HOMAviation Training Center

مرکز آموزش هـــای هوایی هما

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Instrumentation

A.Toopchi

Module objectives

At the end of this module you will be able to Describe the **function of the instruments** based on oxford book.

Module Plan

Part 1: Basic instrument

Part 2: Advanced instrument

Part 1

chapter one:

CHARACTERISTICS AND GENERAL DEFINITIONS.

INTRODUCTION

Pilots receive information about the state of their aircraft and its speed, altitude, position and attitude through instruments and displays.

These can vary from the simplest of dials and pointers to modern electronic displays (the so-called ‘glass cockpits’).

ERGONOMY

Ergonomy (also known as **human engineering**) is defined as the science of relationships between people and machines.

An ergonomic device interacts smoothly with peoples' bodies and actions. In an aviation context this can mean designing the shape and position of controls, levers and knobs so that are easily controlled and unlikely to lead to an incorrect selection.

For instruments or instrument systems it means designing instruments that are unlikely to be misread and locating them in a layout that facilitates easy and correct interpretation of the information displayed. Standard layouts came to be adopted.


TEMP°C
PRESS ALT
TAS
VACUUM
CALIBRATED TO 20,000FT
D.C. ELEC.
TURN COORDINATOR
L
R
2 MIN.
NO PITCH INFORMATION
VERTICAL SPEED
UP
DN
100 FEET PER MIN


A350
A350

With modern electronic systems, although the displays have to be on the flight deck where the crew can see and operate them, the computing units and power units are located remotely in some other part of the aircraft, usually in a separate compartment called the **Avionics Bay** or the **Electrics and Electronics (E&E) Bay**.

A readable instrument should be designed with an **eye reference point** in mind. This is the anticipated position that the pilot's eye will occupy when viewing the instrument under normal conditions .

Color coding

A standardized system of color coding for operating ranges for conventional non-electronic instrument is widely used. These are:

Green: Normal operating range

Yellow or Amber: Cautionary range

Red: Warning, or unsafe operating range

For more complex instruments, usually electronic displays :

White: Present status

Blue: Temporary situation

Green: Normal operating range

Yellow or Amber: Cautionary range

Red: Warning, or unsafe operating range

SIGNAL TRANSMISSION

Signals are transmitted from the sensor where they are measured to the instrument where they are displayed by a variety of signals transmission techniques:

Mechanical: Early systems had mechanical feedback to an indicator on the flight deck to show the position of a valve, flap or control surface. However, these systems have been largely replaced by remote transmission systems on modern aircraft.

Pneumatic: Pneumatic pressure is air pressure conveyed in a tube or pipe. Airspeed and altitude instruments use pneumatic transmission from the pitot or static probe/vent to the instrument.

Hydraulic: Hydraulic pressure is liquid pressure conveyed in a tube or pipe. Older versions of oil pressure gauges receive direct oil pressure down a pipe into the back of the indicator.

Electric or Electronic: Older systems used DC transmission, known as desynn indicators. Modern aircraft use an AC transmission system, known as **synchro** transmission.

Some methods are available such as : Digital _ Data buses and etc.

Chapter 2 :

PRESSURE GAUGE

Definitions

Pressure : Is defined as a force that is applied at right angles to the surface of a body

Absolute pressure : Is the pressure that is measured relative to a vacuum

Differential pressure : Is the pressure difference between two specified points.

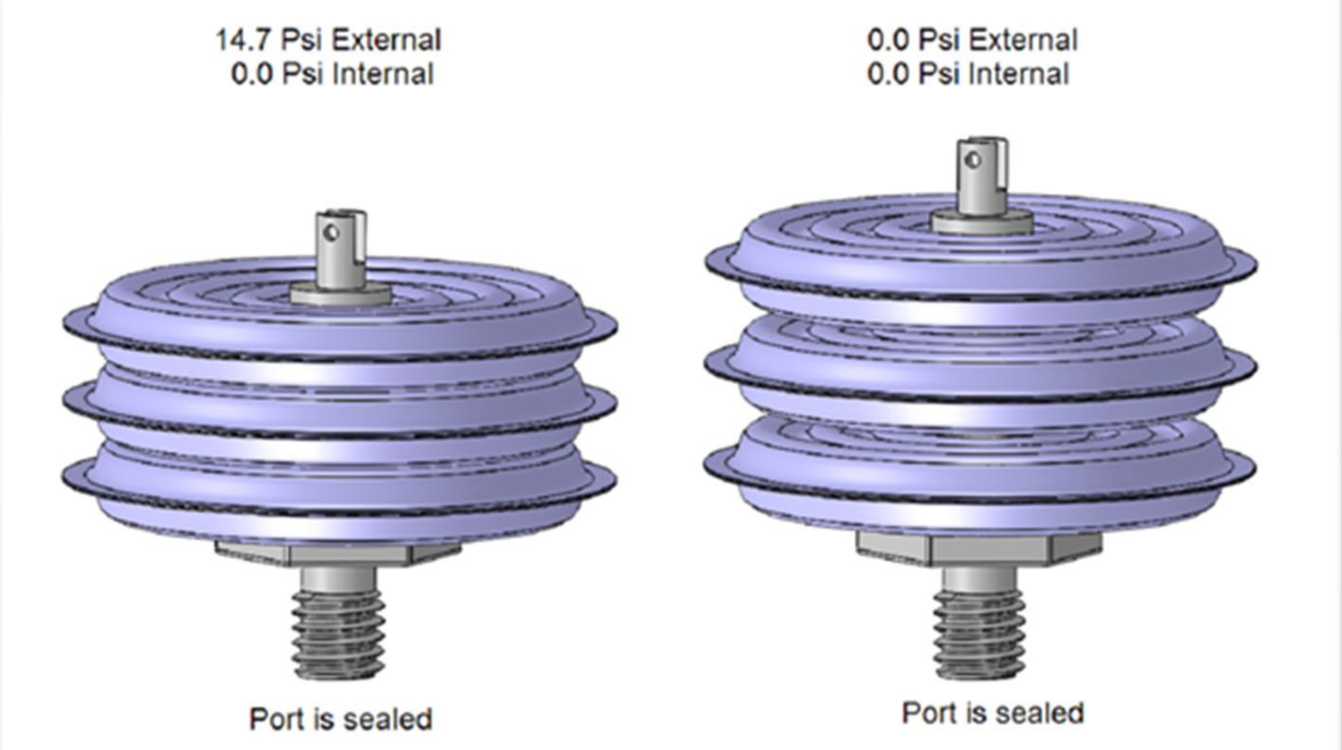
Pressure units

Pressure unit	Atmosphere
Pascal _ Hectopascals	1013.25 hpa
Bar _ Milibar	1013.25 mb
Inches of mercury	760 mmhg
Pounds per square inch	14.7 psi

Most pressure gauges measure the difference between absolute pressure and the atmospheric pressure. This is gauge pressure

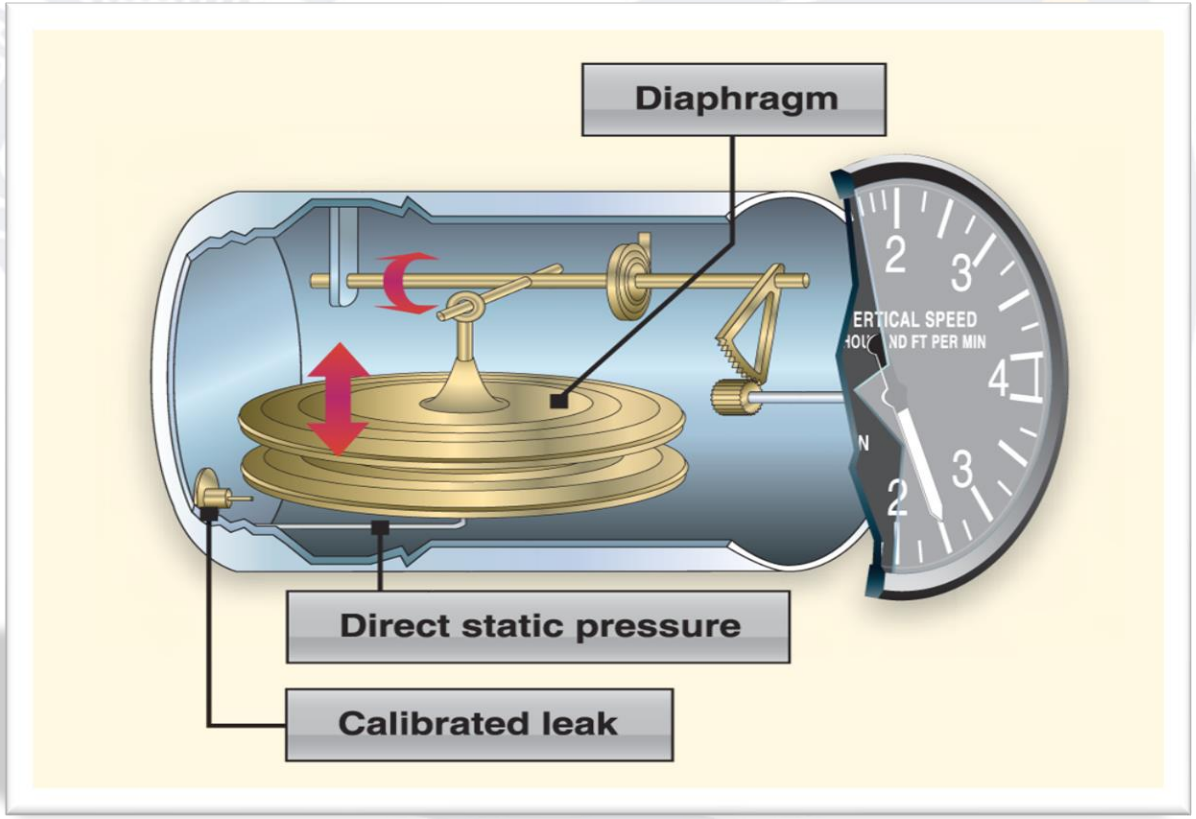
To measure pressure in a system , elastic pressure sensing elements are used to convert the forces that result from applied pressure into mechanical movements. The movement then operates a direct reading gauge or an electrical transmitter. Sensing elements commonly used include diaphragm, capsules, bellows and bourdon tubes.

Capsules: consist of two diaphragms that are placed together and joined at their edges. This form a chamber that , when sealed is called an aneroid capsule , and open to a pressure source is called pressure capsule . Like diaphragm they are used to measure low pressure , but they are more sensitive to small pressure change .



Aneroid Capsule Graphic

Diaphragm : consist of corrugated circular metal discs that are secured at their edges. When pressure is applied to them , they are deflected . Diaphragm are used to measure low pressures.



Bellows: can be considered as an adaption of the corrugated diaphragm principle. They may be used for high , low or differential pressure measurements. Differential pressure is defined as the pressure difference between 2 separate areas. They are typically used to measure output pressures of the LP booster that are fitted aircraft engines.

The manifold absolute pressure gauge or MAP of a piston engine measures both pressure and differential pressure. The gauge measures absolute pressure and the pressure in inches of mercury (inHg). When the engine is running , this gauge can indicate a pressure reading that is lower than atmospheric pressure. Earlier versions of this gauge were calibrated to read boost gauge pressure in PSI , and they were called boost gauge. Under standard conditions the boost gauge will read zero and the MAP gauge will read zero and the MAP gauge will read 30 inHg. This condition is called static boost.

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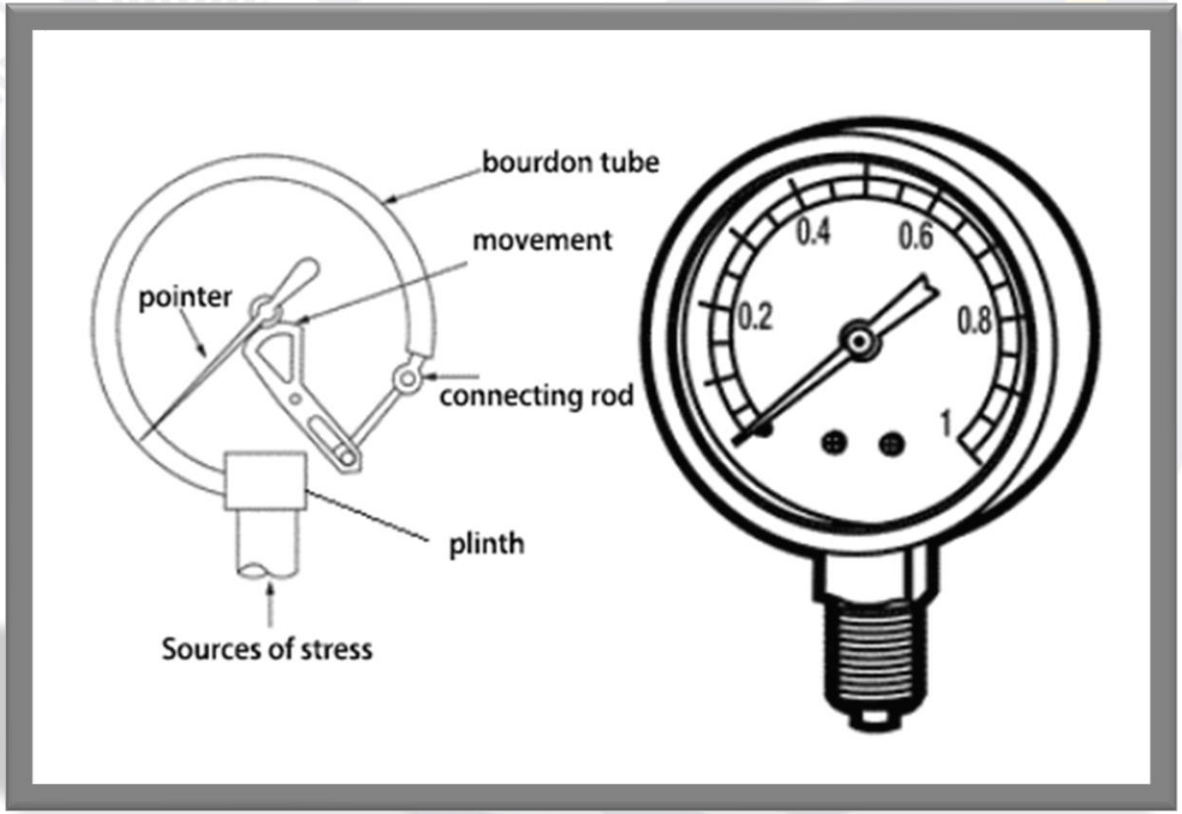
Bourdon tube :

Is one of the oldest of the pressure sensing elements. The element is essentially a length of metal tube with an elliptical cross selection shaped into the letter C .



Chapter 3

Temperature sensing

Temperature :

Is a measure for heat that exists in a particular body. It is expressed according to a relative scale and displayed on a thermometer.

Following units that can be used for temperature measurement :

1- KELVIN

2- CELSIUS

3- FAHRENHEIT

K = C+273

F = (c*2) +30

C = (F-32) +78

Drlogy

Temperature Conversion Chart

Calculator

From/To	Celsius (°C)	Fahrenheit (°F)	Kelvin (K)	From/To
Celsius (°C)	1	1.8	273.15	Celsius (°C)
Fahrenheit (°F)	-17.7778	1	255.92778	Fahrenheit (°F)
Kelvin (K)	-272.15	-459.67	1	Kelvin (K)

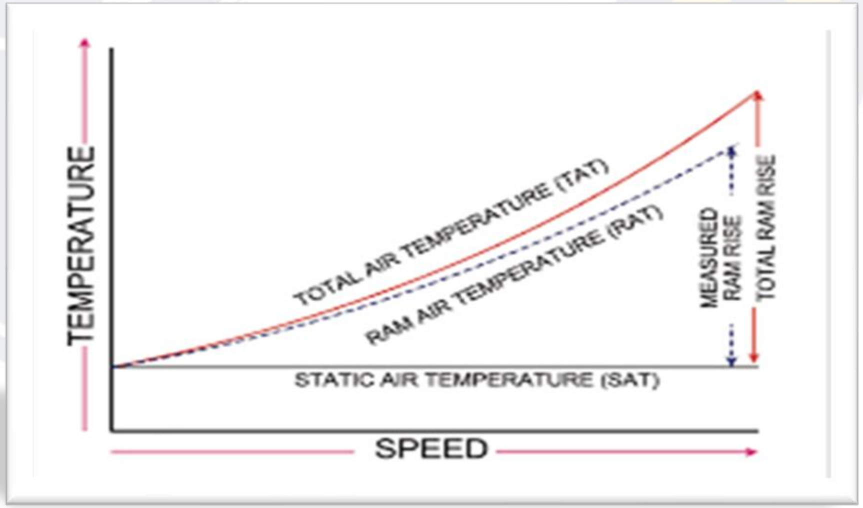
www.drlogy.com

Static Air Temperature (SAT) is the temperature of the undisturbed air through which the aircraft is about to fly.

Total Air Temperature (TAT) is the maximum temperature attainable by the air when brought to rest, adiabatically.

The increase of air temperature at higher speeds as a result of the adiabatic compression of the air is known as the "**Ram Rise**". Also is the difference between the SAT and TAT .

The percentage of the "**Ram Rise**" sensed, and recovered, by a TAT probe is termed the Recovery Factor (Kr).



Air Temperature Thermometers may be divided into two basic types :

1- **Direct Reading**

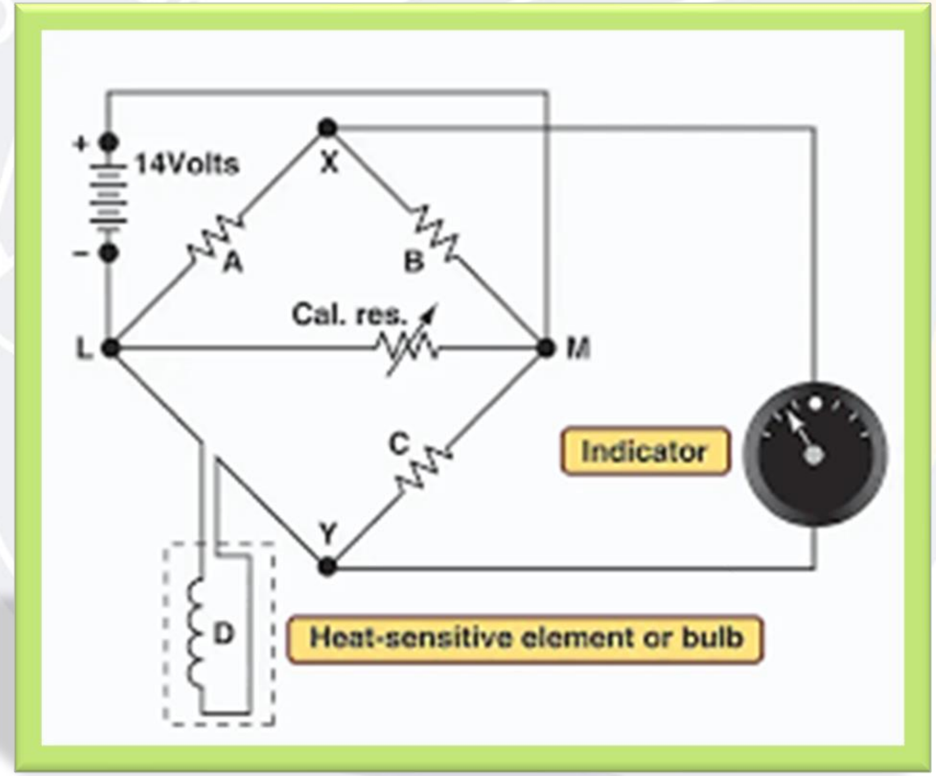
2- **Remote Reading**

Direct reading :

A commonly used direct reading thermometer used in low speed aircraft uses a bimetallic strip consisting of two metals, such as Invar and Brass, bonded together. When this strip is heated, the brass, having a higher coefficient of expansion than the Invar, will expand much more than the Invar, with the result that the strip will bend.

Remote reading :

The probe element forms one part of a resistance bridge circuit. As the temperature changes the resistance of the sensing element changes, and the bridge becomes unbalanced causing current to flow through the moving coil of the indicator. This change in resistance can then be calibrated to display temperature.

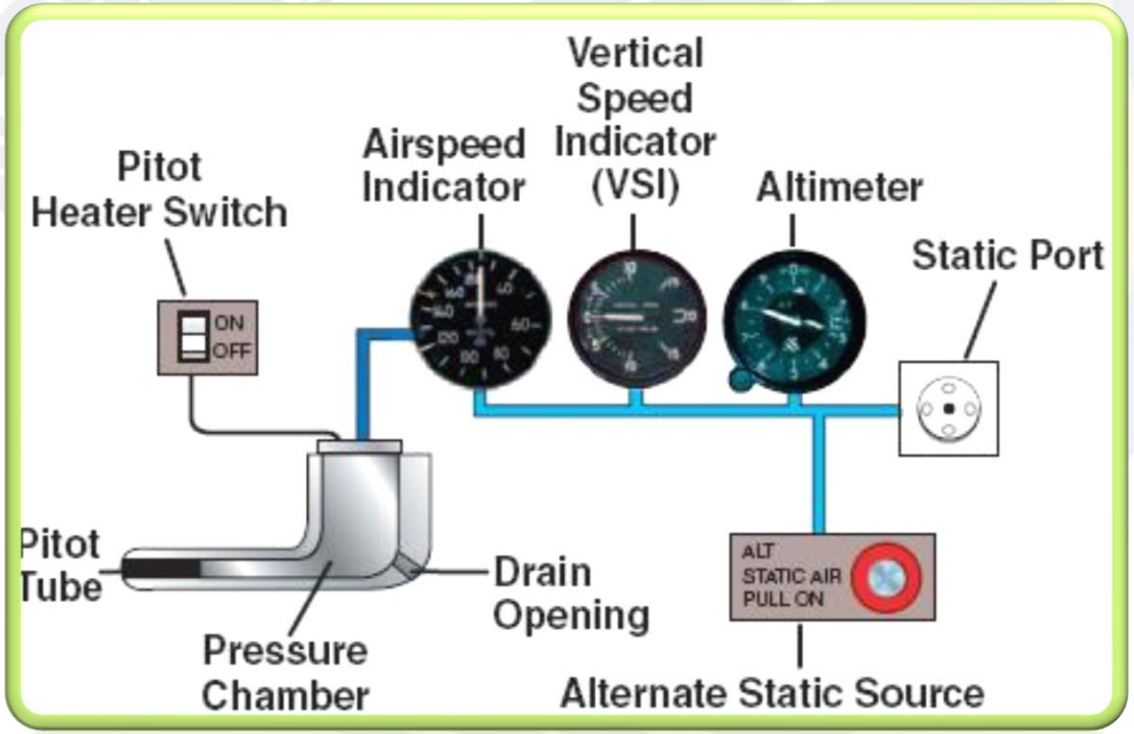


TOTAL AIR TEMPERATURE PROBE :

The probe is in the form of a small strut and air intake made of nickel-plated beryllium copper which provides good thermal conductivity and strength. It is secured at a pre-determined location in the front fuselage section of an aircraft outside of any boundary layer.

Chapter 4

Pressure measurement



An aircraft at rest on the ground, in still air, is subject to normal atmospheric pressure which bears equally on all parts of the aircraft. This ambient pressure is known as **Static pressure**. An aircraft in flight, while still subject to the static pressure at its height, experiences an additional pressure on the leading edges due to the resistance of the air to the aircraft=s movement. This additional pressure is **Dynamic pressure**, and its value depends on the **speed** of the aircraft through the air and on the **density** of the air.

The leading edges, therefore, encounter a total pressure consisting of static pressure plus dynamic pressure. This total pressure is known as **Pitot pressure**.

Two of the pressure-dependent flight instruments, the **altimeter** and **vertical speed indicator**, operate solely on static pressure, whereas the **airspeed indicator** and **machmeter** utilize both static and pitot pressures.

NOTE:

It is not possible to isolate dynamic pressure by direct measurement because it cannot be separated from the associated static pressure . The instruments which require dynamic pressure therefore , measure total (pitot) pressure and also static pressure and then subtract static from pitot within the instrument to derive dynamic pressure.

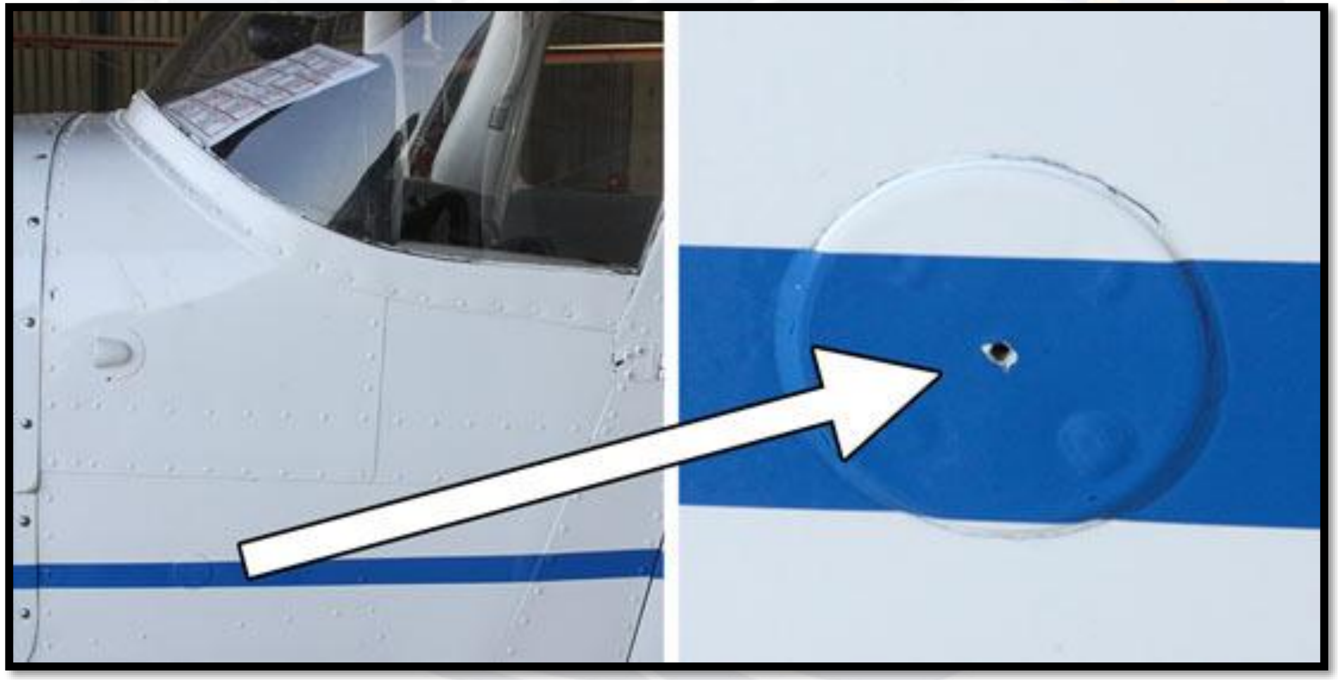
An open-ended tube parallel to the longitudinal axis of the aircraft is used to sense the total pressure . This device is a “pitot tube” mounted in a “pitot head”.

The open end of the tube faces into the moving airstream, the other end leading to the airspeed capsules in the ASI and **Machmeter.**

Wing mounted Pitot Tube on a Cessna 172

ttps://commons.wikimedia.org/wiki/File:Cessna_172_Skyhawk_II_-_Pitot_tube.jpg

Static Vent is a source of static pressure .There is usually some place on the airframe, usually on the side of the fuselage, where true (or nearly true) static pressure obtains over the whole speed range of the aircraft. A flat metal plate is fitted at this position, the static line from the pressure instruments terminating at a small circular hole - the static vent - in this plate. A similar vent may be positioned on the opposite side of the fuselage and the two interconnected for transmission of static pressure to the instruments.



EMERGENCY STATIC SOURCE

An emergency static source is normally provided in the event of the static ports becoming blocked. The emergency static source is inside the cabin (in unpressurised aircraft only).

When an emergency static source is fed from within the cabin, the static pressure sensed is likely to be **lower** than ambient due to aerodynamic suction.

Note: When alternate (standby) pressure systems are used, correction values for the instruments concerned may be found in the Operating Data Manual for the aircraft.

Pitot and static heaters

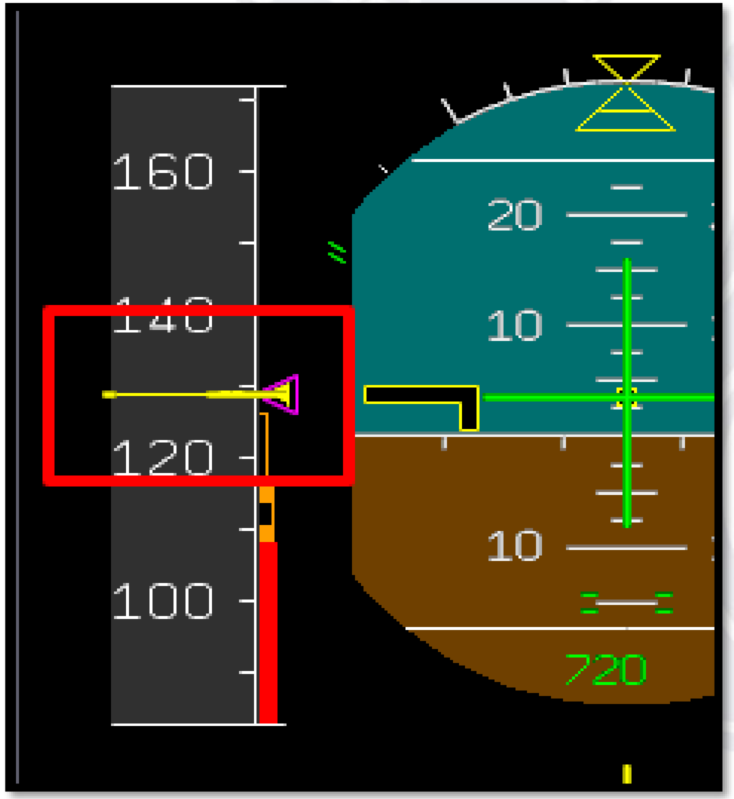
Electrical pitot and static heaters prevent the accumulation of ice on pitot-static probes/ports . Modern systems have an alert warning if the heaters are not switched on in flight .

It is essential to test the operation of the pitot heater prior to flight. This can be done by switching it on for about 30 seconds and carefully feeling the pitot probe to check that it is warm to the touch . Make sure that the pitot covers and static plugs are removed before turning the heaters on to check them .

It is normally part of the pre-takeoff checks to ensure that heaters are switched on again and part of the after-landing to switch them off.

Chapter 5

Air speed indicator

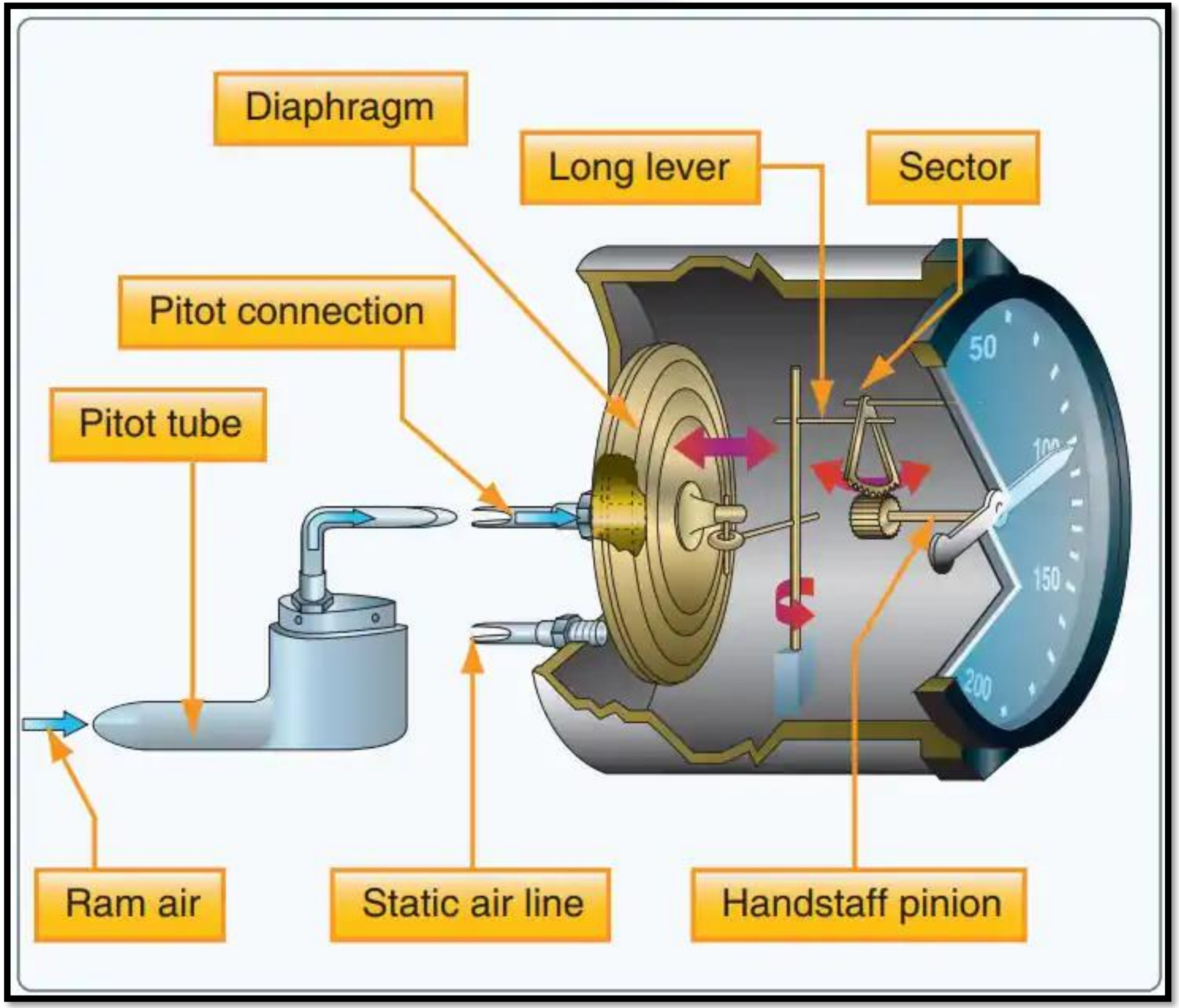


The notes on pressure heads explain that whereas an aircraft on the ground in still air is subject only to atmospheric (static) pressure (S), the leading edges of an aircraft in forward flight are subject to an additional (dynamic) pressure. This results in a total (pitot) pressure (P) on the leading edges of dynamic pressure plus static pressure.

Pitot = Dynamic + Static

The pitot head senses pitot pressure and the static/vent senses static pressure. These two pressures are fed to the airspeed indicator, a differential pressure gauge, which measures their difference PE (the dynamic pressure). Now dynamic pressure is a measure of airspeed , because:

Dynamic Pressure = ½ ρV2


Diaphragm
Long lever
Sector
Pitot connection
Pitot tube
50
100
150
200
Ram air
Static air line
Handstaff pinion

In principle, the simple ASI can be considered as an airtight box divided by a flexible diaphragm, with pitot pressure fed to one side and static pressure to the other side.

The pressure difference across the diaphragm is (Dy + S) - S, which is Dy, the dynamic pressure. Accordingly, the diaphragm deflects by an amount proportional solely to this dynamic pressure, its movement being transmitted by a system of levers to the indicating needle on the face of the ASI. Note that static pressure is common to both sides of the diaphragm, and so does not influence diaphragm movement.

Note that the pressure differential between the inside and outside of the capsule is (Dy + S) - S which is Dy, as with the diaphragm. Expansion or contraction on the capsule will therefore be proportional to the changes in dynamic pressure produced by changes of airspeed.

Indicated airspeed (IAS):

Is the reading you get directly from the Air Speed Indicator

ASI ERRORS

Instrument Error

Manufacturing imperfections and usage result in small errors which are determined on the ground under laboratory conditions by reference to a datum instrument. A correction card can be produced for the speed range of the instrument.

Position Error

Alternatively known as ‘pressure’ error, this arises mainly from the sensing of incorrect static pressure. Position errors throughout the speed range are determined by the aircraft manufacturer during the test flying programme for a particular aircraft type. It is not unusual to compile a joint correction card for position and instrument errors and place it in the aircraft near the ASI concerned.

IAS (indicated air speed) ± P and I correction = CAS

This error is generally greatest at low airspeeds. In the cruising and, higher airspeed ranges, indicated airspeed and calibrated airspeed are approximately the same.

FLAPS UP											
KIAS	40	50	60	70	80	90	100	110	120	130	140
KCAS	49	55	62	70	80	89	99	108	118	128	138
FLAPS 10°											
KIAS	40	50	60	70	80	85	---	---	---	---	---
KCAS	49	55	62	71	80	85	---	---	---	---	---
FLAPS 40°											
KIAS	40	50	60	70	80	85	---	---	---	---	---
KCAS	47	54	62	71	81	86	---	---	---	---	---

Equivalent airspeed (EAS)

Is CAS corrected for compressibility error only . EAS is the most accurate measure of the dynamic pressure over the wing . In practice the difference between EAS and CAS is not great unless altitude becomes significant .

EAS is always lower than or equal to CAS . It is insignificant below 300 knot. Air is compressible and the pressure produced in the pitot tube is higher than it would be for an ideal incompressible fluid, for which the dynamic pressure is ½ ρV2.

Because of this, the instrument will over-read, IAS and CAS will be too high, and a subtractive compressibility correction will have to be applied .

EAS(Equivalent Air Speed) = CAS ± compressibility corrections

Density Error.

Unless the air round the aircraft is at the calibration density of 1225 grammes per cubic metre, which can only occur near sea level, the ASI cannot correctly indicate TAS. The formula in Paragraph 4.1. shows that dynamic pressure is proportional to density, so at altitude, where density is less, the dynamic pressure generated by a given TAS will be less than for the same TAS in flight at sea level. ASI capsule expansion will be proportionately less and the speed indicated will be less than the true speed.

Summarising, the ASI under-reads the true speed at altitude as density is less than 1225 grams/cu metre , this discrepancy being called ‘density error’. If density is greater than ISA at MSL , the ASI will over read the true speed .

***TAS**(True Air Speed) = CAS ± EAS± density error*

TAS is the **actual speed** of your airplane through the air **Or** TAS is EAS corrected for altitude(pressure) and non standard temperature.

There is no single instrument that gives a direct reading of density . Density has to be calculated using the interaction of pressure and temperature .

