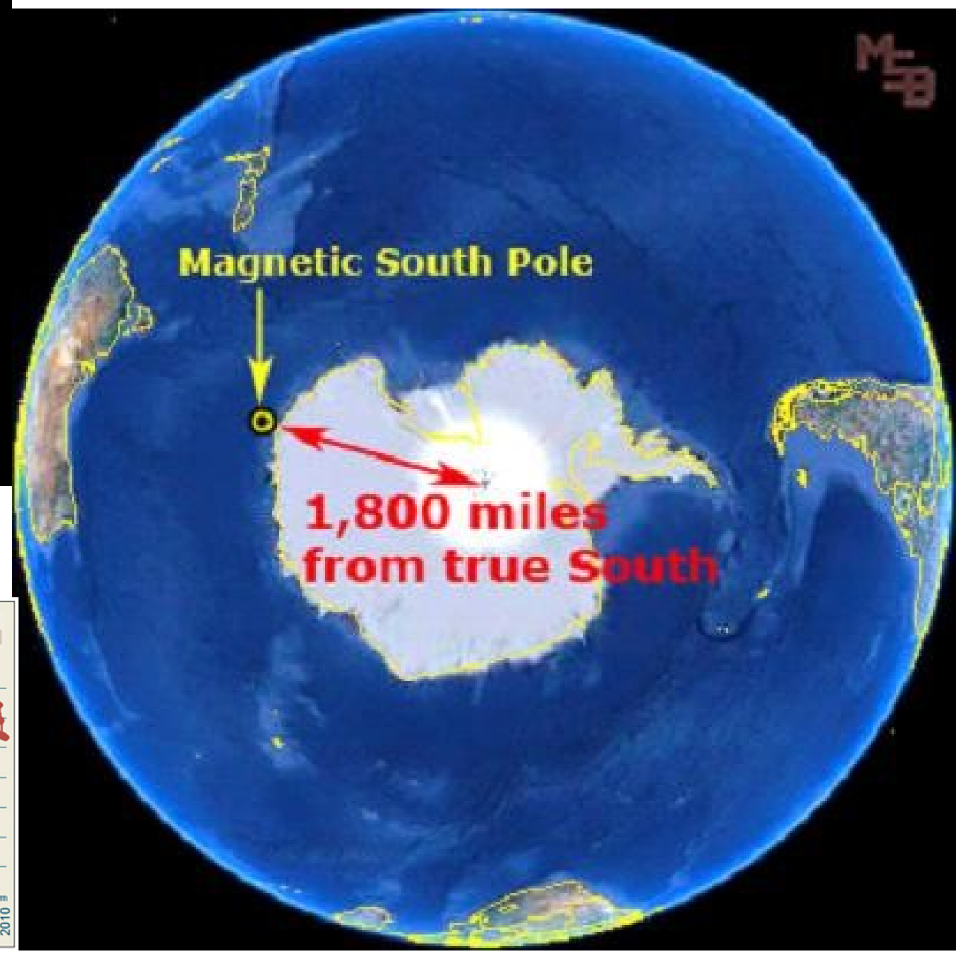




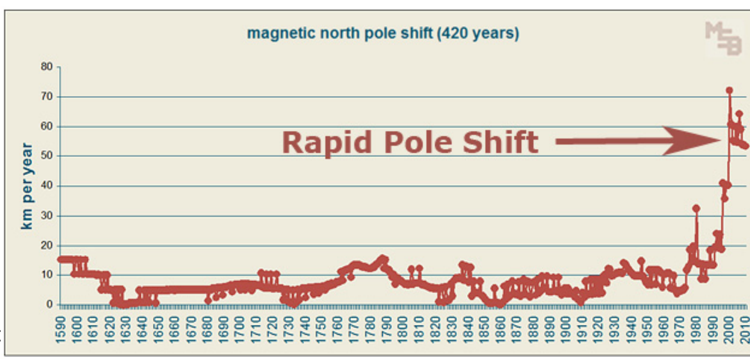
Just to add to the complexity there is a "Magnetic" and a "Geomagnetic" Pole which are both different from the "Geographic"-True North Pole. Offset 11 degrees



NORTHERN HEMISPERE



SOUTHERN HEMISPERE



Instrument Ground Sc

Flight Instruments: Magnetic Compass Errors

Variation, Deviation, Oscillation

Variation: Difference in Magnetic / True North
Deviation: Electrical interference from aircraft
Oscillation: Rough handling or turbulence

Magnetic Dip

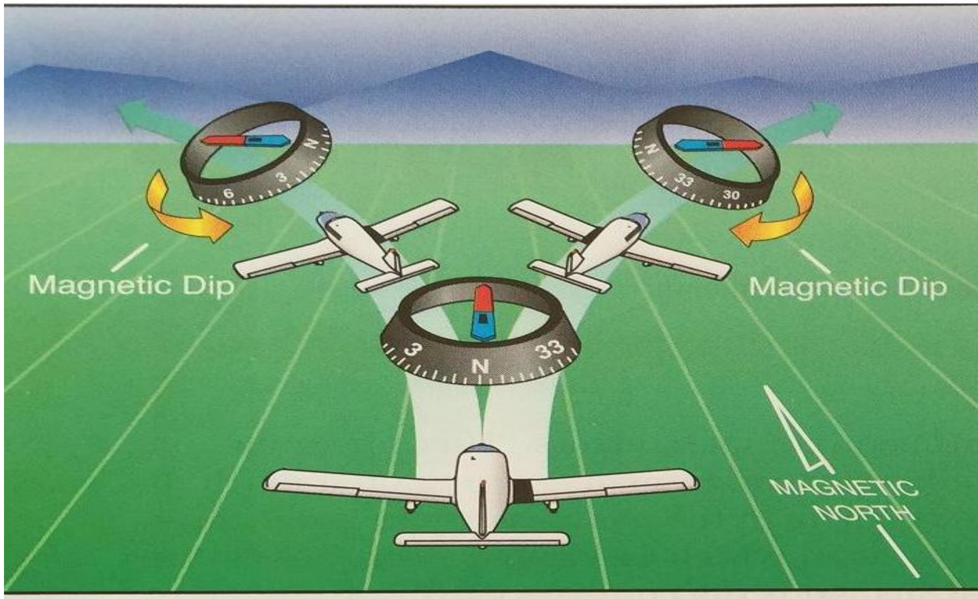
Magnetic dip is the result of the vertical component of the Earth's magnetic field. This dip is virtually non-existent at the magnetic equator. The vertical component increases at higher latitudes. DIP ERRORS are responsible for compass errors in <u>acceleration, deceleration and turns</u>. Magnetic bar is weighted to reduce dipping that is strongest at the poles and least at equator.

