Instrumentation

Eliott Johnson

01 Sensors and Instruments 3

Pressure gauge

1 bar = 15 psi
1 bar = 100'000 Pa
200 bar = 3000 psi

- Sensing elements:
  - Aneroid capsules:
    - Low Pressures
    - Measures absolute pressure, low pressure fuel pump, air intake pressure of gas turbine
  - Bellows
    - Medium pressures
    - Cabin differential pressure, Manifold pressure gauge ← absolute pressure in intake system near inlet valve
  - Diaphragms
  - Bourdon tube
    - High pressures and temperature

- Hydraulic pressure sensed by transducer

Temperature sensing

1) Resistance thermometers
2) Thermocouple thermometers
   - Couple of two metals → cold junction must be kept constant (alumel/chromel)
   - uses thermo electric effect to measure a differential temperature
   - −200 to 2000°
   - measure exhaust gas temperature → outlet of high pressure turbine

$°C = K - 273$

$F = 1.8°C + 32$

TAT = SAT + Kinetic + adiabatic heating

- Bimetalic strip can measure up to 500°C but not higher
- White Sector = special operating range
- Yellow Sector = exceptional operating range
- Red Pointer = moves to corresponding value and remains positioned

Fuel Gauge

- Can be measured in volume or mass
  - ↑ most relevant parameter (invariant)

Mass
- 1 kg = 2.2 lbs
- 1 lb = 0.45 kg

- Float system
  - measures volume
  - easy construction
  - independant of atmospheric pressure
  - indication varies with
    - altitude
    - acceleration
    - fuel temperature → expands fuel
  - usually DC powered

- Capacitance-type
  - measures mass ⚠ if volumes changes, mass of fuel does not!
  - Uses air and fuel as dielectric of the capacitor (charge of condenser)
  - dielectric constant of fuel (Kerosene 2.10, Gasoline 1.95) is twice that of air (1.0) and varies directly with density
  - Failure: sudden full deflection to empty (capacitance to zero)

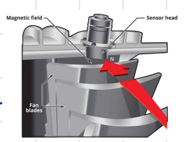
Fuel Flowmeters

- Fuel flow can be measured by $\frac{\text{mass or volume}}{\text{unit time}}$
- mass fuel flowmeter takes into account fuel density
- Total fuel calculated by integration

Tachometer

- Mechanical ("magnetic")
  - permanent magnet turning inside a non magnetic drag cup
- Electrical
  - Measures rotation speed of a synchronous motor (turning a drag cup)
  - three-phase generator that feeds
  - ∝ frequency
- Electronic ← need power supply (bad)
  - notched wheel rotating in front of an electromagnet
  - AC voltage ⎍⎍⎍ squares pulses

- turbine engine speed measured a % of reference speed



Thrust measurement

1) N1
   - LP shaft
   - can select sometimes above 100%
   - N1 automatically adjusted as aircraft climbs
2) EPR
   - if increasing OAT, thrust decrease because lower altitude = higher density = more back pressure
   - $\frac{\text{Turbine outlet}}{\text{Compressor inlet}}$ measured with pressure probes

Engine torquemeter

- Torque [N·m]
- Power = Torque · RPM $= T \cdot \Omega = \frac{\text{Work}}{\text{time}}$ (RPM $\cdot \frac{2\pi n}{60}$)
- Mechanical
  - measure change in phase between torque and reference shaft
  - measures the oil pressure at fixed crown of epicycloidal gears of the reduction gearbox
  - axial movement generated by the helically cut gears when power is transferred from one shaft to another
  - axial forces are proportional to the torque
- Electronic
  - Can be measured with the twist of the shaft of a known length (with increasing power)

Synchroscope

- Gives information about engine speed and sets them to the same speed
- Compares engine speeds to reduces vibrations and ~~avoid asymmetric flight conditions~~ ↳ not main purpose
- Master engine = outer left engine n°1
- Works on the basis of a voltmeter fed by two tachometer
- Measures the difference in output frequencies of both alternator

Engine Vibration Monitoring

- Shows FFT → vibration amplitude at a given frequency
- Removes background noise and normal engine frequencies
- Based on 2 accelerometer
- "4" indicates vibration amplitude no units
- Vibration can display N1 or N2

Systems:
1) Piezoelectric cockpit dials and measures vibration
2) Magnet

2 Measurement of Air Data Parameters 8

1013 hPa
14.5 psi
29.92 inHg

Pressure measurement

- Static source inside feels lower pressure due to aerodynamic suction
  - ↳ altimeter over-reads
  - ↳ airspeed indicator over-reads
- Ultimate emergency → break rate of climb window
- at high speed, if not corrected, altimeter indicates higher altitude (because Venturi, lower pressure)

Temperature measurement

TAT = SAT + Kinetic and adiabatic heating

$$SAT = \frac{RAT}{(1 + 0.2\,M^2 \cdot k_r)}$$

OAT; RAT: indicated/total; k_r: recovery coeff

- T in [K]
- memo divide total to become smaller

$$SAT = \frac{TAT}{(1+0.2M^2)}$$ ⚠ no k_r

SAT is a relative temperature expressed in K
TAT temp resulting from aircraft motion in air
↳ display to become aware of icing

$$220 = \frac{RAT}{(1 + 0.2 \cdot 0.79^2 \cdot 0.96)}$$

Angle of Attack (AoA)