For estimating TAS:

1- add 2% of CAS per 1000 feet of altitude + CAS

2- using the CR3

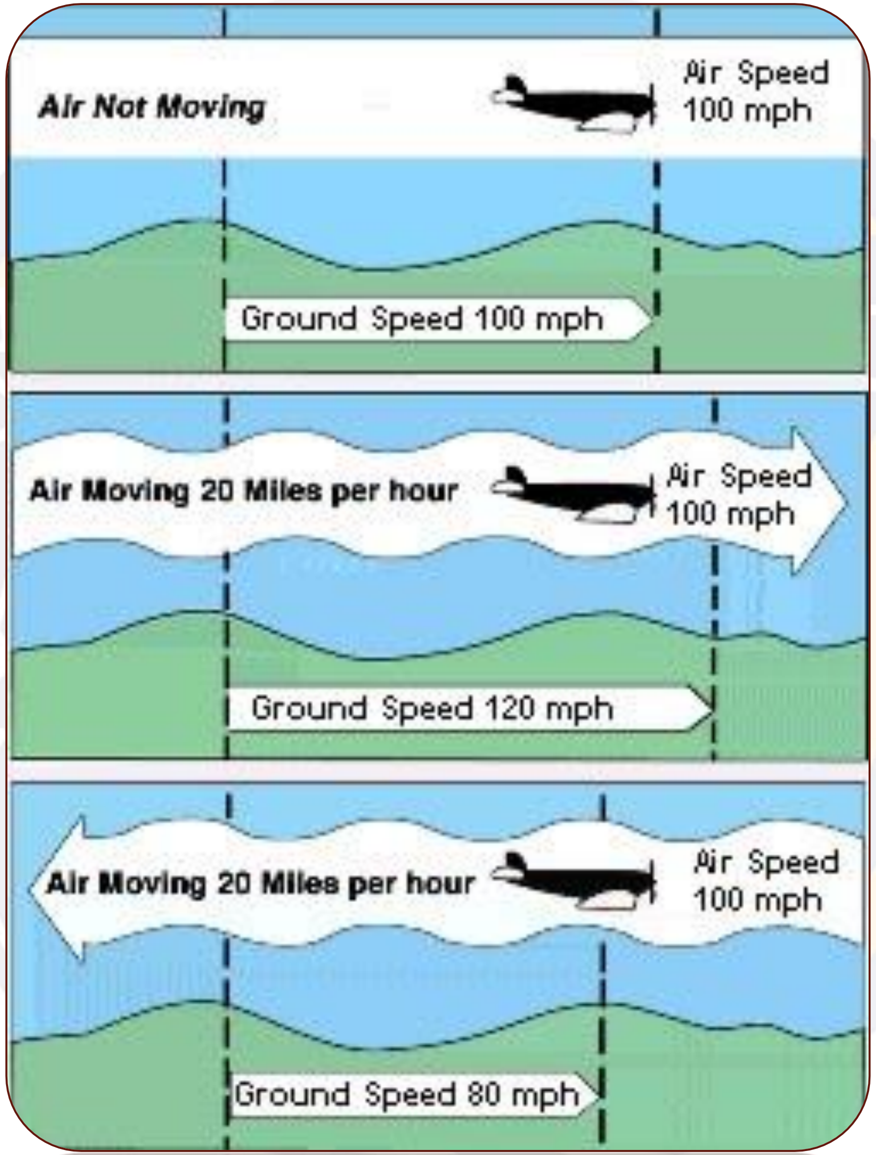
Ground speed (GS)

Is TAS corrected for wind velocity.

GS = TAS -Headwind

GS = TAS + Tailwind

Ground speed **decreases** with a **headwind**, and **increases** with a **tailwind** .


Air Not Moving
Air Speed
100 mph
Ground Speed 100 mph
Air Moving 20 Miles per hour
Air Speed
100 mph
Ground Speed 120 mph
Air Moving 20 Miles per hour
Air Speed
100 mph
Ground Speed 80 mph

More ASI Definitions

Vs

Stall speed or minimum steady flight speed for which the aircraft is still controllable.

V_{S0}

The stall speed or the minimum steady flight speed in the landing configuration.

V_{S1}

The stall speed or the minimum steady flight speed in a specified configuration.

VNO

Maximum structural cruising speed Or maximum speed for normal operations .

Do not exceed it except in smooth air .

VNE

Never exceed speed.

Operating above it may result in damage or structural failure .

VFE

Maximum flaps extension speed .

VFO

Maximum flaps operating speed .

V_{LE}

Maximum landing gear extended speed .

V_{LO}

Maximum landing gear operating speed .

V_{FE} > V_{FO}

V_{LE} > V_{LO}

VA

Design maneuvering speed Is the maximum speed for full & abrupt use of the controls without risk of structural damage .It is maximum speed for flight in TURBULENT Conditions . If during flight, rough air or severe turbulence is encountered, reduce the airspeed to maneuvering speed or less to minimize stress on the airplane structure.

VYSE

Best rate of climb speed with one engine failed

ASI colour coding

Some ASI is incorporate coloured markings on the dial these range markings consist of coloured arcs and radial lines.

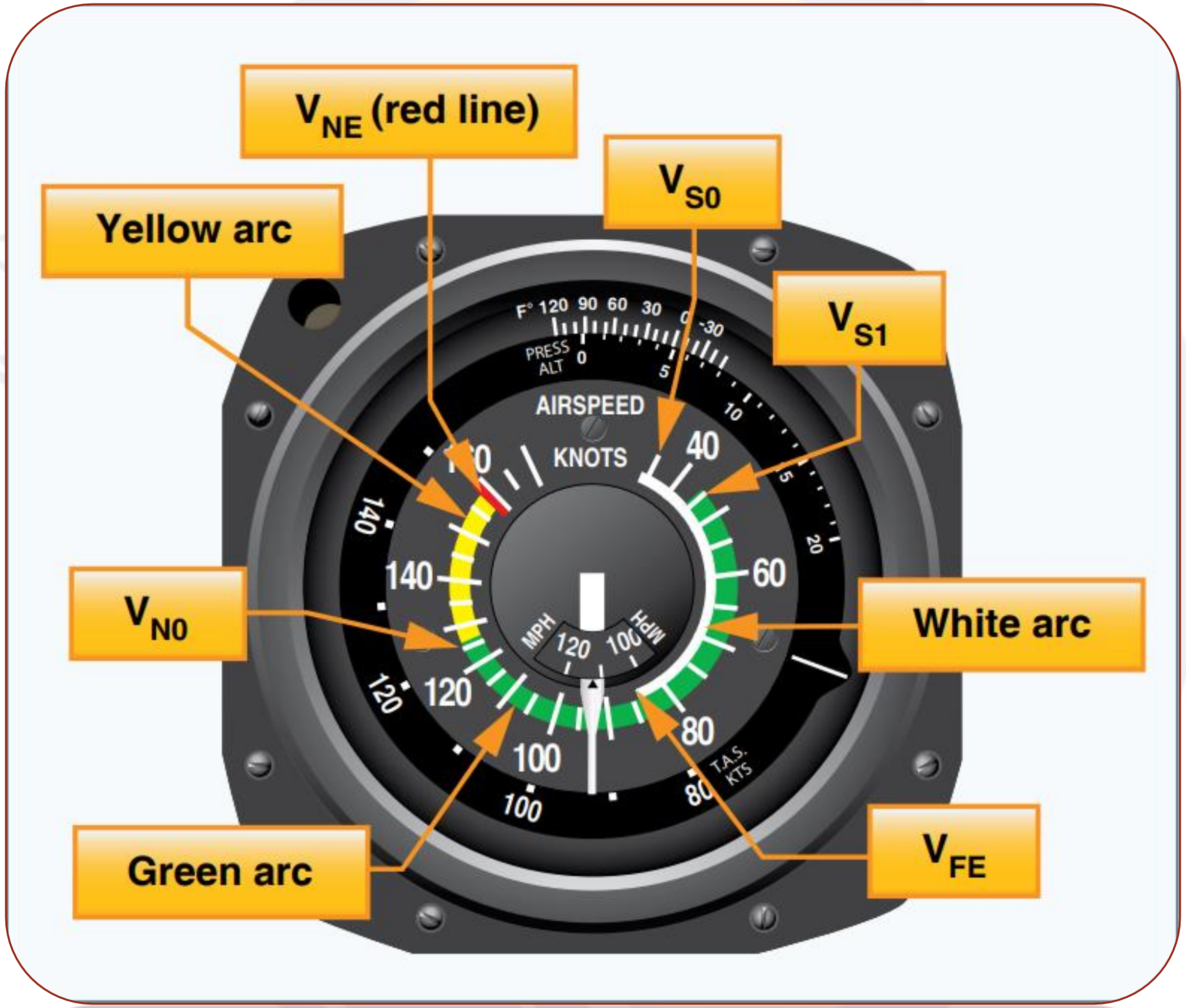
The White Arc denotes the flap operating range, from stall at maximum AUW in the landing configuration (full flap, landing gear down, wings level, power-off) up to VFE (maximum flaps extended speed).

The Green Arc denotes the normal operating speed range, from stall speed at maximum all-up weight (flaps up, wings level) up to VNO (normal operating limit speed or maximum structural cruising speed) which should not be exceeded except in smooth air. Operations at IASs in the green arc should be safe in all conditions, including turbulence.

The Yellow Arc denotes the caution range, which extends from VNO (normal operating limit speed) up to VNE (the never exceed speed). The aircraft should be operated at IASs in the caution range only in smooth air.

A Red Radial Line denotes VNE, the never exceed speed. Some ASIs have blue radial lines to denote certain important speeds, (e.g. best single-engines speed for a light twin-engine aeroplane).

Optionally for piston engined light twins: A **Blue Radial Line** denotes the best rate of climb speed for one engine out, maximum weight, at mean sea level (VYSE).


V_NE (red line)
Yellow arc
V_S0
V_S1
V_N0
White arc
Green arc
V_FE
AIRSPEED
KNOTS
PRESS ALT
T.A.S. KTS
MPH


240
220
200
60
80
100
120
6
8
10
ALT.
30 + 0 − 30
40
TEMP.
200
180
160
140
120
100
80
40
AIRSPEE
TRUE SPEED
KNOTS
M.P.H.
210
200
190
180
170
160
140
T
A
S

Pitot and static blockages

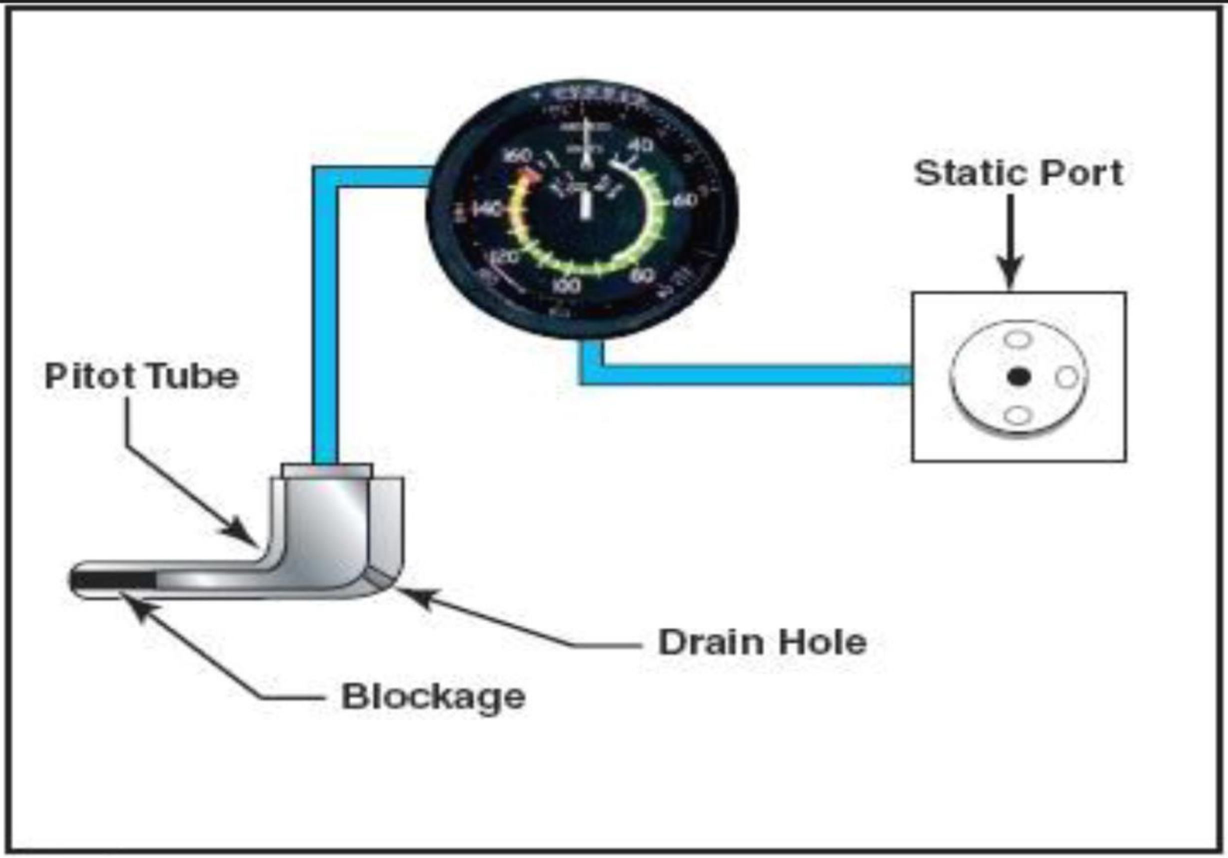
If the pitot tube becomes blocked, the ASI displays inaccurate speeds.

In level cruise, a blockage (probably ice) will lock in the previous pitot pressure and any change in actual airspeed will not be registered.

If altitude is changed with a blocked pitot head and clear static source, the IAS will increase during a climb because the pressure locked inside the capsule remains constant while the static pressure of the air surrounding the capsule decreases . Therefore(pitot-static) results in an under-reading . Conversely the IAS decreases during a descent with blocked head.

- where the pitot tube became blocked , if the aeroplane climbs ,the ASI indicates an increase in airspeed (over-read).
- where the pitot tube became blocked , if the aeroplane climbs, the ASI indicates a decrease in airspeed (under-read).

If both the ram air input and the drain hole of the pitot system becomes blocked, the indicated airspeed will generally Not change during level flight .



A blocked pitot tube, but clear drain hole.

Static port blockage

A static head is more exposed to icing conditions and is therefore more likely to become obstructed than is a static vent. A blocked static source during descent will mean that the 'old' (higher altitude) static pressure surrounding the capsule will be lower than it should be, so that if the pitot supply is normal the ASI will over-read. This could be dangerous in that the aircraft is nearer the stall than the ASI is indicating.

- If the static line is blocked, in Climb Shows a decrease in speed and the ASI indicated Under Reading.
- If the static line is blocked, in Descent Shows a increase in speed and the ASI indicated Over Reading.

Note

If the alternative static source is selected an error may occur. This error will be due to position error. Any dynamic, or turbulence, effects would usually result in a higher static pressure and thus produce an under-reading. This error is known and would be documented in the Flight Manual.

SERVICEABILITY CHECKS

The following checks of the ASI and pressure supply system should be made before flight:

1- Pressure head cover(s) and static vent plug(s) removed and stowed aboard the aircraft.

2- Pitot tube(s), holes/slots in static head(s) and/or static vent(s) should be checked free from obvious obstructions such as insects.

3-Pitot head heater operative (if fitted).

4- Dial glass clean and undamaged.

5- The instrument should indicate airspeed in the correct sense shortly after starting the take-off run

- Sound passes through the air by compressing and expanding the distance between air molecules, transmitting energy to neighboring molecules, which transmit energy to their neighbors and so on.
- Molecules in warmer air move faster, transmitting the sound energy quicker than in cold air.
- The speed of sound varies only with the temperature.
- Therefore the higher the air temperature, the higher the speed of sound, and vice versa.
- Since temperature normally reduces as altitude increases, the speed of sound normally reduces as altitude increases.

LOCAL SPEED OF SOUND

formula for calculating the LSS for a given temperature is:

$$LSS = 38.95 \times \sqrt{\text{Absolute temperature (in } {}^{o}\text{Kelvin)}}.$$

- LSS is given in Knots,
- 38.95 is a constant
- Absolute temp in $^{o}K = {}^{o}C + 273$.
- Temperature (relative) in $^{o}C = {}^{o}K - 273$
- In ISA conditions at mean sea level (+ 15 ^{o}C) the speed of sound is 661.32knots

We can also use an alternative formula

using ºC, but this does not yield a precise result only an estimation:

$$LSS = 644 + (1.2 \times Temp\ ^{o}C).$$

- In ISA conditions at mean sea level (+ 15 ºC) the speed of sound is 661.32 knots
- while at 30000 feet ISA (-45 ºC) the speed of sound will have reduced to 589.18 knots.

Local Speed of Sound =TAS ⟶ 1 Mach

Mach number

Is the ratio of the aircraft’s TAS to local speed of sound and is expressed as a percentage .

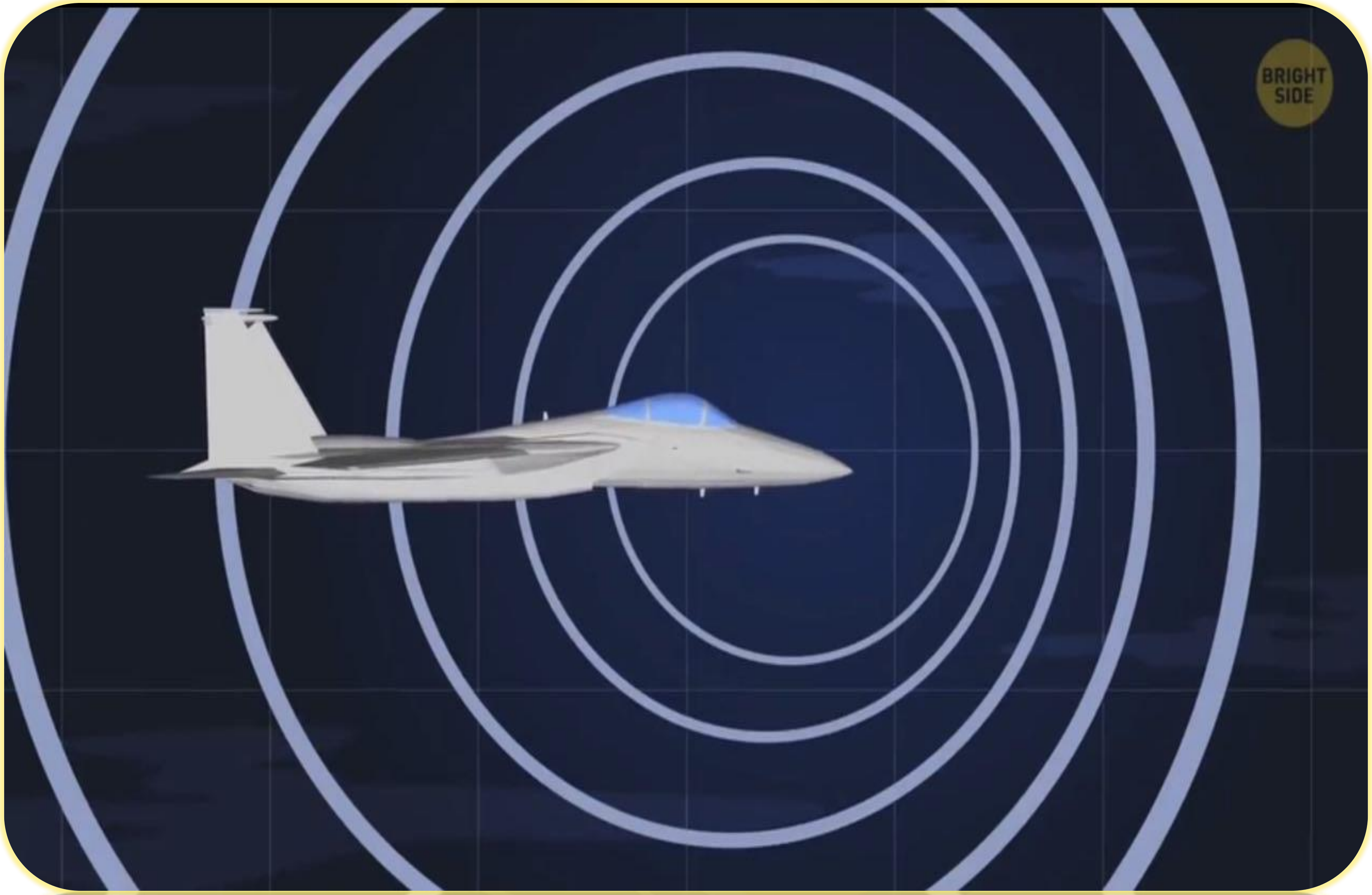
Mach No = TAS ÷ Local Speed of Sound

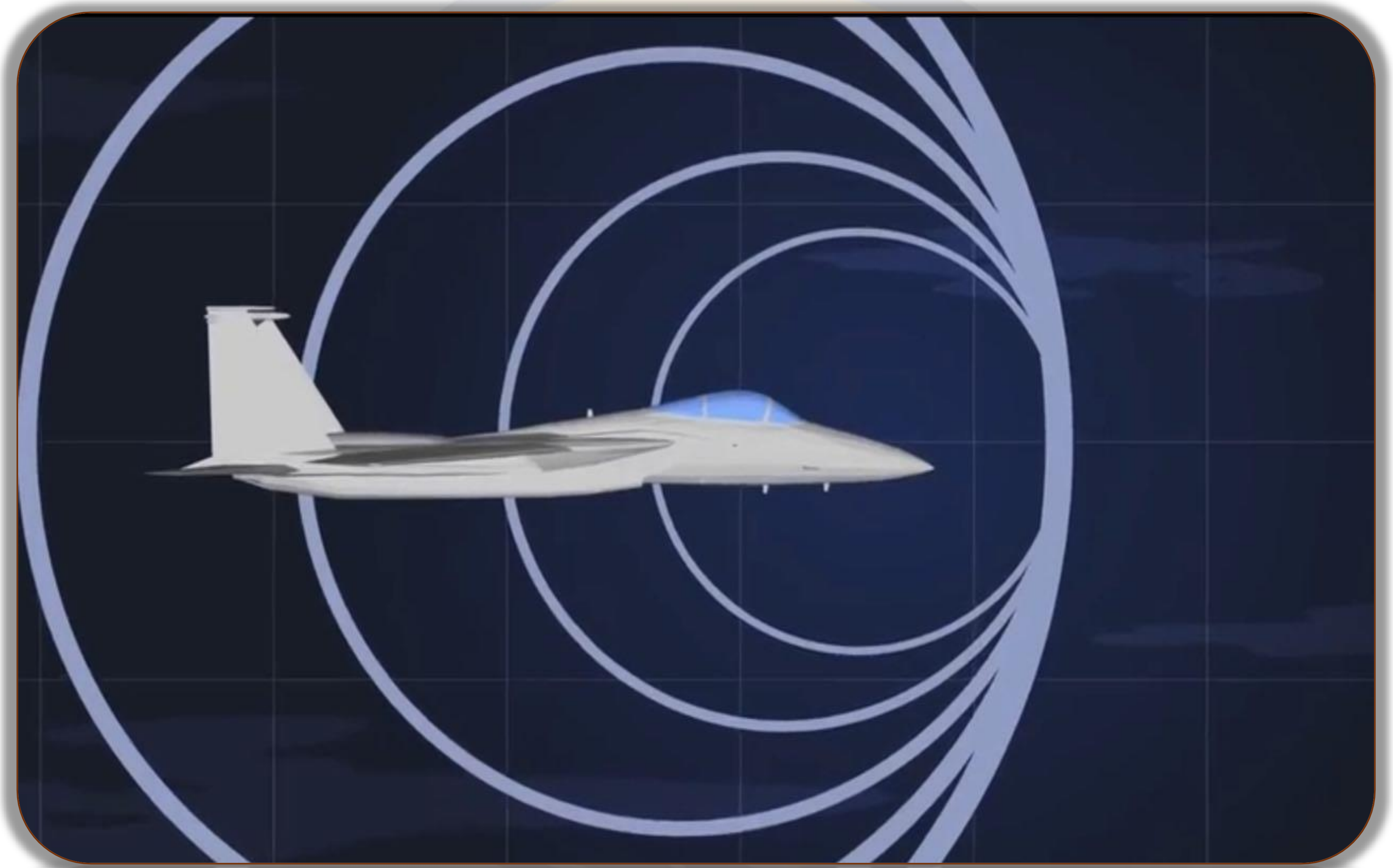
Mach 0.80 means aircraft is flying at 80% of the speed of sound

- As an aircraft reaches speeds close to the speed of sound, some parts of the airflow over the aircraft structure (typically the upper side of the wings) can get accelerates to speeds above the speed of sound and shockwaves will form, increasing the aircraft drag significantly, altering the stability and control characteristics, etc.

- The speed at which airflow over any part of the aircraft first reaches the speed of sound is called the Critical Mach Number (MCRIT).

- It is, therefore important, that aircraft are operated below this Mach number (varies by aircraft design between Mach 0.7 to 0.9).


BRIGHT SIDE



- Actual Mach number is indicated to the pilot by Mach meter.
- An instrument that measures the ratio of the aircraft's speed (TAS) to the local speed of sound and displays it as a Mach number.

- **An increase in altitude and/or air speed results in higher Mach Number**

Chapter 6

Altimeter

The pilot should be familiar with the following definitions.

Height

The vertical distance of a level, point or object considered as a point, measured from a specified datum. (Normally associated with QFE and height above aerodrome level). Or The vertical dimension (size) of an object.

Altitude

The vertical distance of a level, point or object considered as a point, measured from MSL. (Normally associated with QNH)

Cruising Level

This is a generic term describing vertical position for a significant portion of the flight and can be a height, altitude, or flight level depending on the altimeter setting procedure in force.

Elevation

Is the vertical distance of a fixed (non-moving) point or object measured from MSL.

Pressure altitude

Is the altitude of the aircraft with reference to the pressure level of 1013.25 hpa.

True altitude

True height means the height of the aircraft vertically above the surface immediately below . used more often in connection with radio or radar altimeters than with pressure altimeter .

- *The altitude measurement is either feet or meter*

1meter = 3.28 feet

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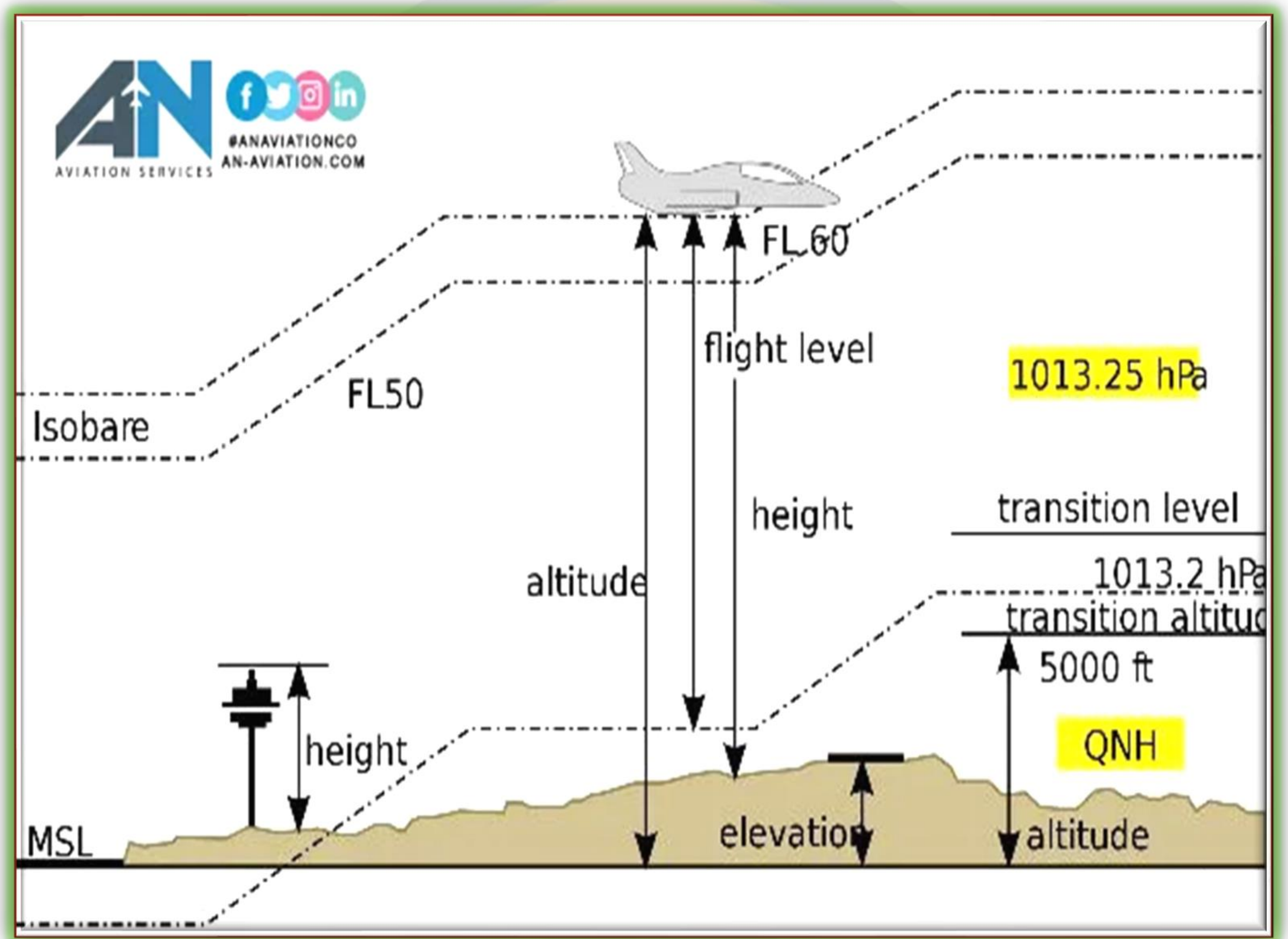


Flight Levels

Surfaces of constant pressure related to the standard pressure datum and separated by specified pressure intervals. In the UK these correspond to 500 foot intervals between transition level and FL 245 while from FL 250 they correspond to 1,000 foot intervals. A flight level is expressed as the number of hundreds of feet which would be indicated at the level concerned by an ISA calibrated altimeter set to 1013.25 mb (29.92 inches). For example, with 1013.25 set and 25 000 feet indicated, the flight level would be 250, (abbreviated to FL 250). With 4,500 feet indicated it would be FL 45.

DENSITY ALTITUDE

Density Altitude in Feet = Pressure Altitude in Feet + (120 x (OAT˚C - ISA Temperature ˚C))

Density altitude can be defined as the altitude in the standard atmosphere at which the prevailing density would occur, or alternatively, as the altitude in the standard atmosphere corresponding to the prevailing pressure and temperature. It is a convenient parameter in respect of engine performance figures. It can be obtained by use of an airspeed chart or by navigational computer. The recommended method for use in the exam is that density altitude = pressure altitude adjusted (+ or -) by ISA deviation x 120. is the pressure altitude that corrected for nonstandard temperature.

absolute altitude

The actual height of the airplane above the surface over which it is flying is referred to as: absolute altitude.

This altitude varies with the height of the airplane , as well as the height of the surface.

Absolute altitude is commonly referred to as height above ground level (AGL).

International Standard Atmosphere (ISA)

Temperature	+15°C - 59 °F
Pressure unit	1013.25 hpa
Pressure unit	29.92 inhg
Pressure unit	14.7 psi
Density	1.225 kg/m^3
Temperature falling	1.98°C/1000 feet

QFE

This is aerodrome level pressure, which when set on the sub-scale, will cause the altimeter of an aircraft on the ground to read zero, assuming there is no instrument error. In flight, with QFE set, the altimeter will indicate height above the aerodrome QFE reference datum, provided ISA conditions obtain between aerodrome level and the aircraft and there are no other altimeter errors. In practice, QFE is used mainly for circuit-flying and gives a good indication of height above the aerodrome, any errors involved being only small.

QNH

This setting is used mainly in flight below transition altitude/level, defined later. It is an equivalent MSL pressure calculated by Air Traffic Control from the aerodrome level pressure assuming ISA conditions prevail between aerodrome level and MSL. With QNH set on the sub-scale, the altimeter of an aircraft on the aerodrome indicates aerodrome elevation, that is, the height AMSL (if there is no instrument error). In flight the altimeter will indicate altitude but this will only be the true altitude if the mean temperature in the column of air beneath the aircraft is the same as in ISA conditions (assuming there are no other altimeter errors). If conditions are different from standard, the indicated altitude, sometimes called QNH altitude, may deviate considerably from true altitude. The navigational computer can be used to make an approximate correction for this temperature error.

Standard setting

When 1013.25 hpa is set on the subscale, the altimeter reading is called pressure altitude . If 1013.25 hpa is set , an aircraft would normally fly flight levels.

QFF

The QFE which is corrected to MSL by actual laps rate .

If above MSL

If the temp > ISA then QNH > QFF

If the temp < ISA then QNH < QFF

If below MSL then this is reversed:

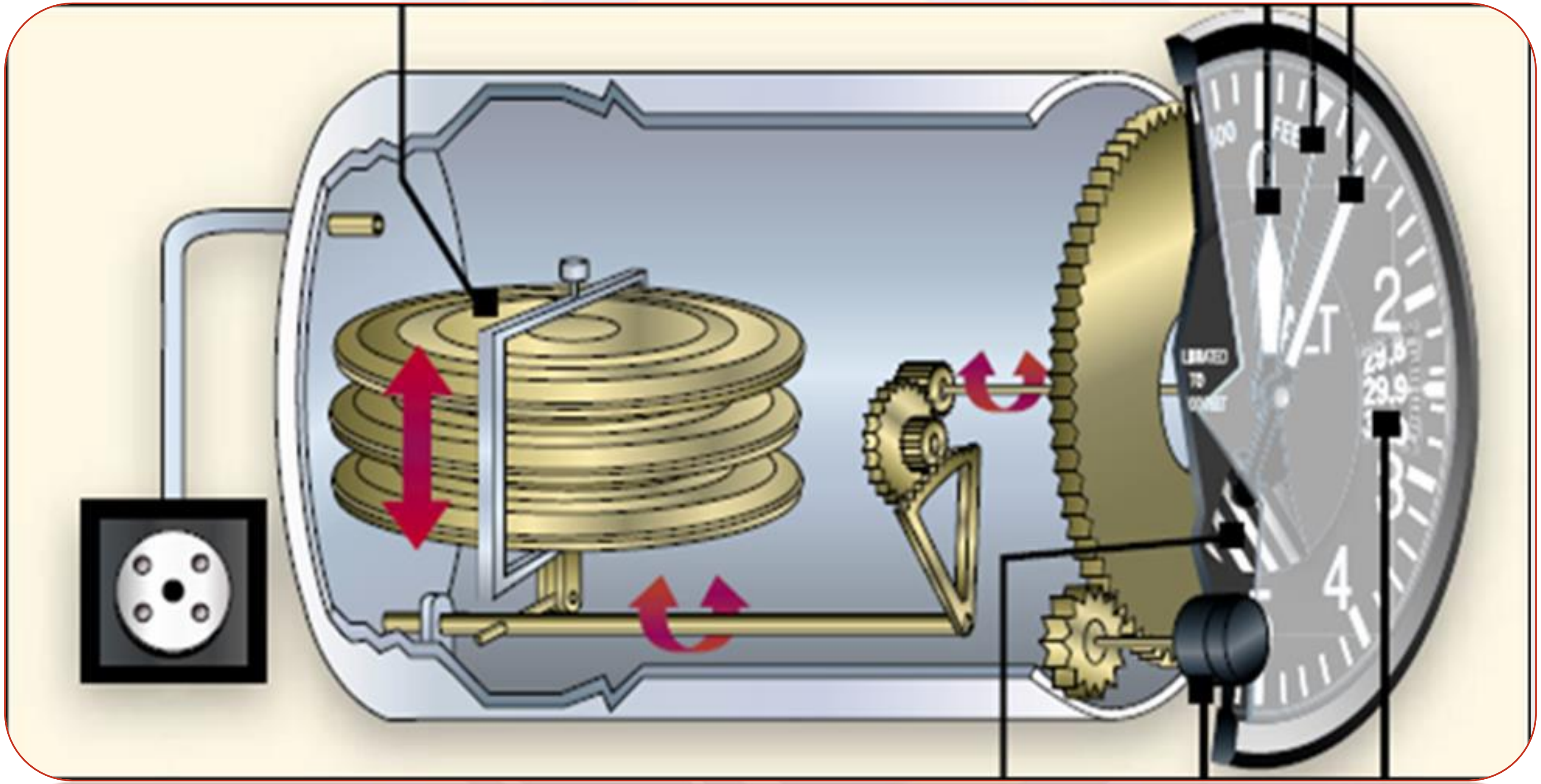
If the temp > ISA then QNH < QFF

If the temp < ISA then QNH > QFF

Barometric Scale


100 FEET
0
1
2
ALT
3
4
5
6
7
8
9
1000 FEET
10000 FEET
1020

How does the ALTIMETER Work?