Acceleration - Deceleration

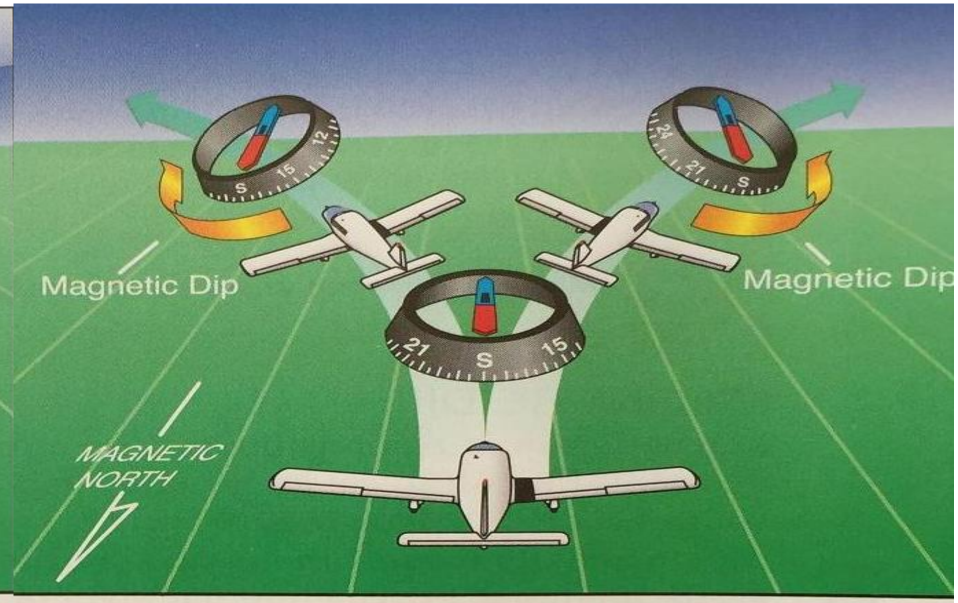
Deviates NORTH when accelerating, and Deviates SOUTH when decelerating. On EASTERLY or WESTERLY HEADINGS. "ANDS" (Accelerate North Decelerate South)

Turning Errors

Deviation turning FROM North or South Heading (Undershoot North, Overshoots South … UNOS-OSUN



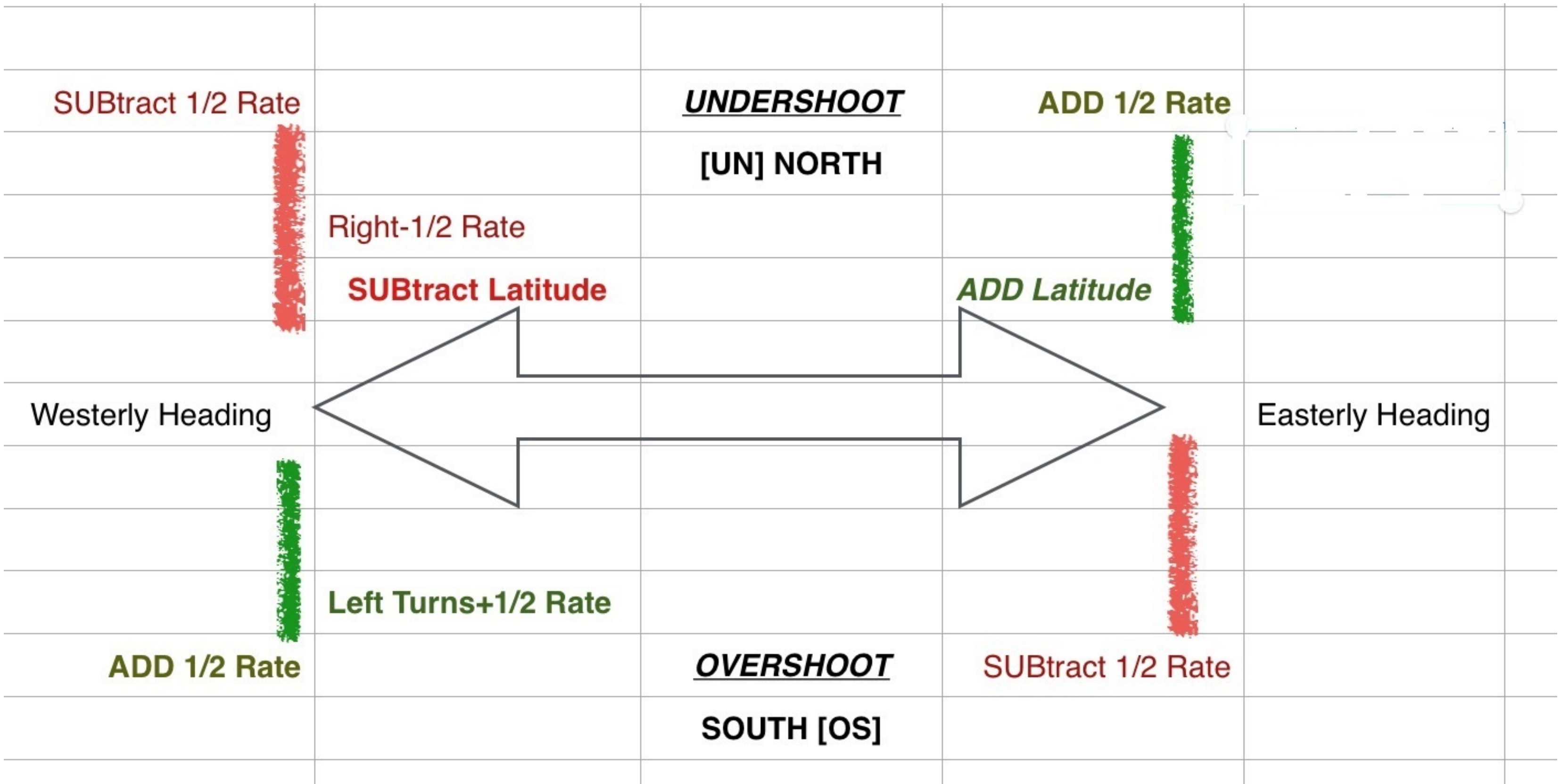
In the northern hemisphere, when entering a turn from a north heading, the compass will initially indicate a turn in the opposite direction.



