ENGLISH for IFR PILOTS

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Úvodem

Tato skripta jsou zpracována jako pomocný studijní materiál pro piloty, instruktory leteckého výcviku, letecké školy a centra leteckého výcviku, které zabezpečují letecký výcvik pro kvalifikace letů podle přístrojů (lety IFR) a případně pro další zájemce o rozšíření znalostí z letecké tématiky.

Navazují na skripta Letecká angličtina a frazeologie pro lety VFR a společně tvoří základní ucelenou sestavu pro přípravu na zkoušku z odborné letecké angličtiny a frazeologi pro lety IFR, která je požadována na ÚCL v souladu z leteckým předpisem JAR-FCL pro piloty letounů a vrtulníků.

Autor

INTRODUCTION

Why an Instrument Rating?

The answer to this question depends upon individual needs. Pilots who fly in familiar un-congested areas, stay alert to weather developments and accept an alternative to their original plan, may not need an **Instrument Rating**.
However, some cross-country destinations may take a pilot to unfamiliar airports and/or through high activity areas in marginal visual or instrument meteorological conditions (**IMC**).

Pilots originally flew aircraft strictly by sight, sound, and feel while comparing the aircraft´s attitude to the natural horizon. As aircraft performance increased, pilots required more in-flight information to enhance the safe operation of their aircraft.

Navigation began by using ground references with dead reckoning and has led to the development of electronic navigational systems. These include the automatic direction finder (**ADF**), very-high frequency omni-directional radio range (**VOR**), distance measuring equipment (**DME**), tactical air navigation (**TACAN**), long range navigation (**LORAN**), global positioning system (**GPS**), instrument landing system (**ILS**), microwave landing system (**MLS**) and inertial navigational system (**INS**).

Perhaps you want an Instrument Rating for the same basic reason you learned to fly in the first place – because you like flying. Earn the rating – not because you might need it sometime, but because it represents achievement and provides training you will use continually and build upon as long as you fly. But most importantly – it means greater safety in flying.

HUMAN FACTORS

INTRODUCTION

Human factors is a broad field that studies the interaction between people and machines for the purpose of improving performance and reducing errors. As aircraft became more reliable and less prone to mechanical failure, the percentage of accidents related to human factors increased. Some aspect of human factors now accounts for over 80 % of all accidents.

Flying in instrument meteorological conditions (IMC) can result in sensation that are misleading to the body´s sensory system. A safe pilot needs to understand these sensations and effectively counteract them. Instrument flying requires a pilot to make decisions using all available resources.

Sensory Systems for Orientation

Orientation - is the awareness of the position of the aircraft and of oneself in relation to a specific reference point.
Disorientation - is the lack of orientation
Spatial disorientation – is the state of confusion due to misleading information being sent to the brain from various sensory organs resulting in a lack of awareness of the aircraft position in relation to a specific reference point.

Orientation is maintained through the body´s sensory organs in **three areas**:

- **visual**
- **vestibular**
- **postural**

The eyes maintain visual orientation; the motion sensing system in the inner ear maintains vestibular orientation and the nerves in the skin, joints and muscles of the body maintain postural orientation.

When human beings are in their natural environment, these three systems work well but when the human body is subjected to the forces of flight, these senses can provide misleading information and pilots become disoriented.

Visual illusions

There are two illusions leading to the spatial disorientation:
False horizon - Inaccurate visual information for aligning the aircraft caused by various and geometric formations that disorient the pilot from the actual horizon.
Autokinesis – Night-time visual illusion that a stationary light is moving, which becomes apparent after several seconds of staring at the light.

Vestibular illusions

The vestibular system in the inner ear is the sensory system responsible for most illusions leading to the spatial disorientation. The major illusions are covered below.

The leans – An abrupt correction of a banked attitude, entered too slowly to stimulate the motion sensing system in the inner ear, can create the illusion of banking in the opposite direction.
Coriolis illusion - An abrupt head movement, while in a prolonged constant-rate turn that has ceased stimulating the motion sensing system, can create the illusion of rotation or movement in an entirely different axis.
Graveyard spiral – The illusion of the cessation of a turn while actually still in a prolonged coordinated, constant-rate turn, which can lead a disoriented pilot to a loss of control of the aircraft.
Somatogravic illusion – The feeling of being in a nose-up or nose-down attitude, caused by a rapid acceleration or deceleration while in flight situations that lack visual reference.
Inversion illusion – The feeling that the aircraft is tumbling backwards, caused by an abrupt change from climb to straight-and-level flight while in situations lacking visual reference.
Elevator illusion – The feeling of being in a climb or descent, caused by the kind of abrupt vertical acceleration that result from up or downdrafts.

Postural illusions

The postural system sends signals from the skin, joints and muscles to the brain that are interpreted in relation to the Earth´s gravitational pull. These signals determine posture.
Because of the forces acting upon the body in certain flight situations, many false sensations can occur due to acceleration forces overpowering gravity.

Physiological and Psychological Factors

Stress – is the body´s response to demand placed upon it. These demands can be either pleasant or unpleasant in nature.
The indicators of excessive stress often show as three types of symptoms:

- emotional
- physical
- behavioral

Pilots need to learn to recognize the symptoms of stress as they begin to occur within themselves.
There are many techniques available that can help reduce stress in life or help people cope with it better.
Good cockpit stress management begins with good life stress management. The following checklist outlines some methods of cockpit stress management.

- ➢ Avoid situations that distract from flying the aircraft
- ➢ Reduce workload to reduce stress level. This will create a proper environment in which to make good decisions
- ➢ If an emergency does occur, be calm. Think for a moment, weight the alternatives, than act
- ➢ Become familiar with the aircraft, its operation and emergency procedures. Also, maintain flight proficiency to build confidence
- ➢ Know and respect personal limits

- Do not allow small mistakes to be distractions during flight; rather review and analyze them after landing
- If flying adds stress, either stop flying or seek professional help to manage stress with acceptable limits

Medical Factors – A "go/no-go" decision is made before each flight. The pilot should not only preflight check the aircraft, but also his/herself before every flight.

There are in fact three main factors degrading the pilot´s performance:
- Lack of the medical fitness
- Alcohol/drugs
- Fatigue

Aeronautical Decision Making Process (ADM)

A systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances.

The ADM process addresses all aspects of decision making in the cockpit and identifies the steps involved in good decision making.
These steps are:

1. **identifying personal attitudes hazardous to safe flight**
2. **learning behavior modification techniques**
3. **learning how to recognize and cope with stress**
4. **developing risk assessment skills**
5. **using all resources**
6. **evaluating the effectiveness of one´s ADM skills**

AERODYNAMIC FACTORS

REVIEW of BASIC AERODYNAMICS

As an instrument pilot, you must understand the relationship and difference between the **aircraft´s flight path**, **angle of attack and pitch attitude**. Also, it is crucial to understand how the aircraft will react to various control and power changes, because the environment in which instrument pilots fly has inherent hazards not found in visual flight.

The basis for this understanding is found in the **four forces and Newton´s laws**:

- **the Law of Inertia**
- **the Law of Momentum**
- **the Law of Reaction**

The four basic forces acting upon an aircraft in flight are:

- **lift**
- **weight**
- **thrust**
- **drag**

The aerodynamic forces produced by the wing create lift.

Lift

Lift always acts in a direction perpendicular to the relative wind and to the lateral axis of the aircraft. The fact that lift is referenced to the wind, not to the Earth´s surface is a source of many errors in learning flight control.

Lift is not always "up".

Its direction relative to the Earth´s surface changes as you maneuver the aircraft

A byproduct of lift is **induced drag.** Induced drag combined with **parasite drag** (which is a sum of form drag, skin friction and interference drag) produce the total drag of the aircraft.

Flight path: - the line, course or track along which an aircraft is flying or is intended to be flown

Angle of attack: - the acute angle formed between the chord line of an airfoil and the direction of the air that strikes the airfoil

Induced drag: - caused by the same factors that produce lift, its amount varies inversely with airspeed. As airspeed decreases, the angle of attack must increase and this increases induced drag.

Parasite drag: - caused by the friction of air moving over the structure, its amount varies directly with the airspeed. The higher the airspeed, the greater the parasite drag.