Transition Altitude

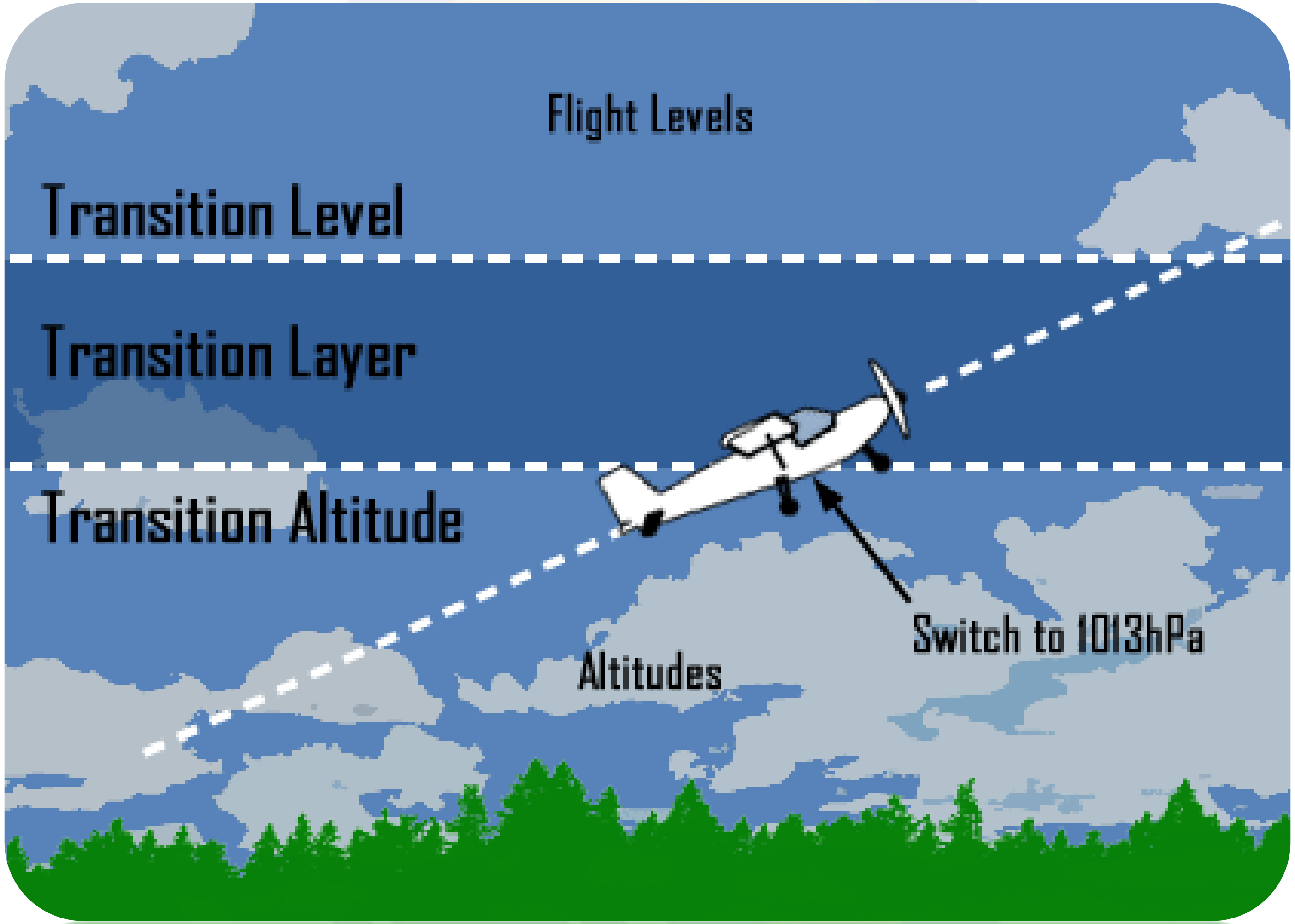
This is the altitude at or below which the vertical position of an aircraft is expressed and controlled in terms of altitude.

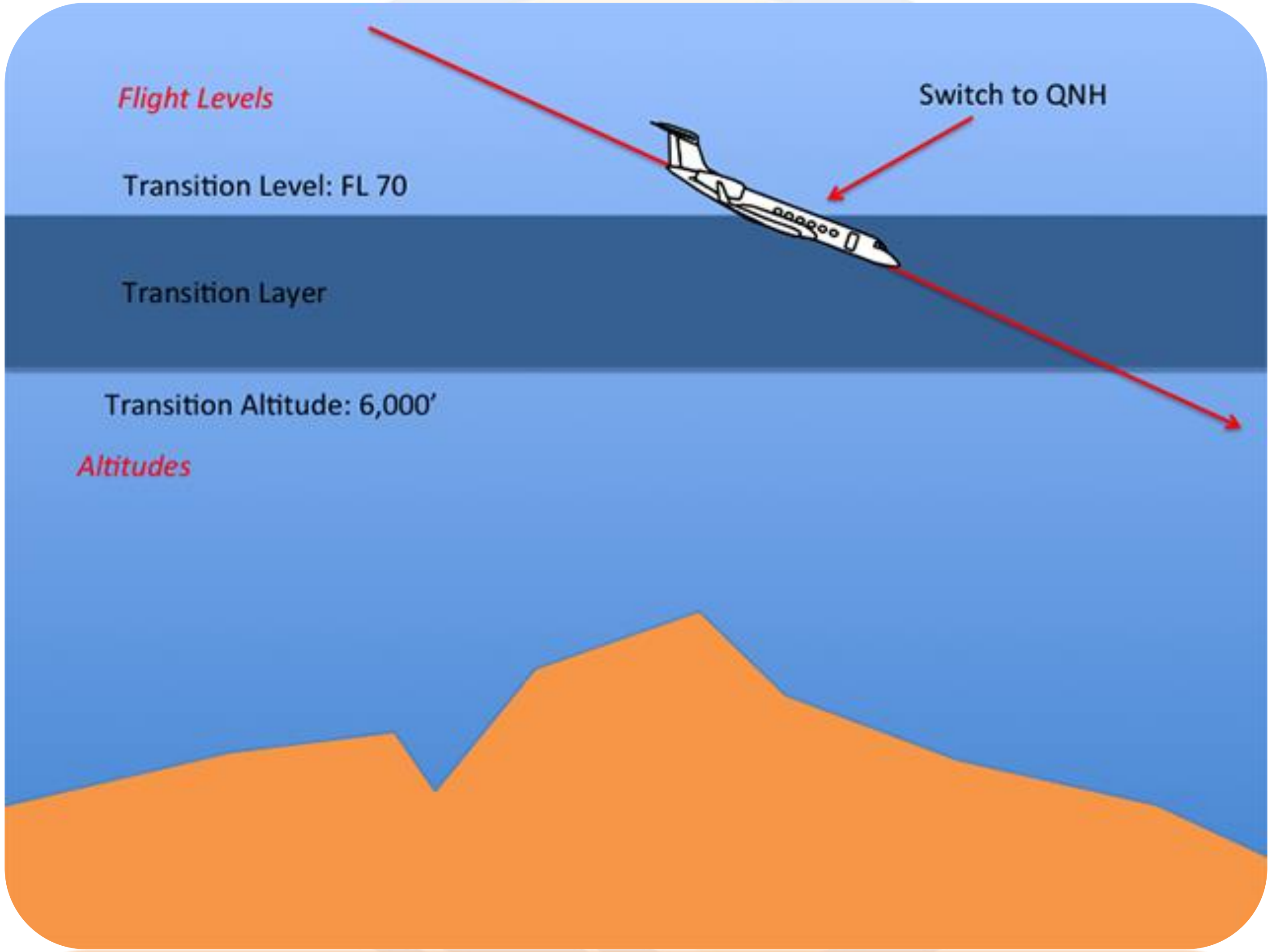
Transition Level

This is the lowest flight level available for use above the transition altitude. At and above transition level, vertical position is expressed as a flight level.

Transition Layer

This is the airspace between transition altitude and transition level. When climbing through it, the aircraft's vertical position is expressed in terms of flight level; when descending through it, in terms of altitude.


Flight Levels
Transition Level
Transition Layer
Transition Altitude
Switch to 1013hPa
Altitudes


Flight Levels
Switch to QNH
Transition Level: FL 70
Transition Layer
Transition Altitude: 6,000’
Altitudes

Indicated altitude

Is the altitude measured by your altimeter, from local pressure setting, and the one you will use most often during flight.

Calibrated altitude

Is indicated altitude corrected to compensate for installation and instrument error.

ALTIMETER ERRORS

Time Lag

With many types of altimeter the response to change of height is not instantaneous. This causes the altimeter to under-read in a climb and over-read in a descent. The lag is most noticeable when the change in altitude is rapid and prolonged. In the laboratory calibration of the sensitive altimeter, the lag between increasing readings and decreasing readings should not exceed 150 feet. With servo-assisted altimeters there is said to be no appreciable lag unless the rate of change of height exceeds 10,000 feet per minute. This is because the servo-altimeter does not suffer from the linkage friction which causes a much larger error in the sensitive altimeter.

Instrument Error

Manufacturing imperfections, including friction in the linkage, cause errors throughout the operating range. The errors are kept as small as possible by adjustments within the instrument, and the calibration procedure ensures that they are within permitted tolerances. Residual errors may be listed on a correction card.

Note: With the sensitive altimeter the error increases with altitude, which also explains why the decrease of accuracy with altitude is less serious with the servo-altimeter.

Position (or Pressure) Error

This is largely due to the inability to sense the true static pressure outside the aircraft, as described in the chapter on Pressure Heads. The error is usually small but increases at high mach numbers (and, consequently, at high altitudes usually associated with high mach numbers).

Manoeuvre-Induced Error

This is caused by transient fluctuations of pressure at the static vent during change of, mainly, pitch attitude and delays in the transmission of pressure changes due to viscous and acoustic effects in the static pipeline.

E. Pressure Error (Barometric Error)

If you fly from an area of

high pressure → lower pressure (without resetting altimeter) indicate higher than the actual (true) altitude.

lower pressure → high pressure (without resetting altimeter) indicate lower than actual (true) altitude

The best way to minimize altimeter error Frequently update altimeter setting .

Temperature Error

When atmospheric temperature is **higher** than standard, pressure levels are raised, and your true altitude is **higher** than your indicated altitude.

When atmospheric temperature is **colder** than standard, pressure levels are lowered, and your true altitude is **lower** than your indicated altitude.

Even with no other errors at all, the pressure altimeter will not indicate true altitude (height AMSL) unless the surface temperature and lapse rate of the column of air are those assumed in the calibration. When flying in colder air (with an air density greater than ISA at that altitude), the altimeter will over-read. Where the temperature at cruising level deviates from standard, an approximate correction can be made with most navigational computers. The correction can only be approximate since temperatures in the rest of the column of air are not known. The correction is considered too inaccurate to be worth making at heights above 25,000 feet.

When flying

From HOT to COLD

Or

From HIGH to LOW

Look out below

When flying

From COLD to HOT

Or

From LOW to HIGH

Watch out sky

Temperature deviation from ISA

For each 10°C lower than ISA

True altitude will be

4% lower than

indicated altitude

If there is for example 14° ISA deviation

Correction will be

5.6%.

TEMPERATURE ERROR CORRECTION

Values to be added by the pilot to published altitudes (feet)

Aerodrome Temp °C	Height above the elevation of the altimeter setting source													
	200	300	**400**	500	600	700	800	900	1,000	1,500	2,000	3,000	4,000	5,000
0	0	20	20	20	20	40	40	40	40	60	80	140	180	220
-10	20	20	40	40	40	60	80	80	80	120	160	260	340	420
-20	20	40	40	60	80	80	100	120	120	180	240	380	500	620
-30	40	40	60	80	100	120	140	140	160	240	320	500	660	820
-40	40	60	**80**	100	120	140	160	180	200	300	400	620	820	1020
-50	40	80	100	120	140	180	200	220	240	360	480	740	980	1220

Note:- The table is based on aerodrome elevation of 2,000 ft; however it can be used operationally at any aerodrome.

BLOCKAGES AND LEAKS

If the static source becomes blocked, the altimeter will not register any change in height - the height at which the blockage occurred will still be indicated regardless of any climb or descent. On many aircraft, an alternative source of static pressure will be available.

Should the static line fracture in a pressurised aircraft, the altimeter will show the (lower) cabin altitude rather than aircraft altitude.

A fracture in the static line within an unpressurised aircraft will normally result in the altimeter over reading, due to the pressure in the cabin being lower than ambient due to aerodynamic suction.

If the aircraft is CLIMBING then the altimeter will UNDER READ.

If the aircraft is DECSCENDING then the altimeter will OVER READ.

If the static tube or vents become blocked ,the pressure with in the instrument case remains constant and the altimeter continues to indicate the altitude of the aeroplane when the blockage occurred.(freeze)

INSTRUMENT CHECK

1 –Set altimeter to current QNH.

2 –Check actual elevation with your Altimeter.

3 –The altimeter error less than 75 feet is acceptable.

4 –The altimeter error less than 50 feet together.

GPS indication

GPS altitude cannot be used to replace the reading altimeter as GPS altitude is an indication of absolute altitude . Absolute altitude is the actual height of an aircraft above the surface .

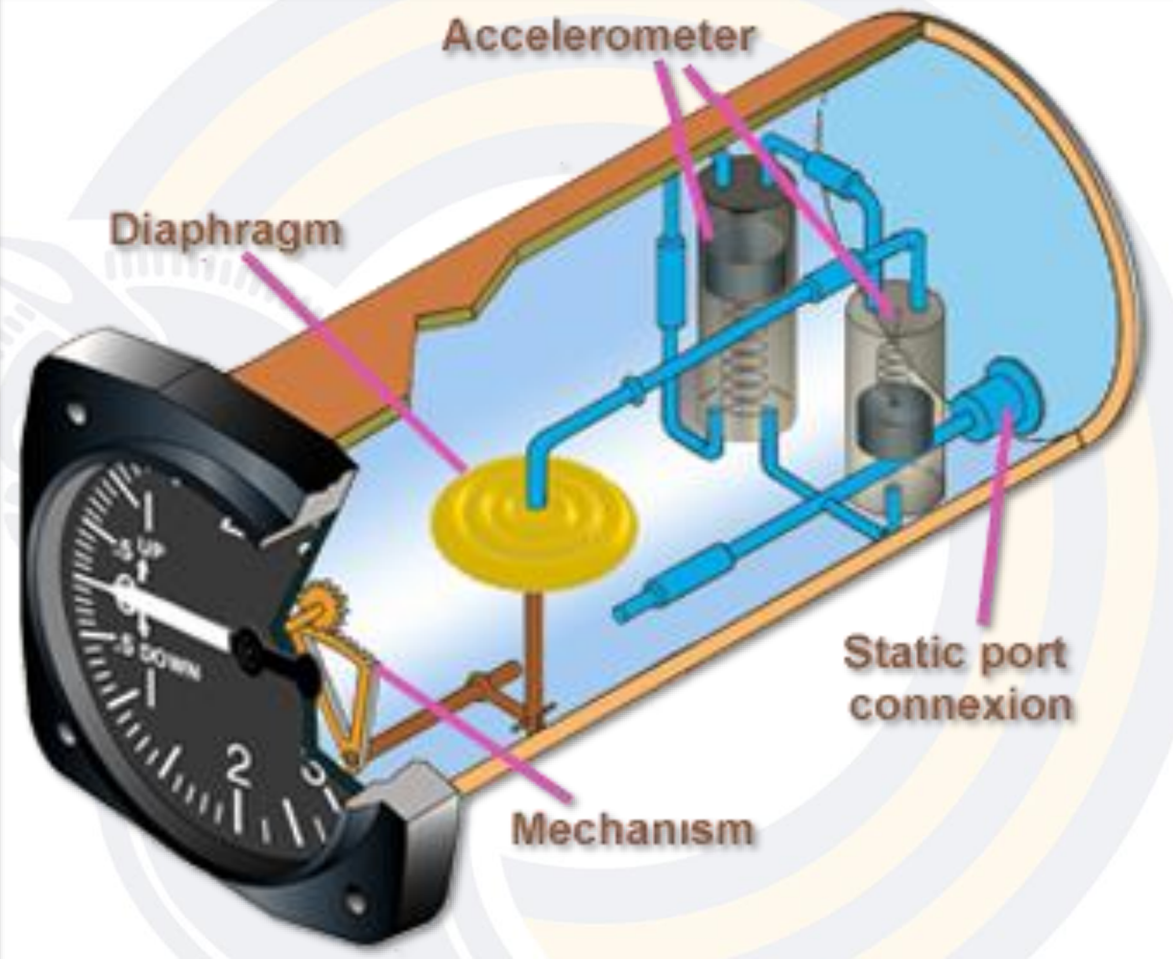
GPS altitude is almost perfectly accurate , so it can therefore be used to check the accuracy of the pressure altimeter when the QFE is set at the aerodrome reference point .

Chapter 7

Vertical velocity indicator (VVI)

A pilot can get some idea of his rate of climb or descent from the angular rate of change of the altimeter pointer. However, there are times when a more accurate indication is necessary, such as achieving a certain height loss within a specified time on airways or in setting up a smooth rate of descent on a glide path on an instrument approach. The Vertical Speed Indicator (VSI) displays rate of climb or descent. The instrument senses rate of change of static by comparing the present static pressure with a recent measurement of static.

When an aircraft departs from level flight, the static pressure will change. The V.S.I. measures the pressure difference between each side of a restricted choke / metering unit. In level flight the pressures on each side of the choke are the same, during a climb or descent, air fed to the choke immediately responds to the change of atmospheric pressure but the choke transmits this change at a lower rate.



Source: www.faa.gov/handbooks_manuals/media


10
15
5
UP
VERTICAL SPEED
FEET PER MINUTE
0
20
DOWN
5
15
10

A capsule within an airtight case is fed with static pressure. The case is also fed with static pressure but through a restricted choke, thus if the static pressure is changed the pressure surrounding the capsule changes at a slower rate than that within the capsule . For example, if the aircraft is climbing, the pressure in the capsule will be less than that in the case, the consequent compression of the capsule is converted by a suitable linkage to a pointer indication of rate of climb.

THE ERRORS OF THE VSI

Instrument Error

Due to manufacturing imperfections.

Position (or Pressure) Error

If the static pressure is subject to position error the V.S.I. will wrongly indicate a climb or descent when speed is suddenly changed, this is most noticeable during take-off acceleration.

Manoeuvre -Induced Error

Any short term fluctuations in pressure at the static vent during attitude changes will cause the instrument to indicate a false rate of climb or descent.

Additionally with most V.S.I.s, the linkage includes a small counterbalance weight, the inertia of which causes delays in the indications of changes in vertical speed during manoeuvres.

Time Lag

The pointer takes a few seconds to steady because of the time taken to build up a steady pressure difference on climb or descent. There will also be a time lag on levelling out because of the time taken for the pressures to equalise. This error is most noticeable after a prolonged climb or descent, especially at a high rate.

Any blockages

Can be any blockage of the static line or vent will cause the needle to return to zero. If the supply of air to this instrument is blocked it is probable that the other pressure instruments (A.S.I., altimeter and machmeter) will also be affected.

THE INSTANTANEOUS VERTICAL SPEED INDICATOR

To overcome the problem of lag, the Instantaneous Vertical Speed Indicator (I.V.S.I) incorporates an accelerometer unit (sometimes called a dashpot or vane-type) which responds quickly to a change of altitude. The piston in the vertical acceleration pump immediately rises in the cylinder and causes a temporary increase of pressure in the capsule. The capsule expands and the pointer will give an instant indication of descent. As the initial acceleration is turned into a steady rate of descent, the piston will slowly descend to its original position, but by this time the correct differential pressure between the capsule and the case will have been set up and the correct rate of descent will continue to be shown.

IVSI Errors

Because of the sensitivity of the dash-pot assembly, the instrument tends to overreact to turbulent flying conditions and small fluctuations should be ignored .

If the aircraft should be turning, the piston will tend to sink towards the bottom of the cylinder and there will be **an indication of a climb.**

The **VSI** is capable of displaying

two different types of information One is called **trend** , and the other is called **rate .**

Trend

information shows you an immediate indication of an increase or decrease in the airplane's rate of climb or descent .

Rate

information shows you a stabilized rate of change.

It has 6-12 second delays

SERVICEABILITY CHECKS

On the Ground

The instrument should read zero, or the error should be within the permissible limits

- +/- 200 feet per minute at temperatures – 20°C + 50°C
- +/- 300 feet per minute outside these temperatures

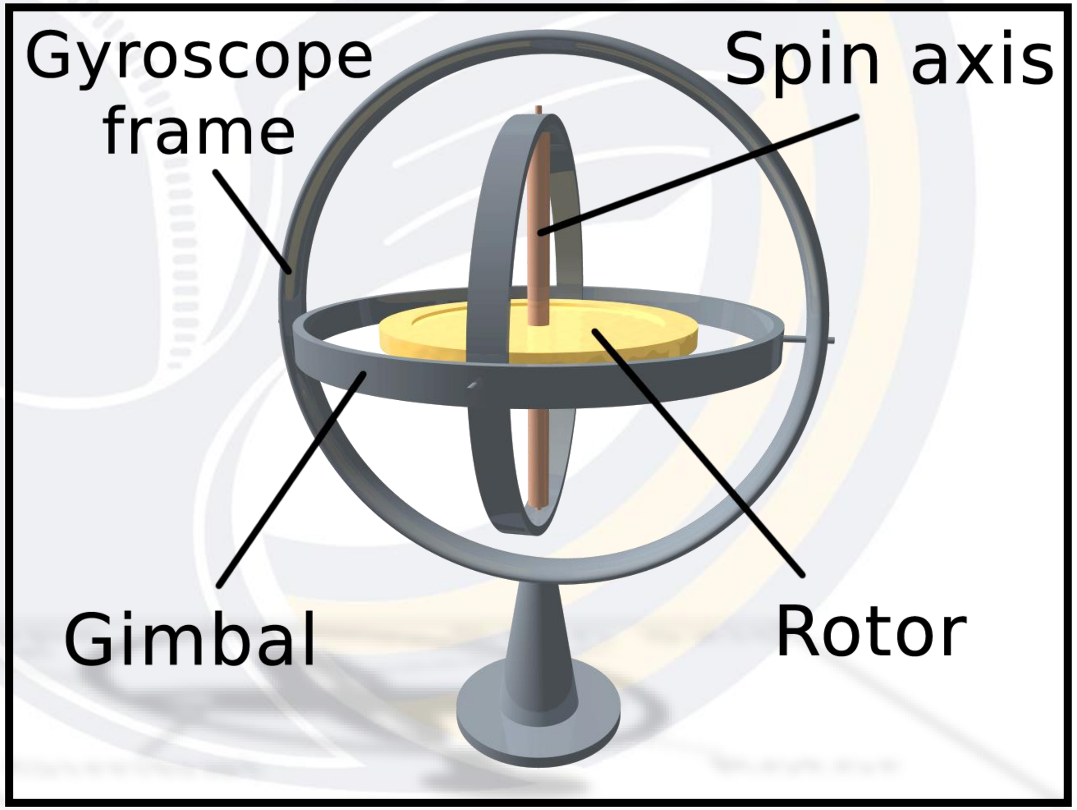
- There should be no apparent damage to the instrument.

In The Air

The accuracy of the instrument may be checked against the altimeter and a stop watch during a steady climb/descent and the instrument should indicate zero climb or descent when in level flight.

Chapter 8

Gyroscopic instruments

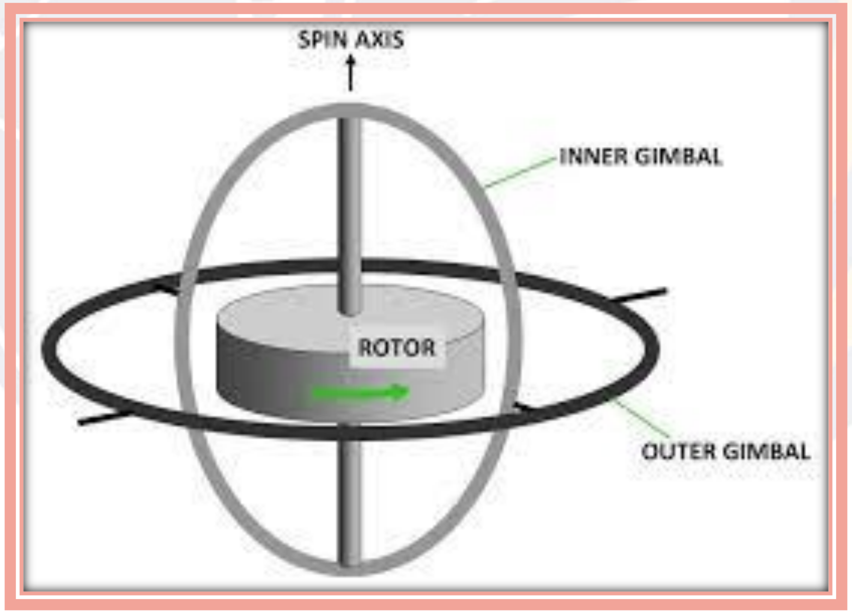


This chapter aims to provide sufficient background knowledge for the study of the Artificial Horizon, Directional Gyro Indicator, and the Rate of Turn Indicator.

Any rotating body exhibits gyroscopic phenomena. The earth is a gyro, spinning about the axis between the geographic poles.

Most aircraft gyros are discs between 2 and 5 cm in diameter , spinning at speeds between 4000 and 55000 rpm , depending on their design .

- **The shaft about which the rotor spins is called the axis**.



- Gimbal rings, These are the supports for the rotor of a gyroscopic instrument which give the rotor’s spin axis its own freedom of movement.

- Gimbal rings, are known briefly as gimbals , and sometimes spelled gimbals

- The gimbal system mounts so that with the gyro in its normal operating position , all of its axes run mutually at right angles to each other ,and intersect at the center of the rotor.

Gyros have 2 basic properties which make them important as the basis of the aircraft attitude and direction instruments . These are rigidity and precession .

Rigidity

Is the gyros property of maintaining its axis in a fixed direction in space , unless subjected to an external force .it is caused by the inertia of the spinning mass. This property is called **rigidity in space** or **gyroscopic inertia** .

Ways to Increase Rigidity

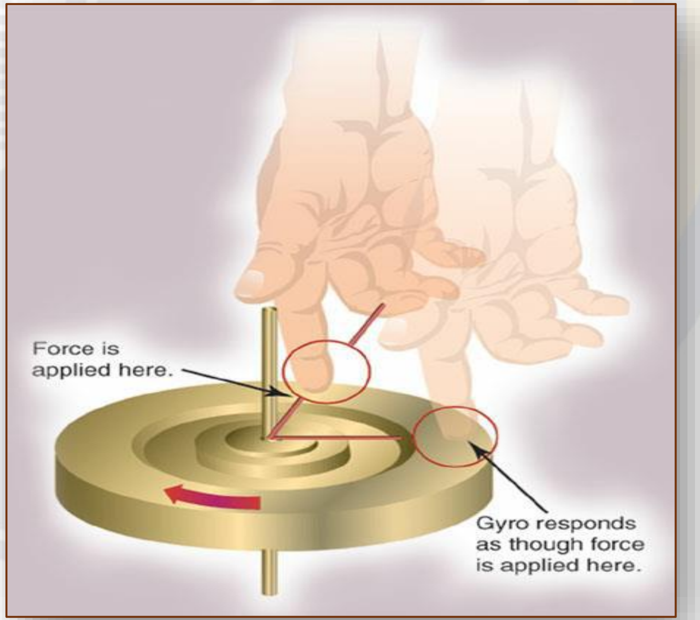
1. Increase the rotor mass
2. Increase the rotor diameter
3. Concentrate the rotor mass around the perimeter of the rotor
4. Increase the speed of rotation

- The greater the rigidity the more difficult it is to move the rotor away from its plane of spin, unless **an external force acts on it.**

Precession

Is defined as the tilting or the turning of a rotor axis due to the application of external forces . The applied force will cause the rotor of the gyroscope to drift or topple 90 degrees in the direction od rotor rotation . Precession only applies to a rotor that is in motion . It does apply to a stationary rotor.

When a force is applied to a gyro ,the reaction to the force occurs in the direction of rotation ,approximately90° ahead of the point where the force was applied.



Chapter 9

Turn coordinator

This instrument incorporates two measuring devices, both indicating on the same instrument face. One of these, the rate of turn indicator, (commonly shortened to ‘turn’ indicator), uses a rate gyro to measure rate of turn about a vertical axis. The other, the slip indicator, is a very simple pendulous device which is used mainly to show whether or not a turn is balanced, (whether the angle of bank is correct for the TAS and rate of turn), and if not, to indicate the extent of slip or skid.

What is the turn ?

Flying around a point

or

Flying on a circle or arc of that

Radius of a turn

- The radius of a circle that aircraft flies around it

What is the rate of turn ?

- The rate of turn is basically the rate of angular movement or change-of-heading rate of the aircraft . How quickly an aircraft changes direction .

rate-1 turn

- A ret-1 turn is achieved when the aircraft steadily changes direction at a rate 3 degrees per second and 360 degrees in 2 minutes.

Standard rate turn (rate one turn):

3degrees in 1sec Or 360degrees in 2minutes

Half Standard Rate Turn:

1.5degrees in 1sec Or 360degrees in 4minutes

(Rate two turn):

6degrees in 1sec Or 360degrees in 1minutes

(Rate three turn):

9degrees in 1sec Or 540degrees in 2minutes

The higher the bank angle , the higher the rate of turn . TAS is inversely proportional to the rate of turn , but directly proportional to the radius of the turn due to the increase in inertia and momentum of the aircraft with an increase in TAS .

Rate of turn depends on:

TAS and Bank angle

Rate of turn formula

TAS< 100 kts

TAS + 5

TAS≥100 kts

TAS + 7

Another formula that can be used is Bank angle = **15% of IAS.**

The slip indicator

This instrument indicates whether or not a turn is balanced . It comprises a solid ball in a curved tube containing liquid that damps out unwanted oscillations . The ball works a pendulum , with the center of curvature of the tube serving as a point of suspension .

Slip

rate of turn is too slow for angle of bank and aircraft yaw to the outside of the turn.

If too much bank were applied for the TAS and the rate of turn

Recovery From Slip

1 –apply rudder pressure on the side where the ball is deflected.

(Step on the ball)

2 –Decrease bank angle

3 –Decrease air speed

Or

Combination of all 3 above

Skid

In skid rate of turn is too great for angle of bank and aircraft yaw to the inside of the turn and Ball is in opposite direction of turn . If insufficient bank were applied , the instrument would indicate that the aircraft is skidding out of the turn .

Recovery From Skid

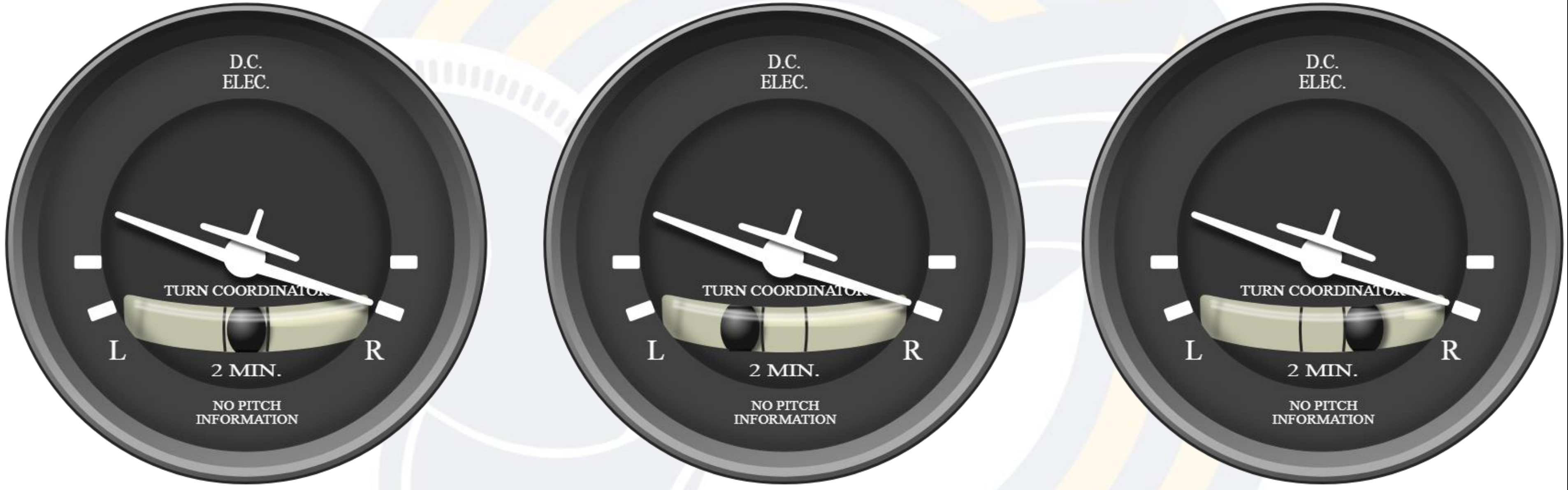
1 –Step on the ball

2 –Increase bank angle

3 –Increase air speed

Or

Combination of all 3 above

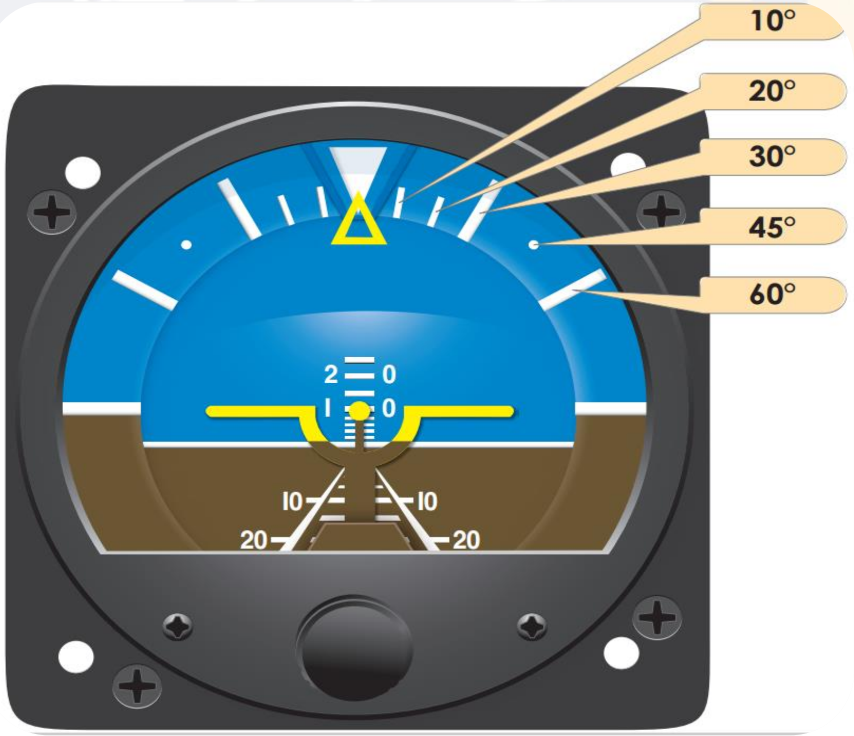


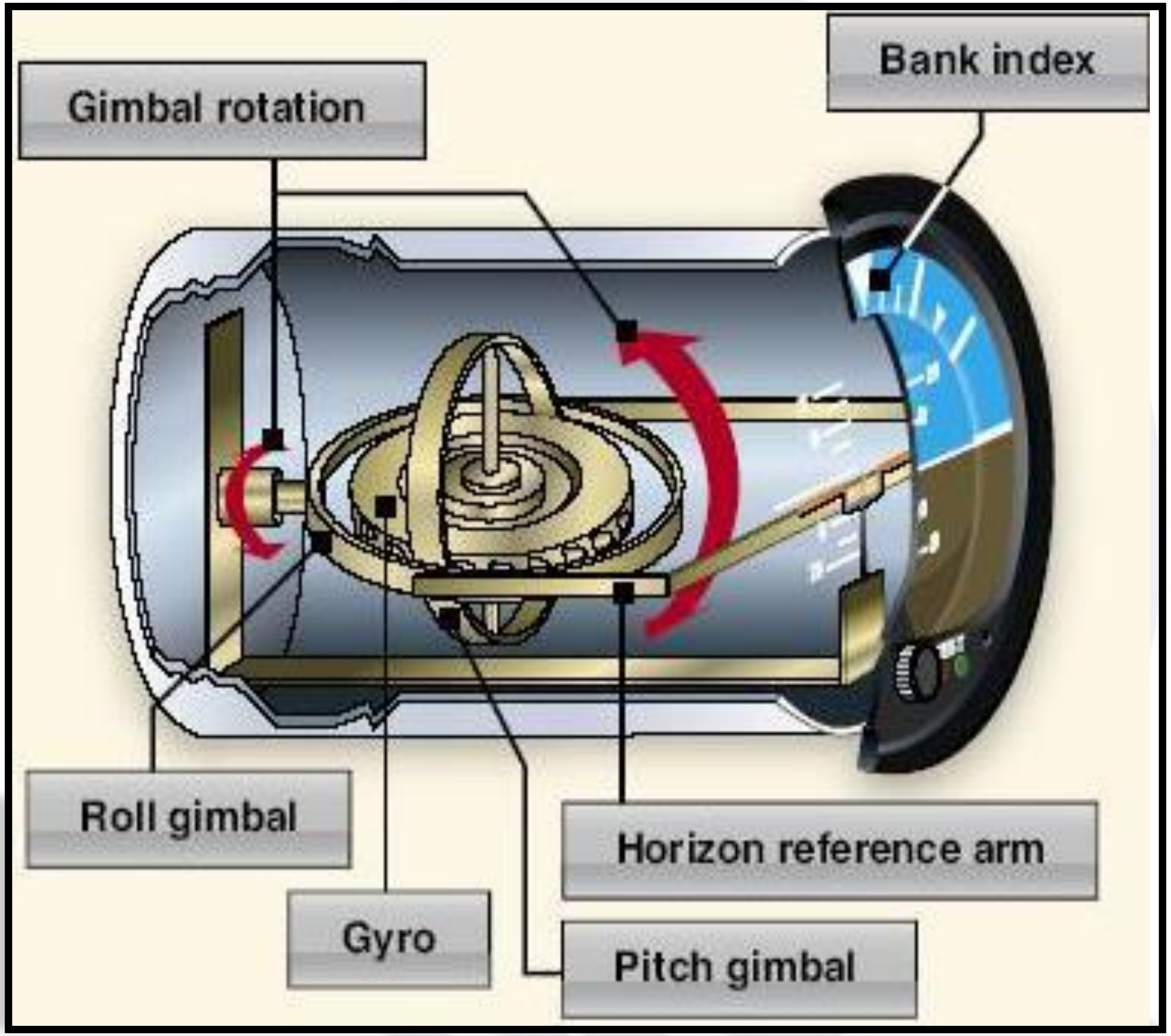
Coordinated turn Skid Slip

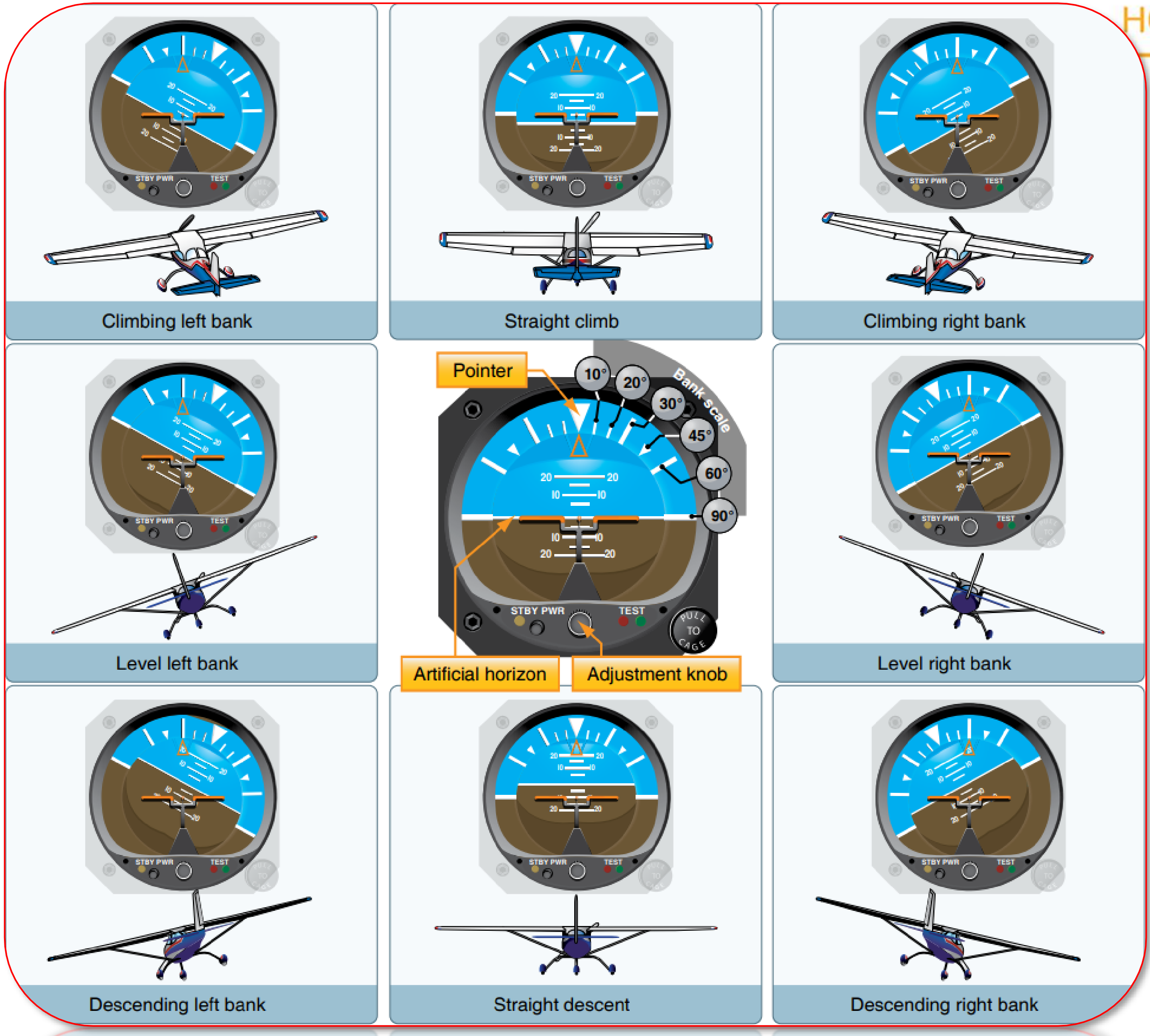
Chapter 10

Attitude indicator (Artificial horizon)

The **attitude indicator** (AI) provides the pilot with **information** in terms of the aircraft's attitude both in **pitch** and **roll**. It is a primary instrument, replacing the natural horizon in poor visibility. The attitude display consists of a miniature aircraft shape or 'gull-wing' (tail view) painted or engraved centrally on the inside of the glass face of the instrument, and therefore fixed to the instrument case and the actual aircraft. Behind this representation of the aircraft is the horizon bar, linked to the gyro in such a way that the bar is gyro-stabilised parallel to the true horizon. The artificial horizon may be suction or electrically driven. It is also known as a gyro horizon and attitude indicator.