When entering a turn from a south heading, the compass will turn in the proper direction, but will lead the turn until on a heading of east or west.

It is essential you use standard-rate turns if relying on the magnetic compass. When performing a compass turn to a northerly heading, you must roll out of the turn before the compass reaches the desired heading. When turning to a southerly heading, you must delay the roll-out until the compass card swings past the desired heading. When determining whether to lag or lead the desired heading on roll-out, remember the acronym, OSUN (Overshoot South, Undershoot North). The amount of correction depends on your latitude and angle of bank. With 15° to 18° bank (a standard-rate turn in a typical piston-powered airplane), the amount of lag or lead approximately matches your latitude, plus the one-half angle of bank you lead the roll-out on any turn. For example, at 35° N latitude and a 16° bank, a right turn to north requires a roll-out point of 317° (360 – 35 – 8). A right turn to south requires a roll-out point of 207° (180 + 35 – 8). When turning left to a north heading the roll-out point is 43° (360 + 35 + 8). When turning left to a south heading it is 153° (180 – 35 + 8).

In



Heading	Turning	Latitude +/-	1/2 Rate +/-
East	Left to North	+	+
East	Right to South	+	-
West	Right to North	-	-
West	Left to South	-	+

PITCH, BANK, AND POWER INSTRUMENTS


Altimeter primary for pitch control


Heading indicator primary for bank control


Airspeed indicator primary for power control


Proper pitch and power produces predictable performance

Climbing – best climb Attitude? On Take off use V_X and V_Y.

Start to Level off when at 10% of rate of climb depending on your airspeed.

Digital Based Instrument Systems

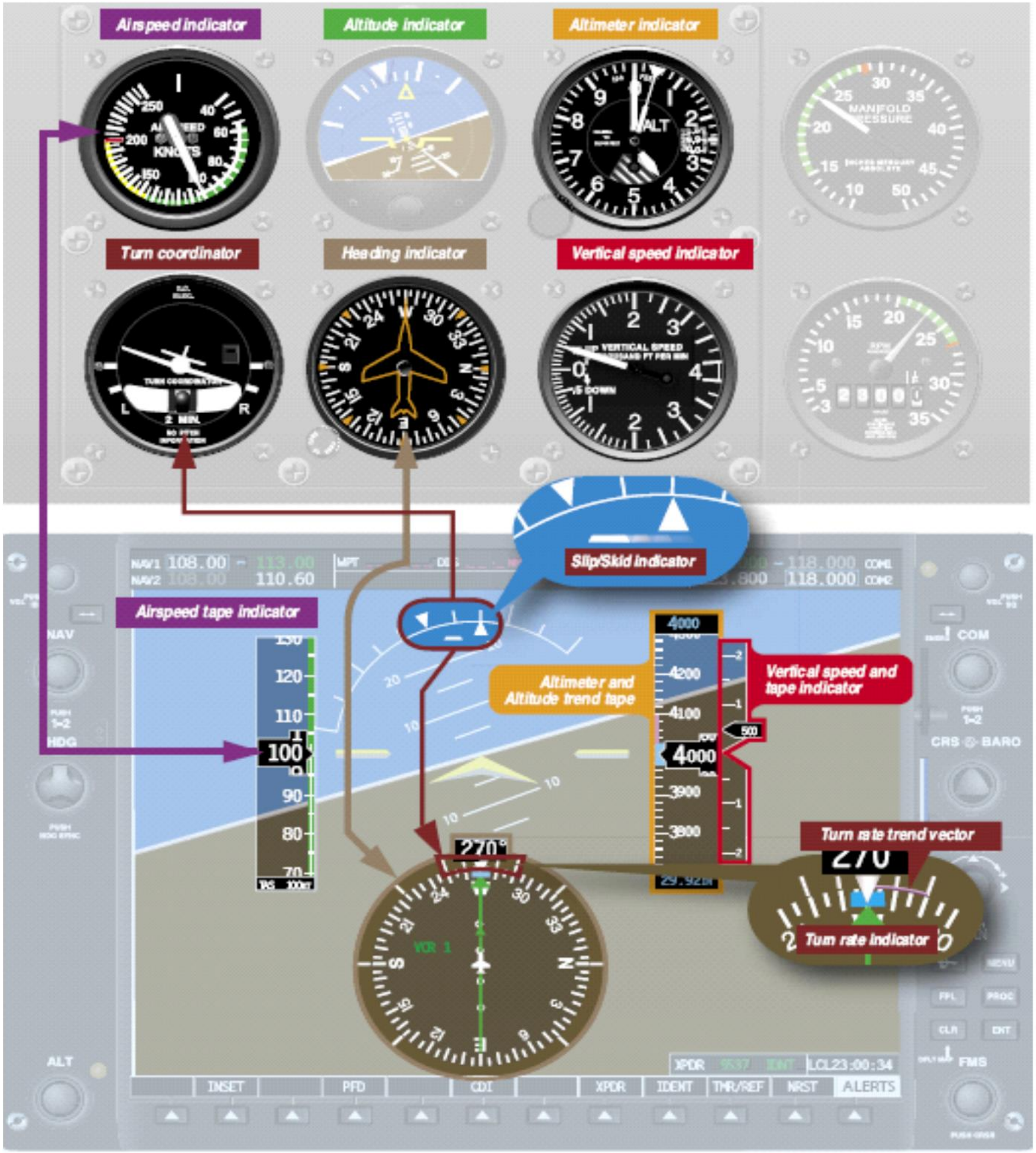
Instrumentation changes are in process to digital based information and displays.