ATMOSPHERE

Air density is a result of the relationship between temperature and pressure. This relationship is such that density is inversely related to temperature and directly related to pressure.

For a constant pressure to be maintained as temperature increases, density must decrease and vice versa.

For a constant temperature to be maintained as pressure increases, density must increase and vice versa.

These relationships provide a basis for understanding instrument indications and aircraft performance.

Standard Atmosphere

The **International Civil Aviation Organization (ICAO)** established the **ICAO Standard Atmosphere** as a way of creating an international standard for reference and computations.
In the standard atmosphere, sea level pressure is **1013,25hPa** (29.92” Hg) and the temperature is **15°C** (59°F).the standard lapse rate for pressure is approximately **33,9hPa** decrease per **1,000ft** increase in altitude. The standard lapse rate for temperature is a 2°C (3,6°F) decrease per **1,000ft** increase up to the tropopause. Because the actual operating conditions rarely fit the standard atmosphere, certain corrections must apply to the instrumentation and aircraft performance.

There are two measurements of the atmosphere that pilots must understand: **pressure altitude and density altitude**.

Pressure Altitude is the height above the standard datum pressure (1013.25hPa) and is used for standardizing altitudes for **flight levels (FL)** and for calculation involving aircraft performance.
Density Altitude is pressure altitude corrected for nonstandard temperature and is used for determining aerodynamic performance in the nonstandard atmosphere. Density altitude increases as the density of the air decreases.

Safety Reminder
As density altitude increases, performance decreases – be aware on hot days at high altitudes.

DRAG

When induced drag and parasite drag are plotted on a graph, the total drag on the aircraft appears in the form of a “drag curve”.
The drag curve also illustrates the two regions of command:

- **the region of normal command**
- **the region of reversed command**

The term “region of command” refers to the relationship between speed and the power required to maintain or change that speed and means the input the pilot must give in terms of power or thrust to maintain a new speed.

The region of normal command occurs where power must be added to increase speed.
The region of reversal command occurs where additional power is needed to maintain a slower airspeed.

Speed stability

If the airspeed is increased with no changes to the power setting, a power deficiency exists. The aircraft will have the natural tendency to return to the initial speed to balance power and drag.

If the airspeed is reduced with no changes to the power setting, an excess of power exists. The aircraft will have the tendency to speed up to regain the balance between power and drag.

Keeping the aircraft in proper trim enhances this natural tendency.

Static longitudinal stability of the aircraft tends to return the aircraft to the original trimmed condition.

Slow Airspeed Safety Hint

Be sure to add power before pitching up while at slow airspeeds to prevent losing airspeed

Reversed Logic

In the region of reversed command, as you slow down you require more power

FLIGHT INSTRUMENTS

INTRODUCTION

The basic flight instruments required for operation under visual flight rules (**VFR**) are:

- airspeed indicator
- an altimeter
- magnetic direction indicator (magnetic compass)
- slip-skid indicator

In addition to these, operation under instrument flight rules (**IFR**) requires:

- gyroscopic rate-of-turn indicator
- sensitive altimeter adjustable for barometric pressure
- clock displaying hours, minutes and seconds with a sweep-second pointer or digital presentation
- gyroscopic pitch-and-bank indicator (artificial horizon)
- gyroscopic direction indicator (directional gyro or equivalent)

Aircraft that are flown in instrument meteorological conditions (**IMC**) are equipped with instruments that provide attitude and direction reference, as well as radio navigation instruments that allow precision flight from takeoff to landing with limited or no outside visual references.

PITOT-STATIC SYSTEMS

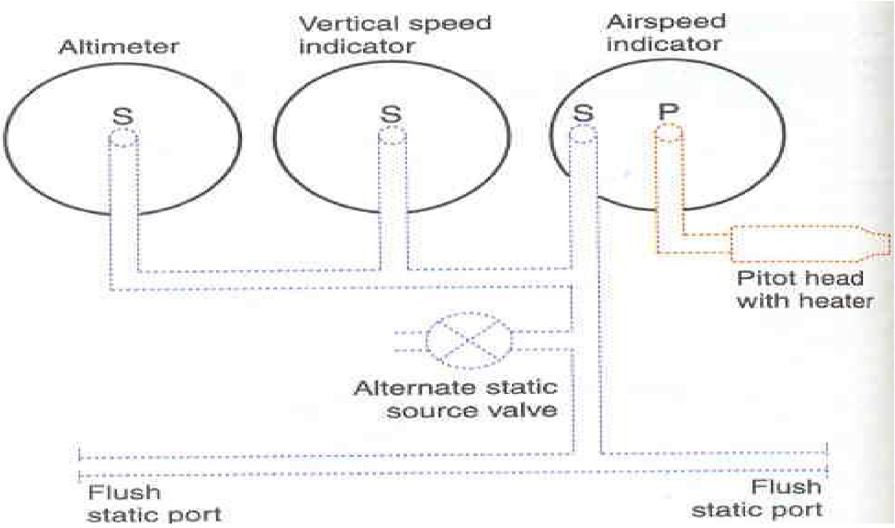
Three basic pressure-operated instruments are found in most aircraft instrument panels:

- **airspeed indicator (ASI)**
- **sensitive altimeter**
- **vertical speed indicator (VSI)**

All of them receive the pressures from the aircraft pitot-static system.

The pressure of the **static, or still air**, is measured at a flush port where the air is not disturbed. On some aircraft, this air is sampled by static ports on the side of the electrically heated **pitot-static head**. Other aircraft pick up the static pressure through flush ports on the side of the fuselage or vertical fin.

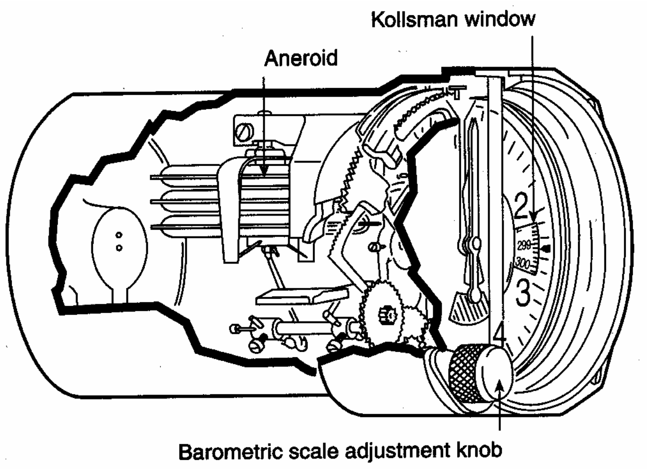
Pitot pressure (impact air pressure, ram air pressure) is taken in through an open-end tube pointed directly into the relative wind flowing around the aircraft.

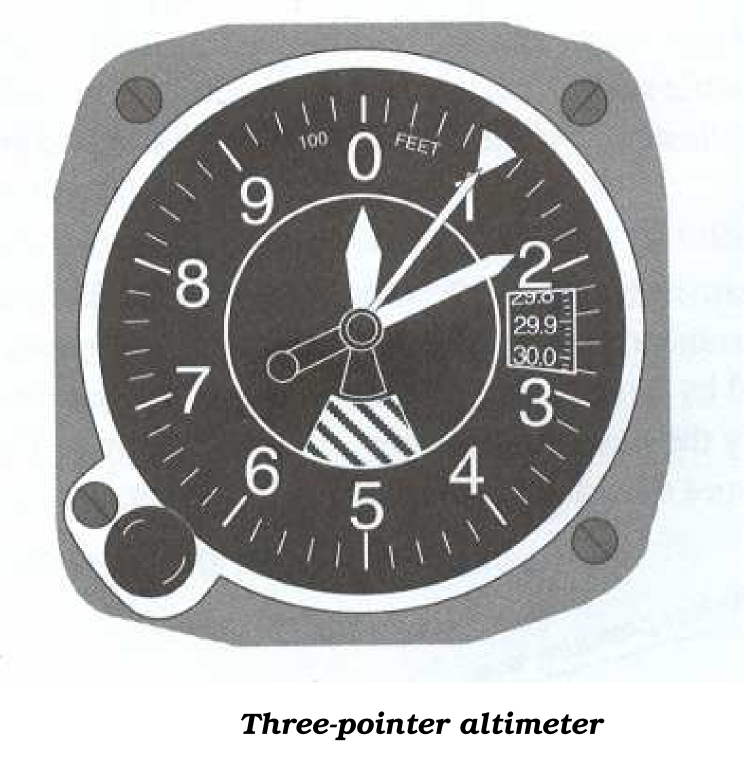


Sensitive Altimeter

Principle of operation

A sensitive altimeter is an aneroid barometer that measures the absolute pressure of the ambient air and displays it in terms of feet or meters above a selected pressure level. The sensitive element is a stack of evacuated, corrugated bronze aneroid capsules as shown. The air pressure acting on these aneroids tries to compress them against their natural springiness, which tries to expand them. The result is that their thickness changes as the air pressure changes.





