Objectives	▪ The student should develop knowledge of the elements related to the operation of flight instruments and characteristics and operation of navigation equipment
Elements	▪ Flight Instrument systems including ○ Pitot static system ○ Gyro systems ○ HSI / RMI ○ Magnetic Compass ○ G1000 system ▪ Navigation equipment and their operating characteristics to include ○ VOR ○ DME ○ ILS ○ ADF/NDB ○ Transponder/ altitude encoding ○ Electronic flight instrument display (in G1000) ○ GPS ○ Auto pilot (in G1000) ○ FMS ○ MFD (in G1000) ▪ Anti-ice/deicing and weather detection equipment and their operating characteristics to include ○ Airframe ○ Propeller or rotor ○ Air intake ○ Fuel system ○ Pitot-Static system ○ Radar/Lightning detection system ○ Other inflight whether systems
Schedule	▪ Review lesson objectives ▪ Review lesson material ▪ Conclusion & Review
Equipment	▪ White Board / Markers ▪ References
CFI Actions	▪ Present lesson ▪ Ask/ answer questions
Student Actions	▪ Participate in discussion ▪ Take notes

	▪ Ask / answer questions
Completion Standards	▪ Student will understand the fundamentals of the flight instruments, nav equipment, and anti-ice/deicing systems found in aircraft

Additional Notes: ____
____
____
____

Introduction

Overview

Review objectives / Elements

What

The flight instruments, navigation equipment and deicing/anti-ice systems are key to safely perform instrument flight.

Why

The pilot should be able to understand the operating characteristics of the equipment that they may encounter including the errors associated with them in order to safely conduct instrument flight.

How

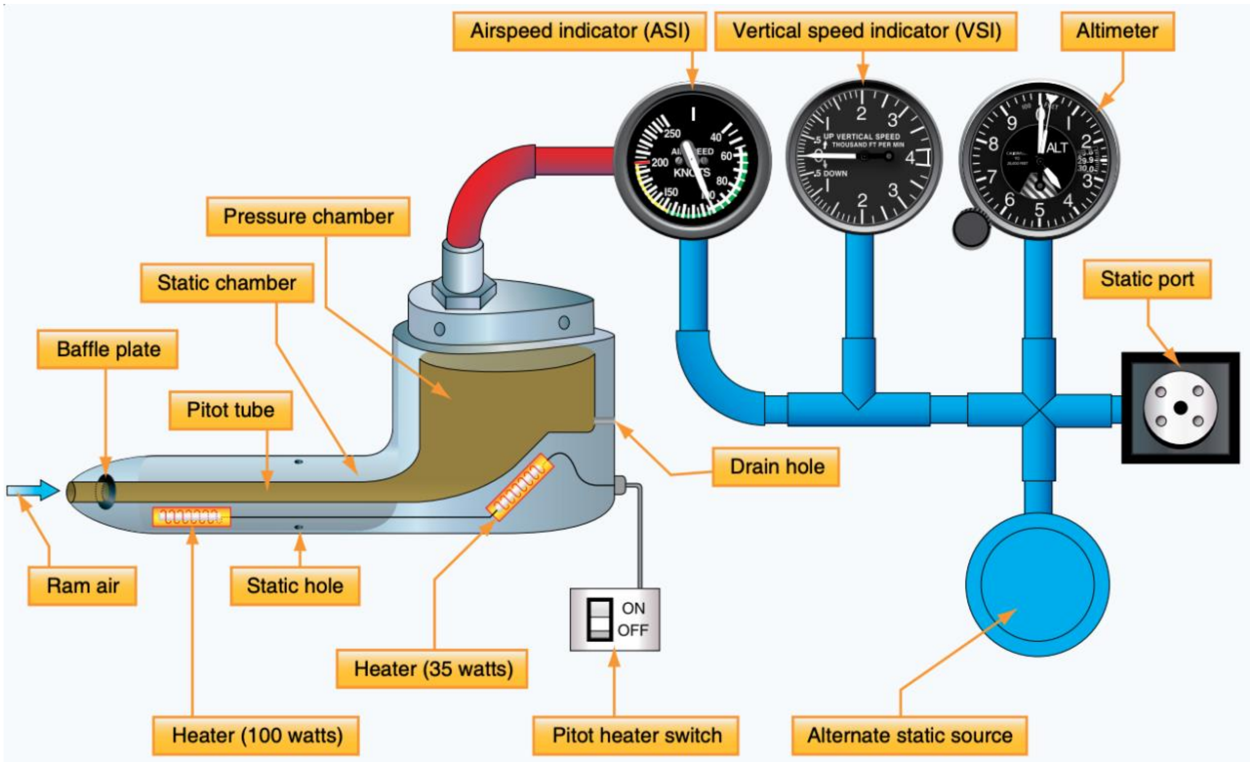
Flight Instrument systems

- **In order to safely operate the aircraft, the pilot must understand how to interpret and operate the flight instruments.**
- **The pilot must be able to recognize the errors associated with the instruments**

Pitot-Static System

Basics

- The Pitot-Static system is a system that uses static air pressure and dynamic pressure due to the planes' motion.
  - All of the instruments compare these to generate readings
  - These pressures are used for operation of the airspeed indicator (ASI), altimeter, and vertical speed indicator (VSI)



Pitot Tube

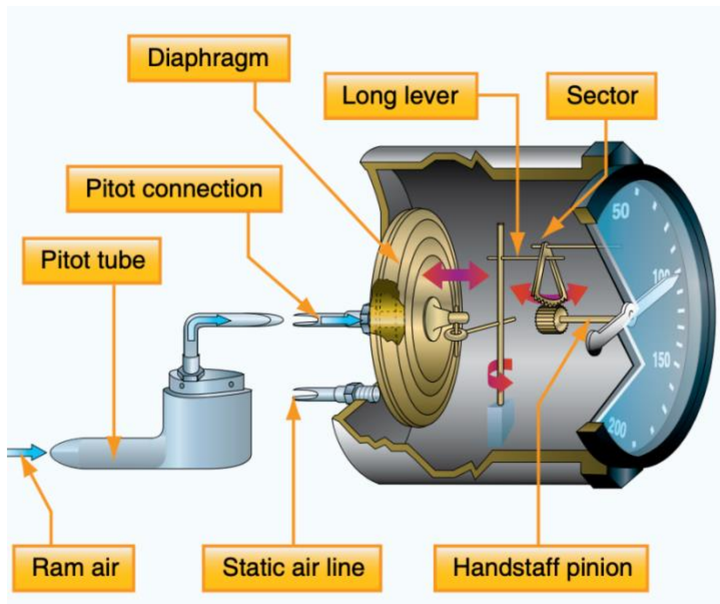
- **The Pitot tube is used to measure the ram air pressure of the aircraft moving through the air**
  - The ram air pressure is only present when the aircraft is in motion
  - A 20-knot headwind will result in a reading equal to flying in calm air at 20knots
- **The pitot tube has a small opening in the front that lets air into the pressure chamber**
- **There is a drain hole at the back of the pitot tube**
- **The airspeed indicator is the only instrument that utilizes the pitot tube**

Static Port

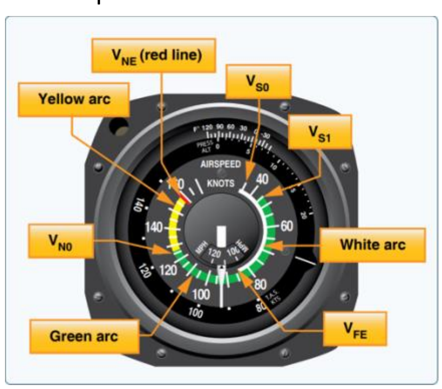
- **The static port provides static pressure for the ASI, Altimeter, and VSI**
  - Static pressure is essentially the ambient pressure (still air), measured perpendicular to the surface

Airspeed indicator (ASI)