- Electronic Flight Information Systems / Primary Flight Displays (EFIS-MFD)
- Engine Monitoring Systems (EMS)
- Synthetic Vision Systems (SV)
- Automatic Dependent Surveillance Broadcast (ADS-B)
- Global Positioning Systems (GPS)

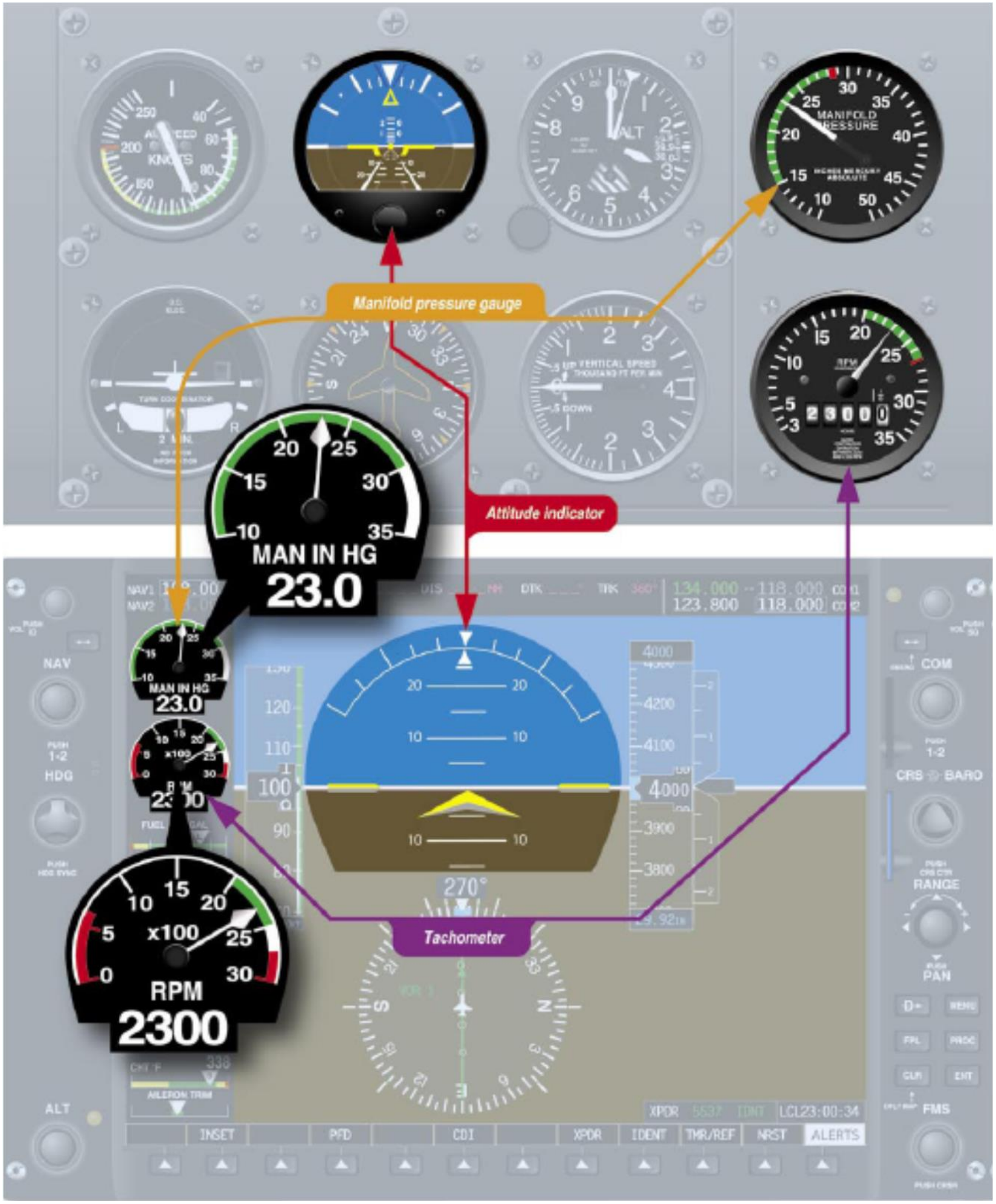
Example 1

“Six-pack”

Equivalent Digital



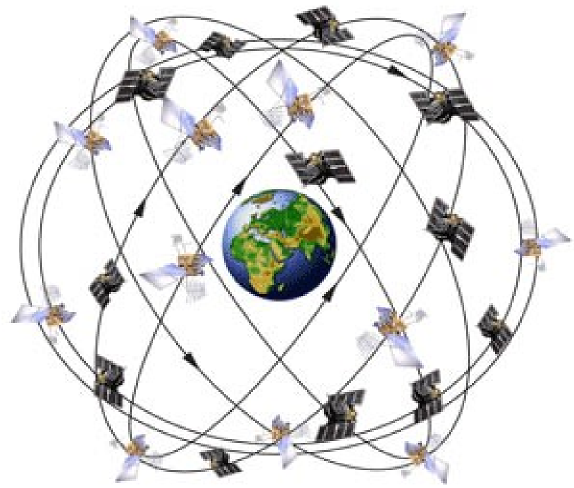
Example 2



Manifold pressure gauge
Attitude indicator
Tachometer
MAN IN HG
23.0
RPM
2300

EFIS/PFD/MFD/GDU

Electronic Flight Information Systems / Primary Flight Displays / Multi-Function Displays/Graphic Display Units



Global Positioning Satellites (GPS)

GPS Positioning

GPS is “line of site” a satellite based system requiring approximately 60 seconds to acquire satellite acquisition. (e-GPS as initially used by mobile devices can triangulate from cell towers which is why you can see 2 dimensional triangulation before 60 seconds).
VFR flights may use portable, mobile, GPS (not e-GPS) as primary navigation. A portable GPS may not be used for primary navigation in IFR flights.