Gimbal rotation
Bank index
Roll gimbal
Gyro
Horizon reference arm
Pitch gimbal


Climbing left bank
Straight climb
Climbing right bank
Pointer
10°
20°
30°
45°
60°
90°
Bank scale
STBY PWR
TEST
PULL TO CAGE
Artificial horizon
Adjustment knob
Level left bank
Level right bank
Descending left bank
Straight descent
Descending right bank

The amount the case can move relative to the gyro is controlled by fixed stops. With older designs, typical limits are ± 60° in pitch and 110° each way in roll. In modern instruments there is complete freedom in roll and up to 85° (plus or minus) in pitch. If the limits are exceeded, the gyro ‘topples’, giving violent and erratic movements of the horizon bar. Unless a fast erection system is incorporated, accurate indications will not be obtained until the gyro has re-erected itself over a period of 10 to 15 minutes.

ACCELERATION ERROR IN THE AIR DRIVEN ARTIFICIAL HORIZON

The control system of the air driven artificial horizon depends on the pendulous vanes being affected by the Earth's gravity. However, the vanes will be affected by any acceleration, not just that due to gravity. When an aircraft **accelerates** in a level attitude (such as during the take-off run) a false nose up, right wing down, or **climbing right hand turn indication** will result. The **pitch error** is due to the effect of acceleration on the **lateral pendulous vanes**. The **roll error** is due to the inertia of the **bottom-heavy rotor housing**. These effects are now considered in more depth.

Pitch Error

During acceleration, the lateral vanes lag, swinging back towards the pilot, opening the starboard slot and closing the port slot. This results in a reaction ‘R’ which acts to port . By the rule of precession the effect on the gyro is as if the direction of application of R had been moved 90° in the direction of rotor spin (anticlockwise). The gyro will now be precessed out of vertical with the base moving backwards towards the pilot. This movement is transmitted via the guide pin and horizon bar arm to bring the horizon bar below the gull-wing giving a nose-up indication.

Roll Error

Due to inertia, the weighted base of the rotor housing tries to lag during acceleration. However, this force will be precessed, resulting in the base of the rotor housing moving to starboard and the gyro axis precessing out of the vertical This rotates the whole rotor / gimbal assembly about the longitudinal axis to give a right wing down indication.

Deceleration will cause a nose down, left wing low error, the opposite of the acceleration error indication. These errors assume that the rotor is rotating anticlockwise when viewed from the top .

However in an uncorrected instrument the following errors will occur. (assume a Classic Instrument - air driven with the gyro rotating anti-clockwise when viewed from above)

Turning through 90°: Under reads bank angle   Pitch error – indicating a climb

Turning through 180°: Bank angle correct   Pitch error – indicating a climb

Turning through 270°: Over reads bank angle   Pitch error – indicating a climb

Turning through 360°: Bank angle correct   Pitch angle correct

The tilts are of the order of **2°**. The setting of the horizon bar has to be similarly modified to indicate correctly in level flight. Small residual errors occur, particularly if the speed and rate of turn are not those for which compensation has been applied, but the errors are very much smaller than they would be had no compensation been made.

SERVICEABILITY CHECKS

Before Flight

Check that the horizon bar takes up a laterally level position with the correct pitch indication for the aircraft type, and that this indication is maintained when taxying. If a caging device is fitted, the instrument should be uncaged at least five minutes before take-off to ensure that the rotor axis has had time to reach alignment with the true vertical.

In Flight

The artificial horizon should give an immediate and correct indication of any change in pitch or roll attitude.

Pitch and roll cut-out switches

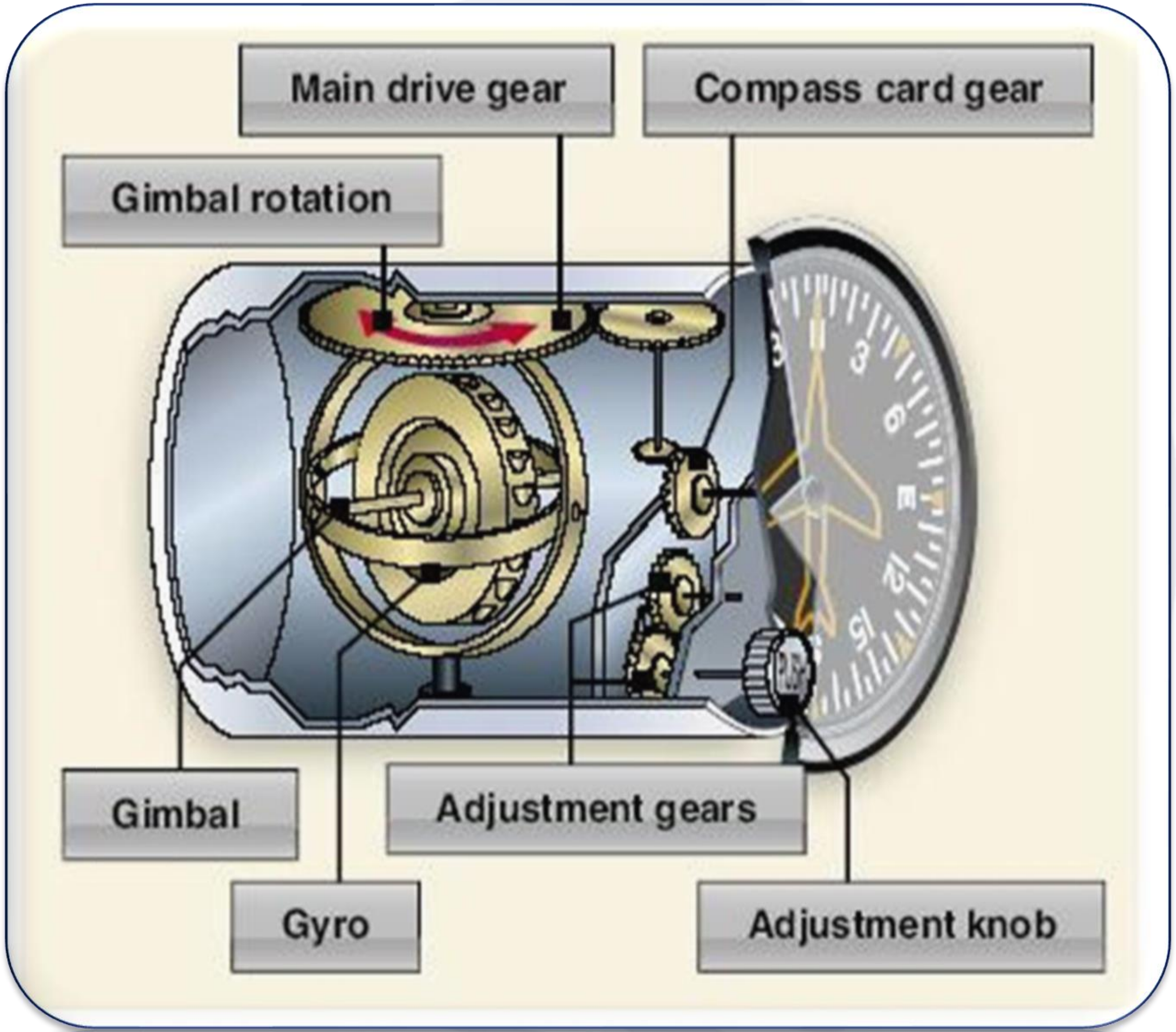
When an aircraft in a level attitude accelerates the pitch levelling switch will falsely complete the circuit as the mercury ‘ball’ moves back in its tube(due to inertia). As this would then result in the pitch torque motor falsely precessing the gyro out of the vertical, a pitch cut-out switch is included in the circuit which activates when an acceleration of 0.18G or greater is detected.

Chapter 11

Directional gyroscope

The **directional gyro indicator (DGI)**, often called the **'direction indicator' (DI)** provides a **stable directional reference** in azimuth for maintaining accurate headings and for executing precise turns. There is no magnetic element in the DI, so it is not North-seeking and must initially be **synchronised** with the **magnetic compass**. Having no magnetic element, the DGI does not suffer from the compass turning and acceleration errors produced by the vertical component of the earth's magnetic field.

Heading is the angle between NORTH and Longitudinal axis of aircraft (clockwise)


Main drive gear
Compass card gear
Gimbal rotation
Gimbal
Adjustment gears
Gyro
Adjustment knob

The rotor is mounted in the inner gimbal (on bearings mounted in the outer gimbal) which has restricted freedom to turn. The outer gimbal can rotate through 360° about the aircraft's vertical axis, on bearings in the case.

During a turn, the aircraft and instrument case turn on the vertical axis bearings of the outer gimbal whilst the gyro rotor, gimbals and indicating scale all remain fixed in azimuth because of gyroscopic rigidity.

Alignment

To align the directional gyroscope to the magnetic compass , the pilot must establish a straight and level aircraft attitude . When the magnetic compass heading has stablished , the caging knob of the directional gyroscope must be pushed inwards and rotated until the heading on the directional gyroscope matches the heading of the magnetic compass .

The heading on the directional gyroscope can be increased by rotating the caging knob clockwise and decreased by rotating the caging knob counter-clockwise .

Once the correct heading has been set on the directional gyroscope , the caging knob can be released if it is spring loaded . If it is not spring loaded , it will have to be pulled back out again .

Chapter 12

MAGNETIC COMPASS

The property of magnetite that attracts the small pieces of iron is known as magnetism

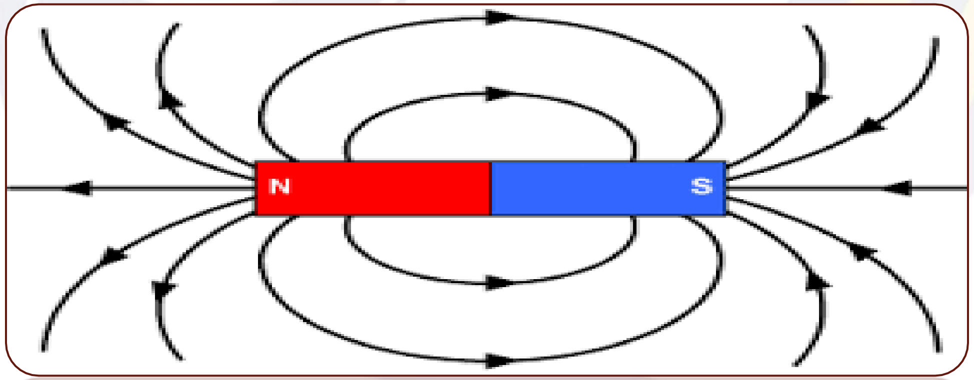
Any magnetized material which align itself in a roughly North-South direction is known as 'magnets'.

A compass is an instrument designed to indicate direction on the surface of the earth, relative to some known datum. The magnetic compass uses the horizontal component of the earth's field as its directional datum. Unfortunately, the earth's field is normally not aligned with the true meridian - the most desirable datum from which to measure direction.

The purpose of a magnetic 'steering' compass in an aircraft is to indicate heading, the direction in which the aircraft is pointing.

MAGNETIC FIELD

The field of a magnet is the space around it in which its magnetic influence is felt.



There are two basic types of direct reading magnetic compasses used in aircraft, **the vertical card** and, less commonly, **the grid ring compass**.

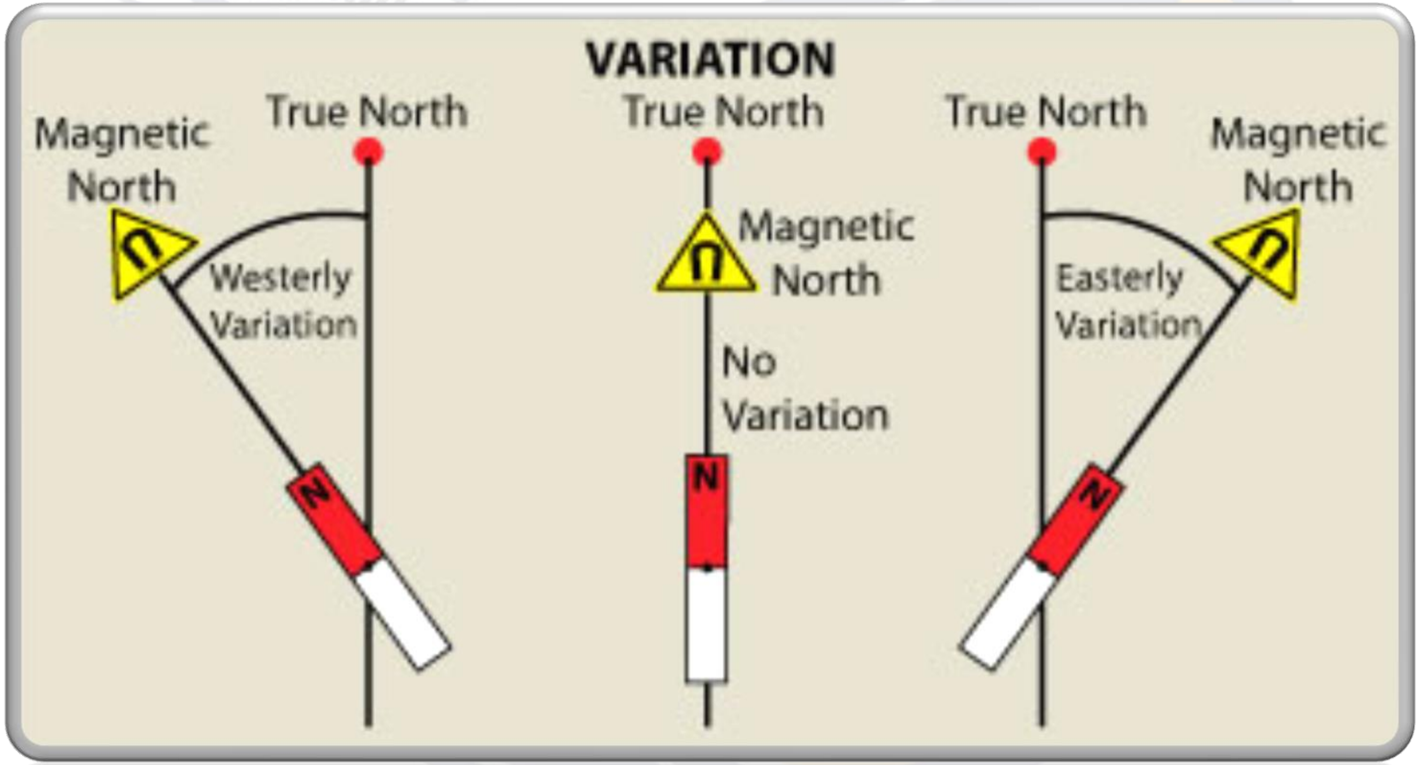
THE VERTICAL CARD COMPASS

The vertical card compass - which is also known as the B-type or E-type - is the direct reading compass in general use. It is usually the main magnetic heading reference in light aircraft and the standby compass in larger aircraft. It consists of a circular compass card attached directly to the magnet assembly. This combined unit is suspended in liquid within the compass bowl. A vertical lubber line on the glass window of the bowl, enables the heading to be read off the compass card.

The magnetic compass is a self contained unit which does not require electrical or suction power.

Variation

The angular difference between true and magnetic meridians is called the magnetic variation .

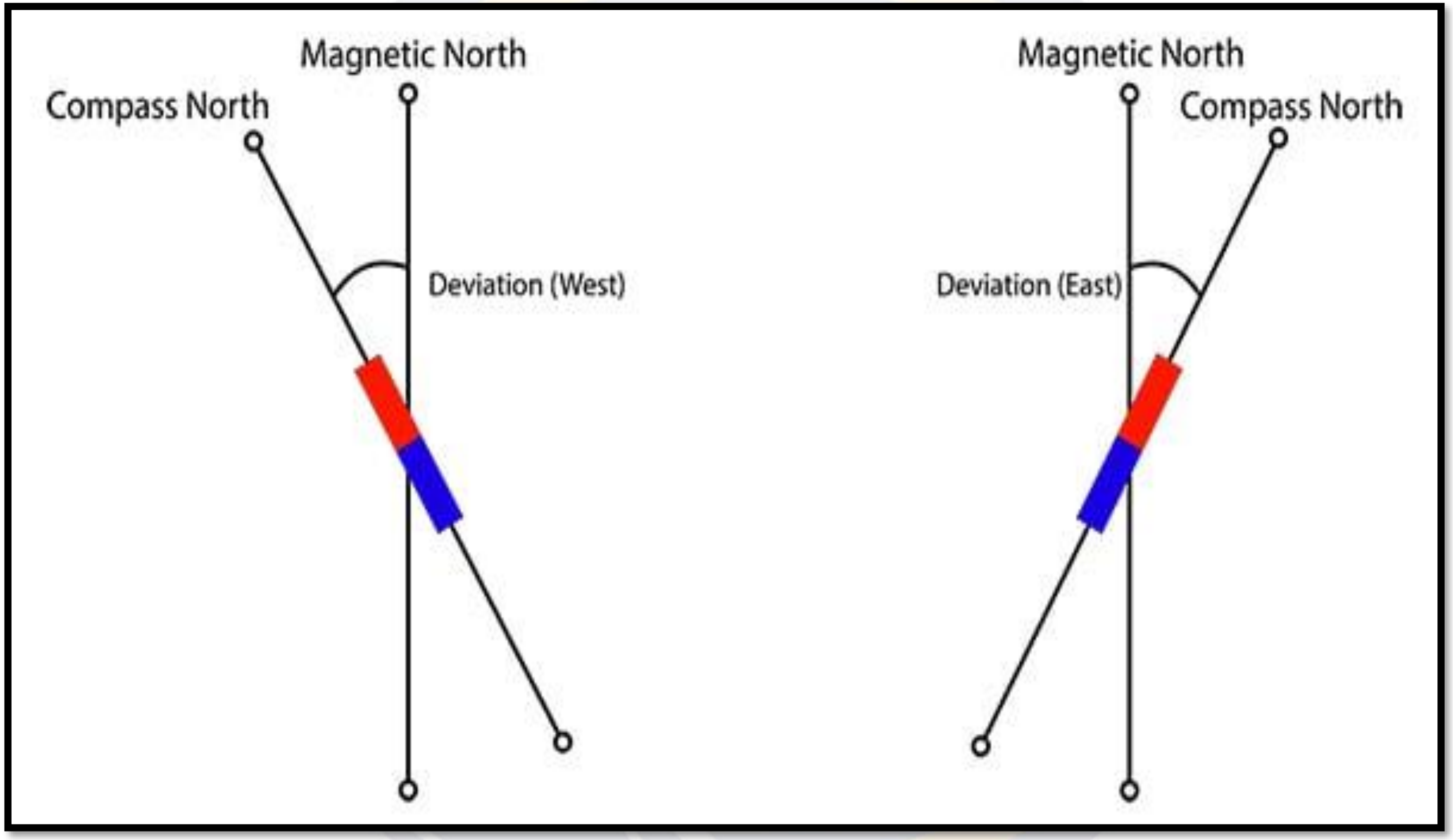


Deviation

- A magnetic compass error caused by local magnetic fields within the aircraft.

- Deviation error is different on each HEADING.

- In other words Magnetic deviation is the difference between the compass indications when installed in the aircraft compared to the indications when the compass is outside the aircraft (free from disturbing magnetic forces of the aircraft).


Magnetic North
Compass North
Deviation (West)
Magnetic North
Compass North
Deviation (East)

Deviation is produced by the iron/steel components in the aircraft. It is the angle between the local magnetic meridian and the direction in which the compass magnets are lying.

Deviation is named Easterly (or plus) if the North-seeking (red) ends of the magnets point to the East of magnetic North. If the North-seeking ends points to the West of magnetic North, deviation is said to be Westerly (or minus).

Deviation varies with heading so it has to be measured on a series of different headings. This is usually done by conducting a **compass swing** Once deviation has been reduced as far as possible, the residual deviation is recorded on a compass deviation card, which is located in the aircraft.

During the swing, normal flying conditions should be simulated as far as possible, with engines running, electrical / radio services switched on, and the aircraft in a level flight attitude.

It is obviously most important that no ferromagnetic objects such as tools, or watches should be placed near the compass as this would introduce unknown amounts of deviation. Furthermore, ferromagnetic payloads should be stowed as far away from the compass as permissible within the loading limits. With exceptionally large ferromagnetic loads, a compass swing may have to be carried out before flight with the load aboard


6 3 N 33
For N 30 60 E 120 150
Steer -1 +1 0 -1 +1 -1
For S 210 240 W 300 330
Steer -1 +1 -1 W -1 +1
AIRPATH

T rue V ariation M agnetic D eviation C ompass

W -

E +

°TRUE	VARN.	°MAG.	DEVN.	°COMP
260		291	3E	
	10W		1E	070
	7W	001	2E	
	17W		0	020
306	10E		1W	
036		031		033
	5E	025		023
359	3W		2E	
	23E		2W	221
312		322		319
002	3W		1W	
260		291	3W	
	5E		1E	070
	3W	001	2E	
022	10W		3W	035

°TRUE	VARN.	°MAG.	DEVN.	°COMP
260	**31W**	291	3E	**288**
061	10W	**071**	1E	070
354	7W	001	2E	**359**
003	17W	**020**	0	020
306	10E	**296**	1W	**297**
036	**5E**	031	**2W**	033
030	5E	025	**2E**	023
359	3W	**002**	2E	**000**
242	23E	**219**	2W	221
312	**10W**	322	**3E**	319
002	3W	**005**	1W	**006**
260	**31W**	291	3W	**294**
076	5E	**071**	1E	070
358	3W	001	2E	**359**
022	10W	**032**	3W	035

ACCELERATION AND TURNING ERRORS

Direct reading compasses are subject to large errors during linear acceleration or deceleration, or during a turn. Most manoeuvres which cause the centre of gravity of the magnet assembly to move away from its normal position, almost directly below the pivot, will produce an error. However, if the manoeuvre displaces the centre of gravity North or South of its usual position so that cg and pivot are still in the plane of the magnetic meridian, the magnet assembly merely changes its North-South tilt angle, with no rotation in azimuth and consequently no error.

Note : also that turning and acceleration errors only occur where there is a significant vertical component (Z) in the earth’s field, so that except for a small liquid swirl effect in turns, the errors are non-existent near the magnetic equator. The north seeking end of the compass magnet should remain pointing in the same direction Magnetic north- whether the aircraft is moving in a straight line or turning.

The size of the acceleration error depends on a number of factors which includes aircraft heading. Acceleration / deceleration errors are **maximum** on **East** and **West** (M) headings and **zero** on **North** and **South** (M) headings

Whenever the magnet assembly is displaced clockwise, the readings will decrease and the compass will under read.

Whenever the magnet assembly is displaced anti-clockwise, the readings will increase and the compass will over read.

TURNING ERRORS

Turning errors are maximum when turning through north and south, and ignoring liquid swirl zero when turning through east and west.

The basic theory of turning errors is much the same as that for linear acceleration errors . Due to the earth's vertical component of the magnetic field, Z, the compass's cg will be displaced from almost beneath the pivot point away from the nearer pole. In a turn, the aircraft accelerates towards the centre of the turn, and therefore an acceleration force acts through the pivot towards the centre of the turn, while the opposing centrifugal force due to inertia acts outward through the cg.

MAGNETIC DIP

Except near the ‘magnetic equator’, where the lines of force are parallel to the surface, one end of the freely-suspended magnet will dip below the horizontal, pointing to the nearer pole.

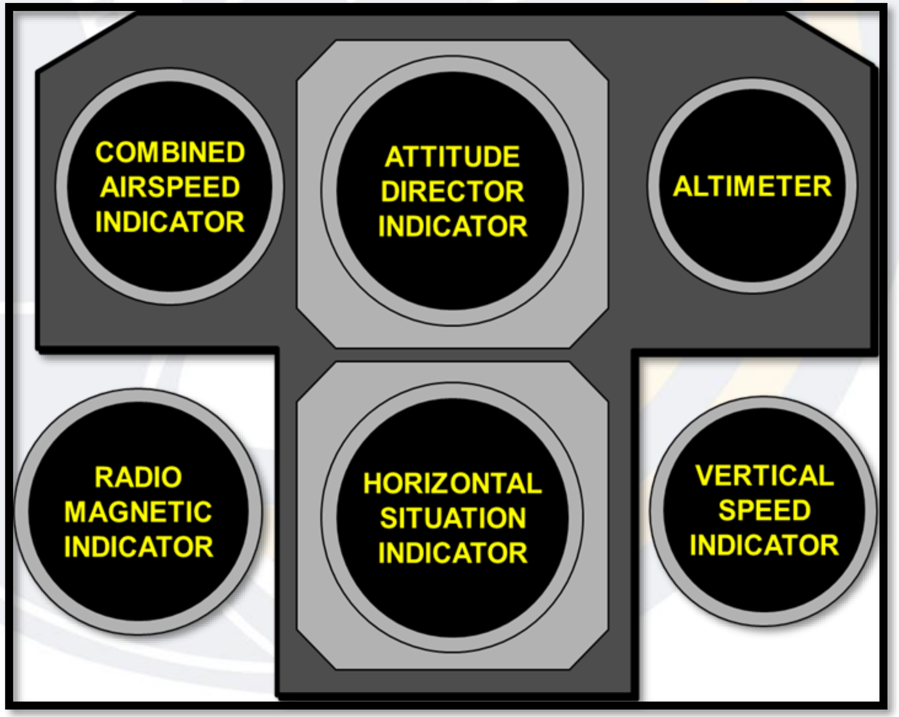
When the bar magnet contained in the compass is pulled by the earth's magnetic field, it tends to point north and somewhat downward.

The **downward pull , called magnetic dip**, Which is greatest near the poles and diminishes as you approach the equator.

If the freely-suspended magnet is moved either North or South of the magnetic equator the dip gradually increases, reaching about 66° in the United Kingdom. Over the earth's magnetic poles the dip is 90° and the magnet is then vertical.

Chapter 13

Instruments Arrangement




AIRSPEED
KNOTS
160
140
120
100
80
60
40
TURN COORDINATOR
2 MIN
VERTICAL SPEED
100 FEET PER MIN
rpm
x100
MANIFOLD
PRESSURE
IN Hg


AIRSPEED
KNOTS
ALT
VERTICAL SPEED
TURN COORDINATOR
L
R
2 MIN.

Part 2

Chapter 1

Autopilot System

The main purposes of an **automatic flight control system (AFCS)** are to enhance the functionality of the flight controls by artificially enhancing the stability characteristics of the aircraft and to reduce the workload of the flight crew. This results in pilots being more alert during the critical phase of flight.

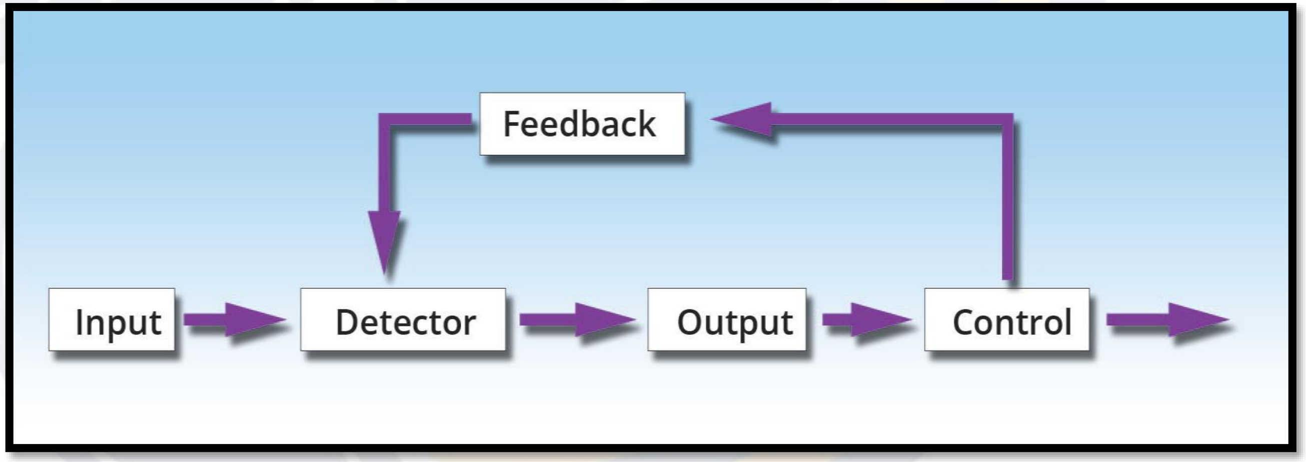
Autopilot systems also enable the aircraft to fly a direct route accurately due to the autopilots ability to react quicker than a human to disturbances.

flight crews of modern transport aircraft do not directly move the control surfaces of the aircraft whilst the autopilot is engaged, it is the autopilot system that moves the control surfaces of the aircraft after the flight crew initiate the instruction to the system via the movement of the flight controls or via the selection of an autopilot command on the mode control panel (mCP).

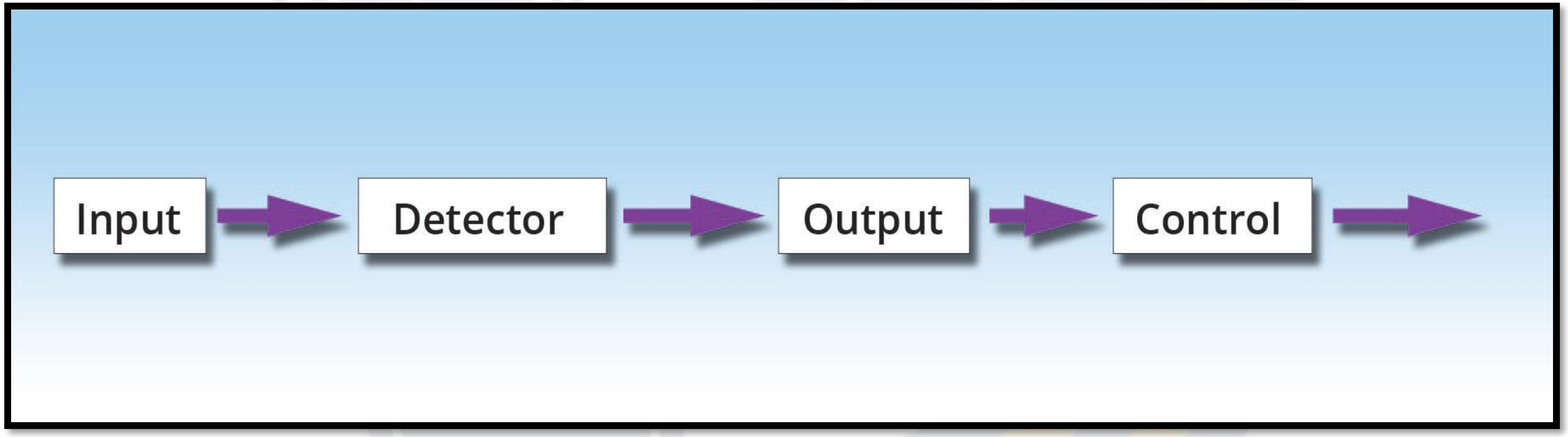
The AFCS also provides the pilot or the autopilot with flight path guidance via the **flight director** and the flight management computer. The guidance is in the form of pitch and roll commands that can be followed by aligning the pitch attitude of the aircraft with the flight director bars on the primary flight display.

An autopilot is a control system that uses control loops. The two types of control loops used in the AFCS are closed loops and open loops. With a closed-loop system, feedback from an action or state is compared to the desired action or state. With an open-loop system, no feedback is provided to the detector after a system input has been implemented.

Closed-loop control



Open-loop control



Air Data Computer (ADC)

In many large aircraft currently in service, the conventional pressure instruments which show altitude airspeed and mach number (Mmo) are replaced by indicators displaying information generated by a central computer the air data computer (ADC) .

The computer unit and displays together with the sensors of the basic data of pitot pressure, static pressure and air temperature, and a power-pack form the aircrafts air data system (ADS) .

ADS output's may also be used in the altitude transponders , flight data recorder navigation computer and more.

The standard ADS instruments show altitude, vertical speed, airspeed and Mmo. Additional instruments can display total air temperature (TAT) static air temperature (SAT) and TAS .

The air data computer in current aircraft is a device that uses analogue or digital computing techniques to convert pressure and temperature data into electrical signals which are transmitted to the display instruments and to other systems .

Advantages of an Air Data System

An ADS has certain advantages when compared with conventional mechanical instruments.

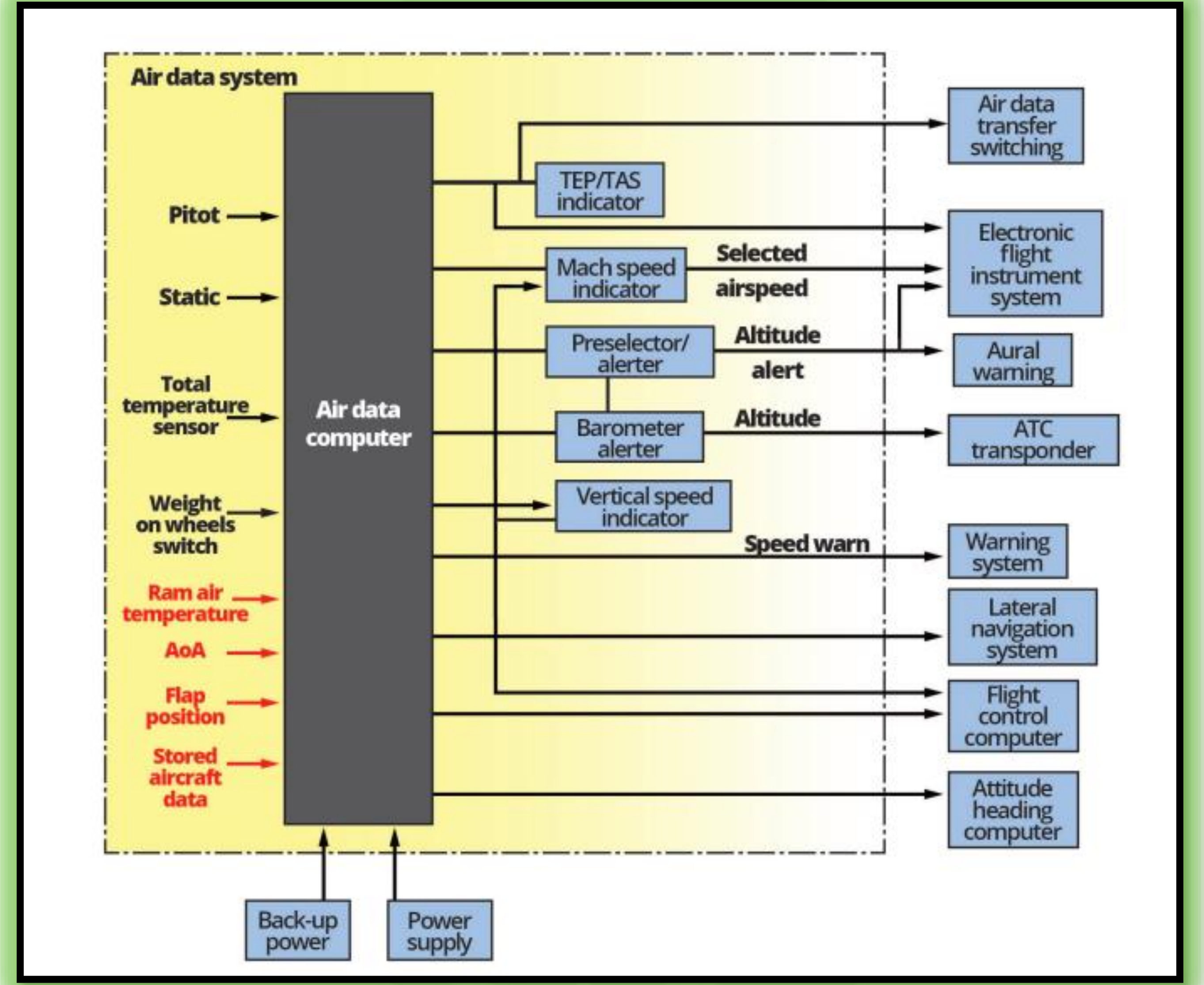
These advantages include the possibility of designing improved instrument display units, reduced instrument and lag errors, the capability to perform automatic error correction calculations, to serve as a central source of information for other systems, and the capability of being manufactured with a clean design.