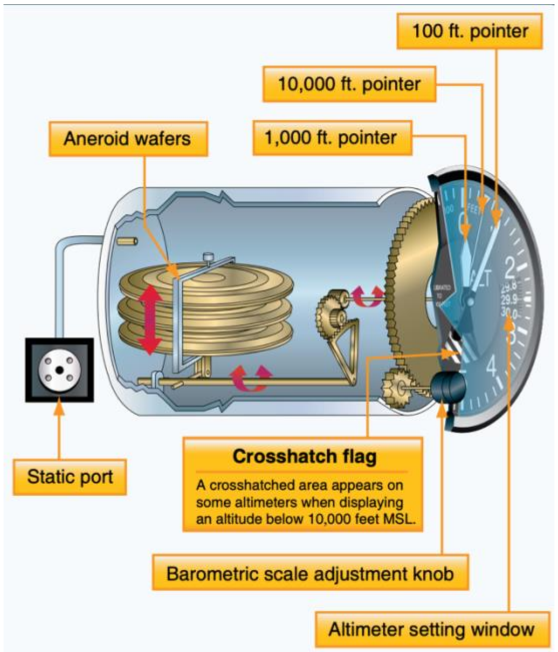
- **The airspeed indicator provides us with indicated airspeed**
  - Works by comparing ram air and static air pressure
- **Components:**
  - A diaphragm is the basis of the dynamic pressure system
  - Casing if the instrument is filled with static air from the static port
  - Ram air is piped into the diaphragm
    - The difference in ram air pressure and static air will determine how much the diaphragm inflates.
    - This movement turns the hands by use of small gears



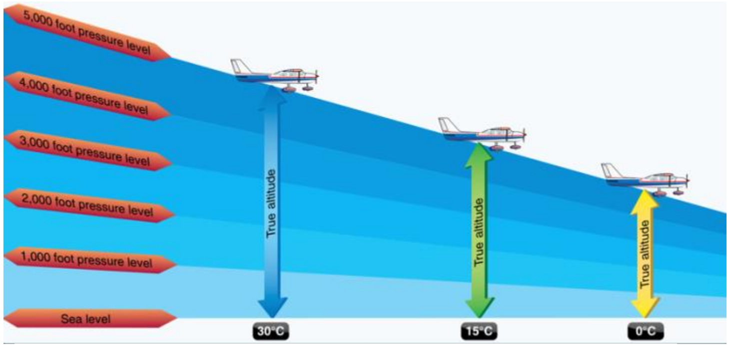
- **When accelerating the increase of ram air pressure will inflate the diaphragm causing the movement of the hand**
- **When decelerating, the diaphragm will begin to deflate and move the hands accordingly**
- **Errors**:
  - Mechanical errors: The airspeed should read 0 when the ambient pressure and ram air is equal

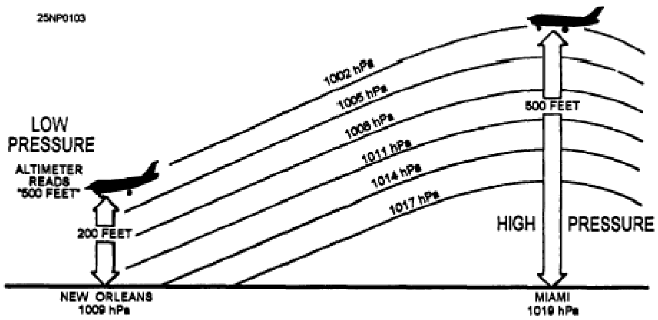


Altimeter



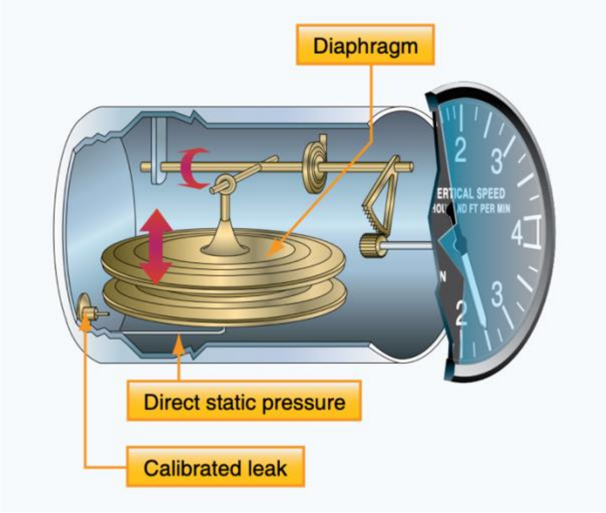
- **The altimeter provides us with altitude above a selected pressure level**
  - Works by comparing static pressure to standard pressure
- **Components:**
  - A stack of aneroid wafers is the primary component in the altimeter
    - These wafers are filled with STD pressure air (29.92 inHg)
    - They are free to expand and contract based on the static pressure
  - Static air is piped into the case of the instrument
  - Hands are controlled by small linkages and gears
  - The assembly can be adjusted for a given "altimeter" using the knob and the Kholsman window.
    - This pre-adjust the hands to indicate the correct indicated altitude for non-standard pressures
- **Errors**:
  - Mechanical Error:
    - The altimeter should read within 75' of field elevation when the correct altimeter setting is input
  - Nonstandard Temperature:
    - **Hot to cold, look out below**
    - Due to the effects of temperature on air density, as temperature decreases, the altimeter will read higher than the aircraft actually is
  - Nonstandard Pressure:
    - **High to low Look out Below**
    - As air pressure changes the altimeter will begin to read incorrectly unless properly adjusted.
    - Frequently updating the altimeter with the most correct setting will help this.





Vertical speed Indicator (VSI)

- **The vertical speed indicator provides us with the rate of static pressure change**
- **Components:**
  - Case with a controlled leak to let static air in or out slowly
  - Diaphragm inside the case connected to the static port
  - The hands are connected to the diaphragm through a series of small linkages



- **Function:**
  - **In a climb (static pressure decreases)**
    - Case: gradually decreases pressure
    - Diaphragm: pressure decreases; diaphragm is compresses due to the case retaining higher pressure
    - Hands: indicate a climb
  - **In a descent (static pressure increases)**
    - Case: gradually increases in pressure
    - Diaphragm: Pressure increase; diaphragm expands to the higher pressure in the static system than the case of the VSI
    - Hands: indicate a descent
  - When the aircraft levels off, the controlled leak will catch up to the static pressure in the diaphragm and the VSI will indicate 0
- Errors
  - Mechanical:
    - VSI should read 0 on the ground

Pitot-Static Blockages

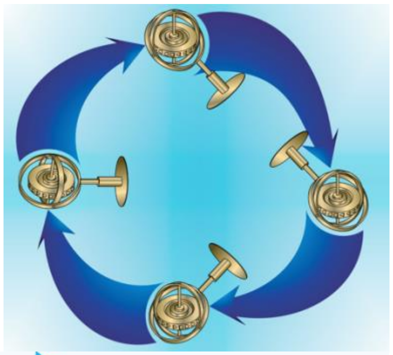
- **Pilots must know the signs of pitot-static blockages as it effects many important flight instruments**

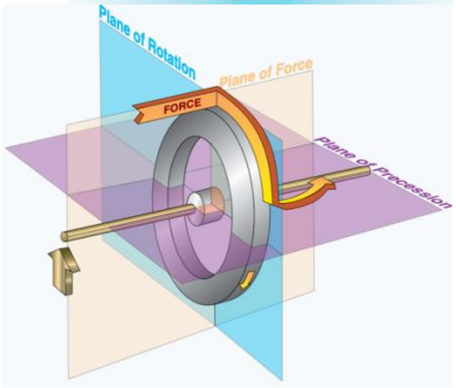
Situation	Airspeed	Altimeter	Vertical Speed
1. Blocked Ram air hole	Zero	Works	Works
2. Blocked Ram and Drain hole	**High** in climb **Low** in descent	Works	Works
3. Blocked Static open Pitot	**Low** in climb **High** in descent	Frozen	Frozen
4. Alternate Static Source	Reads high	Reads high	Momentary climb
5. Broken VSI Glass	Reads high	Reads high	Reverse

Gyroscopic Systems (Attitude Indicator, Heading Indicator, Turn Coordinator)