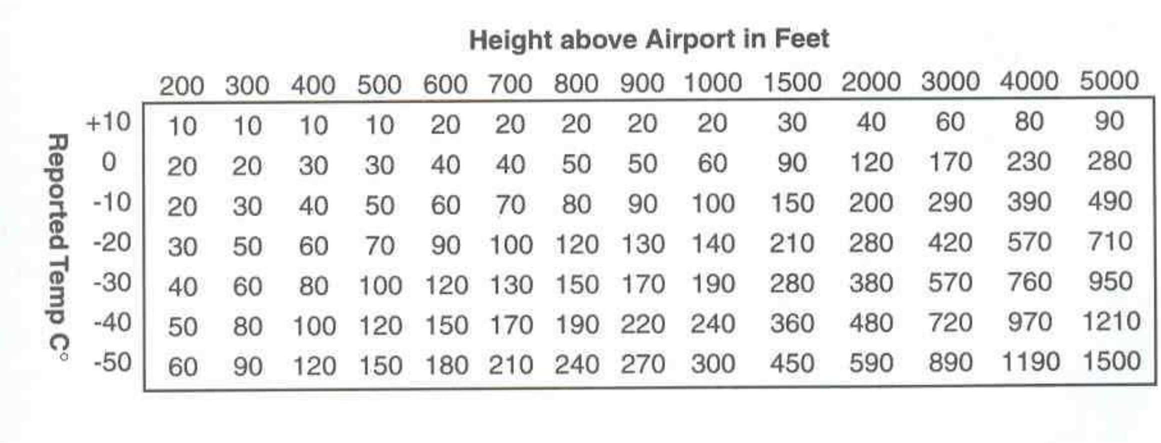
Three-pointer altimeter

Altimeter Errors

A sensitive altimeter is designed to indicate standard changes from standard conditions, but most flying involves errors caused by nonstandard conditions and you must be able to modify the indications to correct for these errors.
If the air is colder than standard, it is denser and the pressure levels are closer together. When the aircraft is flying at an indicated altitude of 5 000ft as an example, the true altitude is lower than it would be if the air were warmer.
The cold temperature induced altimeter error may be significant when considering obstacle clearances when temperatures are well below standard.
Pilots may wish to increase their minimum terrain clearance altitudes with a corresponding increase in ceiling from the normal minimum when flying in extreme cold temperature conditions. Some flight management systems (**FMS**) with air data computers may implement a capability to compensate for cold temperature errors. If compensation is applied by the FMS or manually, ATC must be informed that the aircraft is not flying the assigned altitude.

The following table derived from ICAO standard formulas, shows how much error can exist when the temperature is extremely cold.

ICAO Cold Temperature Error Table



Reported Temp C°	Height above Airport in Feet													
	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000
+10	10	10	10	10	20	20	20	20	20	30	40	60	80	90
0	20	20	30	30	40	40	50	50	60	90	120	170	230	280
-10	20	30	40	50	60	70	80	90	100	150	200	290	390	490
-20	30	50	60	70	90	100	120	130	140	210	280	420	570	710
-30	40	60	80	100	120	130	150	170	190	280	380	570	760	950
-40	50	80	100	120	150	170	190	220	240	360	480	720	970	1210
-50	60	90	120	150	180	210	240	270	300	450	590	890	1190	1500

The fact that the altitude indication is not always true lends itself to the memory aid:

"When flying from hot to cold, or from high to low, look out below"

Encoding Altimeter

It is not sufficient in the airspace for only the pilots to have an indication of the aircraft´s altitude; the ATC on the ground must also know the altitude of the aircraft. To provide this information, the aircraft may be equipped with an encoding altimeter.

When the ATC transponder is set to **Mode C**, the encoding altimeter supplies the transponder with the series of pulses identifying the flight level (in increments of 100ft) at which the aircraft is flying. This series of pulses is transmitted to the ground radar where they appear on the controller´s scope as an alphanumeric

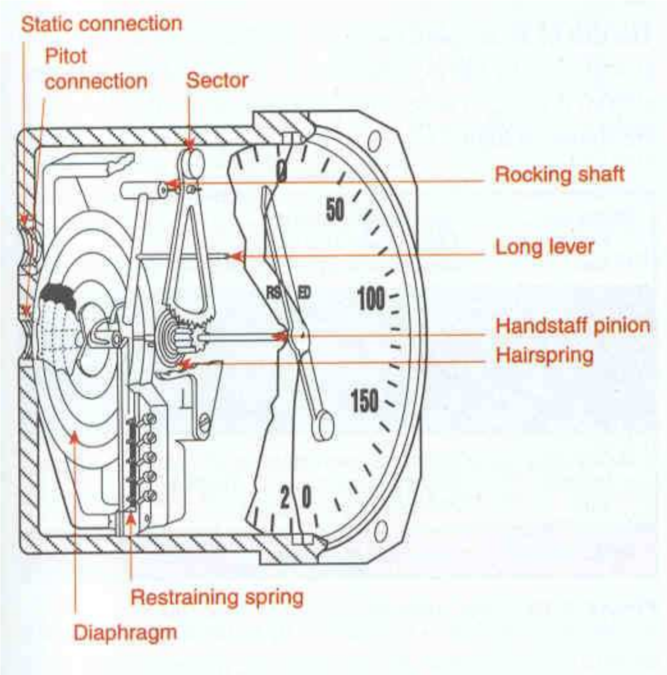
display around the return for the aircraft. A computer inside the encoding altimeter measures the pressure referenced from the standard and delivers this data to the transponder. When the pilot adjusts the barometric scale to the local altimeter setting, the data sent to the transponder is not affected.

Absolute Altimeter

The absolute altimeter, also called a radar or radio altimeter, measures the height of the aircraft above the terrain. It does this by transmitting a radio signal, either a frequency-modulated continuous-wave or pulse to the ground and accurately measuring the time used by the signal in traveling from the aircraft to the ground and returning.
Most absolute altimeters have a provision for setting a **decision height/decision altitude** (**DH/DA**) or a **minimum descent altitude** (**MDA**) so that when the aircraft reaches this height above ground, a light will illuminate and/or an aural warning will sound. Absolute altimeters are incorporated into ground proximity warning systems (**GPWS**) and into some flight instruments.

Airspeed Indicators

An airspeed indicator is a differential pressure gauge that measures the dynamic pressure of the air through which the aircraft is flying. Dynamic pressure is the difference in the ambient static air pressure and the **total** (**ram**) **pressure** caused by the motion of the aircraft through the air. These two pressures are taken from the **pitot-static** system.



Mechanism of an airspeed indicator

Types of Airspeed

Just as there are several types of altitude, there are several types of airspeed:

- **indicated airspeed (IAS)**
- **calibrated airspeed (CAS)**
- **equivalent airspeed (EAS)**
- **true airspeed (TAS)**

Indicated Airspeed

Indicated airspeed is shown on the dial of the instrument, uncorrected for instrument or system errors.

Calibrated Airspeed

Calibrated airspeed is the speed the aircraft is moving through the air which is found by correcting IAS for instrument and position errors.

Equivalent Airspeed

Equivalent airspeed is CAS corrected for compression of the air inside the pitot tube. Equivalent airspeed is the same as CAS in standard atmosphere at sea level. As the airspeed and pressure altitude increase, the CAS becomes higher than it should be and a correction for compression must be subtracted from the CAS.

True Airspeed

True airspeed is CAS corrected for nonstandard pressure and temperature. True airspeed and CAS are the same in standard atmosphere at sea level. But under nonstandard conditions, TAS is found by applying a correction for pressure altitude and temperature to the CAS.