ADC Input Data

- TAT
- Static pressure
- Total pressure
- Measured temperature
- AoA
- Flaps position
- Landing gear position
- Stored aircraft data

ADC Output Data

- IAS
- TAS
- SAT
- TAT
- Mach number
- AoA
- Altitude
- Vertical speed
- VMO/MMO pointers


Air data system
Pitot
Static
Total temperature sensor
Weight on wheels switch
Ram air temperature
AoA
Flap position
Stored aircraft data
Air data computer
TEP/TAS indicator
Mach speed indicator
Selected airspeed
Preselector/ alerter
Altitude alert
Barometer alerter
Altitude
Vertical speed indicator
Speed warn
Air data transfer switching
Electronic flight instrument system
Aural warning
ATC transponder
Warning system
Lateral navigation system
Flight control computer
Attitude heading computer
Back-up power
Power supply

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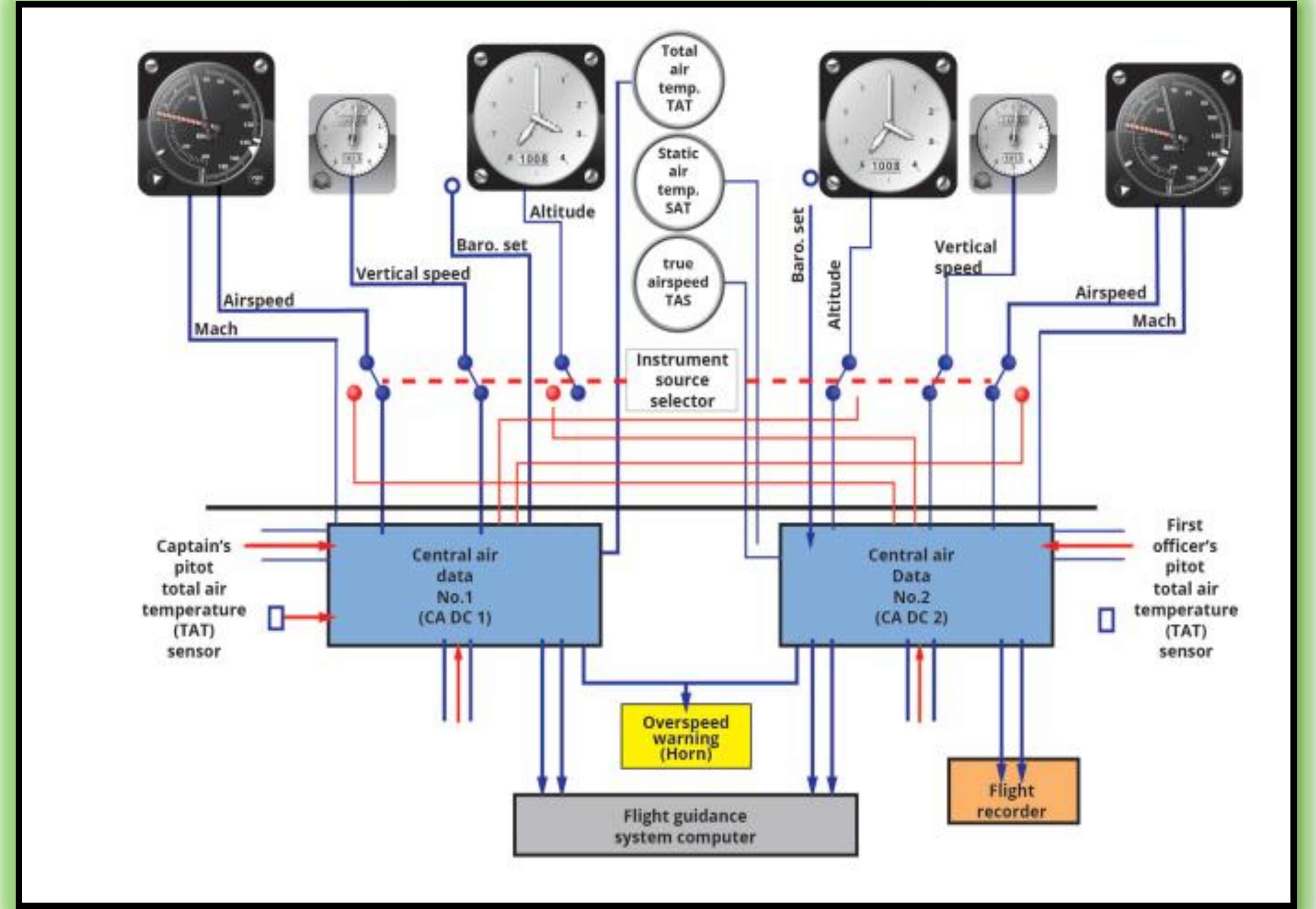


System Redundancy

Provision for blockages and/or failure of an A'C is made through changeover cocks that Permit an alternative static source to be connected to the computer or by the use of electrical switching that enables A'C cross feeding between captain and the first officer instruments.

In some aircraft the ADS is designed so that the outputs from each computer are not directed exclusively to instruments on one side of the panel. By mixing the sources of air data to each side, the possibility of an undetected malfunction is reduced.

In the event of total failure of both ADCs due perhaps to loss of power supply , the flight can be continued by reference to the standby instruments.

Loss of ADC

A comparison monitor can be incorporated to compare the outputs of the ADCs and to give automatic warning to the pilot of malfunction.

With a purely mechanical system, comparison between left-hand and right-hand instruments must be carried out visually.

A warning flag will appear on the appropriate ADS instrument if there is any loss of valid data or if an internal failure has occurred .

In addition, a light will illuminate either on the instrument warning panel or on the central warning system indicator.

Chapter 2

Machmeter

The machmeter uses two capsules and linkages to indicate the aircrafts true airspeed (TAS) as a proportion of the local speed of sound (LSS)

The first capsule is an airspeed capsule which will expand and contract as a result of changes in the dynamic pressure.

$$\text{Mach number} = \frac{TAS}{LSS}$$

The speed of sound is not constant but varies with air temperature. A formula for calculating the local speed of sound (LSS) is as follows.

$$LSS = 38.95\sqrt{T}$$

LSS is given in knots,

38.95 is a constant,

T is the absolute temperature, (0°C = 273°A = 273 K)

Therefore, the higher the air temperature, the higher the speed of sound and vice versa.

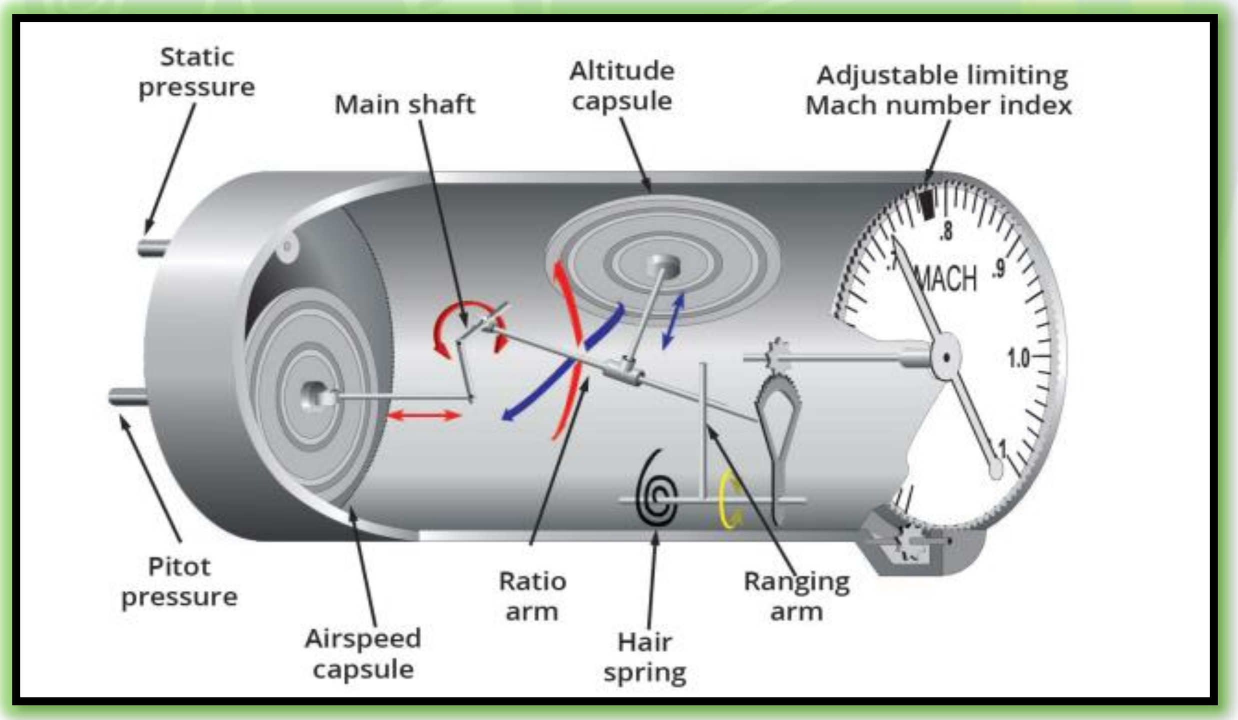
Since temperature normally reduces as altitude increases, the speed of sound normally reduces as altitude increases.

NOTE

In ISA conditions at mean sea level (+15 C) the speed of sound is knots while at 30,000 feet ISA (- 45 C) the speed of sound will have reduced to 589 knots.

In high-speed aircraft the Machmeter is an essential instrument. As an aircraft approaches the local speed of sound the airflow over some parts of the fuselage or wings may be accelerated up to the speed of sound and a shock wave will form. These shock waves cause more drag, less lift 0ach tuck buffeting and reduction in control effectiveness or loss of control. (Mach tuck is a downward-pitching sudden change of trim which can be severe).

In order to avoid danger associated with flight at high mach numbers a limiting mach number will be specified for each aircraft based on manufacturer flight trials. This must not be exceeded. It is known as MMO.




0
60
80
100
120
140
160
180
200
220
240
250
300
350
400
MACH
7 9 6
KNOTS
2 7 0

There are two types of Mach/airspeed indicator:

- A self-contained instrument fed from pitot and static sources
- A combined instrument fed from the Air data computer

- The airspeed pointer moves clockwise over a fixed scale.
- From M0.5 the Mach number is read off the same pointer as it moves over a moving Mach number scale.

Blockage or Leakage

Static Source Blocked

If a blockage occurs in a climb, the altitude capsule will not move. Assuming a constant IAS (and therefore a constant dynamic pressure) the airspeed capsule will contract as the static component of pitot pressure reduces. The machmeter will therefore under-read.

If a blockage occurs in a descent, at a constant IAS, the airspeed capsule will expand due to the increasing static component of pitot pressure. The machmeter will therefore over-read.

Pitot Source Blocked

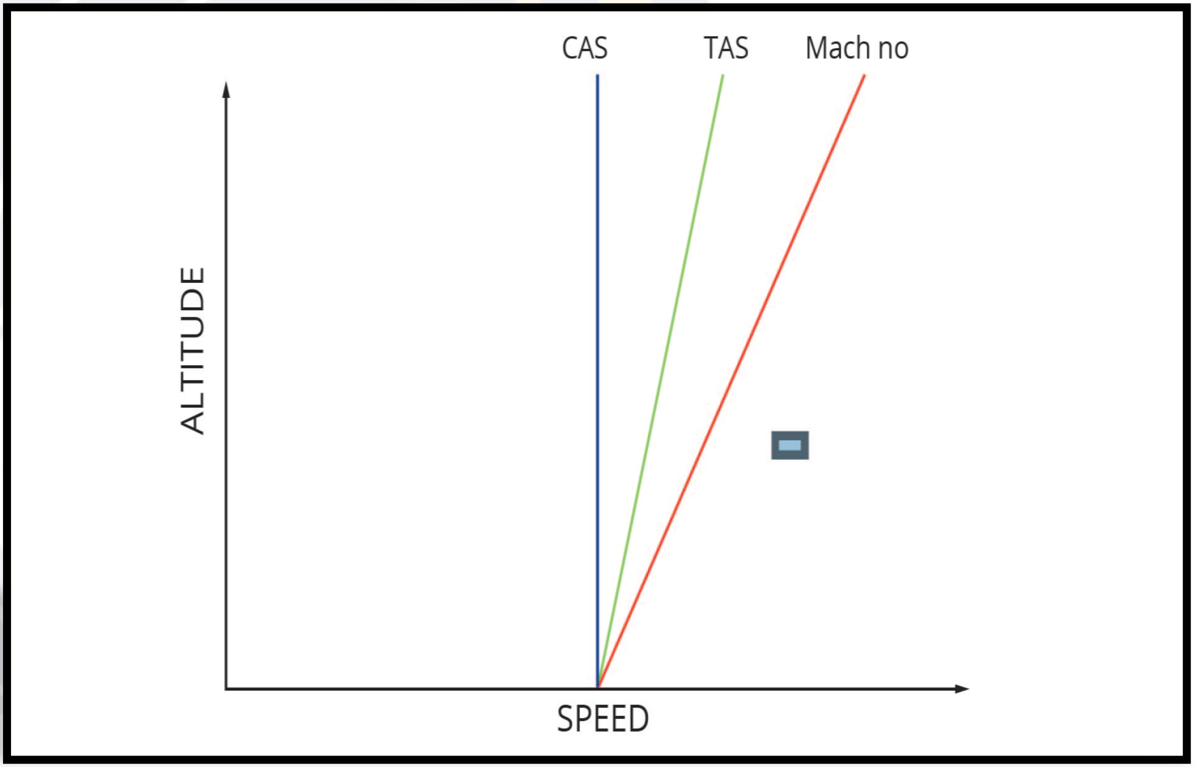
Assuming a climb or descent at a constant IAS (and therefore a constant dynamic pressure) the Machmeter will over-read in the climb and under-read in the descent.

In the climb the airspeed capsule will expand in error because the static component of pitot in the capsule will be greater than the static in the case. In the descent the static component of pitot will be too small and therefore the airspeed capsule will contract.

CAS, TAS and Mach Number

Climb at a Constant CAS in Standard (ISA) Atmosphere

Climbing at a constant CAS , the TAS and mach number will both increase (at the same rate).



Climb/Descent Summary

In summary

• TAS will always increase when an aeroplane climbs at a constant CAS.

• Climbing at a constant TAS the CAS will always reduce. This is because pressure has a greater effect on air density than temperature.

• Climbing at a constant CAS the Mach number will always increase.

• Climbing at a constant Mach number the CAS will always reduce. This is because the CAS/TAS density error dominates over the change in LSS due to temperature variation.

• While climbing at a constant Mach number, TAS decreases and CAS decreases more rapidly, the

LSS also decreases.

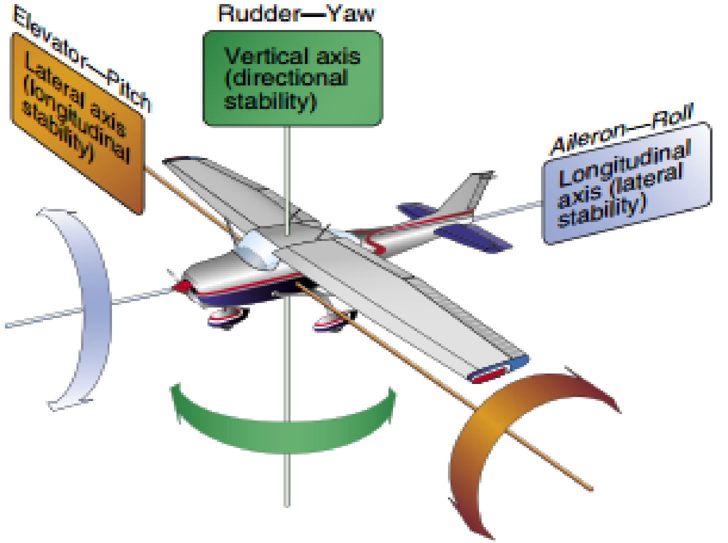
Chapter 3

Autopilot design and operation

An aircraft can be subjected to disturbances about its three control axes i.e. longitudinal, lateral, and vertical or normal. Stabilization must therefore be controlled about the same three axes.

Autopilot systems are broken down into three basic control channels:

- **Roll** to control the ailerons
- **Pitch** to control the elevators
- **Yaw** to control the rudder



Primary Control Surface	Airplane Movement	Axes of Rotation	Type of Stability
Aileron	Roll	Longitudinal	Lateral
Elevator/ Stabilator	Pitch	Lateral	Longitudinal
Rudder	Yaw	Vertical	Directional

Figure 5-4. *Airplane controls, movement, axes of rotation, and type of stability.*

Autopilot Types

The Single Axis System

A single axis attitude control system is normally limited to the roll axis only. At its most basic, the single axis system will only level the wings. The roll axis is known as the primary axis. This system is sometimes simply called a wing leveller.

The Two Axes System

A two axes control system controls the aircraft attitude in the roll and pitch axes. The pitch axis is known as the secondary axis.

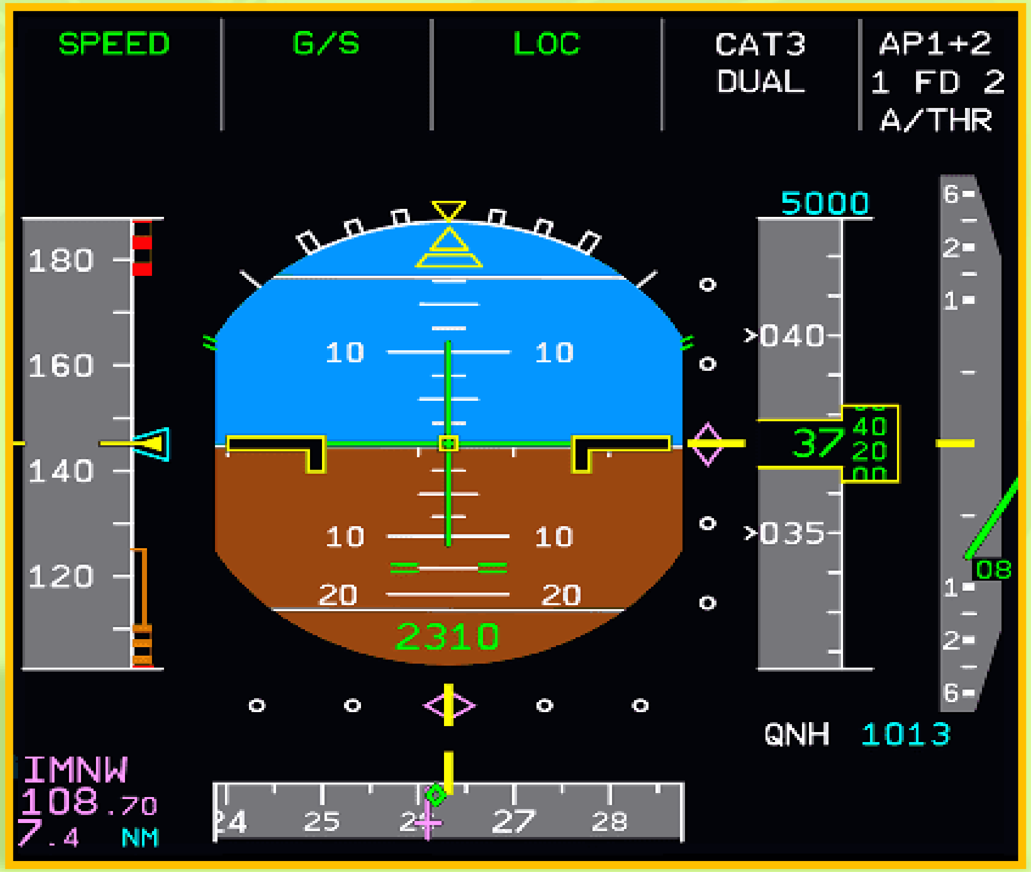
The Three Axes System

A three axes system provides attitude control in all three axes, roll, pitch, and yaw. The yaw axis is the third or tertiary axis.

- The roll and pitch channels are used as the primary control channels.
- The rudder channel is a stability channel.
- Three axis control is required for autoland.

The FMA is located at the top of the primary flight display (PFD) or electronic attitude director indicator (EADI). All autopilot mode selections that are made through the FCU/MCP will be displayed on the FMA so that pilots can be sure what autopilot modes have been selected.

The FCU (Airbus terminology) , and the MCP (Boeing terminology) .



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Actuators

Actuators produce the physical movement of the control surfaces and can be either :

- Electromechanical
- Electrohydraulic
- Pneumatic

Roll Channel

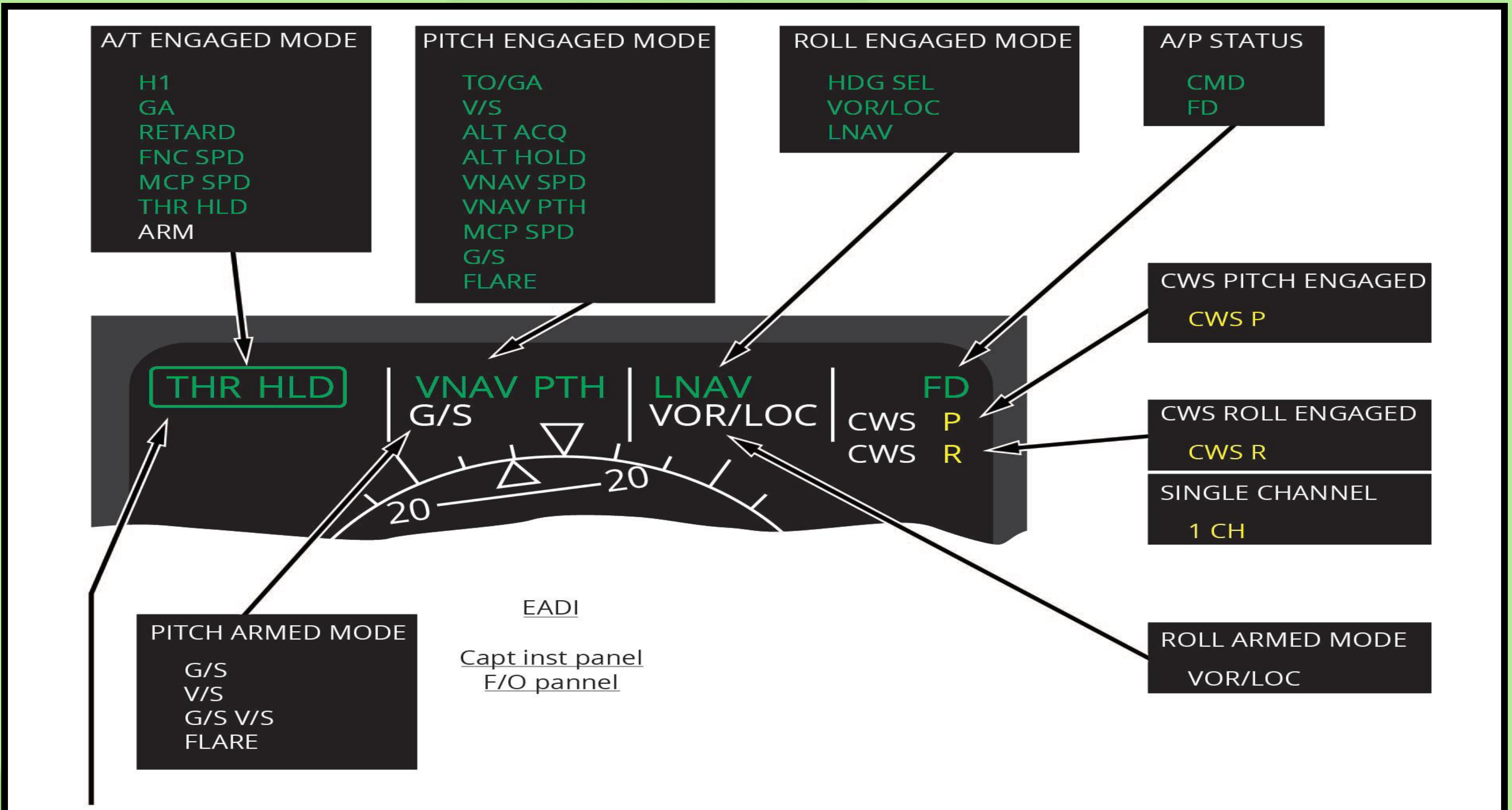
- Heading hold
- Heading select
- VOR intercept and track
- LOC intercept and track
- Inertial Nav or LNAV

Pitch Channel

- Altitude hold
- Speed hold
- Mach hold
- Vertical speed
- Flight path angle
- VNAV

NOTE

Illuminated switches aural warnings, and warning lights indicate whether an autopilot is engaged. They also provide warnings of autopilot disengagement, auto throttle disengagement, a failure to achieve target speed and an auto-trim failure.



Mode change highlight symbol

A mode change highlight symblol (rectangle) is drawn around each pitch, roll, CWS and thrust engaged mode annuntiation for a period of 10 seconds after each engagement.

Chapter 4

Lateral Modes

Lateral Modes

Heading Select and Hold

The heading select mode sends roll commands to turn the aircraft and maintain its heading shown in the MCP/FCU heading display. After mode engagement, roll commands are given to turn the aircraft in the same direction as the rotation selected on the heading selector. The bank angle limit is pre-determined by aircraft type and manufacturer.

The bank angle limit selector on the MCP/FCU is used to select the desired bank angle of the aircraft. Pressing the heading select switch on the MCP/FCU engages the heading select mode.

HDG SEL is subsequently annunciated on the AFDS. The HDG SEL mode automatically disengages upon capture of the selected radio course in the VOR LOC and APP modes.

VOR Localiser Tracking (VOR LOC) Mode

The VOR mode provides roll commands to capture and track the selected VOR course. The LOC mode provides roll commands to capture and track the selected localiser along the inbound front course bearing. Back-course tracking is not available.

Pressing the VOR LOC switch selects the VOR mode with a tuned VOR frequency , and it selects a LOC mode if a localiser frequency has been tuned. The VOR LOC switch will subsequently illuminate and VOR LOC armed will be annunciated on the EADI (electronic attitude direction indicator).

The selected course can be intercepted while engaged in LNAV , HDG SEL or CWS ROLL (control wheel steering) with an autopilot engaged in CMD . The capture point is variable and depends on intercept angle and closure rate. Localiser capture occurs not later than half a dot of deviation on the CDI. When within the course capture area , the VOR LOC annunciation changes from armed to captured and roll commands track the VOR or localiser course.

Tracking Through VOR Cone of Confusion

The cone of confusion is an area overhead a **VOR** navigation beacon where the signals are unusable. An aircraft transiting the VOR will therefore receive no usable signals for a period that will depend on its ground speed and altitude.

As the aircraft approaches the VOR the radials converge , and the course deviation indicator becomes more sensitive. At some point, before the aircraft enters the cone of confusion, the information from the selected inbound radial becomes unusable due to the radial convergence.

At this point the VOR signals are cut off by the over station sensing circuits. Subsequently , the roll channel automatically de-couples from the radio beam and controls the aircraft via the drift corrected heading that occurred when the radio signals were de-coupled. The autopilot therefore enters a heading hold mode for a set period of time.

It reverts back to the VOR mode when the received signals become reliable again. Note that the auto pilot does not revert to a heading select mode , it reverts to a heading hold mode that remains annunciated as a VOR mode.

Lateral Navigation (LNAV)

In the **LNAV** mode , the FMC (flight management computer) controls the AFDS roll function in order to intercept and track the active FMC route. The desired route is activated and modified through the FMC CDUs. In addition to en-route guidance , the active routes can include terminal procedures such as SIDs , STARs and instrument approaches.

Engagement criteria must be met to use LNAV. There must be an active route in the FMC ,capture criteria must be satisfied , and the LNAV switch must be pressed.

LNAV capture criteria is divided into 2 categories. Firstly , any aeroplane satisfies capture criteria when within 3 NM of the active route segment. Secondly , outside of 3 NM the aeroplane must be on an intercept course of 90 degrees or less and intercept the active route segment before the active waypoint.

LNAV will automatically disconnect for several reasons. It will disconnect upon reaching the end of the active route, or upon entering a route discontinuity. Additionally, it will disconnect upon either intercepting or missing the intercept of an inbound approach path track. Finally, either loss of capture criteria or by engaging HDG SEL will disconnect LNAV.

The autopilot must be capable of manoeuvring the aircraft logically and safely in a similar manner to the way a human pilot should.

This means that the autopilot must not exceed aircraft limitations in terms of speed, load factor, pitch, and bank limits, etc. The autopilot should, However, be able to use a satisfactory amount of the aircraft’s performance for timely execution of required demands.

Chapter 5

Vertical Modes

Vertical Modes

The altitude hold mode provides pitch commands to hold the MCP selected altitude or the uncorrected barometric altitude at which the ALT HOLD switch was pressed. ALT HOLD engages in either of the following conditions.

ALT HOLLD at the MCP selected altitude. This is indicated by the annunciation of ALT HOLD and of the ALT HOLD switch light being off.

ALT HOLD is inhibited after glide slope capture. When in ALT HOLD at the selected altitude , LVL CHG , V/S and VNAV climb and descend functions are inhibited until a new altitude is selected.

IAS/Mach Hold (SPD)

This will hold a selected IAS or Mach No. by comparing the selected value with the actual value from the ADC and pitching the aircraft up or down to decrease or increase the speed of the aircraft.

Vertical Speed (V/S)

The V/S mode provides pitch commands to hold the selected vertical speed and engages the auto throttle in the SPEED mode to hold the MCP selected airspeed. The V/S mode has both an armed and an engaged state.

Pressing the V/S switch engages the V/S mode unless the ALT HOLD mode has been engaged or after the glide slope has been captured.

V/S engaged is annunciated, the vertical speed display changes from blank to the pre-set vertical speed. Desired vertical speeds can be selected with the vertical speed thumb-wheel.

Flight Path Angle (FPA)

When engaged in the FPA mode, the elevator of the aircraft is adjusted to maintain the lateral trajectories of the aircraft. The FPA may be also used during non-precision instrument approaches. The flight path vector (FPV) indicates the flight path angle (FPA) and track (TRK) flown by the aircraft.

This helps the pilot maintain stabilized flight path sectors. The FPV is particularly useful while the aircraft is on final approach for landing.

The FPV can be used with or without the flight path director (FPD) being active. The FPD is a variation of the flight director system whereby a single command bar displays the desired FPA and bank angle on the electronic attitude direction indicator (EADI). The FPD was designed to be exclusively used in conjunction with the FPV.

Level Change Mode (LVL CHG)

The LVL CHG mode co-ordinates pitch and thrust commands to make automatic climbs and descents to preselected altitude at selected airspeeds. LVL CHG climbs or descents are initiated by selecting a new altitude and engaging the LVL CHG mode.

During LVL CHG climbs, the annunciations are MCP SPD for pitch and N1 for the auto throttle (A/T). During LVL CHG descents, the annunciations are MCP SPD for pitch and RETARD for the A/T while reducing the thrust to idle.

When at idle thrust , ARM is annunciated for the A/T. If a speed mode was active prior to engaging the LVL CHG mode , the previously selected speed will be retained as the target speed. If the LVL CHG mode is engaged with no active speed mode, the IAS/Mach display and airspeed cursors synchronize to the existing speed and this becomes the LVL CHG target speed. After the LVL CHG mode has been engaged , the target speed can be altered by the speed selector on the MCP.

Vertical Navigation Mode (VNAV)

With the **VNAV** mode engaged , the FMC commands AFDS pitch and A/T channels to fly the pre-selected vertical profile from the FMC CDUs. The profile includes preselected climbs , cruise altitudes , speeds , descents , and it can also include altitude constraints at specified waypoints.

By pressing the VNAV switch , the VNAV mode is selected if the FMC performance initialization was previously completed.

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During a VNAV path descent , VNAV remains engaged until :

- glideslope capture, or
- another pitch mode is selected, or
- Flaps are extended beyond 15 degrees or
- LNAV is disengaged before glide slope capture.
- appropriate MCP altitude selections ensure correct altitude alerting.

Chapter 6

Mixed Modes

APP Mode

Approach (APP) mode allows the localiser and glide slope elements of the ILS system to be coupled to the roll and pitch channels of the autopilot. This enables automatic control of the aircraft down to the decision height, or even to execute a fully automatic landing.

Auto land

Roll Channel	Pitch Channel	Yaw Channel
Localizer	Glide slope	Runway align
Roll-out	Flare	Roll-out

Autopilot in Operation

The modes of operation of the autopilot during the various flight phases can be seen from the following table:

Phase	Roll	Pitch	Autothrottle
Take-off	TOGA	TOGA	THR REF
Climb	LNAV, HDG or VOR	FLCH SPD, VNAV or V/S	THR REF, SPD or MACH
Cruise	LNAV, HDG or VOR	ALT HOLD, VNAV	SPD or MACH
Descent	LNAV, HDG or VOR	FLCH SPD, VNAV or V/S	THR REF, SPD or MACH
Approach	LNAV, HDG or LOC	ALT, G/S, FLARE	SPD
Land	Roll-out		
Go-around	TOGA	TOGA	THR REF

Configurations

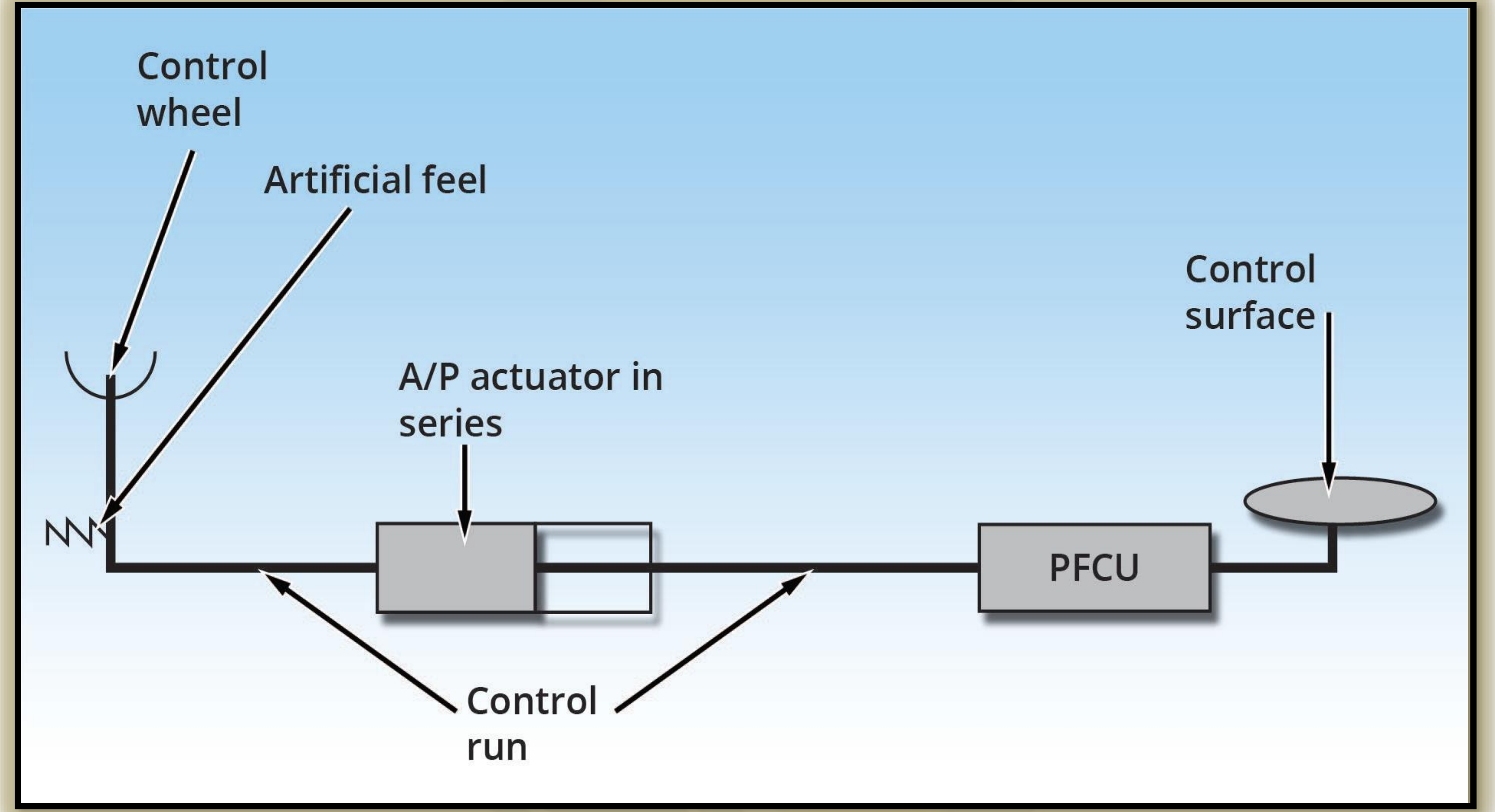
There are two types of configuration in which actuators are connected to the flight controls these are known as parallel and series configurations.

Parallel

The actuator produces the movement of the control surface as well as providing feedback to the control stick, i.e., the stick will move when the autopilot operates the control surfaces.

Series

The actuator moves the control surface but not the control stick. As a result of this , the flight crew may potentially experience a sensory decline when manually manipulating the flight controls of the aircraft.


Control
wheel
Artificial feel
A/P actuator in
series
Control
surface
PFCU
Control
run

Parameter selections common to both FCCs for speed, heading, altitude and vertical speed are made from the MCP.