Gyro Basics

- **A gyroscope is basically a small spinning wheel with its weight concentrated around the outside**
- **Principles of Gyros**
  - Rigidity in space: gyro is rigid causing the aircraft to rotate about it
    - A bike is a great example of this principle
    - Attitude and heading instruments use this principle
  - Precession: when a force is applied to a gyro, the force is felt 90 degrees from the point of application in the direction of rotation
    - Rate of turn and turn coordinator use this principle
    - Gyro precesses proportionate to the rate of turn

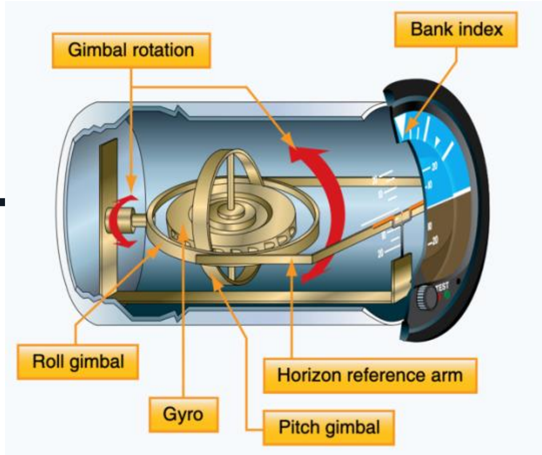




- **Power sources**
  - Electrical system:
    - Gyro is spun via electric motor
  - Pneumatic system:
    - Driven by a stream of air interacting with cups on the edge of the gyro
    - Air is driven by vacuum pump or venturi
      - Vacuum pump evacuates air from the system causing filtered air to be driven over gyro
      - Venturi systems don't use a pump and instead just use the venturi to generate a vacuum
  - Wet-type vacuum system – generally on aircraft that operate at lower altitudes
    - Steel veined vacuum pumps are used to evacuate air from the system
    - The veins are lubricated with oil which is discharged from the air
  - Dry-type vacuum system – generally for high altitude ops
    - Due to the less dense air at high altitudes, more air is required to run the gyros
    - Air is not mixed with oil like the wet-type system
  - Pressure indicating systems (twin engine aircraft that have 2 pumps)
    - A pressure gauge measures any pressure drop across multiple instruments
    - In the event of engine/pump failure, check valves isolate the system to the functioning pump/engine

Attitude Indicator

- **Operation**
  - A small brass wheel is mounted by a vertical spin axis and spooled up using a stream of air from the vacuum system or an electric motor
  - Mounted with a double gimbal to allow the aircraft to pitch and roll about the gyro

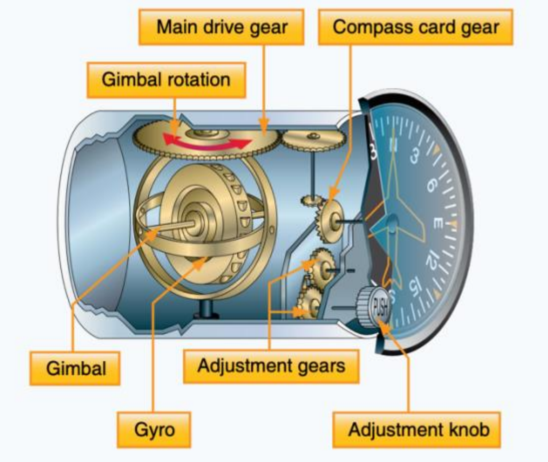


- Some older attitude indicators have pitch/bank limits at which the gyro tumbles and becomes unusable
    - When the pitch/bank limit is reached, the gyro contacts the gimbal limits causing it to tumble.
    - Some models are equipped with a caging mode to lock the gyro vertically, preventing the tumble
    - Newer attitude indicators are designed to eliminate tumble all together
- A horizon card is attached to the gimbal and in turn remains rigid in space
    - Airplane rolls around the horizon disk
- The small airplane is displayed in front of the horizon disk and can be adjusted vertically

- **Errors**
    - Slight nose-up indication can be seen sometimes during rapid accelerations
        - Slight nose-down on rapid deceleration
    - Small bank errors after 180° turn
    - Traditional attitude indicators will tumble at 100-110° Bank and 60-70° Pitch

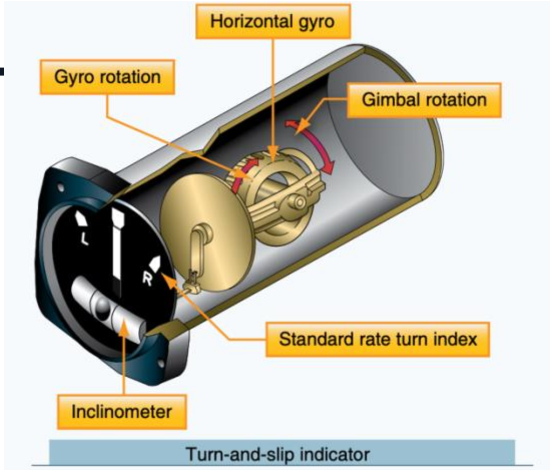
Heading indicator

- **Operation:**
    - Senses rotation about the vertical axis
    - Mounted in a double gimbal like an attitude indicator, however the spin axis is horizontal
- Heading:
    - The heading is manually set to match the magnetic compass
        - Rigidity causes it to maintain position and the aircraft "turns around the gyro"
    - Must be reset to match the compass heading at least every 15 minutes
        - Earth rotates at about 15° an hour.
    - Can tumble during aerobatic maneuvers



Turn-and-Slip Indicator

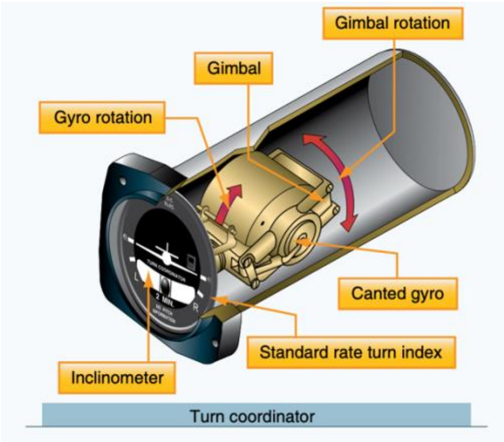
- **Operation:**
    - Gyro is powered by vacuum or electric motor
    - Small gyro is mounted in a single gimble
        - The spin axis is parallel to the lateral axis; gimbal is parallel to longitudinal axis
    - Yawing produces a force in the horizontal plane
        - Precession causes the gyro and its gimbal to rotate about the gimbal axis
        - Rotation is restrained by a spring
        - Indicates when reaching standard rate turn



Turn-and-slip indicator

Turn Coordinator

- **Operation:**
  - Gyro is powered by vacuum or electric motor
  - Similar to turn-and-slip indicator but gyro is tilted (canted) up 30°
    - This allows the gyro to sense both roll and yaw
    - During a turn the turn coordinator initially show rate of bank then, once stabilized, rate of turn
- **The turn coordinator should be used as primary instrument to determine spin direction (if outside references are not available)**



Turn coordinator

Inclinometer Operation

- **Black glass ball sealed inside a curved glass tube that's partially filled with liquid**
- **Inertia will determine where the ball want to go**
  - When in a skidding turn (too much rudder), the ball will go to the outside of the turn
  - Slipping turns (not enough rudder) cause the ball to go to the inside of the turn
- **The ball only determines the relationship between angle of bank and rate of yaw**
- **Ailerons and rudder together**

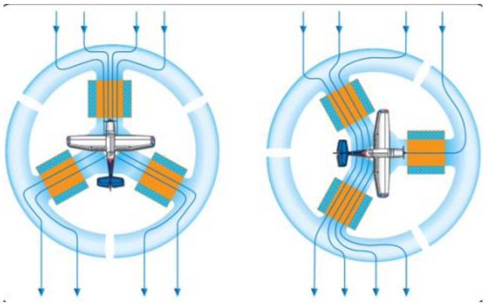
AHRS (Attitude Heading Reference System)