There are 5 satellites required for what activity?

Flights into known *Instrument Meteorological Conditions* have additional requirements to utilize GPS as primary navigation.

The GPS devise is panel mounted (portables not allowed)

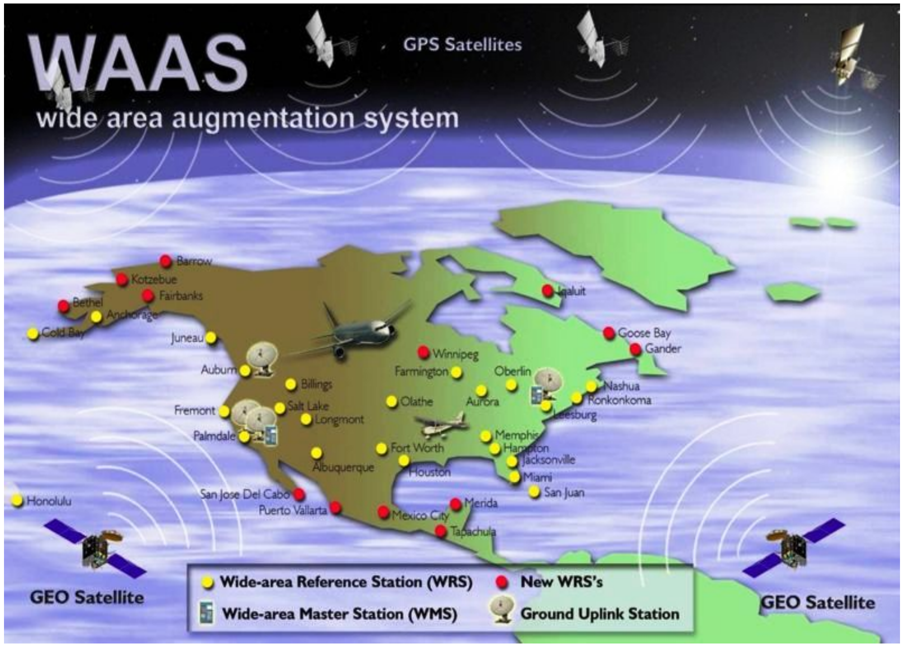
1. External GPS antenna is required do to changes roll and pitch maneuvers during maneuvering and landing. You cannot lose line of site connection with satellites.

2. You have acquired <u>at least 5 satellites</u>,

3. Your equipment utilizing both *<u>Wide Area Augmentation System (WAAS)</u>* *and* *<u>Receiver autonomous integrity monitoring (RAIM)</u>*.

<u>Wide Area Augmentation System (WAAS)</u>

WAAS uses a network of ground-based reference stations, in North America and Hawaii, to measure small variations in the GPS satellites' signals in the western hemisphere. Measurements from the reference stations are routed to master stations, which queue the received Deviation Correction (DC) and send the correction messages to geostationary WAAS satellites in a timely manner (every 5 seconds or better). Those satellites broadcast the correction messages back to Earth, where WAAS-enabled GPS receivers use the corrections while computing their positions to improve accuracy.



Navigation System Accuracies

System	95% Accuracy (Lateral / Vertical)	Details
LORAN-C Measured	50 m / 50 m	The U.S. Coast Guard reports "return to position" accuracies of 50 meters in time difference
GPS Measured	2.5 m / 4.7 m	The actual measured accuracy of the system (excluding receiver errors), with SA turned off, based on the findings of the FAA's National Satellite Test Bed, or NSTB.
WAAS Measured	0.9 m / 1.3 m	The actual measured accuracy of the system (excluding receiver errors), based on the NSTB's findings.
Local Area Augmentation System (LAAS)	< 1 m	The goal of the LAAS program is to provide Category IIIC ILS capability. This will allow aircraft to land with zero visibility utilizing 'autoland' systems and will indicate a very high accuracy of < 1 m

Receiver Autonomous Integrity Monitoring (RAIM)

Provides integrity monitoring of GPS for aviation applications. In order for a GPS receiver to perform RAIM or fault detection (FD) function, a minimum of five visible satellites with satisfactory geometry must be visible to it. RAIM has various kind of implementations; one of them performs consistency checks between all position solutions obtained with various subsets of the visible satellites. The receiver provides an alert to the pilot if the consistency checks fail.

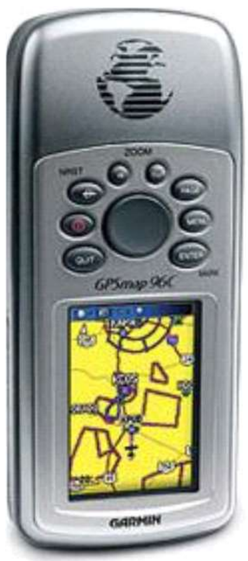
RAIM detects faults with redundant GPS "pseudorange" measurements. That is, when more satellites are available than needed to produce a position fix, the extra pseudoranges should all be consistent with the computed position. A pseudorange that differs significantly from the expected value (i.e., an outlier) may indicate a fault of the associated satellite or another signal integrity problem (e.g., ionospheric dispersion). Traditional RAIM uses fault detection (FD) only, however newer GPS receivers incorporate fault detection and exclusion (FDE) which enables them to continue to operate in the presence of a GPS failure.

The pseudorange (from pseudo- and range) is the *pseudo* distance between a satellite and a navigation satellite receiver (see GNSS positioning calculation) —for instance Global Positioning System (GPS) receivers, by multiplying the speed of light by the time the signal has taken from the satellite to the receiver. As there are accuracy errors in the time measured, the term *pseudo*-ranges is used rather than ranges for such distances.