Airspeed Color Codes

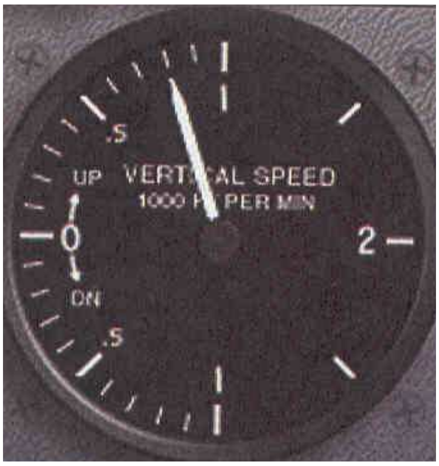
The dial of an airspeed indicator is color coded to alert you, at a glance, of the significance of the speed at which the aircraft is flying.

White arc	**Flap operating range**
Bottom	**Flaps-down stall speed**
Top	**Maximum airspeed for flaps-down flight**
Green arc	**Normal operating range**
Bottom	**Flaps-up stall speed**
Top	**Maximum airspeed for rough air**
Blue radial line	**Airspeed for best single-engine rate-of-climb**
Yellow arc	**Structural warning area**
Bottom	**Maximum airspeed for rough air**
Top	**Never-exceed airspeed**
Red radial line	**Never-exceed airspeed**

Vertical Speed Indicators (VSI)

The vertical speed indicator (VSI) is also called a vertical velocity indicator (VVI) and was formerly known as a rate-of-climb indicator. It is a rate-of-pressure change instrument that gives an indication of any deviation from a constant pressure level.

Inside the instrument case is an aneroid very much like the one in an airspeed indicator. Both the inside of this aneroid and the inside of the instrument case are vented to the static system, but the case is vented through a **calibrated orifice** that causes the pressure inside the case to change more slowly than the pressure inside the aneroid.



Vertical speed indicator

As the aircraft ascends, the static pressure becomes lower and the pressure inside the case compresses the aneroid, moving the pointer upward showing a climb and indicating the number of feet per minute the aircraft is ascending.

When the aircraft levels off, the pressure no longer changes, the pressure inside the case becomes the same as that inside the aneroid and the pointer returns to its zero position.

When the aircraft descents, the static pressure increases and the aneroid expands, moving the pointer downward, indicating a descent.

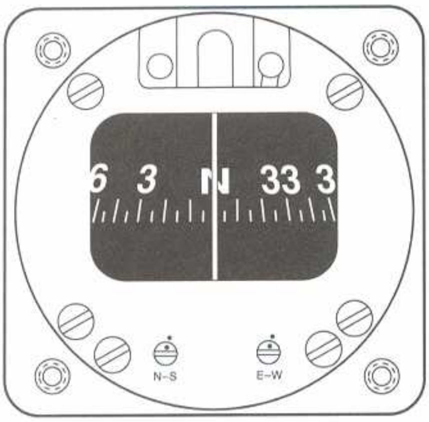
Compass systems

The Earth is a huge magnet, spinning in spec, surrounded by a magnetic field made up of invisible **lines of flux (***invisible lines of magnetic force passing between the poles of a magnet***).** These lines leave the surface at the magnetic north pole and reenter at the magnetic south pole.

Lines of magnetic flux have two important characteristics: any magnet that is free to rotate will align with them and an electrical current is induced into any conductor that cuts across them. Most direction indicators installed in aircraft make use of one of these two characteristics.

Magnetic Compass

One of the oldest and simplest instruments for indicating direction is the magnetic compass. It is also one of the basic instruments required for both VFR and IFR flight. An aircraft magnetic compass, such as the one in the following picture, has two small magnets attached to a metal float sealed inside a bowl of clear compass fluid similar to kerosene. A graduated scale, called a card, is wrapped around the float and viewed through a glass window with a **lubber line** across it. The card is marked with letters representing the cardinal directions and a number for each 30° between these letters. The magnetic compass is the simplest instrument in the panel, but is subject to a number of errors that must be considered.



A magnetic compass

Compass Errors

Variation

The compass error caused by the difference in the physical locations of the magnetic north pole and the geographic north pole.
Variation is always measured from the geographical north pole. When the magnetic north pole is on the left from the geographical north pole, variation is called as **western** and is marked **minus (-)**. When the magnetic north pole is on the right from the geographical north pole, variation is called as **eastern** and is marked **plus (+)**.

Isogonic lines

Lines drawn across aeronautical charts connecting points having the same magnetic variation.

Agonic line

An irregular imaginary line across the surface of the Earth along which the magnetic and geographic poles are in alignment and along which there is no magnetic variation.

Deviation

Is a magnetic compass error caused by local magnetic fields within the aircraft.
Deviation error is different on each heading.

Compass course

A true course corrected for variation and deviation errors. The correction for variation and deviation must be applied in the correct sequence.

To find the compass course when the true course is known:

True Course ± Variation = Magnetic Course ± Deviation = Compass Course

To find the true course that is being flown when the compass course is known:

Compass Course ± Deviation = Magnetic Course ± variation = True Course

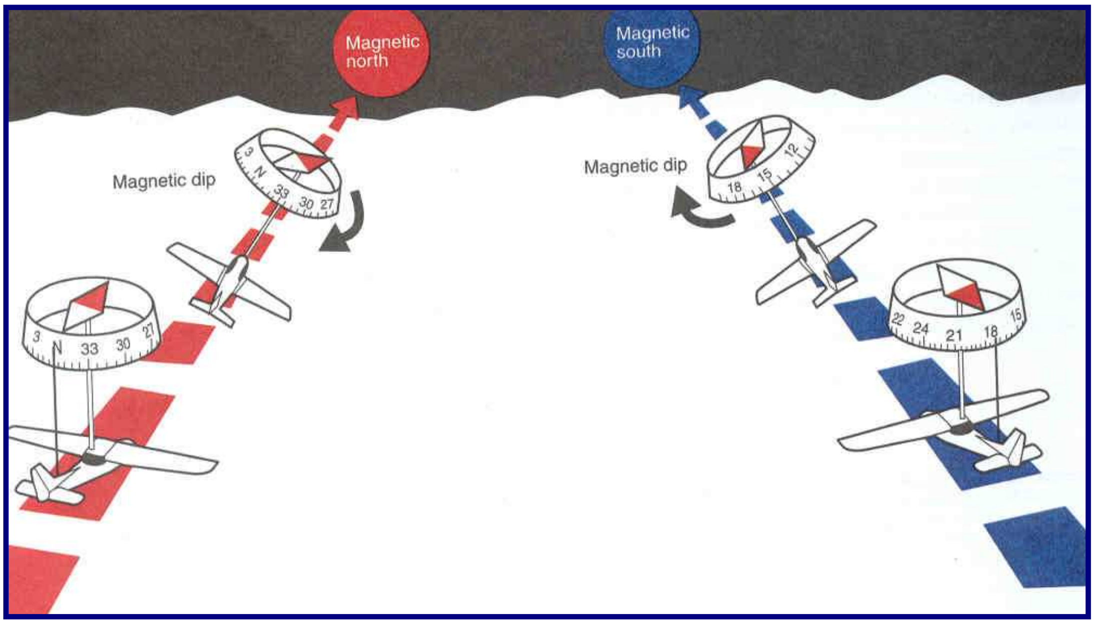
Dip Errors

A turn is made from north to west or from north to east.
The rule for this error is:

When starting a turn from a northerly heading, the compass indication lags behind the turn.