- **Replaces traditional gyroscopic instruments**
- **Gathers Attitude, Heading, Rate of turn, and Slip-skid data to be displayed on a glass cockpit**
  - Uses small solid-state components that include accelerometers, magnetometers, rate gyros, and even satellite reception in some
- **One much more accurate and efficient system is able to replace all the traditional gyros**

RMI/HSI

Radio Magnetic Indicator (RMI)

- **Bearing indicators are overlaid on a heading indicator**
  - This heading indicator doesn't use a gyro, instead it uses signals from a flux valve to determine heading
    - the flux valve is a small segmented ring made of soft iron that accepts lines of magnet flux. As the aircraft changes heading, the current in the flux valve changes, rotating the RMI's heading



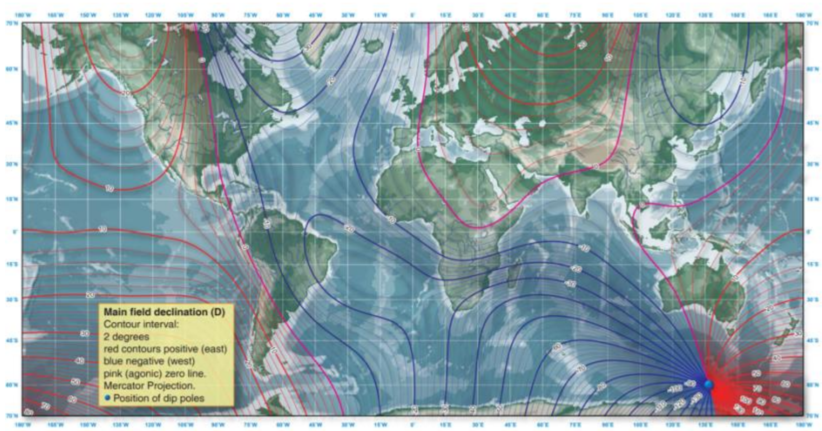
- **The bearing indicators can be used to track NDBs or VORs**
  - **NDB: Head = bearing to station, Tail = Bearing from station**
  - **VOR: Head = bearing to station, Tail = Current radial from station**

Horizontal Situation Indicator (HSI)

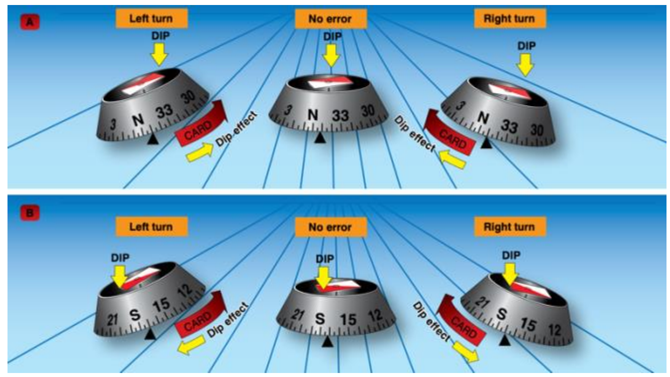
- **Heading indicator and navigation overlay that provides lateral and sometimes vertical course deviation**
  - Basically, takes a RMI to the next level
  - Flux valve is used for heading like the RMI

Magnetic Compass

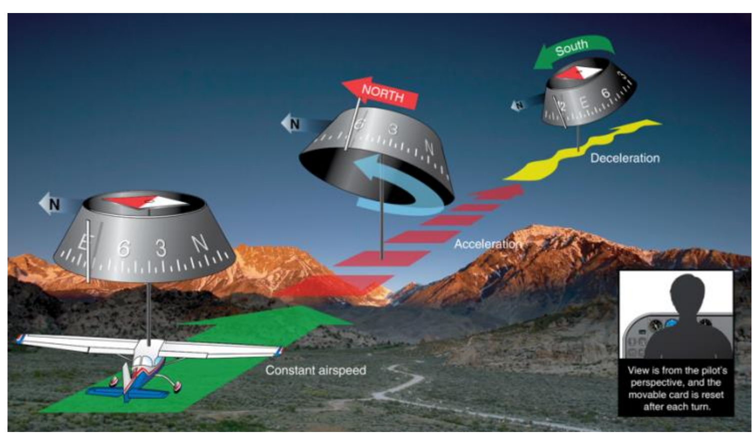
- **The magnetic compass is the oldest instrument in the flight deck**
- **Operation:**
  - Two small magnets attached to a metal float sealed inside of a bowl of clear compass fluid
  - Compass card is wrapped around the float and is read from the outside with a lubber line
  - The float has a steel pivot in the center riding inside a spring loaded, hard glass jewel cup
  - Magnets align with earth's magnetic field and direction is read on the back of the float
    - This is why the compass is backwards
    - Turn away from the desired heading when using the magnetic compass
- **Errors**
  - **VDMONA**
  - **Variation**:
    - Caused by the true poles and magnetic poles not being in the same location
      - True and magnetic north are approximately 1300 miles apart
    - Isogonic lines: lines of equal variation
    - Agonic lines: Lines along which the two poles are aligned and there is no variation
    - East is least, west is best (subtract E, add W)



- **Deviation**:
  - Caused by local magnetic fields in the aircraft
  - Error is depicted on compass card
    - The compass card is filled out when coms are on as they are the primary cause of deviation
- **Magnetic Dip:**
  - As you get further from the equator, the magnetic fields become less parallel from the surface. This causes the compass to be pulled down causing the northernly turning errors and acceleration errors



- **Oscillation:**
  - Movement of the aircraft causes the compass to swing back and forth around the heading being flows
- **Northernly Turning errors**:
  - Dip errors cause these northerly turning errors
  - The compass wants to pull to the north (**NOSE**)
    - When turning from a northernly heading, the compass lags behind and may even turn opposite initially
    - When Turing from a south heading, the compass will exaggerate the turn
  - When making turns to the north and south we must use the **UNOS**
    - Undershoot turns to the north, overshoot to the south.
      - ½ latitude+15= amount of lead/undershoot
- **Acceleration Errors:**
  - Another Dip error that causes the compass to change directions under acceleration and deceleration when flying east or west
  - This is caused by how the compass swings under acceleration and deceleration
    - We will use the **ANDS** to remember this
      - When **accelerating**, the compass will indicate a turn to the **North**, when **Decelerating**, the compass will show a turn to the **South**



G1000 Glass Cockpit

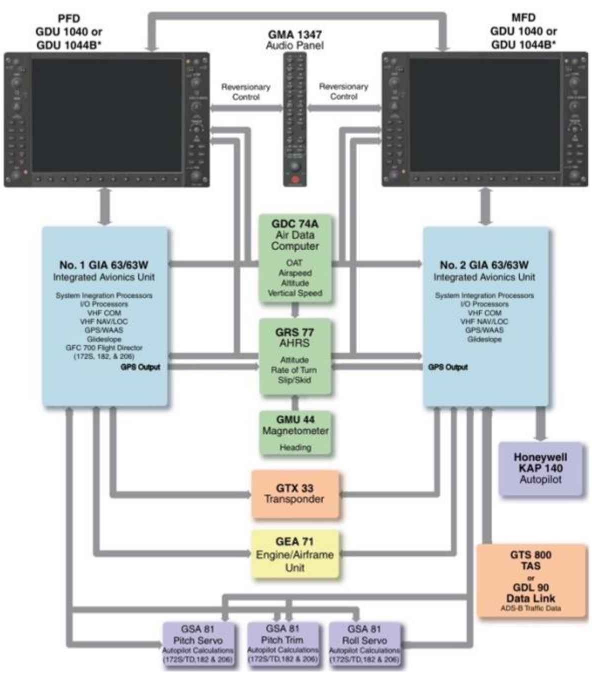
The G1000 is an integrated flight deck system found in many aircraft from light GA, to turboprop planes.