ERROR detection alerts pilots of integrity problems

Garmin 1000 PFD/MFD

Prices range from $495 on bottom row to $30,000 above (2009 pricing)



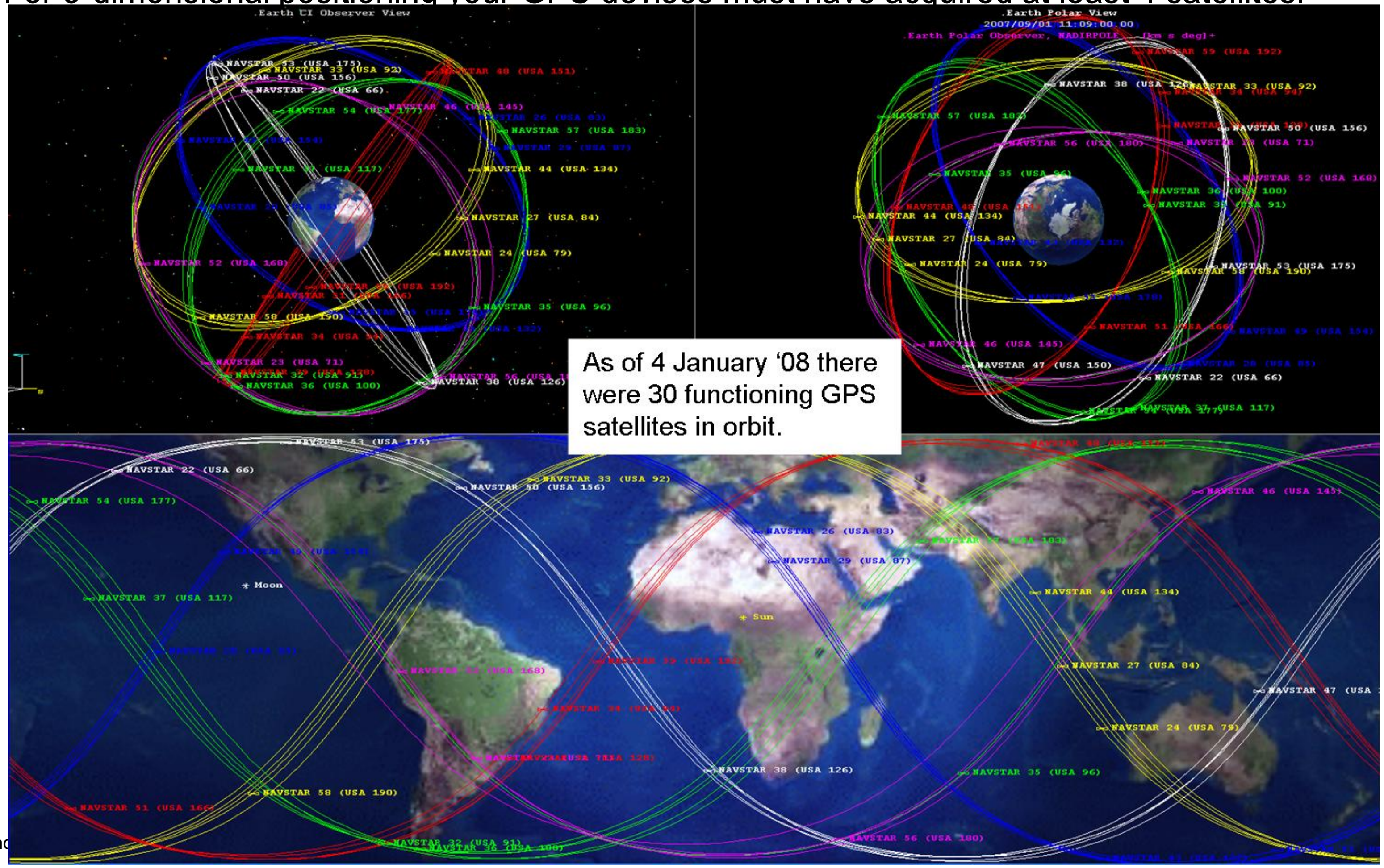
GPS Positioning

GPS is "*line of site*" a satellite based system requiring approximately 60 seconds to acquire satellite acquisition. (e-GPS as initially used by mobile devices can triangulate from cell towers which is why you can see 2 dimensional triangulation before 60 seconds).

VFR flights may use portable, mobile, GPS (not e-GPS) as primary navigation. A portable GPS may not be used for primary navigation in IFR flights.

Otherwise:

1. For 2-dimensional positioning your GPS devises must have acquired at least 3 satellites.
2. For 3-dimensional positioning your GPS devises must have acquired at least 4 satellites.



EMS
Engine Monitoring System

Synthetic Vision Systems

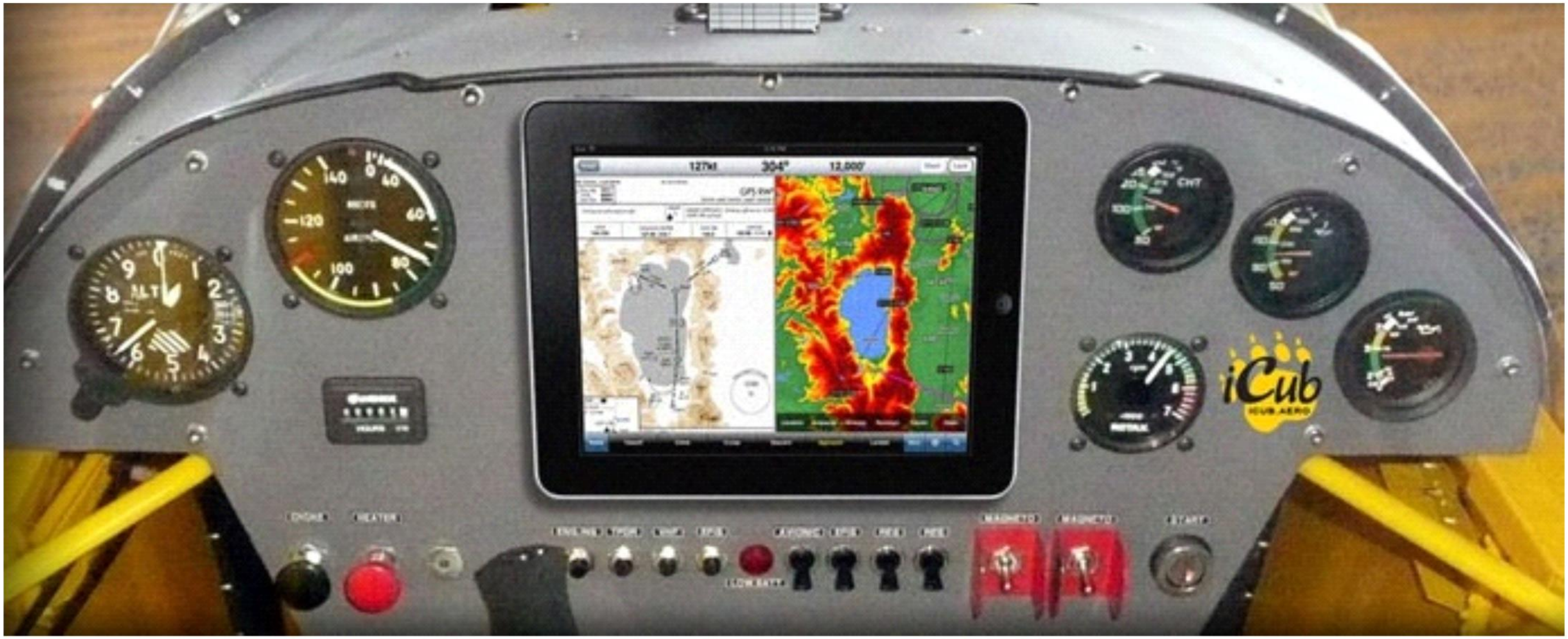
Primary Flight Display OVERLAYED with real time graphic of outside conditions regardless of visibility. Can be panel mounted or used with Tablet Personal Computer OR projected onto the back of the spinning propeller so directly viewed by pilot looking out the windshield.