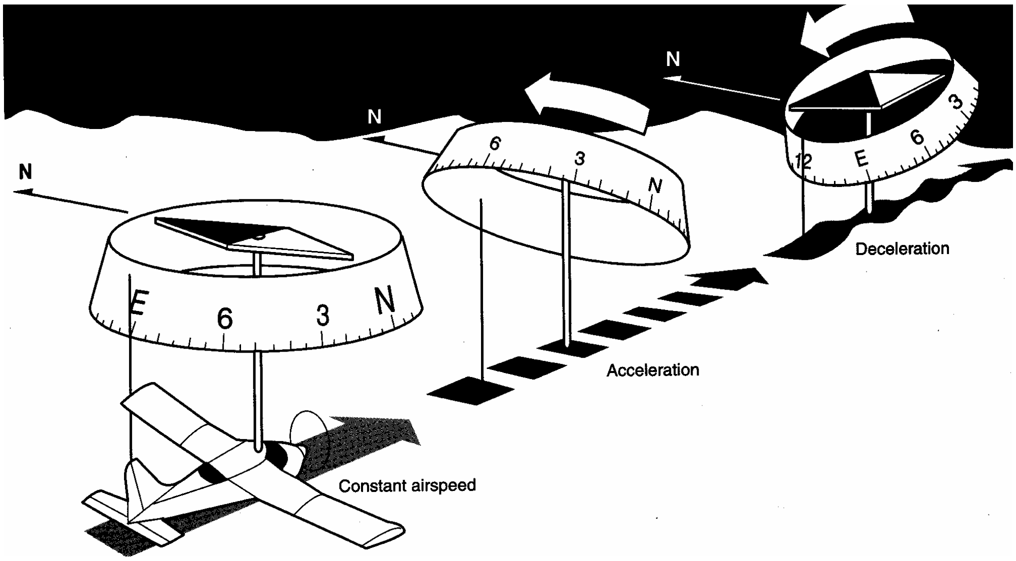
A turn is made from south to west or from south to east.
The rule for this error is:

When starting a turn from a southerly heading, the compass indication leads the turn.



Acceleration and deceleration during the flight

Acceleration causes an indication toward north, deceleration causes an indication toward south.

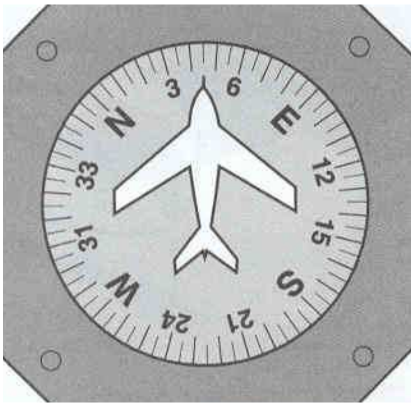


Oscillation Error

Oscillation is a combination of all the other errors and it results in the compass card swinging back and forth around the heading being flown.

Vertical Card Magnetic Compasses

The vertical card magnetic compass eliminates some of the errors and confusion. The dial of this compass is graduated with letters representing the cardinal directions, numbers every 30°, and marks every 5°. Oscillation of the magnet is damped by **eddy currents** induced into an aluminum damping cup.



A vertical card magnetic compass

Flux Gate Compass

The flux gate compass that drives slaved gyros uses the characteristic of **current induction**. The flux valve is a small segmented ring, made of soft iron that accepts lines of magnetic flux each time the current in the center coil reverses. This flux causes current to flow in the three pickup coils. The current in each of the three pickup coils changes with the heading of the aircraft.
The three coils are connected to the similar but smaller coils in a **synchro** inside the instrument case. The synchro rotates the dial of the **Radio Magnetic Indicator (RMI)** or a **Horizontal Situation Indicator (HSI)**.

As instrument panels become more crowded and the pilot´s available scan time is reduced by a heavier cockpit workload, instrument manufacturers have worked towards combining instruments.
One good example of this is the RMI where the compass card is driven by signals from the flux valve and the two pointers are driven by an **Automatic Direction Finder (ADF)** and a **Very-high-frequency Omni-directional Range (VOR)**.

ADF – Electronic navigation equipment that operates in the low and medium frequency bands.
VOR – Electronic navigation equipment in which the cockpit instrument identifies the radial or line from the VOR station measured in degrees clockwise from magnetic north, along which the aircraft is located.

Gyroscopic Systems

Flight without reference to a visible horizon can be safely accomplished by the use of gyroscopic instrument systems and the two characteristics of gyroscopes which are: **rigidity** and **precession**.

Attitude Indicators

The first attitude instrument (**AI**) was originally referred to as an artificial horizon, later as a gyro horizon; now it is more properly called an attitude indicator.
Its mechanism is a small brass wheel with a vertical spin axis, spun at a high speed by either a stream of air impinging on buckets cut into its periphery, or by an electric

motor. The gyro is mounted in a **double gimbal** which allows the aircraft to pitch and roll about the gyro as it remains fixed in space.

A horizon disk with a line representing the horizon and both pitch marks and bank-angle lines is attached to the gimbals so it remains in the same plane as the gyro and the aircraft pitches and rolls about it. The top half of the instrument dial and horizon disc is blue, representing the sky; and the bottom half is brown, representing the ground. A bank index at the top of the instrument shows the angle of bank with lines that represent 10°, 20°, 30°, 60°and 90°.

A small symbolic aircraft is mounted in the instrument case so it appears to be flying relative to the horizon. The width of the wing of the symbolic aircraft and the dot in the center of the wings represents a pitch change of approximately 2°.

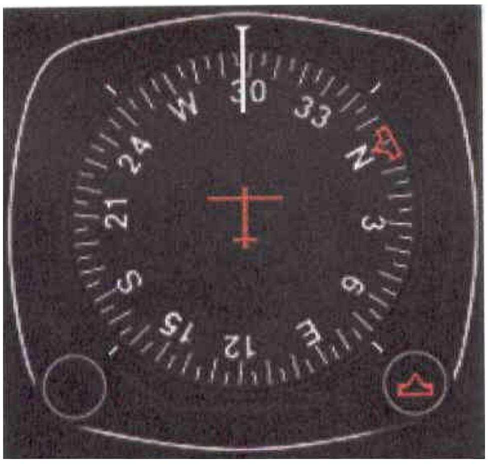
The dial of this attitude indicator has reference lines showing pitch and roll

The older instruments were limited in the amount of pitch or roll they could tolerate and had a caging mechanism that locked the gyro in its vertical position during any maneuvers that exceeded the instrument limits.

Heading Indicators

A magnetic compass is a dependable instrument and is used as a backup instrument. But it has so many inherent errors that it has been supplemented with gyroscopic heading indicators.

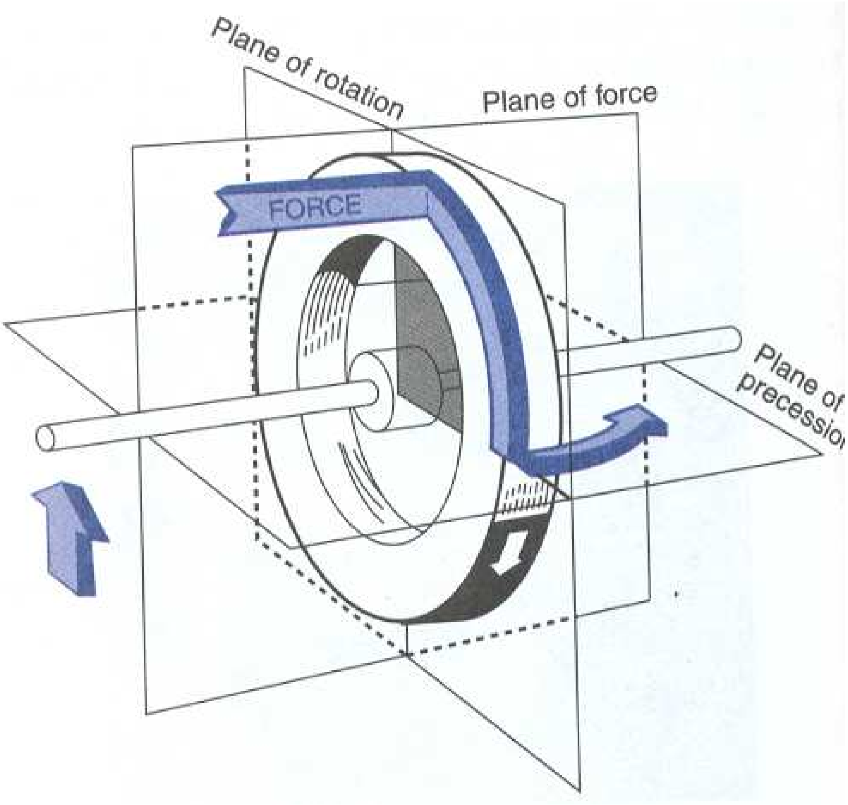
Gyro heading indicators, with the exception of slaved gyro indicators, are not north-seeking and they must be set to the appropriate heading by referring to a magnetic compass.