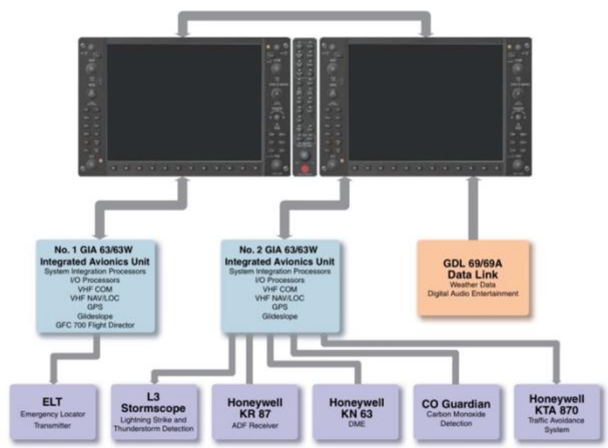
G1000 Components C172

The G1000 is comprised of multiple LRUs:

Name of LRU	Description
GDU 1040/1044B: Primary Flight Display (PFD)	The GDU 1044B features a 10.4-inch LCD display with 1024 x 768 resolution. The left display is configured as a PFD and the right display is configured as an MFD. Both GDU 1044Bs link and display all functions of the G1000 system during flight. The displays communicate with each other through a High-Speed Data Bus (HSDB) Ethernet connection. Each display is also paired via an Ethernet connection with a GIA 63 or 63W Integrated Avionics Unit. Systems that do not use the GFC 700 Automatic Flight Control System use the GDU 1040, which employs the same features as the GDU 1044B without the controls for the Garmin GFC 700 Automatic Flight Control System (AFCS).
GDU 1040/1044B: Multi-Function Display (MFD)	Configured as MFD rather than PFD
GIA 63/63W: Integrated Avionics Unit (IAU)	Functions as the main communication hub, linking all LRUs with the PFD. Each GIA 63/63W contains a GPS receiver, VHF COM/NAV/GS receivers, a flight director (FD) and system integration microprocessors. The GIA 63W contains a GPS SBAS receiver. Each GIA is paired with a respective GDU 1040/1044B display through Ethernet. The GIAs are not paired together and do not communicate with each other directly
GDC 74A: Air Data Computer (ADC)	Processes data from the pitot/static system as well as the OAT probe. This unit provides pressure altitude, airspeed, vertical speed and OAT information to the G1000 system, and it communicates with the GIA 63/63W, GDU 1040/1044B, and GRS 77, using an ARINC 429 digital interface. The GDC 74A also interfaces directly with the GTP 59.
GEA 71: Engine/Airframe Unit (EAU)	Receives and processes signals from the engine and airframe sensors. This unit communicates with both GIA 63/63Ws using an RS-485 digital interface.
GRS 77: Attitude and Heading Reference System (AHRS)	Provides aircraft attitude and heading information via ARINC 429 to both the GDU 1040/1044B and the GIA 63/63W. The GRS 77 contains advanced sensors (including accelerometers and rate sensors) and interfaces with the on-side GMU 44 to obtain magnetic field information, with the GDC 74A to obtain air data, and with both GIAs to obtain GPS information. AHRS modes of operation are discussed later in this document.
GMU 44: Magnetometer	Measures local magnetic field. Data is sent to the GRS 77 for processing to determine aircraft magnetic heading. This unit receives power directly from the GRS 77 and communicates with the GRS 77 using an RS-485 digital interface.

GMA 1347: Audio System with Integrated Marker Beacon Receiver	The GMA 1347 Audio Panel integrates NAV/COM digital audio, intercom system and marker beacon controls. The GMA 1347 also controls manual display reversionary mode (red DISPLAY BACKUP button) and is installed between the MFD and the PFD. The GMA 1347 communicates with both GIA 63/ 63Ws using an RS-232 digital interface.
GTX 33: Mode S Transponder	The GTX 33 is a solid-state, Mode-S transponder that provides Modes A, C and S operation. The GTX 33 is controlled through the PFD and communicates with both GIA 63/63Ws through an RS-232 digital interface.
GDL 69A: Satellite Data Link Receiver	A satellite radio receiver that provides real-time weather information to the G1000 MFD (and, indirectly, to the inset map of the PFD) as well as digital audio entertainment. The GDL 69A communicates with the MFD via HSDB connection. A subscription to the SiriusXM Satellite Radio service is required to enable the GDL 69A capability
GTS 800: Traffic Avoidance System (opt)	The GTS 800 Traffic Advisory System (TAS) uses active interrogations of Mode S and Mode C transponders to provide Traffic Advisories to the pilot independent of the air traffic control system.
GDL 90: ADS-B/FIS-B Data Link Transceiver (opt)	A digital data link transceiver designed to transmit, receive and decode ADS-B traffic information, as well as FIS-B weather information. It broadcasts aircraft position, velocity, projected track, altitude, and flight identification to other equipped aircraft in the vicinity, as well as to FAA ground stations. The GDL 90 receives FIS-B weather information which is displayed on the MFD as NEXRAD radar and METARs.
GSA 81: AFCS Servos	The GSA 81 servos are used for the automatic control of roll, pitch, and pitch trim. These units' interface with each GIA 63/63W
GSM 85: Servo Gearboxes	The GSM 85 servo gearbox is responsible for transferring the output torque of the GSA 81 servo actuator to the mechanical flight-control surface linkage.

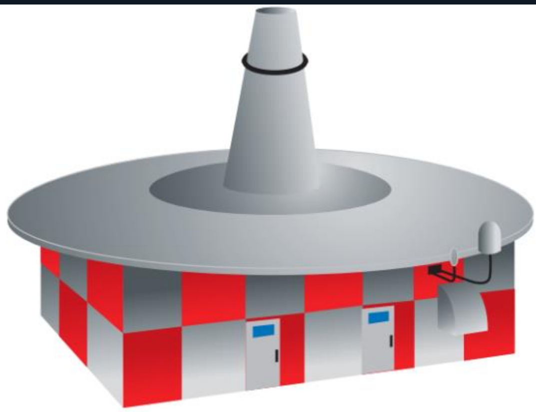




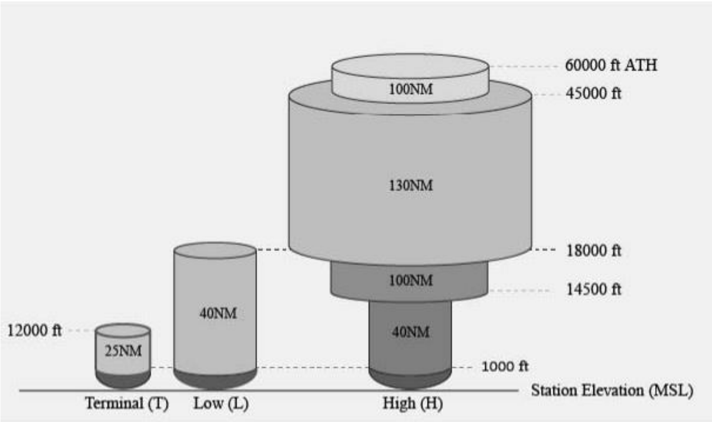
Navigation Equipment

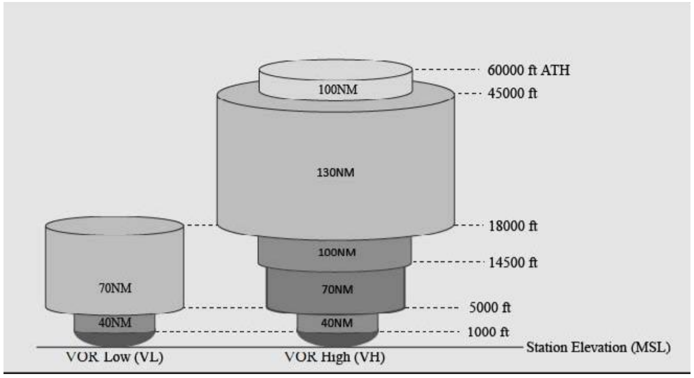
Navigation equipment is at the heart of instrument flying and understanding it is a key to being a proficient instrument pilot

Very High Frequency Omnidirectional Range (VOR)