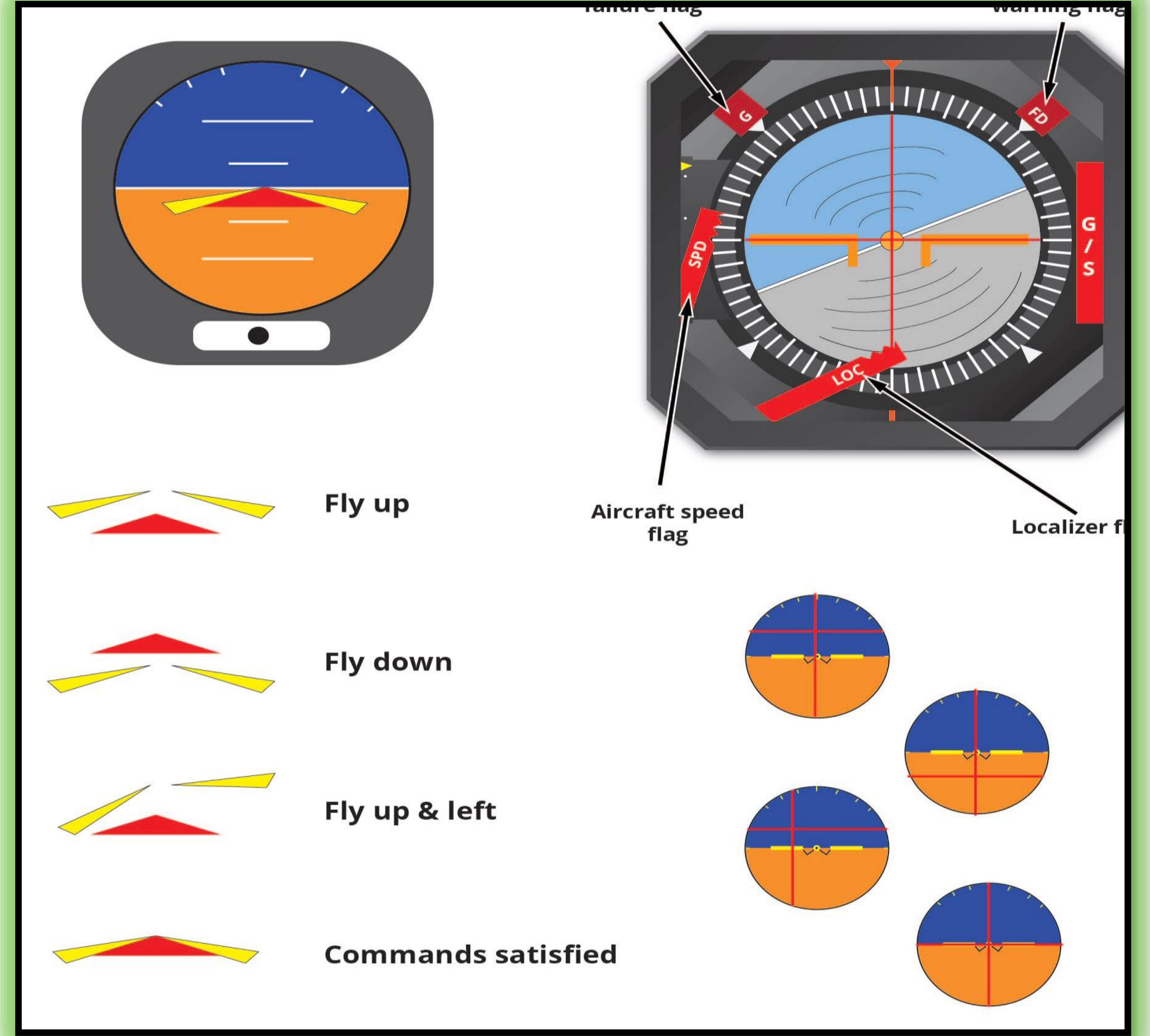
Chapter 7

Flight Director System (FDS)

The flight director system (FDS) was originally developed as an aid that was used by pilots during the approach and landing phase of a flight.

The FDS reduces the workload of pilots by computing and indicating the required direction and magnitude of control inputs to achieve the correct attitude to follow a specific trajectory.

Signals produced by the FDS can be coupled to the autopilot, allowing it to perform more complex tasks.


G
FD
SPD
G/S
LOC
Aircraft speed flag
Fly up
Fly down
Fly up & left
Commands satisfied

Flight Director vs Autopilot

The main difference between the FDS and the autopilot is that the FDS only provides control and guidance commands to the pilot or the autopilot.

Unlike the autopilot, it never physically manipulates the control surfaces of the aircraft. The FDS can however provide an accurate means of cross-checking the control/guidance commands that are sent to the autopilot.

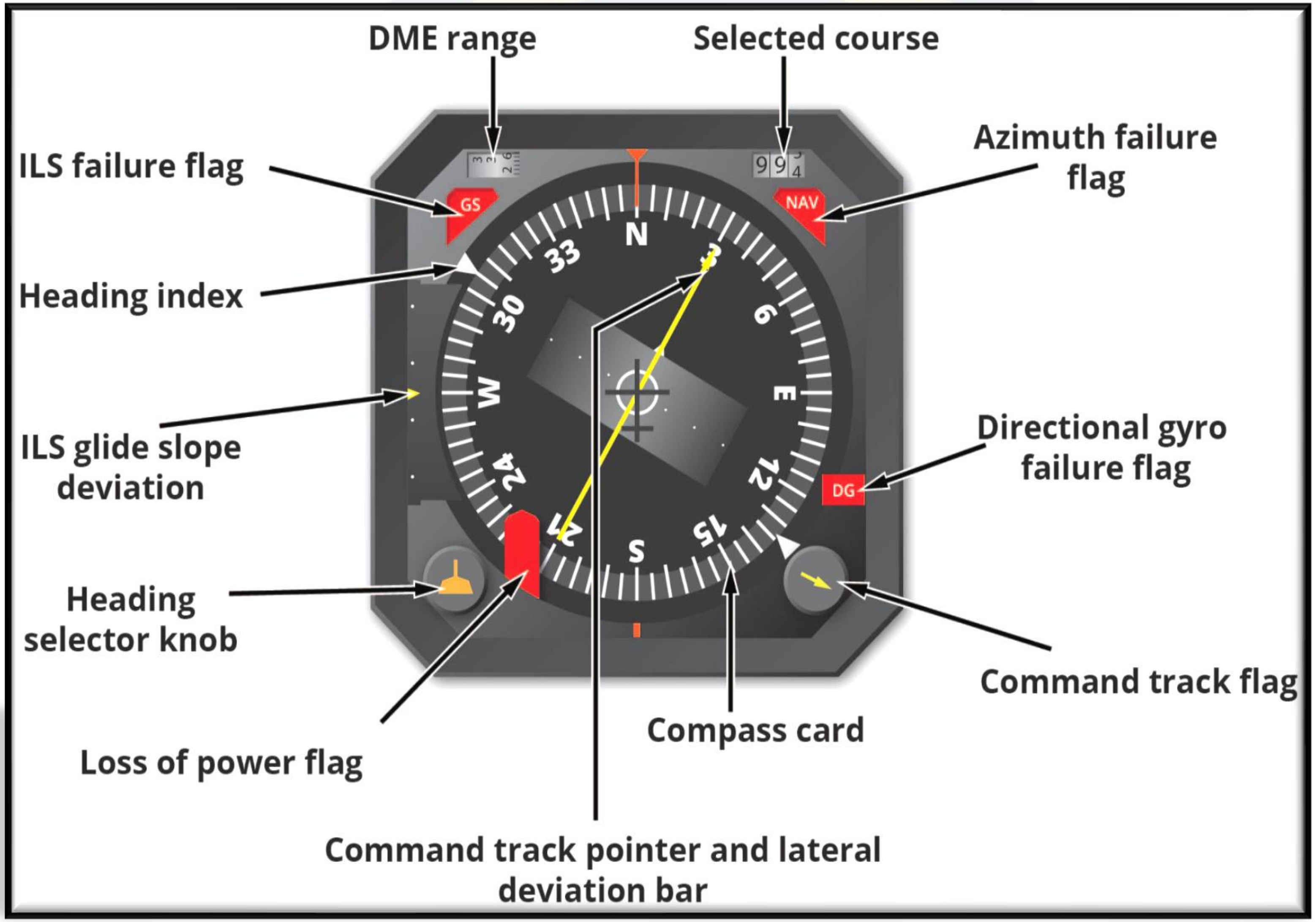
For example, if the FDS commands the autopilot to pitch the aircraft upwards and the autopilot pitches the aircraft downwards, then there is a system integration error.

Electronic Horizontal Situation Indicator (EHSI)

An **HSI** is a gyro-magnetic compass display with a **course deviation indicator (CDI)** bar, a series of dots representing deviation in degrees , a TO/FROM pointer , a selected course window , a DME range display, and a heading bug.

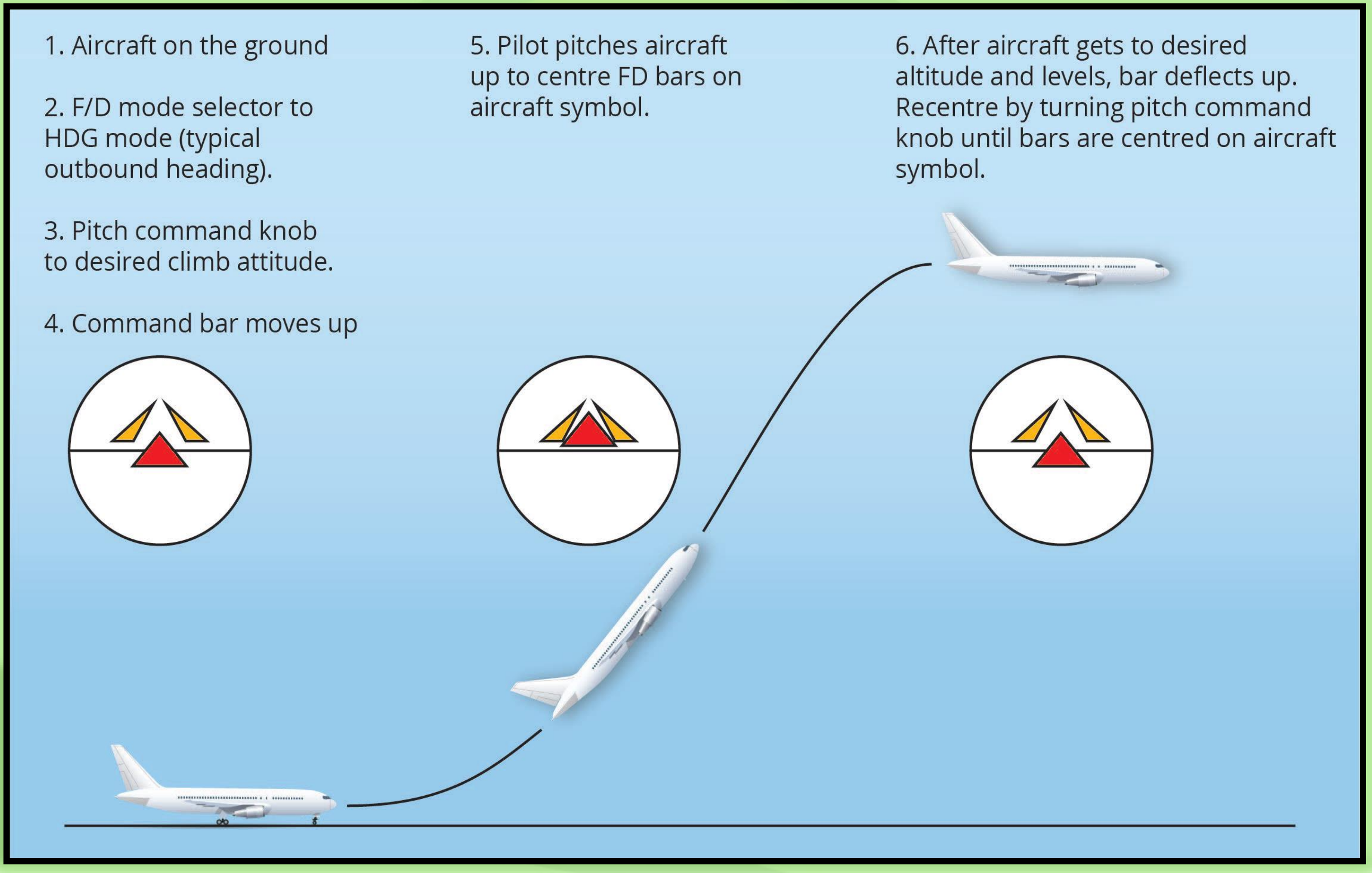
In older systems the course selection is done directly on the HSI using an attached knob. The EHSI that we will refer to uses a remote centralized FD mode control and AP panel called the auto-flight mode control panel (AMCP or simply MCP).

HSI display



DME range
Selected course
ILS failure flag
Azimuth failure flag
Heading index
ILS glide slope deviation
Directional gyro failure flag
Heading selector knob
Command track flag
Compass card
Loss of power flag
Command track pointer and lateral deviation bar
GS
NAV
DG
N
33
30
W
24
21
S
15
12
E
6
3

Electronic horizontal situation indicator (EHSI)


1. Aircraft on the ground
2. F/D mode selector to HDG mode (typical outbound heading).
3. Pitch command knob to desired climb attitude.
4. Command bar moves up
5. Pilot pitches aircraft up to centre FD bars on aircraft symbol.
6. After aircraft gets to desired altitude and levels, bar deflects up. Recentre by turning pitch command knob until bars are centred on aircraft symbol.

Chapter 8

Auto land

The auto land system was designed so that pilots can conduct a fully automated landing that allows for operations with much lower weather minima.

For an auto land to be conducted , the aircraft to which the system is fitted must be equipped with two independent autopilots and flight director systems capable of following ILS signals , an auto-thrust system, two independent radio altimeters to give accurate height from the ground Information , ILS receivers for both the flight crew , and the required ILS ground installation at the airport where the automatic landing is being conducted.

The Fail-Passive Automatic Landing System

A **fail-passive** (also known as fail-soft) **automatic landing system** is defined as the capability of the system to withstand a failure without endangering passenger safety, and without producing excessive deviations in the flight path but removing its capability to complete an automatic landing.

The minimum number of autopilots required for fail-passive capability is two.

The Fail-Operational Automatic Landing System

A **fail-operational** (also known as fail - active) **automatic landing system** is defined as the capability of a system to withstand a failure without affecting the overall functioning of the system and without causing degradation of performance beyond the limits required for an automatic landing.

The system requires a minimum of three autopilots.

Radio Altimeter

Essential height information for vertical guidance to touchdown is always provided by signals from a radio altimeter that becomes active as soon as the aircraft's height above the ground is within the altimeter's operating range (typically 2,500 feet).

Chapter 10

Instrument Landing System (ILS)

The Instrument Landing System (ILS)

An **instrument landing system (ILS)** is a short-range navigational aid that provides azimuth and vertical guidance during the approach to an airport runway. The system comprises ground based transmitting elements. Receiving elements are carried on board the aircraft.

The ground-based elements are:

- A localiser transmitter that sends runway azimuth approach information
- A glideslope transmitter that provides vertical approach information
- Marker beacons that transmit information about the distance to the runway threshold

The airborne elements are:

- A localiser signal receiving antenna
- A glideslope signal receiving antenna
- A dual ILS receiver installation
- An indicator that shows whether the aircraft is on the correct approach path
- A marker beacon antenna and receiver
- Marker lights on the main instrument panel

Category of Operation

Category 1

A precision instrument approach and landing with a decision height no lower than 60 m (200 ft) and with either a visibility not less than 800 m or a runway visual range not less than 550 m

Category 2

A precision instrument approach and landing with decision height lower than 200 ft but not lower than 100 ft, and a runway visual range not less than 300 m.

Category 3A

A precision instrument approach and landing with a decision height lower than 100 ft and a runway visual range not less than 200 m.

Category 3B

A precision instrument approach and landing with a decision height, if any, lower than 50 ft and

a runway visual range less than 200 m but not less than 75 m.

Category 3C

To and along the surface of the runway and taxiways without external visual reference.

Decision Height (DH)

This is the wheel height above the runway elevation at which a go-around must be initiated by the pilot if the required visual reference to the runway has not been established.

Minimum values of DH and RVR are known as weather minima and they are specified by the national licensing authorities for various types of aircraft and airports. When traffic controllers advise that the RVR is above the specified minimum , pilots may descend to the specified decision height.

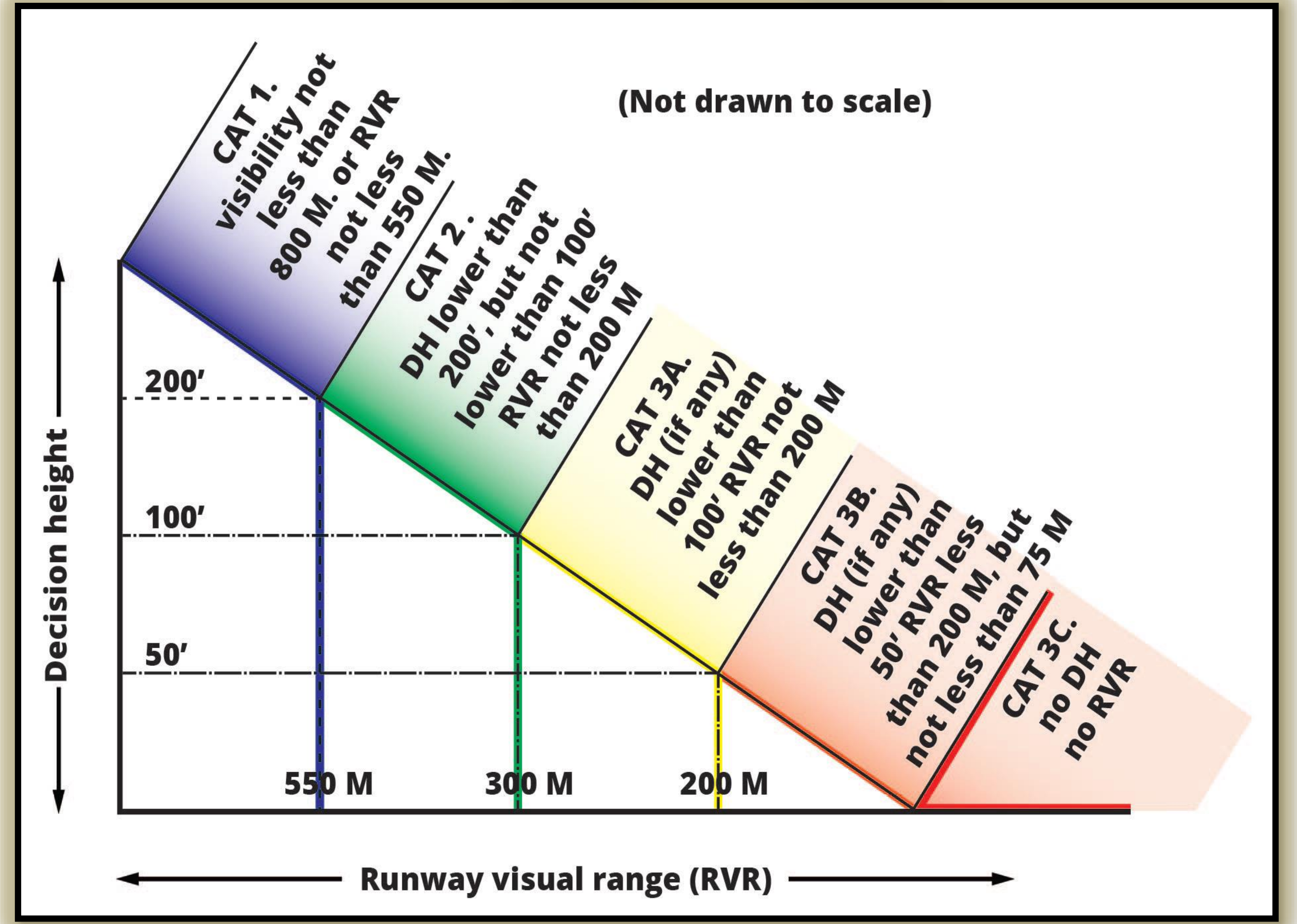
If by then they have visually established a sufficiently large segment of the ground to enable them to be confident of their judgement , they may commence the approach for landing. Pilots must otherwise overshoot, and either enter a holding pattern pending another approach, or divert to an alternative airport.

During the approach , the pilot’s line of sight is down the glide path and not along the runway. This gives rise to another factor called slant visual range. Pilots must consider this in order to avoid misinterpreting visual cues.

Runway Visual Range (RVR)

This is an instrumentally derived value that represents the range at which high-intensity lights can be seen in the direction of landing along the runway.

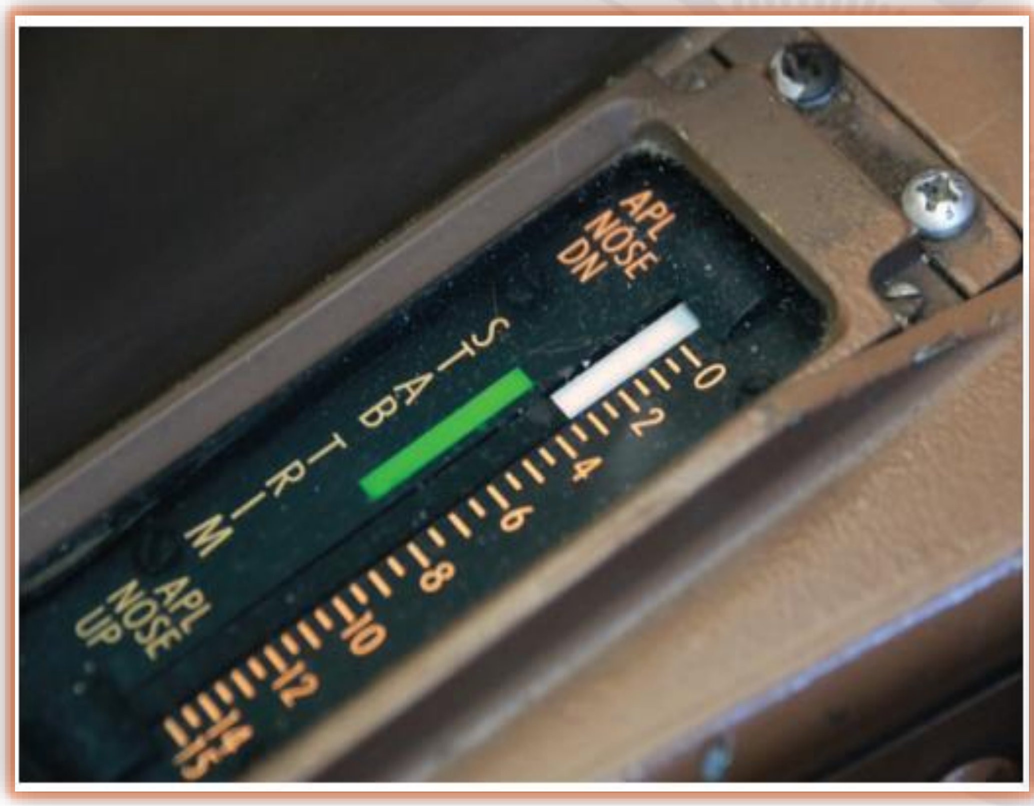
The measurements are transmitted to the air traffic controller who can inform the pilot of the very latest visibility conditions.


(Not drawn to scale)
CAT 1. visibility not less than 800 M. or RVR not less than 550 M.
CAT 2. DH lower than 200', but not lower than 100' RVR not less than 200 M
CAT 3A. DH (if any) lower than 100' RVR not less than 200 M
CAT 3B. DH (if any) lower than 50' RVR less than 200 M, but not less than 75 M
CAT 3C. no DH no RVR
200'
100'
50'
550 M
300 M
200 M
Decision height
Runway visual range (RVR)

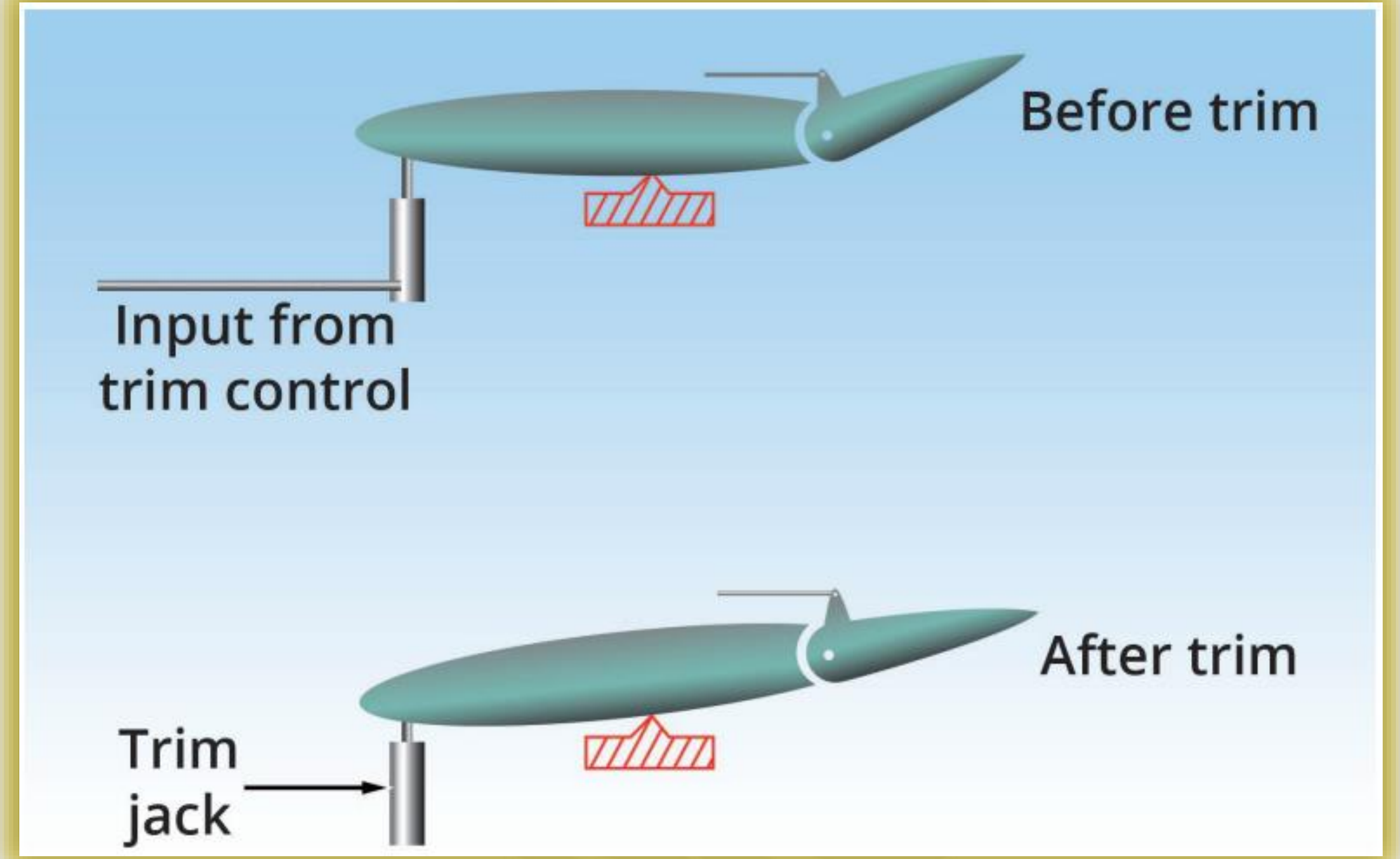
Chapter 11

Trims - Yaw Damper

The purpose of the trim system is to adjust the aerodynamic forces on the control surfaces so that the aircraft maintains the set attitude without any control input from the pilot or auto-pilot. In manual control, trim on light aircraft is provided in all three axes through mechanical linkages to trim tabs on the control surfaces.



The green area on the scale of the trim indicator represents the takeoff trim range. An aural alert will sound if takeoff is attempted with the stabiliser outside of the takeoff trim range.


Before trim
Input from
trim control
After trim
Trim
jack

Mach Trim

Mach trim operates independently of the autopilot. A Mach-trim system is provided in aeroplanes that fly at high subsonic speeds and are susceptible to Mach tuck.

As the aeroplane approaches its critical Mach number, the centre of pressure moves aft resulting in a nose down attitude called Mach tuck. This condition is automatically trimmed out by the Mach-trim system. The Mach-trim system is armed at all stages of flight but will only activate at high subsonic speeds.

Fly-by-Wire

Fly-by-wire aeroplanes function differently to conventional aeroplanes in that the pilot or autopilot input is implemented via a flight control computer.

The computer translates this input into an aircraft attitude using all three axes that it maintains until another input is made. Even if configuration , thrust or speed changes are made , which would affect the pitch attitude of the Aeroplane , the flight control computer will maintain the aircraft attitude selected , regardless of inputs made on the aircrafts pitch attitude.

Yaw Damper

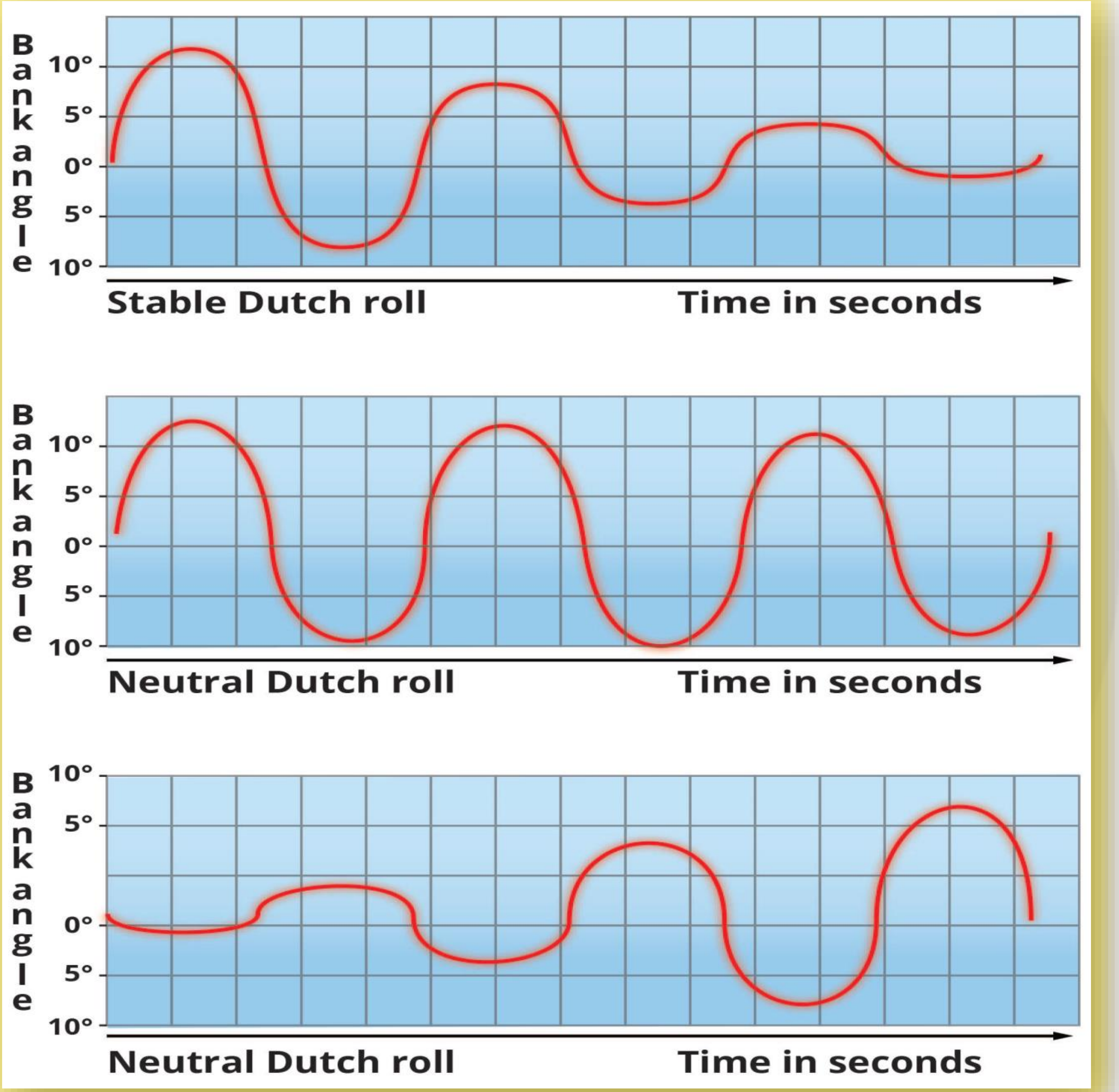
The purpose of the **yaw-damper system** is to prevent **Dutch roll.** Dutch roll results from the interaction between lateral stability around the longitudinal axis and longitudinal stability around the vertical axis of an aircraft in flight. An aircraft with excessive lateral stability will have poor directional stability , and therefore , it will be susceptible to Dutch roll.

A disturbance of an aircraft in yaw results in a secondary disturbance in roll and vice versa. Stability is an aircraft's tendency to resist a disturbance and return to the same conditions that existed before the disturbance occurred. If the lateral stability of an aircraft is greater than its directional stability , then Dutch roll will occur.

Consider an aircraft that has been disturbed by a gust causing it to yaw. As the aircraft yaws, one wing will travel slightly faster through the air and the other wing will travel slightly slower.

The faster moving wing will produce slightly more lift than before, and the slower wing will produce slightly less. This will cause the aircraft to roll.

As lift increases, so will lift induced drag. Therefore the higher, faster moving wing will produce more drag, and the lower slower moving wing will produce less. This causes a yawing moment in the opposite direction to the initial disturbance.


Bank angle
10°
5°
0°
5°
10°
Stable Dutch roll
Time in seconds
Bank angle
10°
5°
0°
5°
10°
Neutral Dutch roll
Time in seconds
Bank angle
10°
5°
0°
5°
10°
Neutral Dutch roll
Time in seconds

Chapter 12

Auto thrust System

An **autothrottle (A/T)** system is a computer controlled, electromechanical system capable of controlling the thrust of an aircraft’s engines within precise design parameters.

The throttle position of each engine is controlled to maintain a specific value of thrust in terms of :

- Fan speed (N1)
- Engine pressure ratio (EPR) or
- Target airspeed (set by SPD on mode control panel)

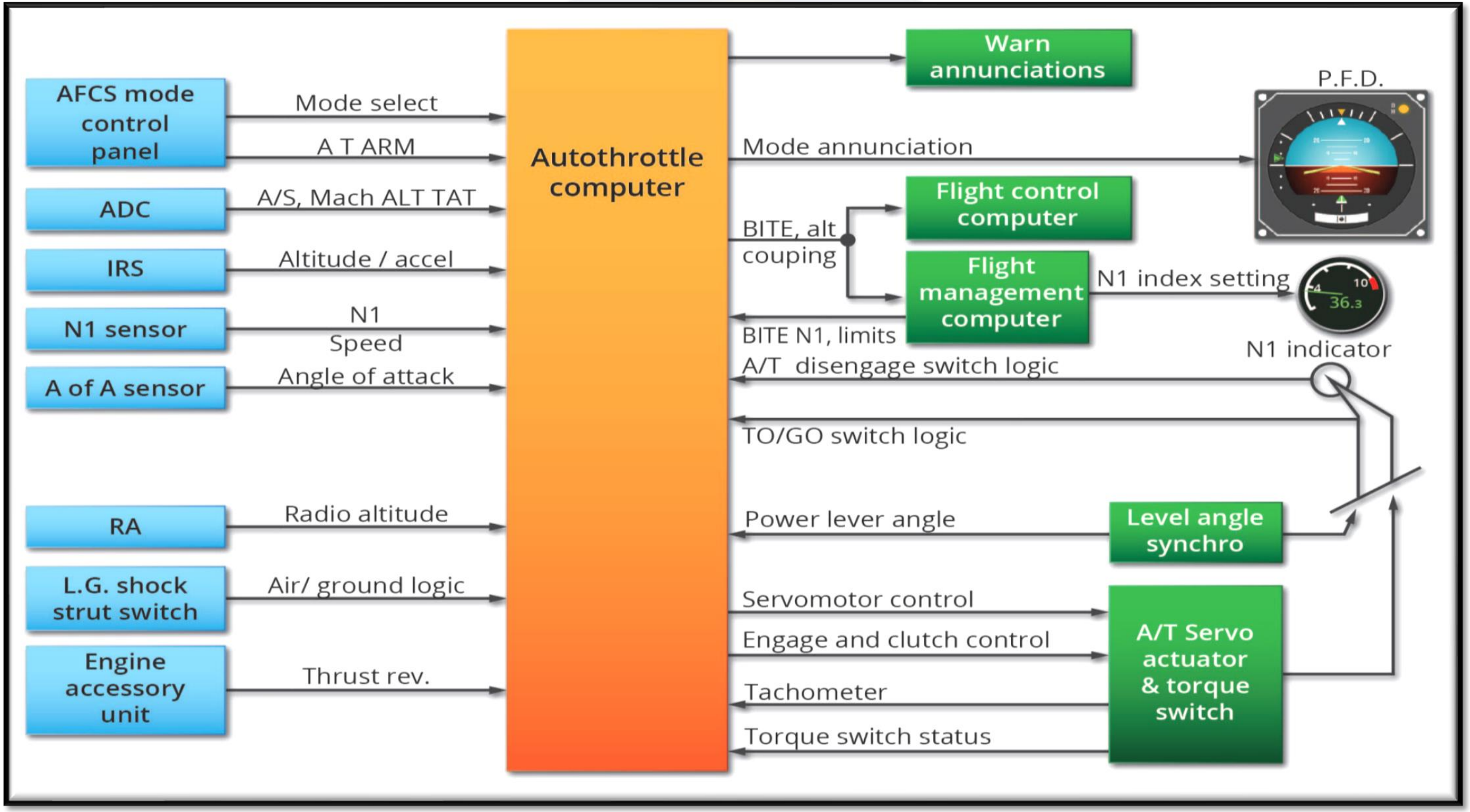
- The autothrottle can also be called the **thrust management system (TMS)** that works in conjunction with the autopilot and the FMS.

Inputs

- The mode selection and A/T Arm switch on the MCP
- TAS , Mach No. , and TAT from the ADC
- Attitude and acceleration from the IRS
- N1 speed and/or EPR from engine sensors
- Angle of attack from AoA sensor
- Radio altitude from the radio altimeter
- Air/ground logic from the landing gear switch
- Reverse thrust requirement from the engine accessory unit
- Thrust command from the FMS or thrust mode selection from the trust mode select panel
- A/T disconnect switch on the throttles
- Power lever angle (PLA) Position from transducers
- Flap position

Outputs

- A/T servo-actuator to move the throttles
- A/T disengage circuit
- Built-in test equipment (BITE) circuits in the FCC and the FMC
- Mode annunciation to the EFIS symbol generator
- Thrust limits and to the EICAS/ECAM display
- Failure warnings annunciations (lamp and/or aural , electronic display)


AFCS mode control panel
Mode select
A T ARM
ADC
A/S, Mach ALT TAT
IRS
Altitude / accel
N1 sensor
N1 Speed
A of A sensor
Angle of attack
RA
Radio altitude
L.G. shock strut switch
Air/ ground logic
Engine accessory unit
Thrust rev.
Autothrottle computer
Warn annunciations
P.F.D.
Mode annunciation
Flight control computer
BITE, alt couping
Flight management computer
N1 index setting
BITE N1, limits
N1 indicator
A/T disengage switch logic
TO/GO switch logic
Level angle synchro
Power lever angle
Servomotor control
Engage and clutch control
A/T Servo actuator & torque switch
Tachometer
Torque switch status

Chapter 13

Alerting Systems

Alerts Categories and Criteria

The alerting and warning system produces the following levels of alerts:

- Warnings or Level A alerts require immediate crew action. Warnings are also required to attract the attention of the flight crew in enough time for them to initiate the required action to be taken.

- Cautions or Level B alerts require immediate crew alertness and subsequent crew action.