The heading indicator

Turn Indicators

These rate instruments operate on the principle of precession. Precession is the characteristic of the gyroscope that causes an applied force to produce a movement, not at the point of application, but at a point 90° from the point of application in the direction of rotation.

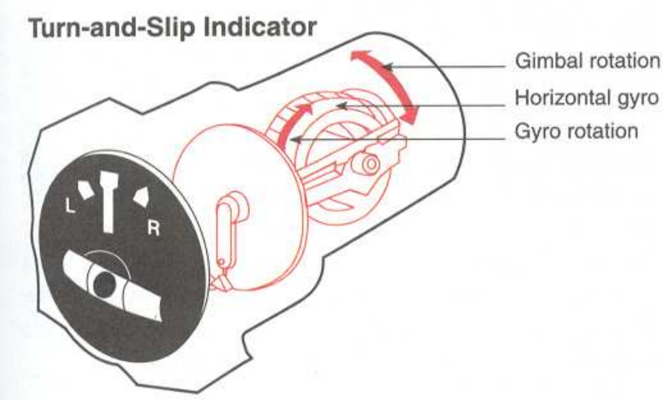


Precession causes a force applied to a spinning wheel to be felt 90° from the point of application in the direction of rotation

Turn-and-Slip Indicator

One of the first gyroscopic instruments has two indicators: the inclinometer and turn indicator.
The inclinometer is a black ball sealed inside a curved glass tube that is partially filled with a liquid, much like compass fluid. This ball measures the relative strength of the force of gravity and the force of inertia caused by a turn.

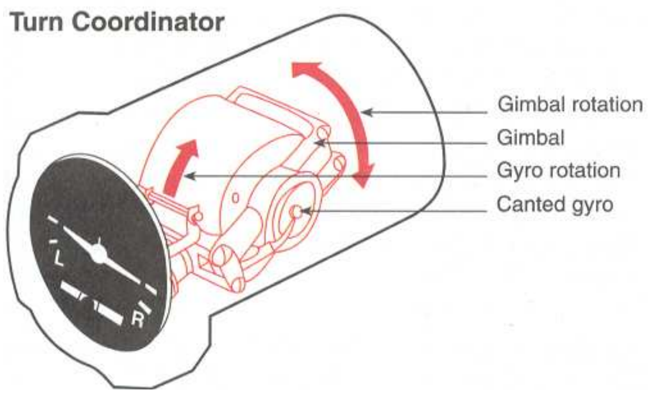
The inclinometer does not indicate the amount of bank but it only indicates the relationship between the angle of bank and the rate of yaw.
The turn indicator id a small gyro spun either by air or by an electric motor. The gyro is mounted in a single gimbal with its spin axis parallel to the lateral axis of the aircraft and the axis of the gimbal parallel with the longitudinal axis.



When the aircraft yaws, or rotates about its vertical axis, it produces a force in the horizontal plane that, due to precession, causes the gyro and its gimbal to rotate about the gimbal axis. It is restrained in this rotation plane by a calibration spring; it rolls over just enough to cause the pointer to deflect until it aligns with one of the **doghouse** shaped marks on the dial, when the aircraft is making a standard-rate turn.

Turn Coordinator

A turn coordinator operates on precession, the same as the turn indicator, but its frame is angled upward about 30° from the longitudinal axis of the aircraft. This allows it to sense both roll and yaw.

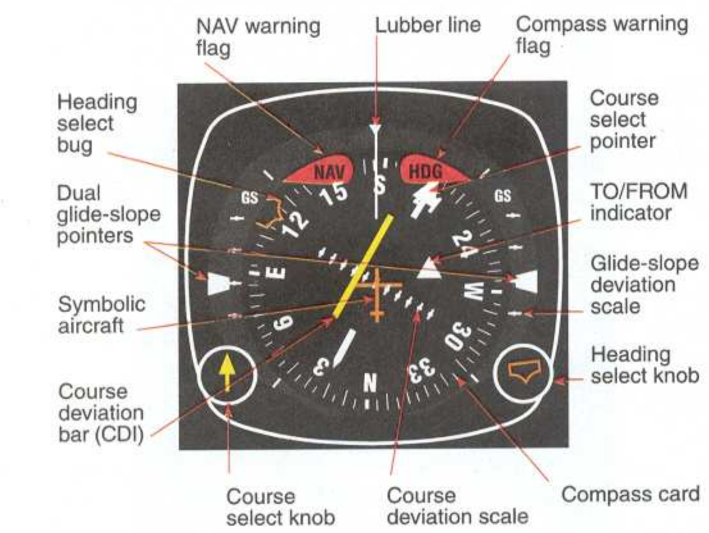


Rather than a needle as an indicator, the gimbal moves a dial on which is the rear view of a symbolic aircraft. The bezel of the instrument is marked to show bank angles for a standard-rate turn.

Flight Director Systems

Horizontal Situation Indicator (HSI)

The HSI is a direction indicator that uses the output from a flux valve to drive the dial, which acts as the compass card. The instrument shown on the picture combines the magnetic compass with navigation signals and a glide slope.

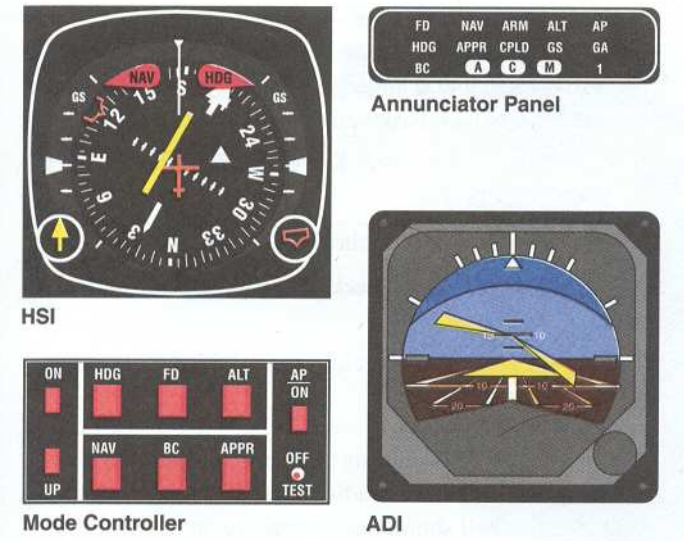


Attitude Director Indicator (ADI)

The **ADI** furnishes the same information as an attitude indicator, but has the additional feature of a set of computer-driven bowtie-shaped steering bars. Instead of the symbolic aircraft, a delta-shaped symbol represents the aircraft being flown.

The **mode controller** provides signals through the ADI to drive the steering bars. 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.

The integrated flight director system components in the instrument panel include the **mode controller, ADI, HSI and annunciator panel**.



NAVIGATION SYSTEMS

Introduction

This section provides the basic radio principles applicable to navigation equipment, as well as an operational knowledge of how to use these systems in instrument flight.

Nondirectional Radio Beacon (NDB)

Description

The **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 transmitting station. The indicator may be mounted in a separate instrument in the aircraft panel.

The ADF needle points to the NDB ground station to determine the **relative bearing (RB)** to the transmitting station. **Magnetic heading (MH)** plus RB equals the **magnetic bearing (MB)** to the station.

NDB Components

The ground equipment, the NDB, transmits in the frequency range of **190 to 535 kHz**. Most ADFs will also tune the AM broadcast band frequencies above the NDB (**550** to **1650** kHz). However these frequencies are not approved for navigation because stations do not continuously identify themselves and they are more susceptible to sky wave propagation especially from dusk to dawn. NDB stations are capable of voice transmission and are often used for transmitting the automated weather observing system **(AWOS)**. The aircraft must be in operational range of the NDB.
Before relying on ADF indications, identify the station by listening to the Morse code identifier. NDB stations are usually **two letters** or an **alpha-numeric** combination.