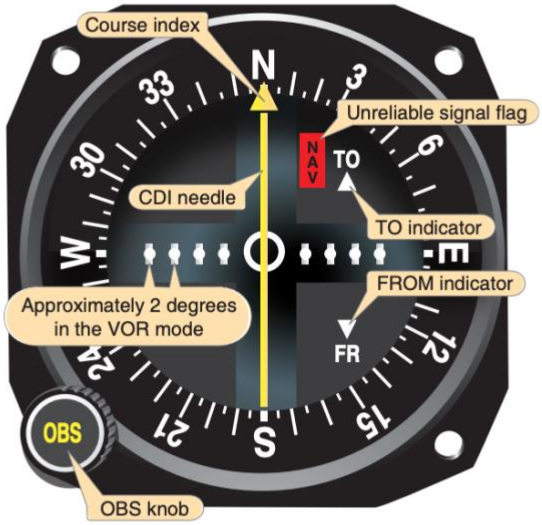
- **The VOR is a ground-based navigation station that provides azimuth information for the aircraft**
    - It transmits 360 to/from courses to the aircraft
- **The VOR looks like a small building topped by a white disk shaped like a sombrero**
- **Operates in the frequency range of 108.0 to 117.95 MHz**
    - The VOR uses VHF thus, there must be line of sight to use it
    - They are assigned even tenth digits in order to avoid conflict with ILS
- **VOR Classes (AIM 1-1-8)**





- **VOR types:**
    - VOR – The VOR by itself. Provides magnetic bearing information to and from the station
    - VOR/DME –DME (Distance Measuring Equipment) is installed with the VOR (more info below)
    - VORTAC – Military tactical air navigations (TACAN) equipment is installed with a VOR
        - DME is always an integral part of a VORTAC

Airborne Equipment



- **Omnibearing Selector (OBS):**
  - The desired course is selected by turning the OBS knob until course is aligned with the course index marking on the instrument window
- **Course Deviation Indicator (CDI)**
  - Indicates the aircraft position in relation to the radial selected by the OBS
  - Full scale deflection is usually 12 degrees or more off the selected course (each dot will be 2 degrees) (4 on g1000)
- **TO/FROM Flag**
  - Shows whether the selected course takes the aircraft To or from the VOR
  - Does not indicate whether the aircraft is currently heading To or from the VOR
- **Flags or other signal strength indicators**
  - OFF flag indicates unreliable/unusable signal

VOR Basics

- Identify it
  - Tune and listen for the station's morse code ID or a voice stating the name and VOR
  - If the VOR is out of service, the ID is not going to be heard; this should not be used for navigation
- Orientation – Radial/to or from the station
  - Rotate the OBS to center the CDI needle
    - If there is a TO flag, this is the course to fly to the VOR
    - If there is a FROM flag, this is the radial you are currently on

VOR Checks

- 14CFR 91.171 – VOR check within the preceding 30 days for IFR operations

Type of check	Tolerance
VOR Test Facility (VOT)	±4°
Airborne Checkpoint or airway	±6°
Ground Checkpoint	±4°
Dual VOR Check	±4°

VOR MON (Minimum Operating Network)

- **Due to the increases in performance-based navigation (PBN) the number of VORs will be reduced and two new service volumes will enable continuous VOR navigation over 5000' AGL**
  - VORs will be reduced from 896 to 590 by 2030
- **Designed to enable aircraft to revert to conventional navigation in the event of lost GPS**

VOR Errors (CARL)

- **Cone of Confusion**
  - While over the station, multiple radials are being detected at once. This causes confusion for the CDI and causes rapid changes of the cdi needle and to/from flag
- **Area of ambiguity**
  - The zone perpendicular to the selected radials where ethe to from flag is expected to flip. This area is prone to improper on unusable TO/FROM flag indications
- **Reverse Sensing**
  - Flying while with improper TO/FROM flag may result in the CDI being reversed
- **Line of sight**
  - VHF requires Line of sight to the VOR in order to function

Distance Measuring Equipment (DME)

Function – provides slant range distance from a station

- **With VOR and DME, a pilot can determine bearing and distance TO or FROM a station**
- **Can be used to determine position along a radial or fly a constant distance from a station**

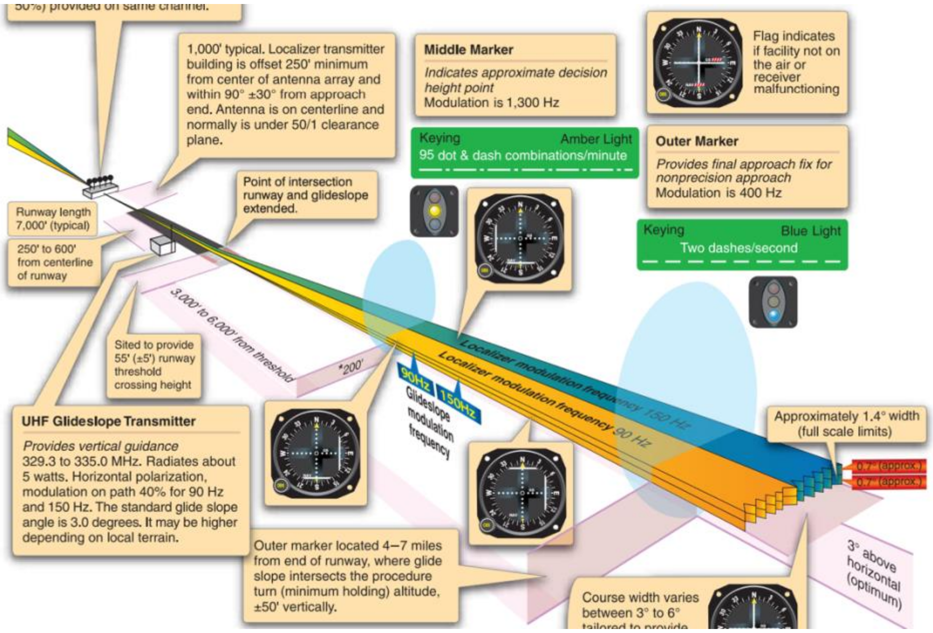
How it Works

- **The aircraft DME transmits interrogating RF pulses which a DME antenna on the ground receives**
- **The signal triggers ground receiver equipment to respond back to the interrogating aircraft**
- **The aircraft DME measures the elapsed time between the sent signal and the reply signal**
  - The time measurement is converted into NMs from the station
- **Some receivers provide ground speed by monitoring the rate of change of position to the station**
- **DME operates on UHF frequencies between 962 MHz and 1213 M**

Errors

- **DME signals are line-of-sight**
- **Slant Range Distance**
  - The mileage readout is the straight-line distance from the aircraft to the ground facility
  - Not the same as the distance from the station to the point on the ground below the aircraft
  - This error is the smallest at low altitudes and long range
    - Greatest when over the DME station, when it will display altitude above the station
    - Negligible if 1 mile or more away from the facility for each 1,000' above facility elevation

Instrument Landing System (ILS)



- **The ILS is an electronic system providing both horizontal and vertical guidance to a specific runway**
  - Used to execute a precision instrument approach

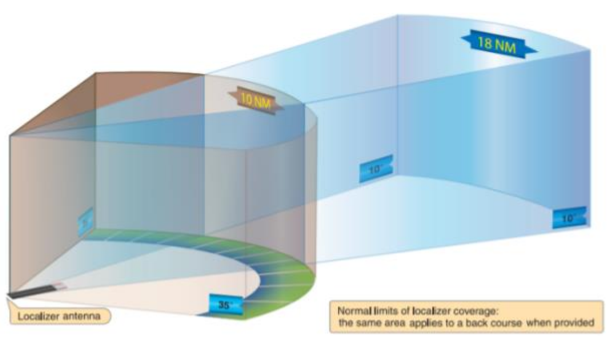
Categories of approaches

- **Category I: provides approach guidance to a DH of not less than 200'**
- **Category II: provides approach guidance to a DH of not less than 100'**
- **Category III: Provides lower minimums for approaches without a decision height minimum (usually a RVR minimum)**
  - Category II and III approaches require special certification for pilots as well as special equipment

Components

Guidance Systems

- **Localizer (LOC) – Provides horizontal guidance along the centerline of the runway**
  - Operates on VHF between 108.1 and 111.95MHz (odd tenths)
  - Has a service volume of 35° out to 10 NM and 10° out to 18NM. The ceiling is 4500' AGL
  - The localizer course is very narrow and normally only 5°
    - This means that full deflection is only 2.5° off the center
    - Course narrows closer to the runway (increases sensitivity)
  - The LOC antenna is located on the opposite end of the runway