- Advisories or Level C alerts require crew alertness

NOTE

Alerting and warning messages are presented to the crew in visual, aural, and sensory forms.

Visual

• Master warnings are displayed in red (an example of a situation that would trigger a master warning is an overspeed condition).

• Master cautions are displayed in amber or yellow (an example of a situation that would trigger a master caution from the altitude alert system is a deviation of 200 ft to ft or more from the MCP selected altitude).

• Advisories are displayed in any colour other than red or green (an example of a situation that would trigger an advisory light is when the altitude alert system alerts the flight crew that the aircraft is approaching its preselected altitude).

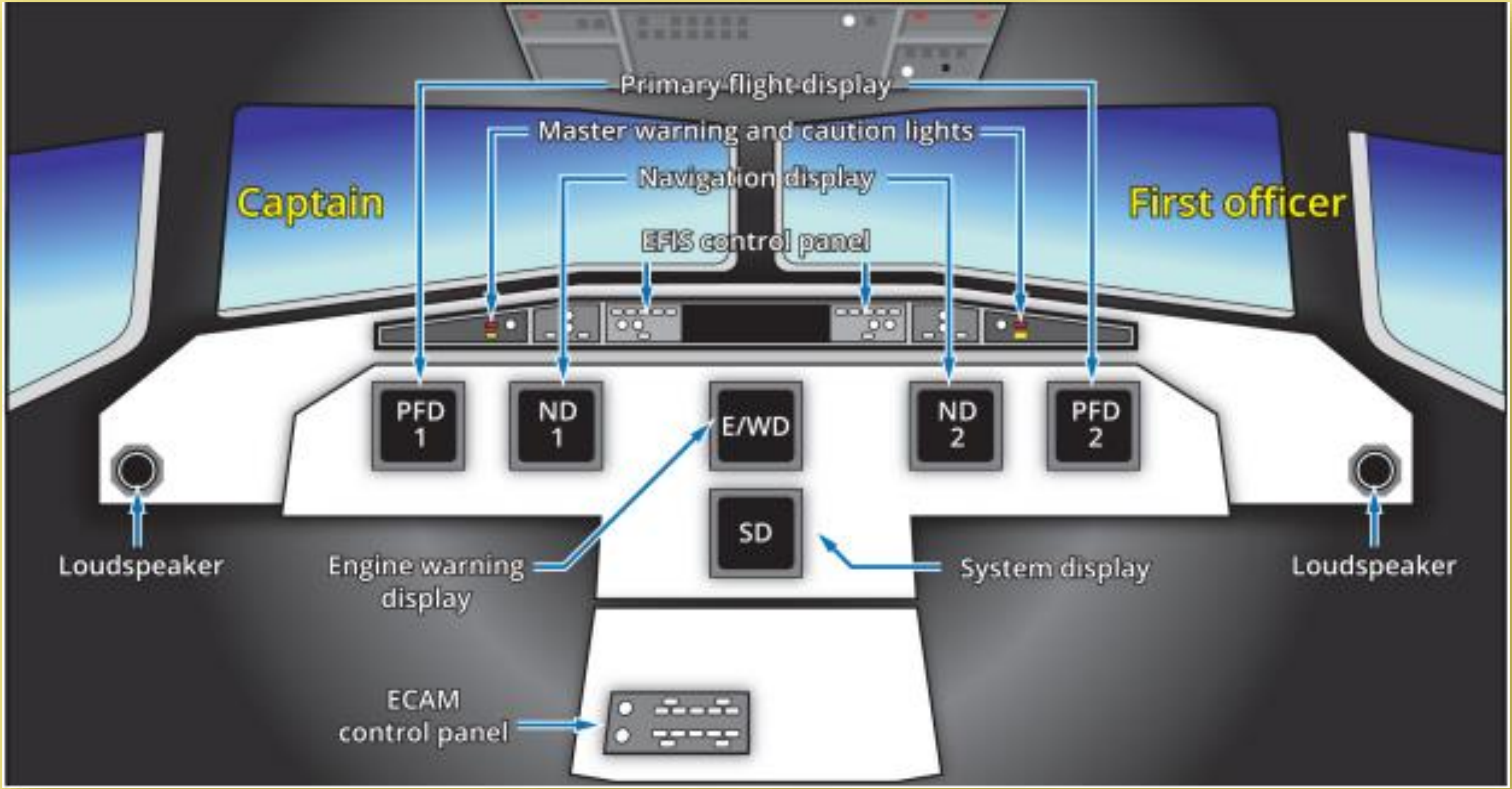
Aural

The alert can be in the form of sounds, synthetic voice messages, or a combination of both. For multiple alerts, the warnings are prioritized . Stall warnings are prioritized over wind shear warnings, wind shear warnings are prioritized over the rest of the ground proximity warning system (GPWS) warnings and GPWS warnings are prioritized over airborne collision avoidance system (ACAS) warnings.

Sensory

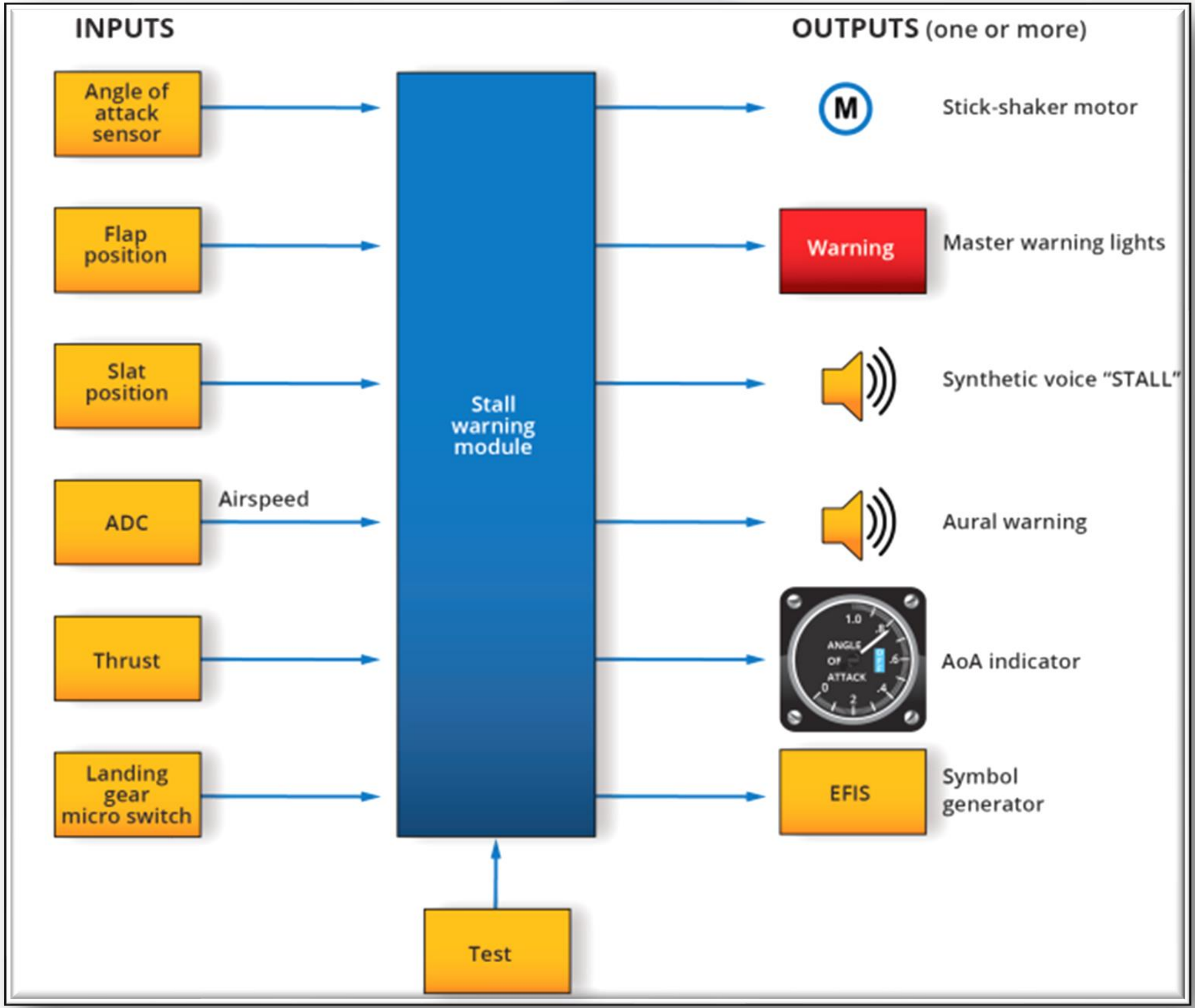
A vibratory mode (stick shaker) on the flight controls is used to indicate an approaching stall. It demands immediate action of the flight crew to avert the loss of control of the aircraft. In some aircraft, a stick-pusher automatically helps prevent the stall from occurring altogether.

HOMAviation Training Center
مرکز آموزش هـــای هوایی همـــا



Stall Warning Systems

The function of the stall warning system is to warn the flight crew of an impending stall. It does so when the aircraft approaches the stalling angle of attack that corresponds to the current speed and configuration of the aircraft. It is important to note that aural stall warnings are unique in how they sound when compared to other aircraft warnings. The reason for this is that stall warnings have been given the highest level of priority than compared to other aircraft warnings.


INPUTS
OUTPUTS (one or more)
Angle of attack sensor
Flap position
Slat position
ADC
Airspeed
Thrust
Landing gear micro switch
Stall warning module
Test
M
Stick-shaker motor
Warning
Master warning lights
Synthetic voice "STALL"
Aural warning
AoA indicator
EFIS
Symbol generator

Takeoff warning

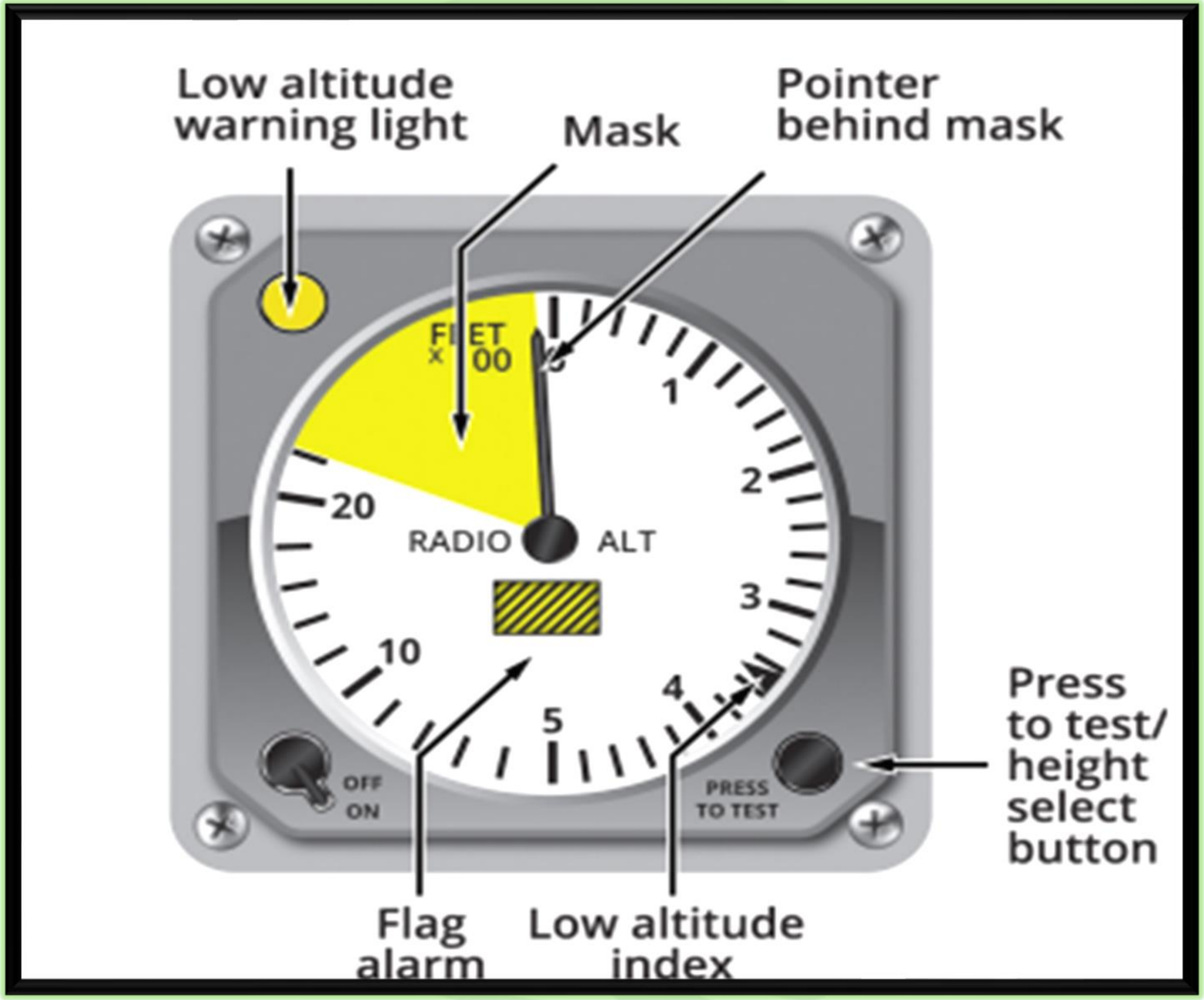
The takeoff configuration warning (T2CW) alerts the flight crew with an audible warning when the aircraft is not in the correct takeoff configuration. The T2CW typically sounds when :

- the throttles are advanced with flaps not in the takeoff position.
- slats not in the takeoff position.
- stabiliser trims being outside the takeoff range.
- spoilers being deployed.
- remotely operated flight control locks not being disengaged.
- external doors or hatches not being locked and closed.
- the parking brake still being on.

Radio Altimeter

The radio altimeter measures the height of an aircraft above ground with a high degree of accuracy. Apart from providing a flight deck display of height above ground level (AGL) , the radio altimeter supplies the automatic flight system with data that affects automatic landings when used during an ILS or MLS approach.

The radio altimeter also provides crucial height information and rate of change of height to the ground proximity warning system (GPWS).


Low altitude warning light
Mask
Pointer behind mask
FEET x 100
1
2
3
4
5
10
20
RADIO
ALT
OFF
ON
PRESS TO TEST
Press to test/ height select button
Flag alarm
Low altitude index

Height Scale

The scale is logarithmic. It is expanded from zero to 500 ft and reduced from 500 to 2,500 ft.

Mask

The height pointer disappears behind a mask when the height exceeds 2,500 ft, when there is any fault with the transmitted signal, or when the system is switched off.

Failure Warning Flag

A flag appears when too much radio noise corrupts the returning radar signal, if local reflections are received through the airframe itself, or if the system loses electrical power.

Press to Test Button/Height Selector

When this button is pressed, the height pointer swings round to a pre-set height. This provides a confidence check to the user as it indicates that the equipment is likely to operate satisfactorily. Additionally, when depressed, this button selects the reference Low Altitude Index to the desired height.

Low Height Warning

The warning light illuminates when the aircraft is flown below any pre-selected height. This is also audibly supplemented by an alert tone that sounds increasingly louder from approximately 100 ft above the pre-selected height.

Ground-Proximity Warning System (GPWS)

The aim of the system is to give visual and audible warning signals to pilots when the aircraft's proximity to the terrain poses a potential threat to its safety.

Although not a fool proof means of preventing a collision with the earth's surface a GPWS will enhance flight safety and it can prevent accidents that could result from distracted flight crews caused by an increased cockpit workload, malfunction resolution, misinterpretation of navigational equipment, or incorrect ATC instructions.

The system begins to operate below 2,500 ft above the surface .

GPWS Mode		Advanced Equipment: Alert	Advanced Equipment: Warning
1. Excessive descent rate		"Sink rate"	"Whoop whoop pull up"
2. Excessive terrain closure rate		"Terrain terrain"	"Whoop whoop pull up"
3. Altitude loss after take-off or go-around		"Don't sink"	---
4. Unsafe terrain clearance while not in the landing configuration	4a. Proximity to terrain Gear not locked down	"Too low gear"	"Too low terrain"
	4b. Proximity to terrain Flaps not in a landing position	"Too low flaps"	"Too low terrain" (see note below)
5. Descent below glide slope		"Glide slope"	---
6. Descent below "minimums"	6a.	"Minimums"	---
	6b.	"Bank angle"	---
7. Wind shear warning		---	"Wind shear"

MODE 1

Aural alert - “SINK RATE, SINK RATE”
Aural warning - “WHOOP WHOOP PULL UP”

Visual

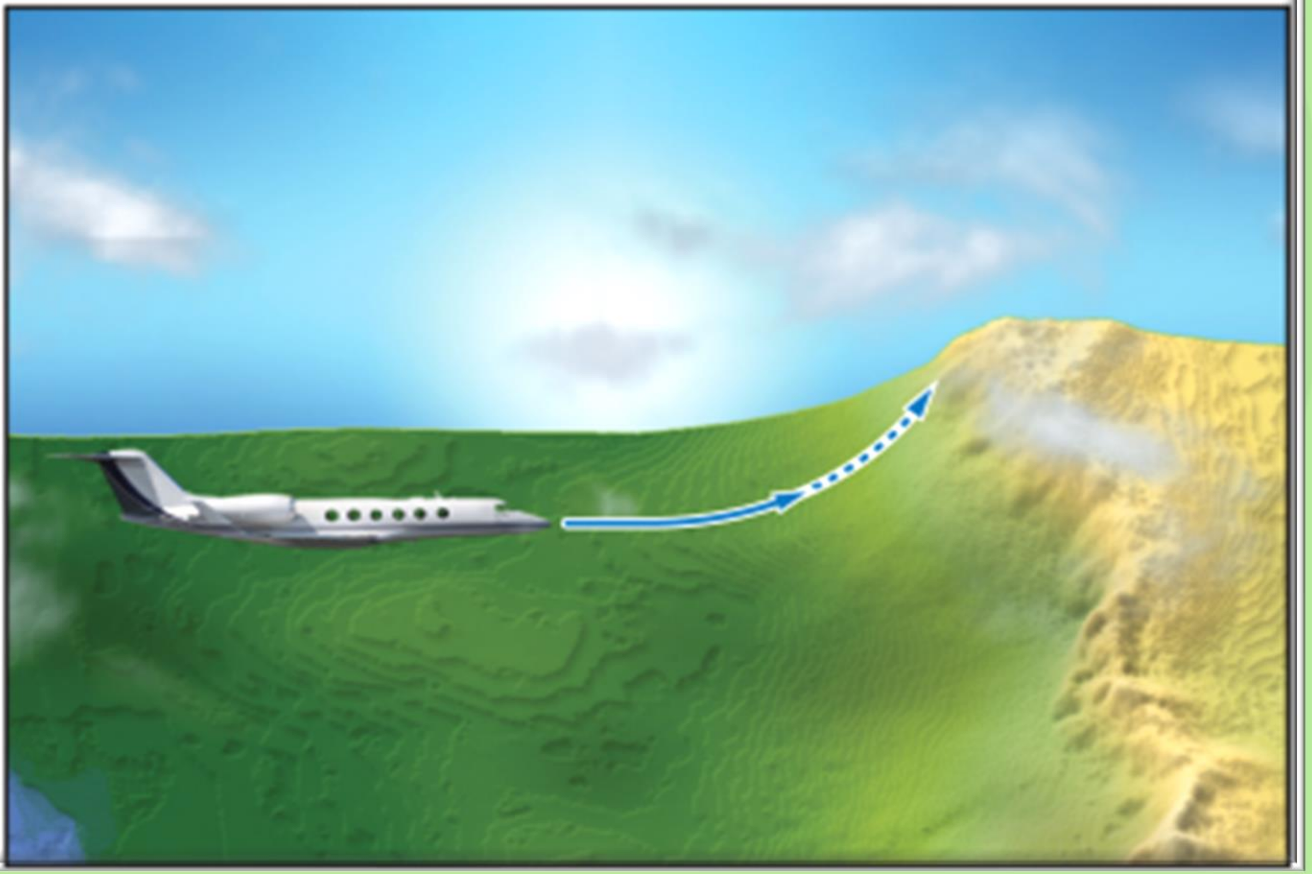
Pull up

MODE 2

Visual

Pull up

Aural alert - “TERRAIN, TERRAIN”
Aural warning - “WHOOP WHOOP PULL UP”

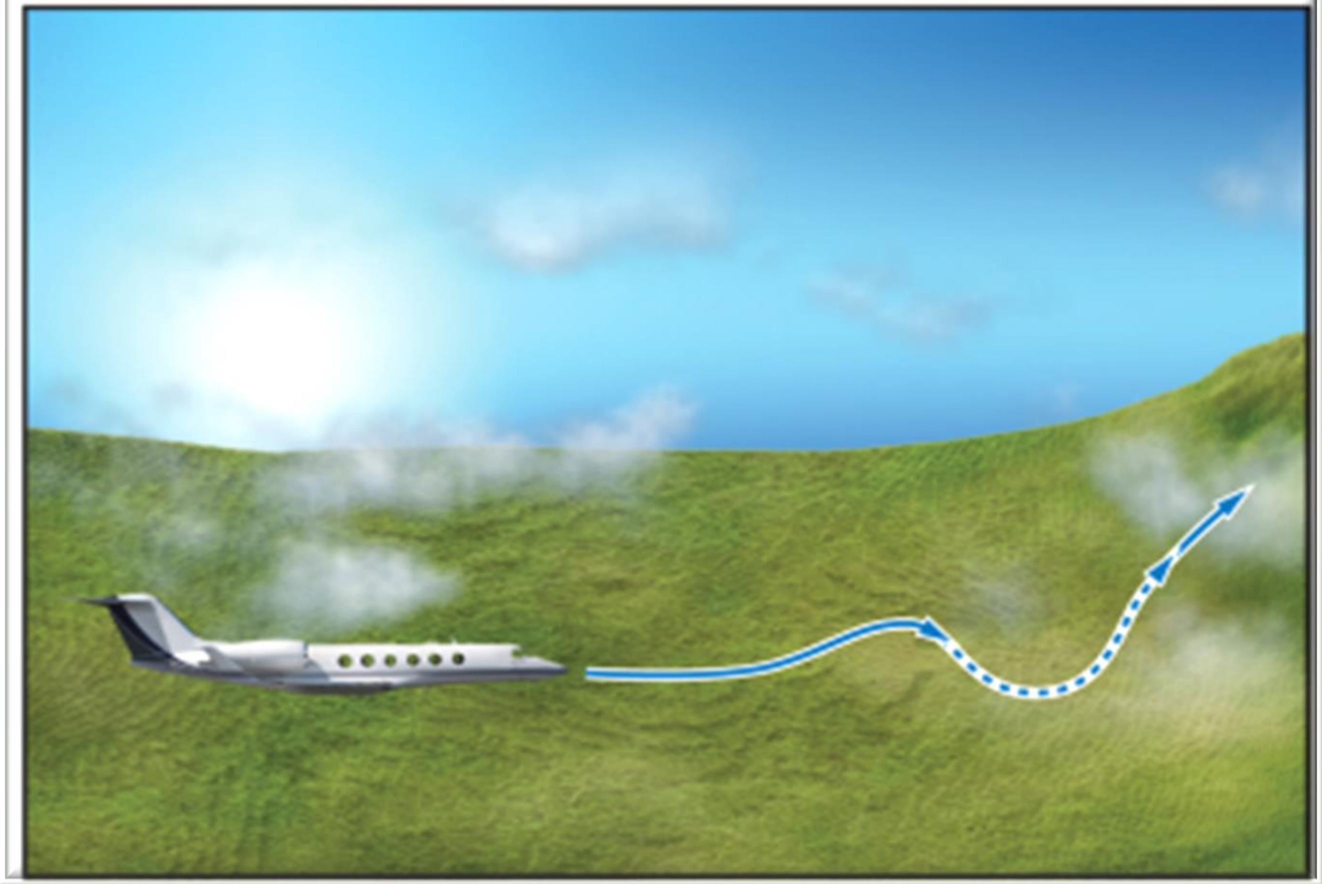


MODE 3

Aural alert - “DON’T SINK”

Visual

Pull up

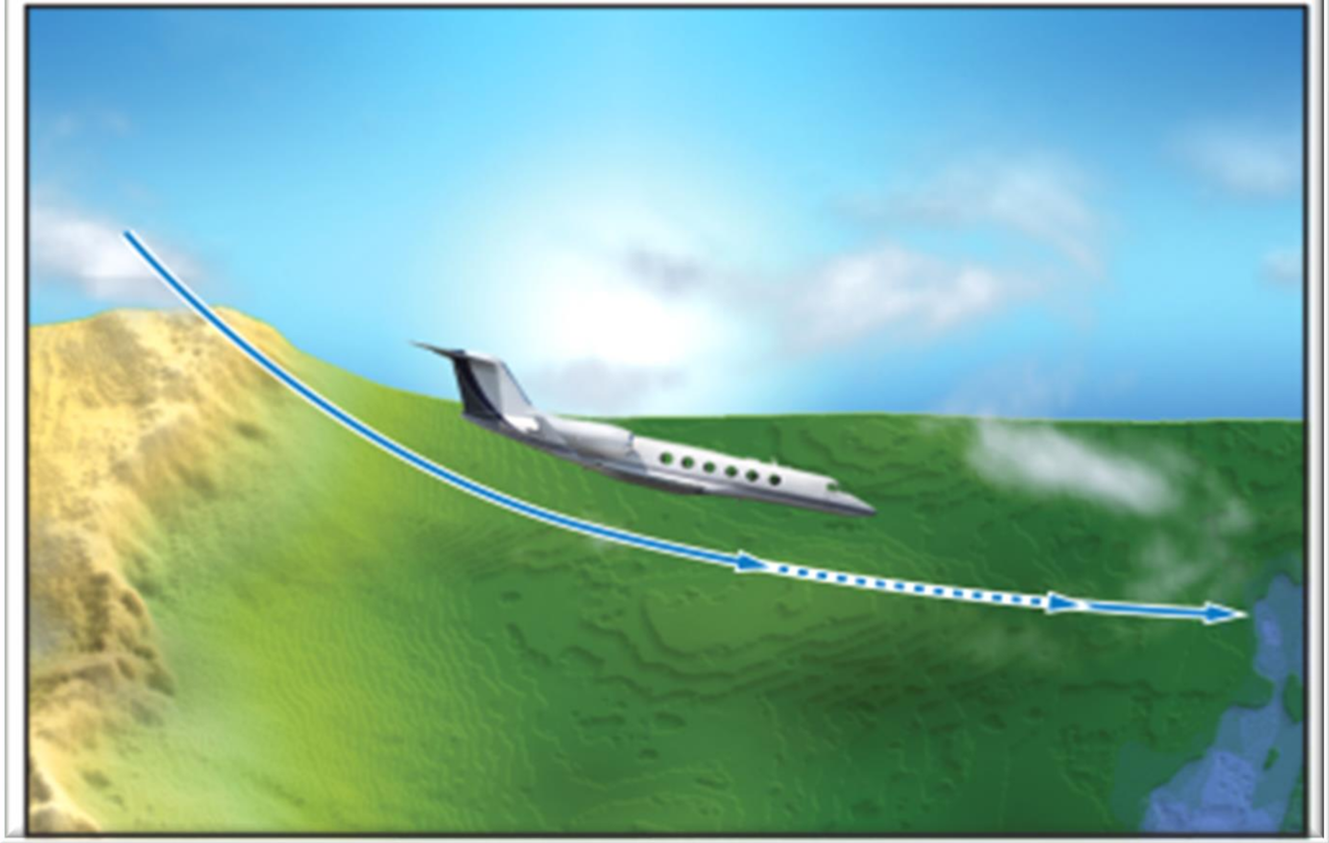


MODE 4A

Aural alert - “TOO LOW GEAR”
“TOO LOW TERRAIN”

Visual

Pull up

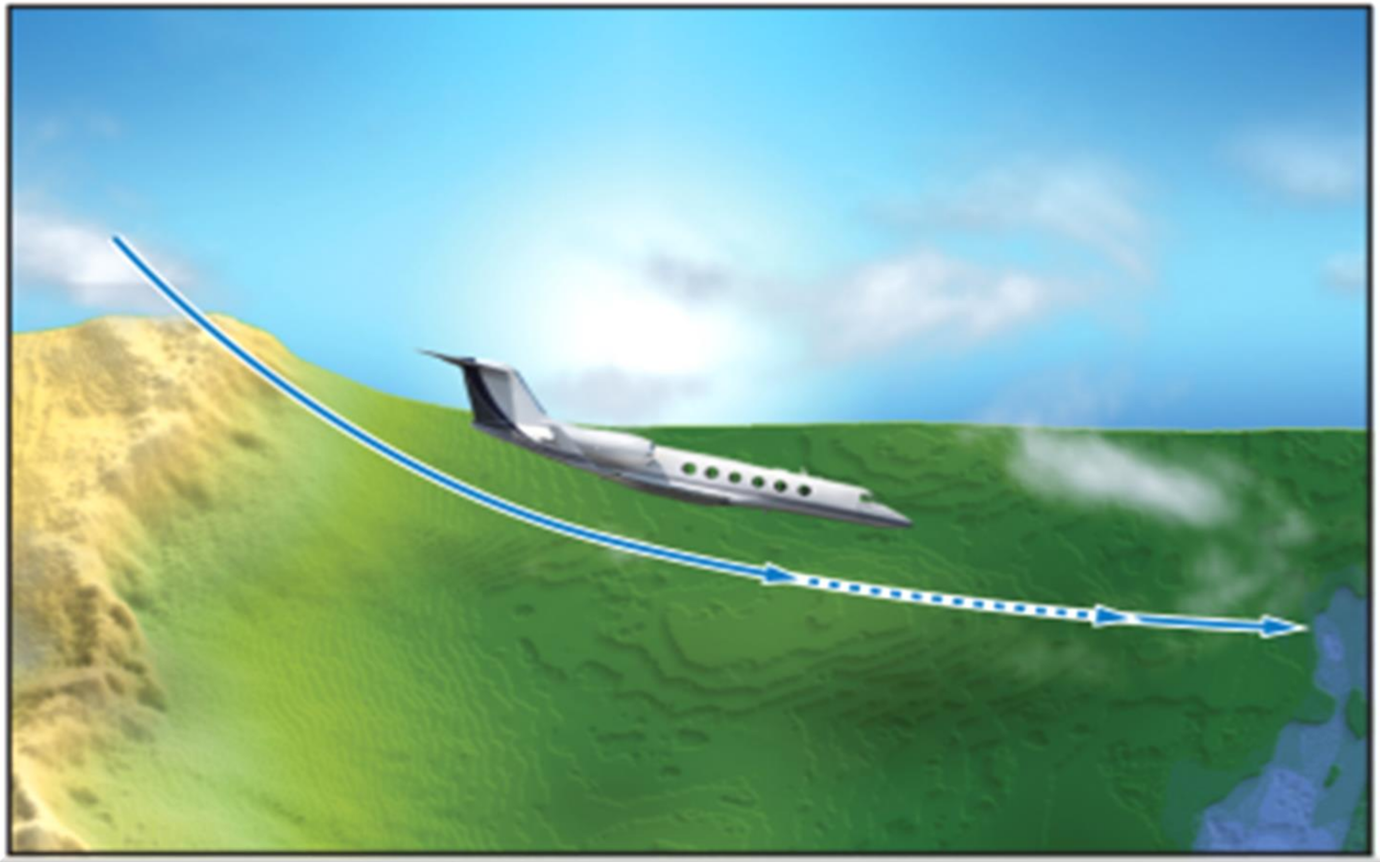


MODE 4B

Aural alert - “TOO LOW FLAPS”
“TOO LOW TERRAIN”

Visual

Pull up

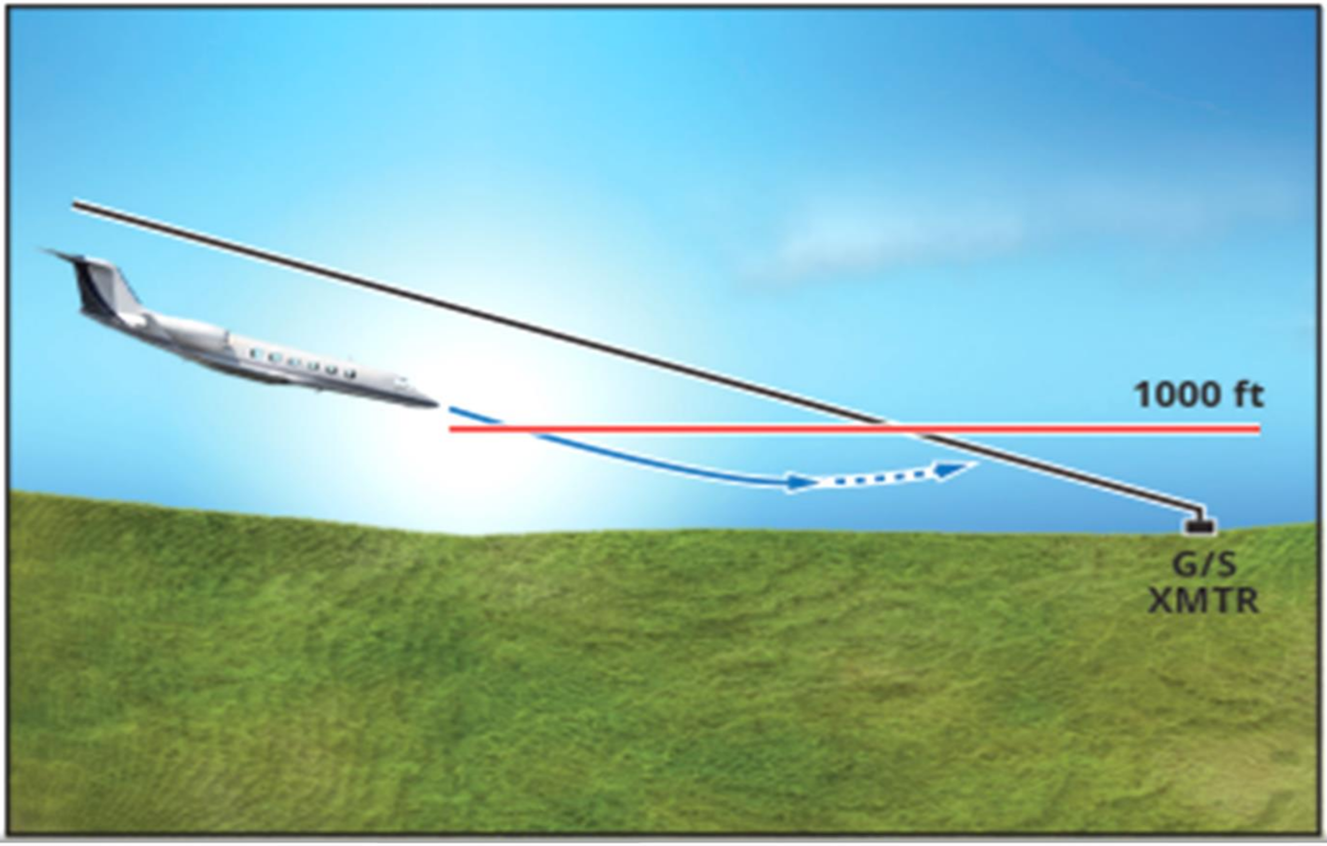


MODE 5

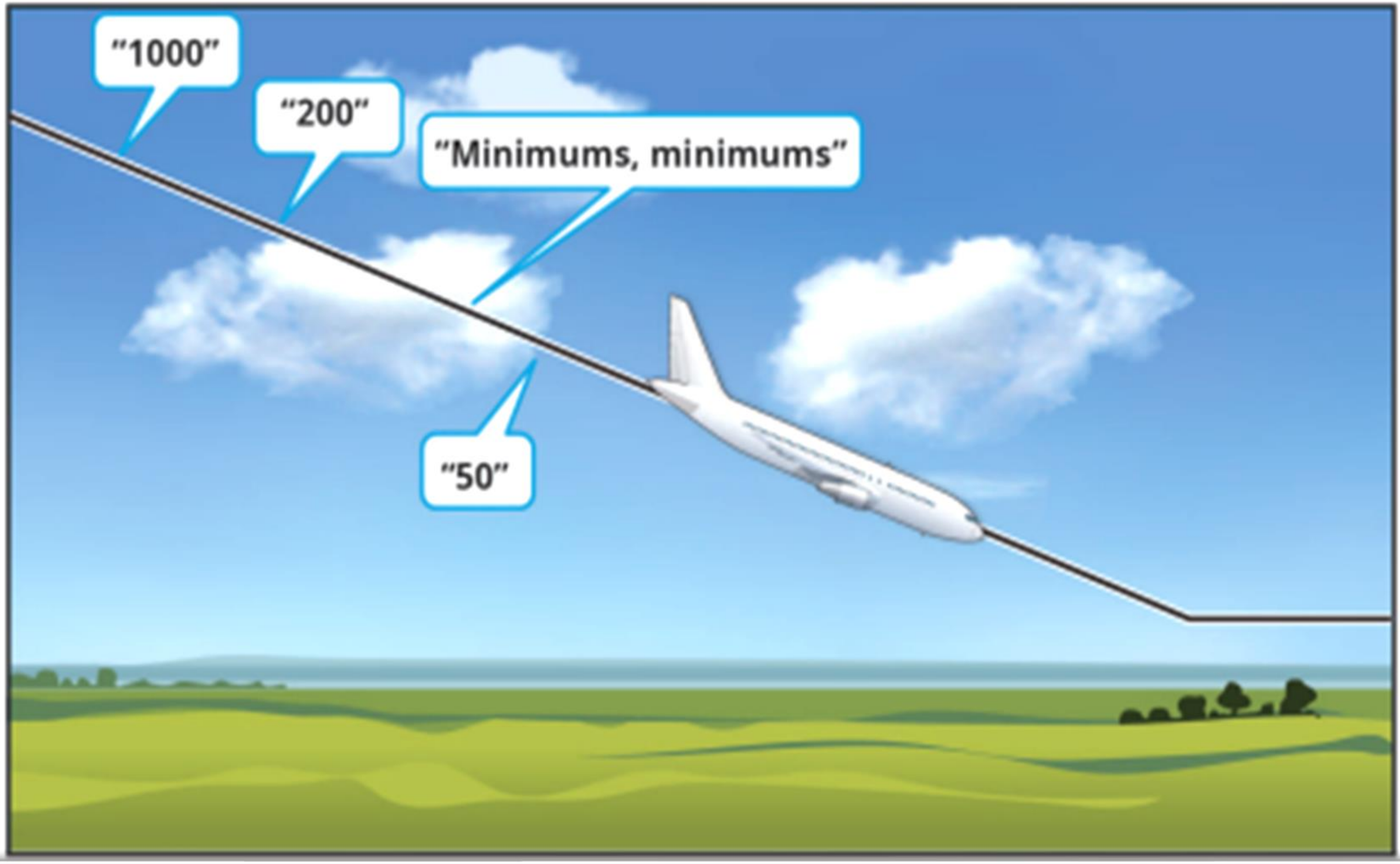
Aural alert - "GLIDE SLOPE"