Primary Flight Display OVERLAYED with real time graphic of outside conditions regardless of visibility. Can be panel mounted or used with Tablet Personal Computer OR projected onto the back of the spinning propeller so directly viewed by pilot looking out the windshield.

[Infrared Display for enhanced Night Flights]

[EFIS Runway Seeker]

iCub - iPad



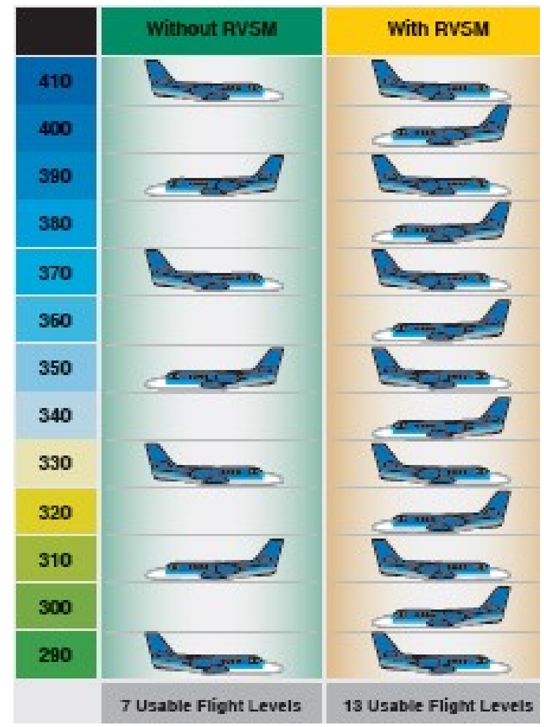
iPad currently has over 400 Aviation applications – check http://www.aviatorapps.com/

Including tons of documents, EFB, EFIS, PFD-MFD, HUD, all radial Instruments, & bunches of flight planning, cross-country tracking, weather radar, all charts. You can Get latest flight briefings and even file flight plan directly using the iPad. Recommended as backup-not primary instrumentation, and also use of external GPS.

Reduced Vertical Separation Minimum (RVSM)

Below 31,000 feet, a 1,000 foot separation is the minimum required between usable flight levels. Flight levels (FLs) generally start at 18,000 feet where the local pressure is 29.92 "Hg or greater. All aircraft 18,000 feet and above use a standard altimeter setting of 29.92 "Hg, and the altitudes are in reference to a standard hence termed FL. Between FL 180 and FL 290, the minimum altitude separation is 1,000 feet between aircraft. However, for flight above FL 290(primarily due to aircraft equipage and reporting capability; potential error) ATC applied the requirement of 2,000 feet of separation. FL 290, an altitude appropriate for an eastbound aircraft, would be followed by FL 310 for a westbound aircraft, and so on to FL 410, or seven FLs available for flight. With 1,000-foot separation, or a reduction of the vertical separation between FL 290 and FL 410, an additional six FLs become available. This results in normal flight level and direction management being maintained from FL 180 through FL 410. Hence the name is *Reduced Vertical Separation Minimum (RVSM).* Because it is applied domestically, it is called United States Domestic Reduced Vertical Separation Minimum (DRVSM). The aircraft must be equipped with at least one automatic altitude control.

- Within a tolerance band of ±65 feet about an acquired altitude when the aircraft is operated in straight-and level flight.
- Within a tolerance band of ±130 feet under no turbulent, conditions for aircraft for which application for type certification occurred on or before April 9,1997 that are equipped with an automatic altitude control system with flight management/performance system inputs.



Flight Director System (FDS)

A Flight Director System (FDS) combines many instruments into one display that provides an easily interpreted understanding of the aircraft's flightpath. The computed solution furnishes the steering commands necessary to obtain and hold a desired path. They become exceptionally powerful when coupled to the autopilot and attenuator panel.

FDI(ADI) "yellow bar"

Figure 5-39. *A typical cue that a pilot would follow.*

Figure 5-40. *Components of a typical FDS.*

Major components of an FDS include an ADI, also called a Flight Director Indicator (FDI), an HSI, a mode selector, and a flight director computer. It should be noted that a flight director in use does not infer the aircraft is being manipulated by the autopilot(coupled), but is providing steering commands that the pilot (or the autopilot, if coupled) follows. Typical flight directors use one of two display systems for steerage. The first is a set of command bars, one horizontal and one vertical. The command bars in this configuration are maintained in a centered position (much like a centered glideslope). The second uses a miniature aircraft aligned to a command cue.