- **Glideslope (GS) – Provides vertical guidance to the runway touchdown point**
  - Functions like a localizer on its side
    - The signal is projected up at 2.5°-3.5° normally (3° is found on many approaches)
  - Normally 1.4° thick (the glideslope is very sensitive)
  - Doesn't have a back course like the LOC
  - The Antenna is located on a orange and white checkered building located usually 750'-1250' down the runway off to the side (usually 400'-600')
  - Functions on UHF in the range of 329.15 MHz, to 335.00 MHz
    - Automatically tuned when the ILS frequency is tuned

Range Systems

- **Marker Beacons – Provide range information throughout the approach**
  - A low powered transmitter that directs its signal upward in a small, fan shaped pattern. Used along the flightpath when approaching an airport for landing, marker beacons indicate, both aurally and visually, when the aircraft is over the facility
  - 2 VHF marker beacons. Outer/Middle, are commonly found in the ILS installation
    - The Inner marker is found on CAT II certified installations
  - **The Outer Marker** (OM) (- - -) – on localizer front course 4-7 miles from the airport
    - Indicates where one should intercept the glideslope if at proper altitude
  - **The Middle Marker** (MM) (.-.-) – Approximately 3500' from the threshold on the front course
    - Position where the glideslope is roughly 200' above the landing threshold
  - **The Inner Marker** (IM) (. . . .) – Located on the front course between the MM and the threshold
    - Indicates the decision height of a CAT II ILS approach
- DME – Explained in DME

Visual Components

- **Approach Lights – Assist in the transition from IMC to VMC**
  - Set of light to assist in identifying and orienting the runway
    - ALSF, SSALR, MALSR, REL, MALSF, ODALS, VASI
  - ASLF Approach lighting systems are equipped with red sidebars and termination bars that allow for the pilot to descend to the runway in accordance with 14CFR 91.175 (c)(3)(i)
- Runway lights or VGSI

Errors

- **False Slopes – The Glideslope will transmit false courses at improper angles**
  - This can be countered by flying the altitudes published on the approach plate
- **Reflection – Surface aircraft and aircraft <5000' agl may disturb the signal**
  - This is the reason for the ILS hold short lines on taxiways

Automatic Direction Finder (ADF) & Nondirectional Beacon (NDB)

- **An NDB is a ground-based radio transmitter that transmits radio energy in all directions**
    - The ADF, when used with an NDB, determines the bearing from the aircraft to the station
- **The ADF needle points to the NDB ground station to determine the relative bearing**
    - Relative Bearing: The number of degrees measured clockwise between the heading of the aircraft and the direction from which the bearing is taken

NDB Components

- The ground equipment: the NDB (transmits between 190 to 535 kHz)
- Aircraft must be in operational range of the NDB - dependent on the strength of the station

ADF Components

- **The airborne equipment: 2 antennas, a receiver, and the indicator instrument**
- **Two Antennas**
    - Sense Antenna: (Non-directional) Receives signals nearly equally from all directions
    - Loop Antenna: (Bi directional) Receives signals better from two directions
    - When the two are combined, the ADF can receive a radio signal well in all directions except for one, thus resolving all directional ambiguity
- **Indicator Instrument**
    - 3 kinds: Fixed card, Movable Card, or the RMI (1 or 2 needles)
    - **Fixed Card ADF** (or relative bearing indicator, RBI)
        - Always indicates 0 at the top; Needle indicates RB to the station
        - Pilot must calculate MB based on MH and RB
        - **Magnetic Heading + Relative Bearing = Magnetic Bearing**
            - **Mary Had + Roast Beef= Marry Barfed**
            - Magnetic Heading: The direction an aircraft is pointed with respect to magnetic North
            - Magnetic Bearing: The direction to/from a station measured relative to magnetic North
    - **Adjustable Card ADF**
        - Can be rotated to current heading using the adjustment knob
        - Head of the needle indicates the MB to the station
        - The tail indicates MB from the station
        - Instrument provides MB, pilot doesn't have to calculate it
    - **RMI**
        - Automatically rotates to display aircraft heading
        - Can have two needles which can be used for navigation information from either ADF or VOR receivers
        - ADF needle:
            - Head indicates the MB To the station
            - Tail indicates the MB From the station
        - VOR needle: Indicates location radially with respect to the station

- Head of needle points the bearing TO the station
- Tail points to the radial the aircraft is currently on/crossing

Using the NDB

- **Fixed card ADF**
    - Pilot must do the MH+RB=MB to find bearing to station
- **Movable Card/RMI**
    - Turn toward the head of the needle indicating the MB to the station (adjust card if needed)
    - Adjust for wind to maintain the desired course
- **Homing Vs. Tracking**
    - Homing is when you fly the heading of the needle without correcting for wind. This will result in a semicircular path towards the station
    - Tracking – Crabbing to fly directly to the station (you won't be flying the exact heading of the needle because of the wind)

Compass Locators

- **Allow Transition from Enroute to Approach segment without the use of R-NAV or similar systems.**
- **Usually found coupled with the OM and are identified with LOM**
    - Many times, the LOM will be one of the IAF of the ILS (if installed)
- **These are just low powered NDBs that usually work within 15 miles**
- **The LOM will have the first 2 letters of the localizer in morse code (i.e. CG if the ICGZ approach had compass locators)**

Transponder/Altitude Encoding

- **ATC's Primary radar (energy reflected off the physical aircraft) is limited thus the need for transponders arise**
- **A transponder is a radar beacon transmitter/receiver installed in the aircraft**
    - ATC radar sends out interrogation signals continuously and when these are received by the transponder, a coded reply is sent where it can be seen by ATC
    - The IDENT button intensifies the return on the radar screen allowing for identification of an aircraft

Mode C (altitude Reporting)

- **Aircraft equipped with Mode C transmit the aircrafts current pressure altitude with the transponder transmission**
    - This allows ATC to see your current altitude at all times

Global Positioning System (GPS)

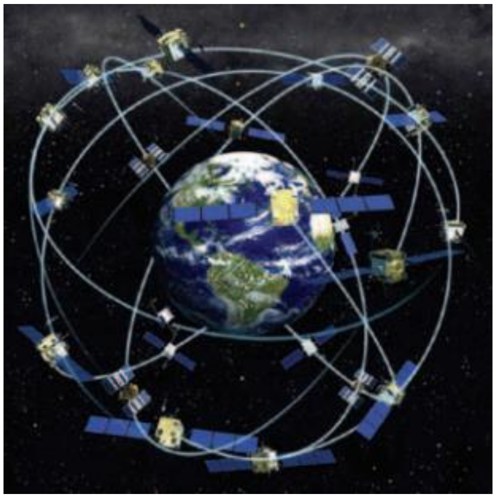
Satellite based navigation systems include

- GPS (Global Positioning System), WAAS (Wide Area Augmentation System), LAAS (local Area Augmentation System)

Global Positioning System (GPS)

The GPS system is composed of 3 major elements:

- **The Space Segment**
  - Constellation of over 30 Navigation System Using Timing and Range satellites (NAVSTAR) 24 are active at any given time.
  - They orbit on 6 orbital planes spaced 60° apart at about 11,000 miles above earth
    - At any Given time, 5 satellites are in view to any receiver
    - It takes about 12 hours for one satellite to orbit earth
    - Equipped with atomic clocks which are the most accurate type of clock



- **The Control Segment**
  - Consists of a master station, 5 monitoring stations, and 3 ground antennas
  - Distributed to allow continual monitoring/communication with the satellites
    - Updates are uplinked as necessary as the satellites pass over the ground antennas
- **The User Segment**
  - Consists of all the components associates with the GPS receiver
    - The receivers can range from handheld to permanently installed systems
  - The receiver uses the signals from the satellite to solve for position, velocity and precise timing