ADF Components

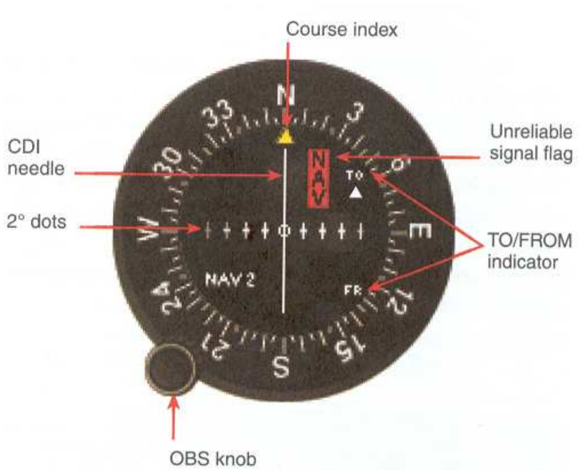
The airborne equipment includes two antennas, a receiver and the indicator instrument. The "**sense**" antenna (non-directional) receives signals with nearly equal efficiency from all directions. The "**loop**" antenna receives signals better from two directions (bidirectional).
The indicator instrument can be one of three kinds: the fixed-card ADF, movable-card ADF or the radio magnetic indicator (**RMI**). The fixed-card ADF (also known as the relative bearing indicator – **RBI**) always indicates zero at the top of the instrument and the needle indicates the RB to the station.
The movable-card ADF allows the pilot to rotate the aircraft´s present heading to the top of the instrument so that the head of the needle indicates MB to the station.
The RMI differs from the movable-card ADF because it automatically rotates the

azimuth card to represent aircraft heading. The RMI has two needles, which can be used to indicate navigation information from either the ADF or the VOR receivers.

Very-High frequency Omnidirectional Range (VOR)

Description

VOR is the primary navigational aid (**NAVAID**) used by civil aviation. The VOR ground station is oriented to magnetic north and transmits azimuth information to the aircraft, providing **360°** courses **TO** or **FROM** the VOR station. When DME is installed with the VOR, it is referred to as a **VOR/DME** and provides both azimuth and distance information. When military tactical air navigation (TACAN) equipment is installed with VOR, it is known as a VORTAC and provides both azimuth and distance information. The courses oriented FROM the station are called **radials**. The VOR information received by an aircraft is not influenced by aircraft attitude or heading.



VOR indicator instruments have at least following essential components:

Omnibearing selector (OBS) when desired course is selected by turning the OBS knob,

Course deviation indicator (CDI) Composed of an instrument face and a needle hinged to move laterally across the instrument face.

TO/FROM indicator showing whether the selected course will take the aircraft to or from the station.

Flags or other signal strength indicators displaying a usable or unreliable signal.

The indicator instrument may also be a horizontal situation indicator (HSI) which combines the heading indicator and CDI.

Distance Measuring Equipment (DME)

Description

When used in conjunction with the VOR system, DME makes it possible for pilots to determine an accurate geographic position of the aircraft, including the bearing and distance TO and FROM the station.

A DME is used for determining the distance from a ground DME transmitter. Compared with other VHF/UHF NAVAIDS, a DME is very accurate. The distance information can be used to determine the aircraft position or flying a track that is a constant distance from the station. This is referred to as **DME arc**.

Area Navigation (RNAV)

Description

Area navigation (RNAV) equipment includes VOR/DME, LORAN, GPS and inertial navigation systems (INS). RNAV equipment is capable of computing the aircraft position, actual track, ground speed and then presenting meaningful information to the pilot.
VOR/DME RNAV is based on information generated by the present VORTAC or VOR/DME systems to create a **waypoint** using an airborne computer.
LORAN (Long Range Navigation) uses a network of land-based transmitters to provide an accurate long range navigation system.
GPS (Global Positioning System) permits Earth-centered coordinates to be determined and provides aircraft position referenced to the DOD (Department of Defense) World Geodetic System of 1984 (WGS-84).
GPS operation is based on the concept of ranging and triangulation from a group of satellites in space which act as precise reference points.

Instrument Approach Systems

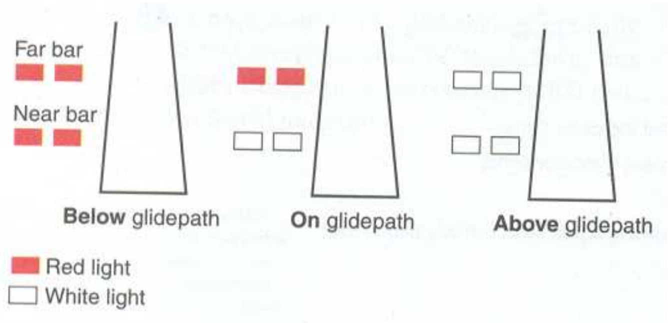
Description

Most navigation systems approved for en route and terminal operations under IFR, such as VOR, NDB and GPS may also be approved to conduct IAPs. The most common systems in use are the **ILS**, simplified landing facility (SDF), localizer directional aid (LDA) and microwave landing system (MLS). These systems operate independently of other navigation systems.

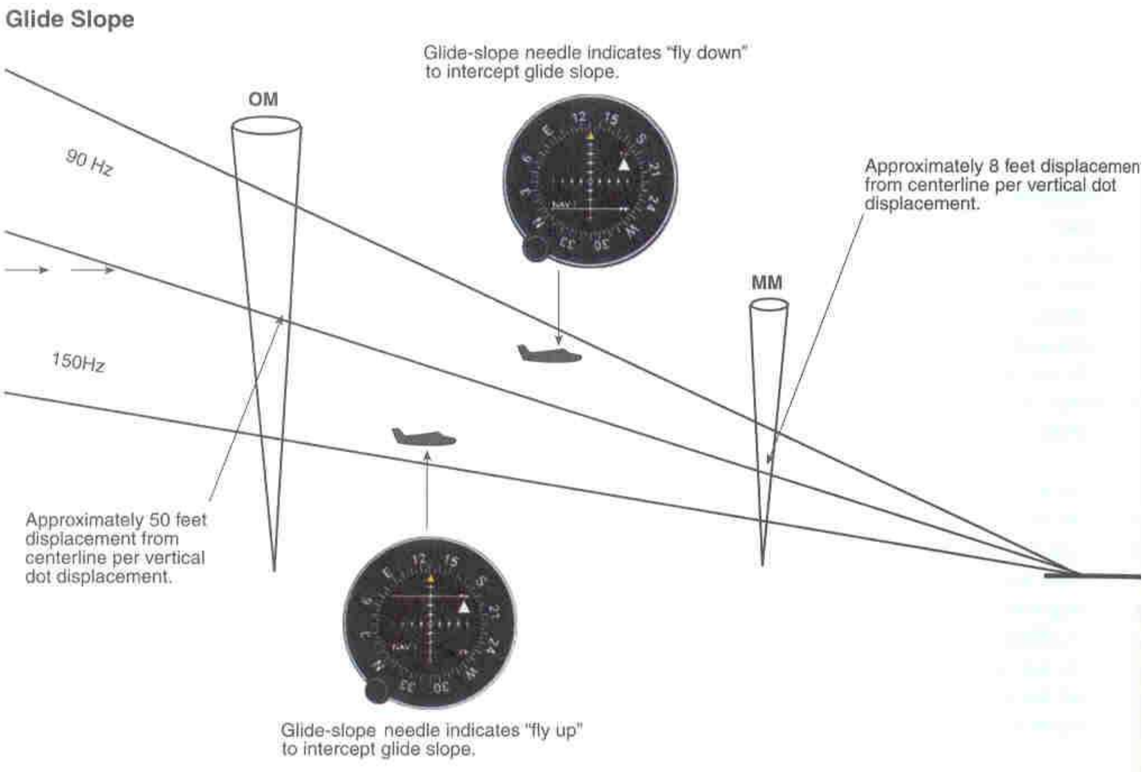
Instrument Landing Systems (ILS)

The ILS provides both course and altitude guidance to a specific runway. The ILS system is used to execute a precision instrument approach procedure or **precision approach**. The system consists of the following components:

- A **localizer (LOC)** provides horizontal (left/right) guidance along the extended centerline of the runway
- A **glide slope (GS)** provides vertical (up/down) guidance toward the runway touchdown point, usually at a 3°slope
- **Marker beacons** provide range information along the approach path
- **Approach Lighting Systems (ALS)** assist in the transition from instrument to visual flight



Standard 2-bar VASI



Glide-slope receiver indication and aircraft displacement

Radar Navigation (Ground based)

Description
Radar works by transmitting a pulse of RF energy in a specific direction. The return of the echo or bounce of that pulse from a target is precisely timed. From this, the distance traveled by the pulse and its echo is determined and displayed on a radar screen.