Visual

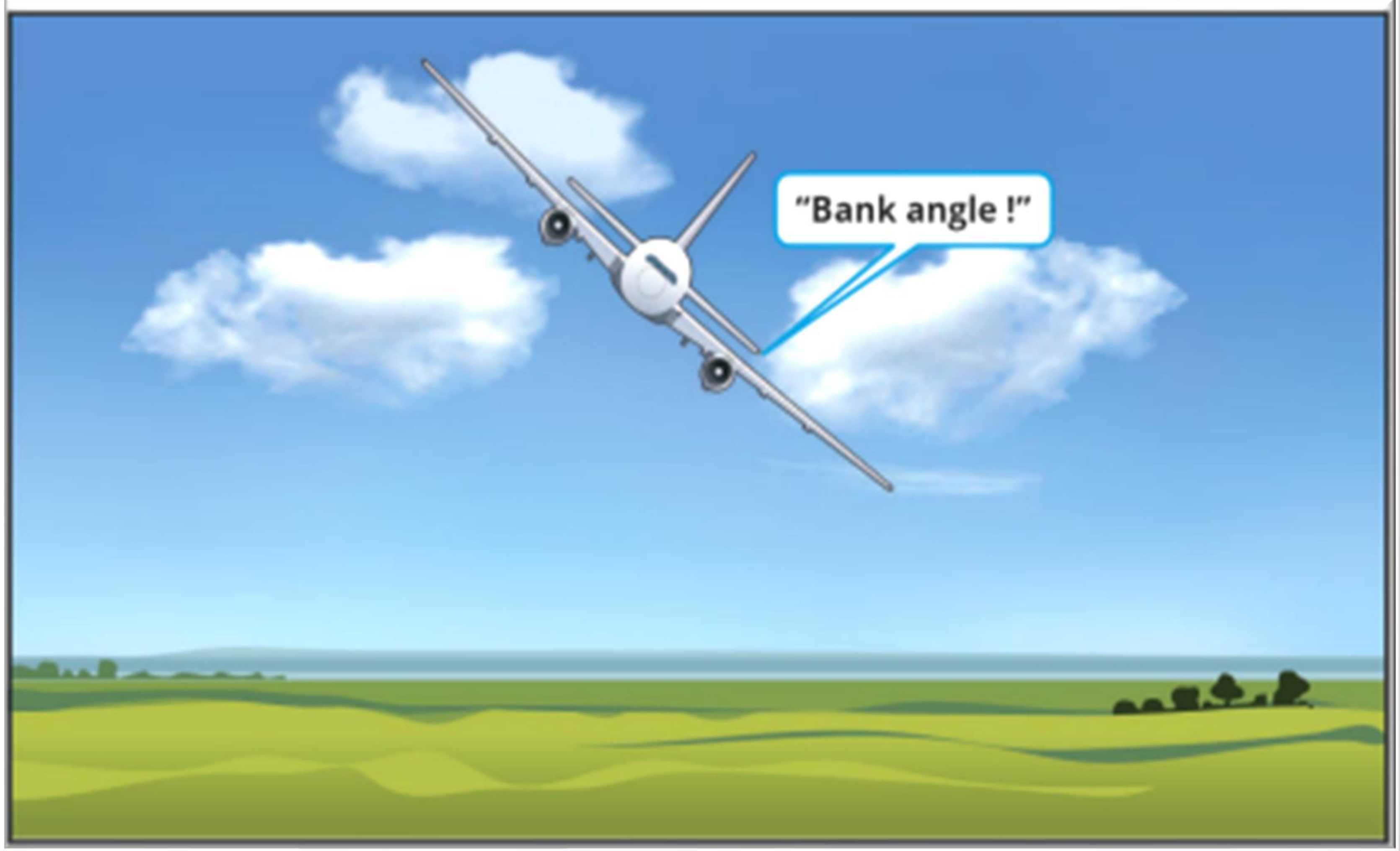
Below G/S P to INHIBIT



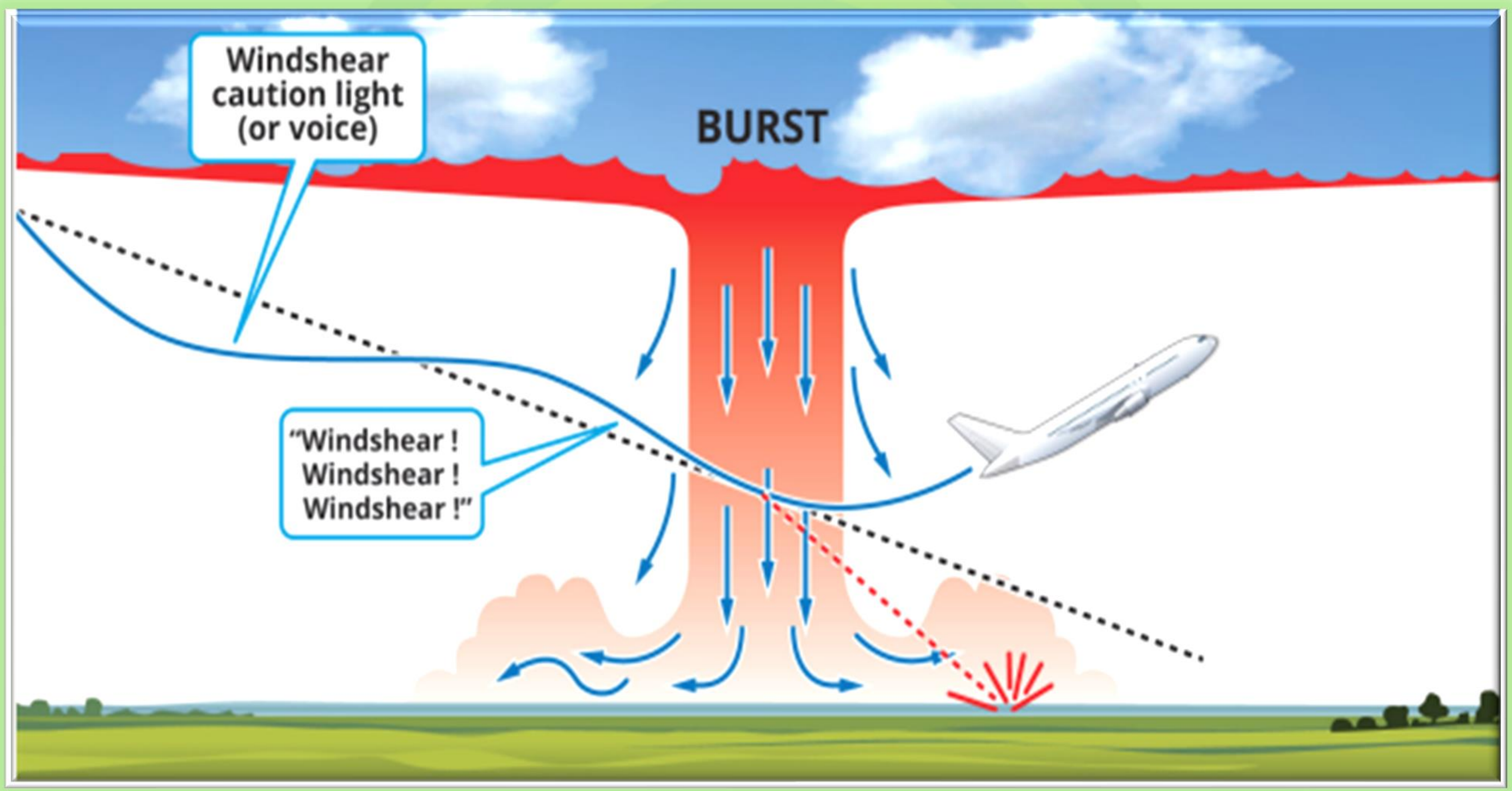
Mode 6 A



Mode 6 B



Mode 7


Windshear caution light (or voice)
BURST
"Windshear ! Windshear ! Windshear !"

PULL UP warning light (Red)

ILLUMINATED
- Excessive descent rate
- Excessive closure rate
- Altitude loss after takeoff or go-around
- Non landing configuration descent

BELOW G/S alert light (Amber)

ILLUMINATED
- Aircraft more than 1.3 dots below the glide slope

PRESS

Inhibits or cancels glide slope alerting if pressed when below 1,000 ft

Traffic collision avoidance system

High traffic densities and high-speed differences between the aircraft that are currently operated created a need for the airborne collision avoidance system. Although ICAO named it an ACAS II system, the principle system manufacturer in the US named their product the traffic alert and collision avoidance system II (TCAS II), which is now a widely accepted alternative name for the system.

TCAS II Outputs

- Other traffic : Are surrounding air traffic that are outside a 10 horizontal radius of the TCAS II equipped aircraft or more than 1,200 ft vertically separated from the TCAS II equipped aircraft

- Proximate traffic : Are surrounding traffic that are within a 10 horizontal radius of the TCAS II equipped aircraft and less than 1,200 ft vertically separated from the TCAS II equipped aircraft

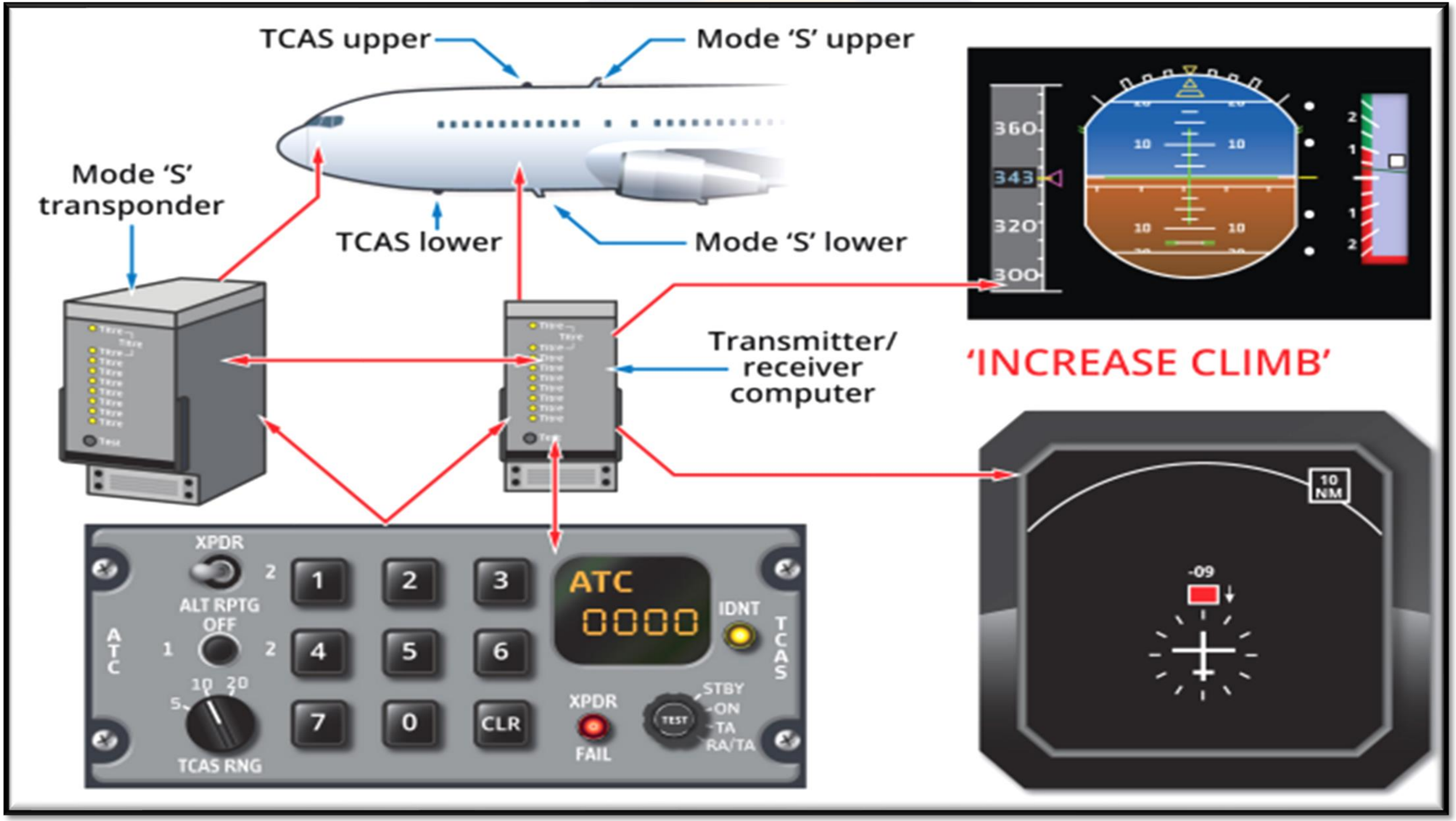
- Traffic advisories (TAs): are surrounding air traffic that are between and seconds from the collision area. The different times are based on the fact that the sensitivity level of the equipment can be adjusted by the operator of the aircraft.

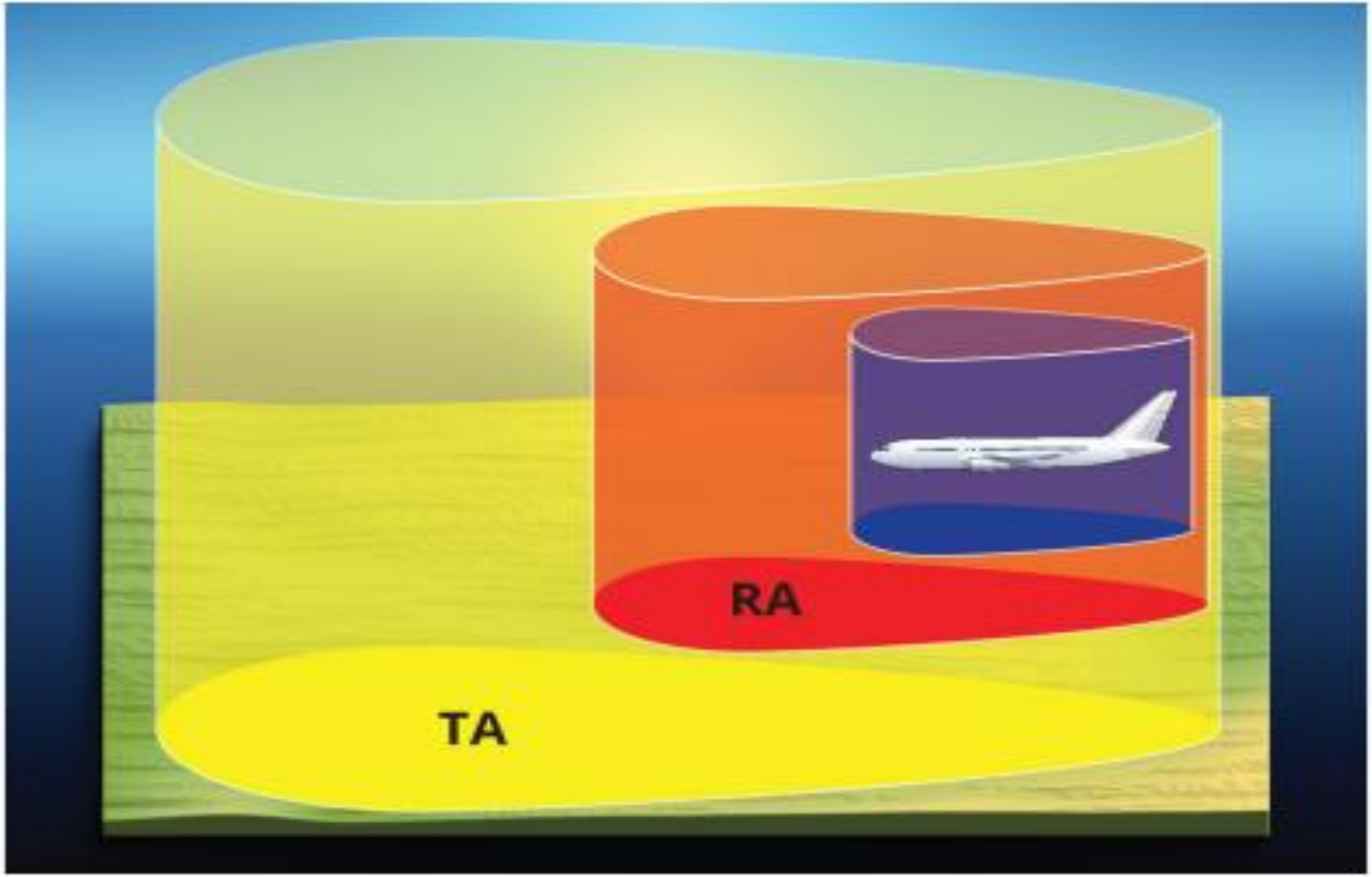
- Resolution advisories (RAs): are surrounding air traffic that are between and seconds from the collision area. Again the different times are based on the fact that the sensitivity level of the equipment can be adjusted by the operator of the aircraft.

ACAS II Commands

The ACAS II will only issue avoidance commands in the vertical plane. The command will be to climb, to descend, or even to maintain the current pitch attitude.

The commands must be complied with as a manual manoeuvre . This means that if an RA is received by the flight crew of a TCAS II equipped aircraft , they should disconnect the autopilot ignore the commands of the flight director and follow the pitch commands of the TCAS II system.


TCAS upper
Mode 'S' upper
Mode 'S' transponder
TCAS lower
Mode 'S' lower
Transmitter/
receiver
computer
'INCREASE CLIMB'
360
343
320
300
10 NM
-09
XPDR
ALT RPTG
OFF
ATC
TCAS RNG
1
2
3
4
5
6
7
0
CLR
ATC
0000
IDNT
TCAS
XPDR
FAIL
TEST
STBY
ON
TA
RA/TA


RA
TA

NOTE

The typical standard detection range for TCAS II is to 10 horizontally and approximately 2,000 ft above and below the aircraft in any setting.

There are no instructions given at all when the aircraft is below 400 ft AGL.

No descent RAs are given below 1,000 ft AGL and no increase rate of descent commands below 1,450 ft AGL.

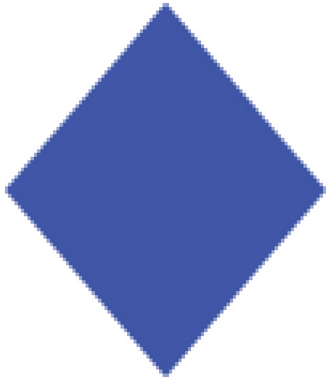


Figure 12.33 Proximate traffic

Proximate traffic appears as a solid cyan diamond and represents transponder equipped aircraft that are within 6 NM and within +/- 1,200 ft relative height. This traffic is not considered as being a threat, and it is only displayed to improve the situational awareness of the flight crew.

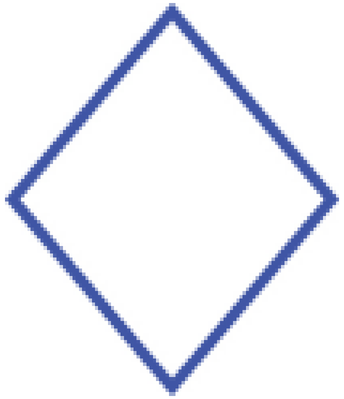
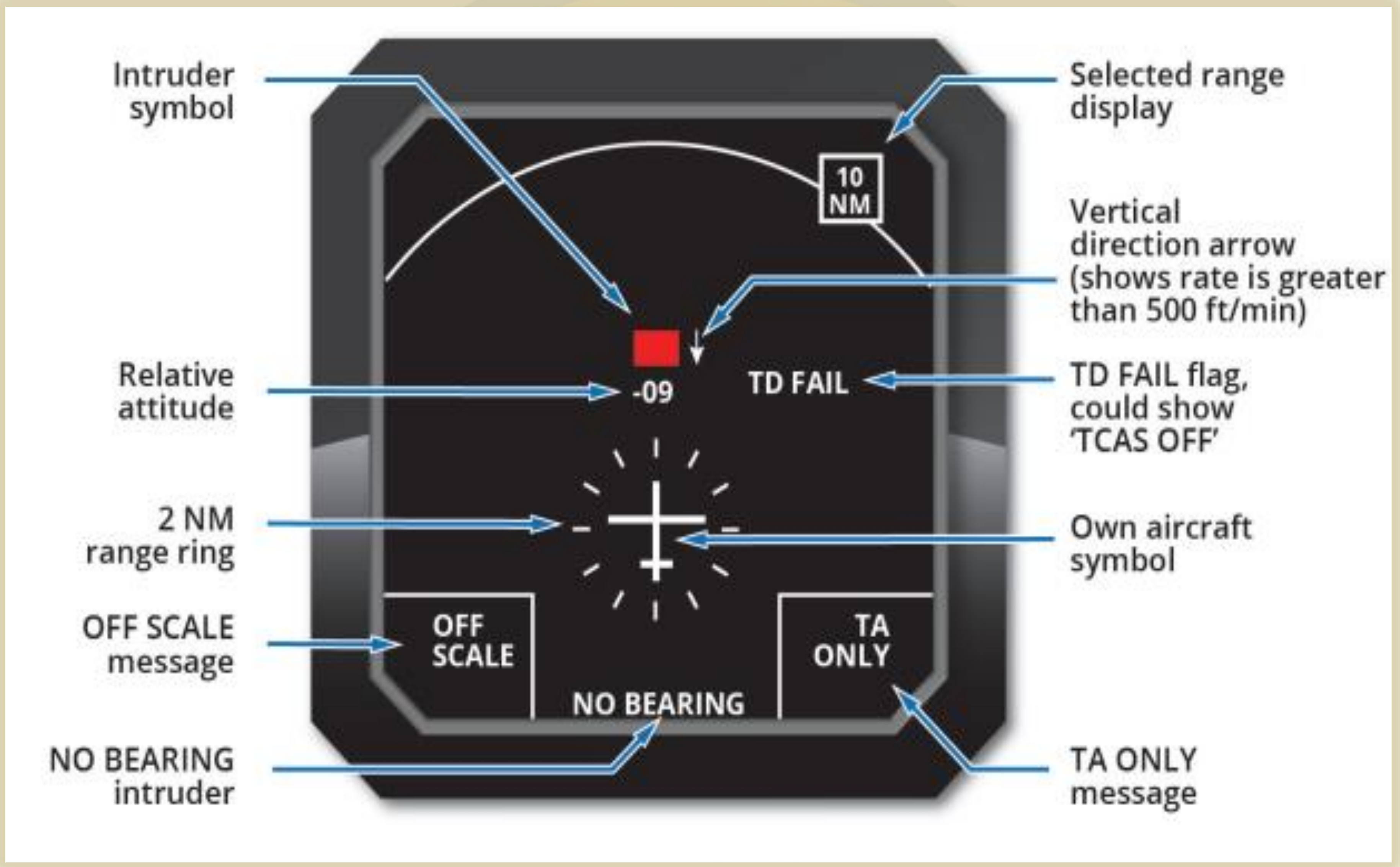
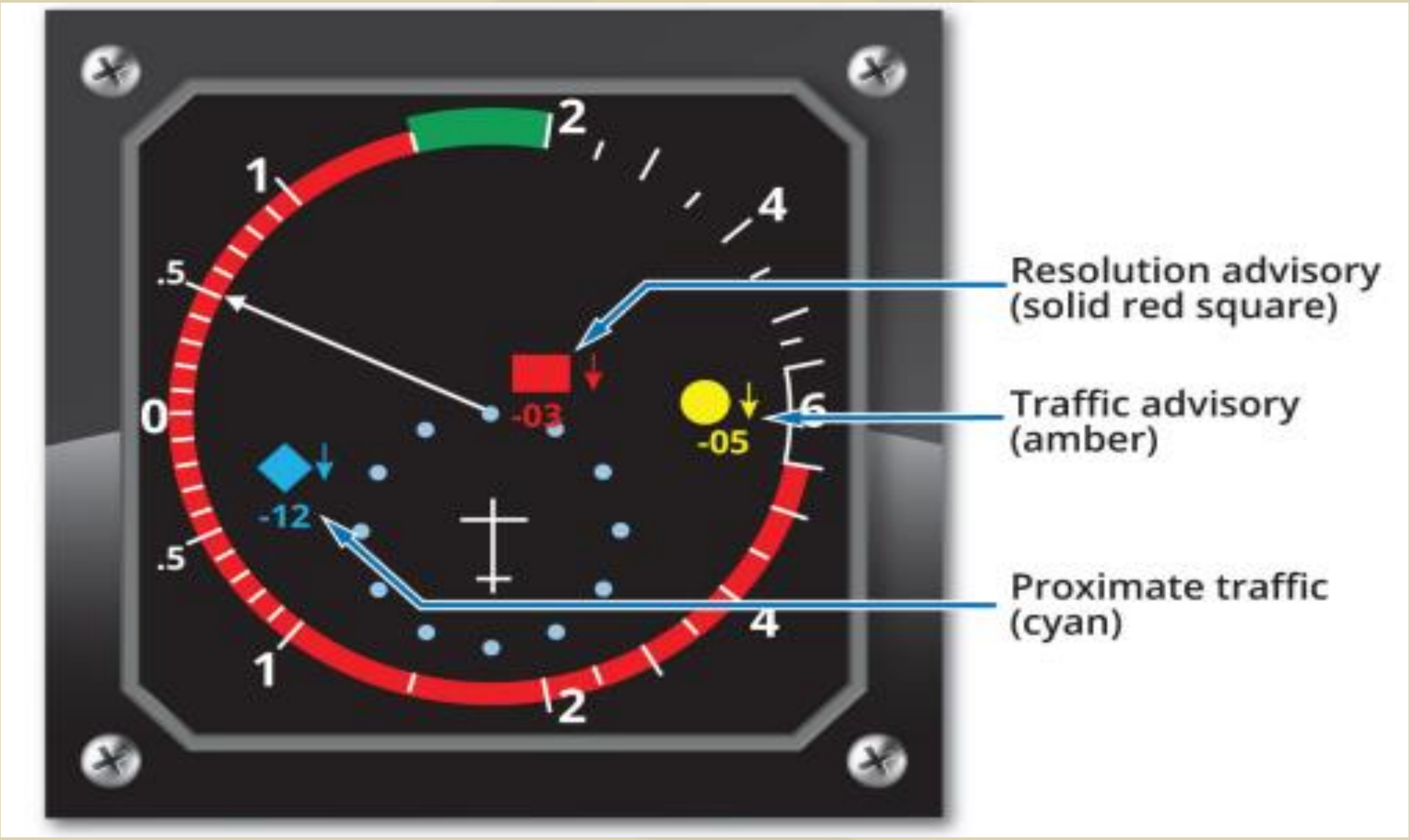


Figure 12.34 Other traffic

Other traffic appears as hollow cyan diamonds that represent transponder equipped aircraft within +/- 2,700 ft relative height. This increases to +8,700/-2,700 in the climb, and +2,700/-8,700 in the descent as a function of the "Above/Below" switch. Other Traffic is also displayed to improve the situational awareness of the flight crew.


Intruder symbol
Selected range display
10 NM
Vertical direction arrow (shows rate is greater than 500 ft/min)
Relative attitude
-09
TD FAIL
TD FAIL flag, could show 'TCAS OFF'
2 NM range ring
Own aircraft symbol
OFF SCALE message
OFF SCALE
TA ONLY
NO BEARING
NO BEARING intruder
TA ONLY message


Resolution advisory
(solid red square)
Traffic advisory
(amber)
Proximate traffic
(cyan)
-03
-05
-12
0
.5
1
2
4
6

Aural Warnings

TAs appear as solid amber circles on the TCAS display, and they are accompanied by the synthetic voice saying "TRAFFIC, TRAFFIC".

RAs appear as solid red rectangles on the TCAS display, and they are accompanied by a variety of synthetic voice warnings. Examples of RAs include "CLIMB", "INCREASE CLIMB", "DESCEND", "INCREASE DESCENT", "MONITOR VERTICAL SPEED", "DECREASE CLIMB", and "DECREASE DESCENT".

Reduce climb | Increase climb | Descend | Reduce descent

Chapter 14

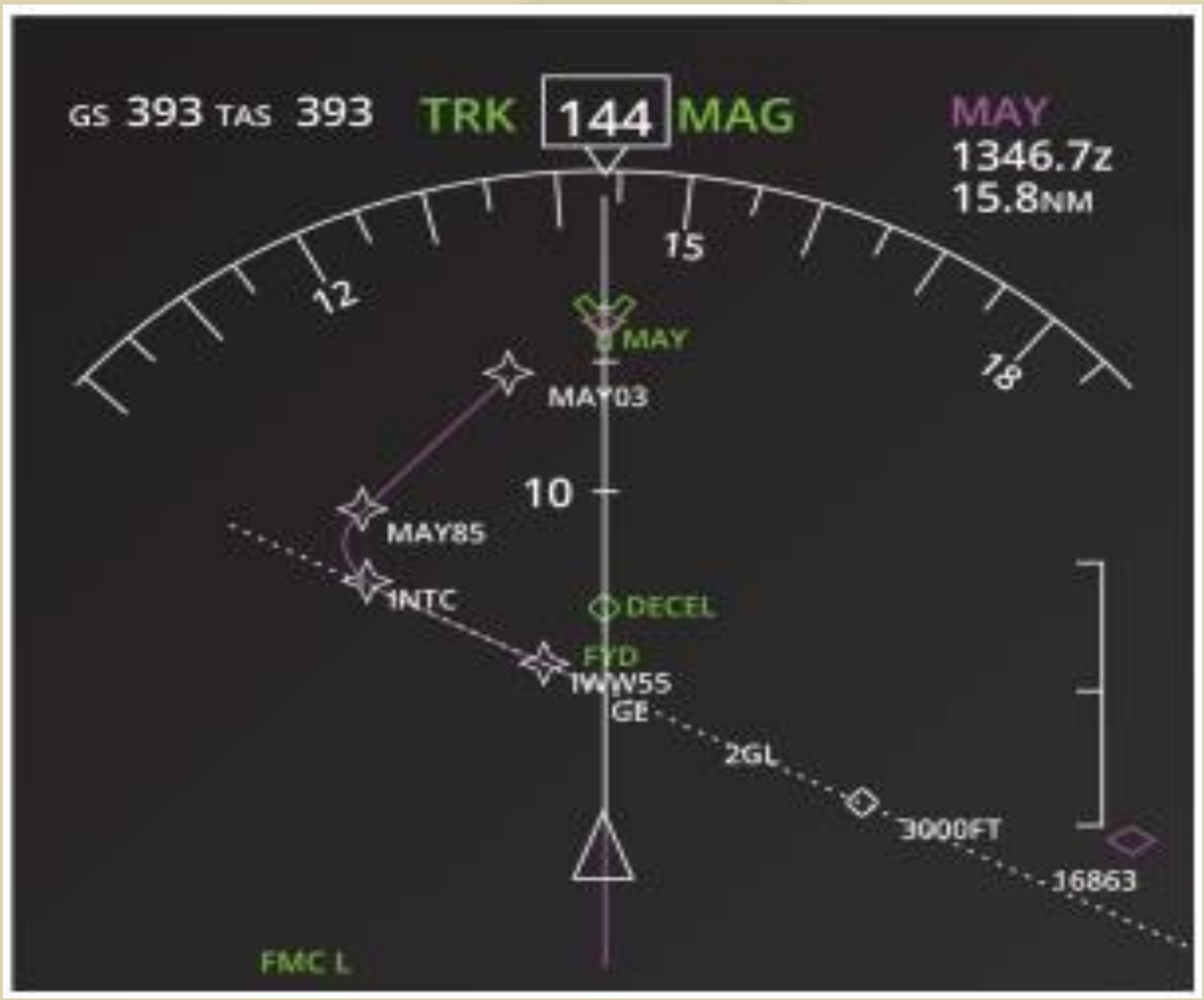
Navigation Display (ND), Electronic Horizontal Situation Indicator (EHSI)

The EHSI presents a selectable dynamic colour display of flight progress in a plan view orientation.Four principal display modes may be selected :

- VOR
- ILS
- MAP
- Plan

Of these modes the VOR and ILS modes can be displayed with full or expanded compass displays.


RADIO
MINS
BARO
RST
FPV
MTRS
IN
BARO
HPA
STD
VOR 1
OFF
ADF 1
VOR
MAP
APP
PLN
CTR
10
20
40
80
160
5
320
640
TFC
VOR 2
OFF
ADF 2
WXR
STA
WPT
ARPT
DATA
POS
TERR


GS 393 TAS 393
TRK 144 MAG
MAY
1346.7z
15.8NM
12
15
18
MAY
MAY03
10
MAY85
1NTC
DECEL
FYD
1WW55
GE
2GL
3000FT
16863
FMC L

Full VOR Mode

With a VOR frequency selected, the mode displays a full compass rose with the VOR source in the lower left-hand corner, and the frequency in the lower right-hand corner of the display.

Track selection is displayed by the magenta track needle. The tip of the needle points to the selected track, 150° in this case. Track deviation is indicated by the traditional deviation bar that moves across a two dot left and two dot right scale.

A TO/FROM pointer is indicated in addition to the TO/FROM annunciation.

DME distance is displayed in the top left-hand corner.

Current heading is indicated in the window above the lubber line at the top of the compass rose, 130° in this case. The current selection is Magnetic Heading as indicated either side of the window.

Current track is indicated by the white triangle on the inside edge of the compass rose.

Selected heading is indicated by the magenta heading bug on the outer scale of the compass rose.

Wind speed and direction are indicated in the lower left-hand corner and orientated according to the display selection. For example, Heading or Track, Magnetic or True.

Weather radar displays are not available in this mode.

Full ILS Mode

With an ILS frequency selected, the EHSI displays a full compass rose with the ILS source in the lower left-hand corner of the display and the frequency in the lower right-hand corner of the display.

The localiser track selection is displayed by the magenta needle. The tip of the needle points to the selected track of 150°. Localiser deviation is indicated by the traditional deviation bar that moves across a two dot left and a two dot right exponential scale.

Glideslope deviation is indicated by a magenta triangle that moves up and down on the right-hand side of the display.

DME distance is displayed in the top left-hand corner.

Current heading is indicated in the window above the lubber line at the top of the compass rose, in this case 130°. The current selection is Magnetic Heading, and it is indicated on either side of the window.

Current track is indicated by the white triangle on the inside edge of the compass rose.

Selected heading is indicated by the magenta heading bug on the outer scale of the compass rose.

Wind speed and wing direction are indicated in the lower left-hand corner. It is orientated to the display selection that can either be Heading or Track, Magnetic or True.

Weather radar displays are not available in this mode.


WXR
VOR
ILS
MAP
PLAN
ON
MAP
EXP ARC
NAV AID
ARPT
RTE DATA
WPT
ON
ON
ON
ON
ON


26.3 nm
TRK
130
M
1347.6z
120
150
90
180
ZAPPO
1412z
CAD
40
BANTU
10000
1359z
AFS
DUBRY
EDNOR
12000
1347z
EYY
EXOR
EGGD
PIL
EGYN
100° / 20

Map Mode

The most frequently used mode is the MAP mode. In conjunction with the flight plan data that is programmed into a flight management computer, this mode displays information in the form of a moving map background that displays all elements of the moving map in a common scale.

The symbol representing the aircraft is at the lower part of the display, and an arc of the compass scale covers 45° on either side of the instantaneous track. The instantaneous track can be found at the upper part of the display.

Heading information is supplied by the appropriate Inertial Reference System, and the compass rose is automatically referenced to magnetic north via a crew-operated MAG/TRUE selector switch when between latitudes 73°N and 65°S. It is referenced to true north when above these latitudes. When the selector switch is set at TRUE, the compass rose is referenced to true north regardless of latitude.

The active route as derived from the FMC is indicated as a magenta coloured line joining the waypoints. The active waypoint, which is the waypoint that the aircraft is currently navigating towards is displayed as a magenta coloured star. The other waypoints that make up the active route are called inactive waypoints. They are displayed as white stars. All waypoints are identified by name.

Indications of other data such as wind speed and direction and lateral and vertical deviations from the selected flight path are also displayed.

The flight management computer (FMC) can predict events by combining the current ground speed and lateral acceleration to indicate a display of a curved trend vector. This vector is white during turns. The range to altitude arc is green while climbing or descending. Off route waypoints, airports, and nav aids can all be indicated in their relative position to the aircraft's progress and selected range. Additional waypoint information can be displayed when selected.

Plan Mode

In the PLAN mode, a static map background is used with active route data that is orientated to true north. Any changes to the route may be selected at the alphanumeric keypad of the flight management computer. The display will then be indicated on the EHSI, so that the route data can be checked before being entered into the FMC.

The top portion of the EHSI remains the same as with in the MAP mode.

This mode allows the pilot to review the planned route by using the FMC/CDU LEGS page.

Weather radar display data is inhibited.

No wind speed or wind direction information is indicated.

The arc of the indicated compass is in real time. The planning section below this, however, is north orientated. The heading from TOBIX to LOGAN, in other words, is approximately 020°, not 155°.

Chapter 15

Cockpit Voice Recorder (CVR)

The main purpose of the cockpit voice recorder (CVR) is to preserve vital recoverable information for the Accident Investigation branch (AIB) to use in the event of an accident.

The CVR automatically records the last 30 minutes (2 hours on some aircraft) of communications and conversations that occurred on the flight deck. It is operational whenever electrical Sower is applied to the aircraft, any engine is running, or when the aircraft is airborne.


Underwater
locator
beacon

Recording Parameters

- Voice communications transmitted from or received on the flight deck
- The aural environment of the flight deck
- Voice communication of flight crew members using the aeroplanes interphone system
- Voice or audio signals introduced into a headset or speaker
- Voice communication of flight crew members using the PA system

Chapter 16

Flight Data Recorder
(FDR)

The FDR records various aircraft parameters during the entire duration of the flight. The main function of the fight data recorder (FDR) is to preserve the aircraft data in order to determine the cause of any aircraft accident. It is also used to gather information for trend analysis and trouble shooting. In smaller aircraft the FDR may be combined with a cockpit voice recorder.

The FDR records the last 10 or 25 hours of aircraft data on a digital storage device housed in a shock resistant box that is painted red and located at the rear of the aircraft, normally under the fin. On the front of the unit there is an underwater locating device (ULD)

Information from the data interface and acquisition unit (DIAU) is sent to the aeroplane condition monitoring system (ACMS) , along with inputs from aircraft systems , such as air conditioning , auto-flight , flight controls , fuel , landing gear, navigation systems, pneumatic systems, APU and engines.

This information is used for system monitoring and trend analysis, and can be downloaded via the aircraft printer, via ACARS or via the ATSU.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