A flight director displays steerage commands to the pilot on the ADI. As previously mentioned, the flight director receives its signals from one of various sources and provides that to the ADI for steerage commands. The mode controller provides signals through the ADI to drive the steering bars, e.g., the pilot flies the aircraft to place the delta symbol in the V of the steering bars. "Command" indicators tell the pilot in which direction and how much to change aircraft attitude to achieve the desired result.

Autopilot Systems

An autopilot is a mechanical means to control an aircraft using electrical, hydraulic, or digital systems. Autopilots can control three axes of the aircraft: roll, pitch, and yaw. Most autopilots in general aviation control roll and pitch.

Autopilots also function using different methods. The first is “position based”. That is, the attitude gyro senses the degree of difference from a position such as wings level, a change in pitch, or a heading change.

The second method is “rate based”. Rate-based systems use the turn-and-bank sensor for the autopilot system. The autopilot uses rate information on two of the aircraft’s three axes: movement about the vertical axis (heading change or yaw) and about the longitudinal axis (roll). This combined information from a single sensor is made possible by the 30° offset in the gyro’s axis to the longitudinal axis.

Other systems use a combination of both position and rate based information to benefit from the attributes of both systems while newer autopilots are digital.

Flight Management Systems (FMS)

An FMS uses an electronic database of worldwide navigational data including navigation aids, airways and intersections, Standard Instrument Departures (SIDs), STARs, and Instrument Approach Procedures (IAPs) together with pilot input through a CDU to create a flight plan. The FMS provides outputs to several aircraft systems including desired track, bearing and distance to the active waypoint, lateral course deviation and related data to the flight guidance system for the HSI displays, and roll steering command for the autopilot/flight director system. This allows outputs from the FMS to command the airplane where to go and when and how to turn. To support adaptation to numerous aircraft types, an FMS is usually capable of receiving and outputting both analog and digital data and discrete information. Currently, electronic navigation databases are updated every 28 days. The use of the Global Positioning System (GPS) has provided extremely precise position at low cost, making GPS the dominant FMS navigation sensor today. Currently, typical FMS installations require that air data and heading information be available electronically from the aircraft. The FMS provides not only real-time navigation capability but typically interfaces with other aircraft systems providing fuel management, control of cabin briefing and display systems, display of uplinked text and graphic weather data and air/ground data link communications.

DIGITAL INSTRUMENATION WILL BE REQUIRED TO SUPPORT ADS-B

"Automatic Dependent Surveillance Broadcast"

A – **A**utomatic in that it is Always On

D - **D**epends on accurate Global Navigation Satellite Systems (GPS for us)

S - Radar like **S**urveillance

B - Continuous **B**roadcasting position and other data to aircraft and ground stations if ADS-B equipped.

ADS-B represents the Next Generation Airspace Navigation System (NextGen) in the future with National Airspace System reconfigured no later than 2020.

Safety Systems

Radio Altimeters commonly referred to as a radar altimeter, is a system used for accurately measuring and displaying the height above the terrain directly beneath the aircraft. It sends a signal to the ground and processes the timed information. Its primary application is to provide accurate absolute altitude information to the pilot during approach and landing. The radar altimeter also provides its information to other onboard systems such as the autopilot and flight directors while they are in the glideslope capture mode below 200-300 feet above ground level (AGL).

The Traffic Information Service (TIS) is both a ground-based and satellite-based (ADS-B) service providing information to the flight deck via data link using the S-mode transponder and altitude encoder or ADS-B Out transmitters. TIS improves the safety and efficiency of “see and avoid” flight through an automatic display that informs the pilot of nearby traffic.

Traffic Alert and Collision Avoidance Systems*(TCAS)* is an airborne system developed by the FAA that operates independently from the ground-based ATC system. TCAS was designed to increase flight deck awareness of proximate aircraft and to serve as a “last line of defense” for the prevention of mid-air collisions. There are two levels of TCAS systems.

TCAS I was developed to accommodate the general aviation (GA) community and the regional airlines. This system issues traffic advisories(TAs) to assist pilots in visual acquisition of intruder aircraft. TCAS I provides approximate bearing and relative altitude of aircraft with a selectable range. It provides the pilot withTA alerting him or her to potentially conflicting traffic. The pilot then visually acquires the traffic and takes appropriate action for collision avoidance.

TCAS II is a more sophisticated system which provides the same information of TCAS I. It also analyzes the projected flightpath of approaching aircraft and issues resolution advisories to the pilot to resolve potential mid-air collisions. Additionally, if communicating with another TCAS II equipped aircraft, the two systems coordinate the resolution alerts provided to their respective flight crews.

Terrain Alerting Systems

Ground Proximity Warning System *(GPWS):* An early application of technology to reduce controlled flight into terrain (CFIT) was the GPWS. In airline use since the early 1970s, GPWS uses the radio altimeter, speed, and barometric altitude to determine the aircraft's position relative to the ground.

Terrain Awareness and Warning System *(TAWS)* uses GPS positioning and a database of terrain and obstructions to provide true predictability of the upcoming terrain and obstacles. The warnings it provides pilots are both aural and visual, instructing the pilot to take specific action. Because TAWS relies on GPS and a database of terrain/obstacle information, predictability is based upon aircraft location and projected location. The system is time based and therefore compensates for the performance of the aircraft and its speed.

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Automatic - Periodically transmits information with no pilot or operator input required.
Dependent - Position and velocity vector are derived from the GPS or a Flight Management System (FMS)
Surveillance - A method of determining position of aircraft, vehicles, or other asset
Broadcast - Transmitted information available to anyone with the appropriate receiving equipment

Surveillance Broadcast Services (En Route, Terminal, Surface provided by *ADS-B In Services*)

• Traffic/Flight Information Broadcast Services made available when you *add ADS-B Out equipment to your aircraft*
• Enhanced Visual Acquisition
• Enhanced Visual Approaches (1)
• Final Approach and Runway Occupancy Awareness
• Airport Surface Situational Awareness
• Conflict Detection

ALL features of ADS-B will be reivewed in the class on Navigation.

Onward and upward to

ATTITUDE INSTRUMENT FLYING