Solving For Location

- **The receiver utilizes the signals from at least 4 of the best positioned satellites to yield a 3D fix**
  - 3 Satellites – 2D position
  - 4 Satellites – 3D position
  - 5 Satellites - RAIM Fault detection (4 with Baro-Aiding)
  - 6 Satellites – RAIM Fault Detection + Exclusion (5 with Baro-Aiding)
- **Uses time and position of the satellites in order to triangulate position using simple math**

Receiver Autonomous Integrity Monitoring (RAIM)

- **RAIM allows the receiver to verify the integrity of the signals received from the satellites**
  - Without RAIM, the pilot cannot verify the accuracy of the GPS
- **RAIM requires a minimum of 5 satellites (or 4 with baro-aiding GPS) to detect faults in the system**

- **Some Receivers can isolate bad satellites when there are 6 satellites available (5 with baro-aiding)**
- **Generally, the two most common RAIM messages are:**
    - There are not enough satellites to provide RAIM
    - There is a potential error that exceeds the limits of the GPS for the rest of the flight
- **Aircraft using GPS navigation equipment under IFR must be equipped with and approved and operational alternate means of navigation appropriate to the route of flight**
    - Monitoring of the alternate is not required if the GPS uses RAIM
    - Active monitoring of the alternate equipment is required if RAIM capability is lost
    - Use other equipment, delay departure, or cancel if loss of RAIM capability is predicted

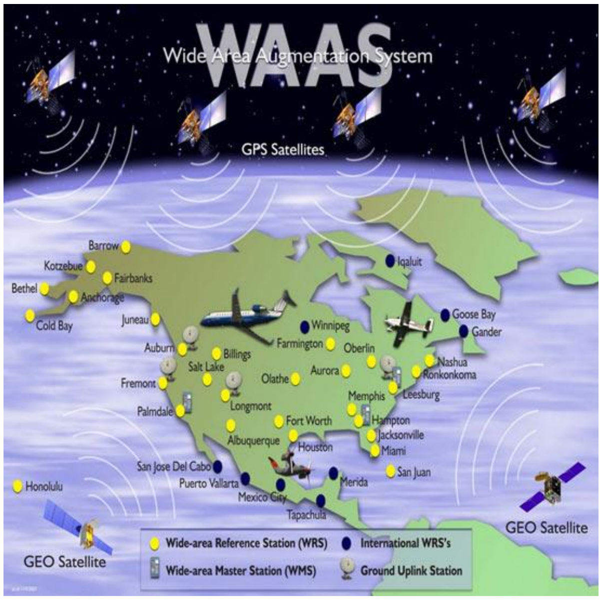
GPS Substitution (AIM 1-2-3c)

- **GPS systems, certified for IFR en-route and terminal operations, may be used as a substitute for ADF and DME receivers when conducting the following operations within the NAS:**
    - Determining the aircraft position over a DME fix
    - Flying a DME arc
    - Navigation TO/FROM an NDB/Compass Locator
    - Determining the aircraft position over an NDB/compass locator
    - Determining position over a fix defined by an NDB/Compass Locator bearing crossing a VOR/LOC course
    - Holding over an NDB/Compass Locator

Wide Area Augmentation System (WAAS)

- **Designed to improve the accuracy, integrity, and availability of GPS signals**
    - Integrity is improved through real-time monitoring of the satellites
        - Provides timely warnings when the signal is potentially hazardous/misleading
        - WAAS certification required proving there is only an extremely small probability that an error would go undetected – equivalent of no more than 3 seconds of bad data per year
    - Accuracy is improved by providing corrections to the satellites to reduce errors
        - A network of ground-based stations measures small variations in satellite signals (38 refs)
        - Measurements are routed to a master station
        - Master station sends the correction messages to the satellites
    - Performance improvements enable approach procedures with GPS/WAAS glidepaths
        - WAAS requires a position accuracy of 25' or less at least 95% of the time
            - Typically provides better than 1 meter laterally and 1.5 meters vertically

38 Ref stations
3 masters
6 uplinks
3 sats



    - Capable of Category 1 precision approach accuracy: 16 meters lateral/4 meters vertical
- **Approach Capabilities**
  - WAAS receivers support all basic GPS approach functions and provide additional capabilities
    - Allows approach procedures to be built without ground stations at each airport
    - Eliminates cold temperature effects, incorrect altimeter setting/lack of altimeter setting
- **New APV (Approach with Vertical Guidance) approaches can be flown with WAAS**
  - Basically, satellite-based approaches with a WAAS generated glidepath
  - Like a Cat 1 ILS: Decision altitudes as low as 200', Visibility requirements as low as ½ mile
- **Can be further enhanced with LAAS**

Local Area Augmentation System (LAAS) – Commonly known as GBAS now

- **Similar to WAAS, but with more ground augmentation**
- **All-weather aircraft landing system based on real-time differential correction of the GPS signal**
- **Local receivers located around the airport send data to a central location at the airport**
  - A correction message is then transmitted to users via a VHF Data Link
- **A receiver on an aircraft uses this information to correct GPS signals, which then provides a standard ILS-style display to use while flying a precision approach**

Flight Management Systems (FMS)

- **The FMS is not a navigation system in itself, instead it automates the tasks of managing onboard navigation systems**
- **The FMS has a database of airport locations, NAVAIDS, SIDS, STARS and approaches**
  - User waypoints can be stored in the FMS
- **The FMS can plan a route to any point in the database and complete the proper performance calculations to give an overall picture of the route to the flight crew**
- **VORs can be used by the FMS**

Anti-Ice/Deicing and Weather Detection Equipment

Anti-Ice – Prevent buildup of ice

Deice – Remove built up ice

- **Icing can be categorized into 3 categories; Structural, Induction, and Instrument (critical systems)**

Structural Icing

- This is the ice that is built on the surfaces of the aircraft
- 3 types:
  - **Clear** – Clear far back on the wing – Temps from 0C - -10C
  - **Mixed** – Mix of Clear and Rime – Temps -10C - -15C
  - **Rime** – Rough, milky – Temps -15C - -20C

Induction Icing

- Icing in the engine
- Systems to counter induction icing include
    - Carb heat – Redirects intake air into a shroud around exhaust to heat it
    - Alternate air source – Found on the fuel injected planes – Opens automatically

Instrument Icing (Critical Systems)

- Icing that effects the flight instruments
- Protection against this is in the form of pitot heat and alternate static
    - 100W and 35W heating element in the pitot tube precent buildup of ice
    - Alternate static provides alternate static error when static port is blocked
        - Breaking the VSI is another means of alternate static air
    - Pitot-Static blockages discussed here

Airframe & Propeller

Airframe deicing and anti-ice systems aim to prevent or remove ice from the leading edge of the wing (where the buildup usually begins)

- **The common forms of deicing system include:**
    - Weeping wings
    - Rubber boots
    - Heated surfaces (bleed air) (*on props too)*

Air Intake

The Air intake deicing and anti-icing systems include:

- Carb Heat
- Alternate air inlet

Pitot Static System

- The Pitot heat protects the pitot-tube from icing by an electric heating element (usually 100W and 35W)

Conclusion & Review

Conclusion:

Brief review of the main points

PTS Requirements:

To determine that the applicant exhibits instructional knowledge of aircraft:

- Flight instrument systems and their operating characteristics to include-

- pitot-static system.
- attitude indicator.
- heading indicator/horizontal situation indicator/radio magnetic indicator.
- magnetic compass.
- turn-and-slip indicator/turn coordinator.
- electrical system.
- vacuum system.
- electronic engine instrument display.
- primary flight display, if installed.

- Navigation equipment and their operating characteristics to include–
  - VHF omnirange (VOR).
  - distance measuring equipment (DME).
  - instrument landing system (ILS)
  - marker beacon receiver/indicators.
  - automatic direction finder (ADF).
  - transponder/altitude encoding.
  - electronic flight instrument display.
  - global positioning system (GPS)
  - automatic pilot.
  - flight management system (FMS).
  - multifunction display, if installed.
- Anti-ice/deicing and weather detection equipment and their operating characteristics to include-
  - airframe.
  - propeller or rotor.
  - air intake.
  - fuel system.
  - pitot-static system.
  - radar/lightning detection system.
  - other inflight weather systems.