Functions of Radar Navigation
The radar systems used by ATC are:

Air Route Surveillance Radar (ARSR) – Air route traffic control center radar used primarily to detect and display an aircraft´s position while en route between terminal areas
Airport Surveillance Radar (ASR) – Approach control radar used to detect and display an aircraft´s position in the terminal area

Precision Approach Radar (PAR) – A specific type and installation of radar, usually found at military or joint-use airfields. It uses two radar antennas, one for left/right information and one for glide path information to provide a precision approach

Airport Surface Detection Equipment (ASDE) – Radar equipment specifically designed to detect all principle features and traffic on the surface of an airport presenting the entire image on the control tower console.

RADIOTELEPHONY

General Procedures

Introduction

Radiotelephony provides the means by which pilots and ground personnel communicate with each other. Used properly, the information and instructions transmitted are of vital importance in assisting in the safe operation of aircraft.

Transmission of Letters

A	**Alpha**	**N**	**November**
B	**Bravo**	**O**	**Oscar**
C	**Charlie**	**P**	**Papa**
D	**Delta**	**Q**	**Quebec**
E	**Echo**	**R**	**Romeo**
F	**Foxtrot**	**S**	**Sierra**
G	**Golf**	**T**	**Tango**
H	**Hotel**	**U**	**Uniform**
I	**India**	**V**	**Victor**
J	**Juliet**	**W**	**Whiskey**
K	**Kilo**	**X**	**X-ray**
L	**Lima**	**Y**	**Yankee**
M	**Mike**	**Z**	**Zulu**

Transmission of Numbers

0	**Zero**	**7**	**Seven**
1	**One**	**8**	**Eight**
2	**Two**	**9**	**Nine**
3	**Three**	**Decimal**	
4	**Four**	**Hundred**	
5	**Five**	**Thousand**	
6	**Six**		

When transmitting messages containing aircraft call sign, altimeter settings, flight levels (with the exception of FL 100,200,300 etc), headings, wind speeds/directions, pressure settings, transponder codes and frequencies, each of the digits shall be transmitted separately.

All numbers used in the transmission of altitude, height, cloud height, visibility and runway visual range information which contain whole hundreds and thousands shall be transmitted by pronouncing each digit in the number of hundreds or thousands followed by the word HUNDRED or TOUSAND as appropriate.

Numbers containing a decimal point shall be transmitted with the decimal point in appropriate sequence being indicated by the word decimal.

All six digits shall be used when identifying frequencies irrespective of whether they are 25 kHz or 8.33 kHz spaced. When the final two digits of the frequency are both zero, only the first four digits need to be given.

Transmission of Time

When transmitting time, only minutes of the hour are normally required. However, the hour should be included if there is a possibility of confusion. Time checks shall be given to the nearest minute. **Coordinated Universal Time (UTC)** is to be used at all times, unless specified.

24 00 hours designates midnight, the end of the day, and **0000** hours the beginning of the day.

Standard Words and Phrases

The following words and phrases shall be used in radiotelephony communications as appropriate and shall have meaning given below:

ACKNOWLEDGE	**Let me know that you have received and understood this message.**
AFFIRM	**Yes.**
APPROVED	**Permission for proposed action granted.**
BREAK	**Indicates the separation between messages.**
BREAK BREAK	**Indicates the separation between messages transmitted to different aircraft in a busy environment.**
CANCEL	**Annul the previously transmitted clearance.**
CHANGING TO	**I intend to call …(unit) on … (frequency).**
CHECK	**Examine a system or procedure. (**Not to be used in any other context. No answer is normally expected**)**
CLEARED	**Authorized to proceed under the conditions specified.**
CLIMB	**Climb and maintain.**
CONFIRM	**I request verification of: (**clearance, instruction, action, information**).**
CONTACT	**Establish communication with …**
CORRECT	**True or accurate.**
DESCEND	**Descent and maintain.**
DISREGARD	**Ignore**
FANSTOP	**I am initiating a practice engine failure after take off (**used only by pilots of single engine aircraft**). The response should be "REPORT CLIMBING AWAY"**
FREECALL	**Call …. (unit) (**your details have not been passed – mainly used by military ATC**)**
HOLD SHORT	**Stop before reaching the specified location** Note: only used in limited circumstances where no defined point exists
HOW DO YOU READ	**What is the readability of my transmission?**
I SAY AGAIN	**I repeat for clarity or emphasis.**
MAINTAIN	**Continue in accordance with the conditions specified or in its literal sense, e.g. "Maintain VFR"**
MONITOR	**Listen out on (frequency)**
NEGATIVE	**No; or permission not granted; or that is not correct; or not capable**
OUT	**This exchange of transmission is ended and no response is expected**
OVER	**My transmission is ended and I expect a response from you**
PASS YOUR MESSAGE	**Proceed with your message**
READ BACK	**Repeat all, or the specified part of this message back to me exactly as received**

REPORT	**Pass requested information**
REQUEST	**I should like to know … or I wish to obtain …**
ROGER	**I have received all your last transmission** ***Note: Under no circumstances to be used in reply to a question requiring a direct answer in the affirmative (AFFIRM) or negative (NEGATIVE)***
SAY AGAIN	**Repeat all, or the following part of your last transmission**
SPEAK SLOWER	**Reduce your rate of speech**
STANDBY	**Wait and I will call you**
UNABLE	**I cannot comply with your request, instruction and clearance (**normally followed by a reason**)**
WILCO	**I understand your message and will comply with it**
WORDS TWICE	**As a request: communication is difficult, please send every word twice** **As information: since communication is difficult, every word in this message will be sent twice.**

Callsigns for Aeronautical Stations

Aeronautical stations are identified by the name of the location followed by a suffix which indicates the type of services being provided.

SERVICE	**SUFFIX**
Area Control	**CONTROL**
Radar (in general)	**RADAR**
Approach Control	**APPROACH**
AERODROME CONTROL	**TOWER**
Approach Control Radar Arrival/Departure	**DIRECTOR/DEPARTURE (RADAR-when tasks combined)/ARRIVAL – (when approved)**
Ground Movement Control	**GROUND**
Precession Approach Radar	**TALKDOWN (Military – FINAL CONTROLLER)**
Flight Information	**INFORMATION**
Air/Ground Communication Service	**RADIO**
Ground Movement Planning	**DELIVERY**

When satisfactory communication has been established, and provided that it will **not be confusing**, the name of the location or callsign suffix may be omitted.

Callsigns for Aircraft

When establishing communication, an aircraft shall use the full callsigns of both stations.

Ruzyně Tower, OK-ABC	**OK-ABC, Ruzyně Tower**

After satisfactory communication has been established and provided that no confusion is likely to occur, the ground station may abbreviate callsigns (see the table).

A pilot may **only** abbreviate the callsign of his aircraft if it has **first** been abbreviated by the aeronautical station.

Full callsign	**Abbreviation**
OK - ABC	O – BC
Speedbird GBGDC	Speedbird DC
N31029	N029
CSA 932	CSA 932 (no abbreviation)

The name of either the aircraft manufacturer, or name of aircraft model, or name of the aircraft category may be used as a prefix to the callsign.
Aircraft with the heavy vortex wake category shall include the word "**HEAVY**" immediately after the aircraft callsign in the initial call to each **ATSU**.

Continuation of Communications

The placement of the callsigns of both the aircraft and the ground station **within** an established RTF exchange should be as follows:

Ground to Air: **Aircraft callsign – message or reply**

Air to Ground:
a) Initiation of new information/request etc – Aircraft callsign then message
b) Reply – Repeat of pertinent information/readback/ acknowledgement then aircraft callsign

OK – ABC descend FL 80	**Descend FL 80 OK – ABC** **OK – ABC maintaining FL 80** **O – BC**
OK – ABC request descend	**O – BC descend FL 40** **FL 40 O – BC**

Corrections and repetitions

When an error is made in a transmission the word "**CORRECTION**" shall be spoken

CSA 546FL 80, correction FL 85	**CSA 546 roger**