- Angle between chord line and airflow
- Critical AoA is the stalling angle
- The AoA vane feeds its output to the ADC
- System AOA sensor ← needs Flaps/slats input data
  - conical
  - vane
  - ~~inertial~~
  - ~~Slaved pitot~~

- null seeking probe uses potentiometer for measurement and is subject to position error
  - ↳ protected by electric heating

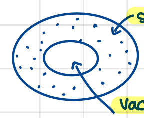
Altimeter

uses induction pickup for the capsules

- Servo-altimeter reduces lag
  - ↳ more accurate design

sensitive altimeter (aneroid)

- Altimeter consists of aneroid capsule →



static pressure; vaccum; uses 2 aneroid capsules

  - ↳ indicates true altitude in ISA only
- Density altitude: Altitude of standard atmosphere on which density is equal to actual density of the atmosphere
- if QNH set to 1013 → altimeter shows a pressure altitude
- Hysteris = time lag ← most often seen as we fly FL
  - under-reads in a climb
  - varies a lot with time spent at altitude
  - pressure P_s prevailing, in standard atmosphere
- Temperature correction applied at MDH/MDA and step-down fixes inside the FAF

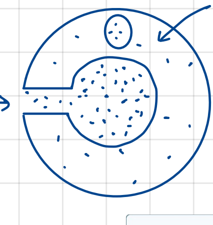
Vertical speed indicator (VSI)

- Can be improved by accelerometer sensor (to make reaction time quicker)
- VSI measures static pressure at T and T_{-1}

Airspeed indicator (ASI)

I C E - T
- I: instrument + position
- C: compressibility
- E: density
- EAS = TAS if 1013 hPa +15°C
  - ↳ always negative, depends on Mach only

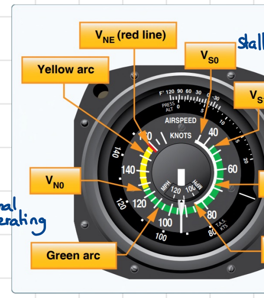
ASI capsule



Total pressure →; Static pressure

ASI = Total − static
= $P_{Dynamic}$

- Barber pole (striped needle) indicates V_{MO} (altitude)



stall full flap; stall clean; normal operating; Flaps extended

- TAS = CAS + $\frac{1\%}{600 ft}$
- Calibration using Saint-Venant formula for compressibility
  - ↳ if no static or instrument error indicates EAS
- On a twin-engine, blue radial line → best single engine climb
- Unreliable airspeed
  - ↳ does not trigger warning

Machmeter
$EAS = CAS \cdot K$

Clicken Tikka Massalla

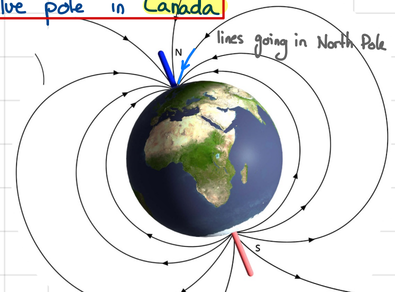
$Mach = \frac{TAS}{LSS}$

- Compressibility correction from CAS to EAS
  - ↳ is always negative
  - → depends on Mach number only
- Mach number obtained from: indicated speed and altitude using speed indicator equipped with altimeter type aneroid
- Position error concerns both pilot and static port
- Mach constant = CAS constant if steady cruise (even if temp change)
- Stripped barber arrow → aneroid capsule only
- Max TAS obtained at FL at $CAS = V_{MO}$ and $M = M_{MO}$
- Mach indicator is independ of outside temperature (only take P_0, P_S)
  - ↳ $\frac{P_D}{P_S}$

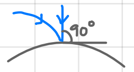
Air data computer (ADC)
- Inputs: AOA is a peripheral
  - TAT
  - Static pressure
  - Total pressure
- Outputs
  - Pressure/Barometric Altitude from static source → Transponder
  - TAS, CAS, Mach number → EFIS / TCAS/ AFCS
  - SAT
- Only pressure/barometric altitude not true altitude

03 Magnetism - Direct Reading Compass and Flux Valve 2

Earth's magnetic field
Blue pole in Canada



- force greatest at equator
- Magnetic meridian = Horizontal component
- Magnetic variation = angle between horizontal component of magnetic field and True North direction
- Inclination at Pole is 90°
  - ↳ equator is 0°



- Magnetic dip = angle between compass needle and local horizontal
- $dip = \cos^{-1}(H/T)$
- Directive force → aligns the compass needle
  - ↳ decreases at the poles

C D M V T

- Magnetic heading can be derived from true heading by map showing isogonal lines
- Variation is because of the difference between geographic and magnetic pole

Aircraft magnetic field
- Compass swing after 1 year stationary on the ground
  - ↳ compass swinging curve converts compass heading to magnetic heading
  - ↳ determines the effect of hard and soft iron
  - ↳ needs to be done after lightning / latitude change
- Compass calibration valid for → any heading
  - ↳ determine residual deviation (noted after compass swinging procedure)
- Quadrantal deviation due to soft iron influenced by geomagnetic field

Direct reading magnetic compass
- For northern hemisphere
- Acceleration errors: (ANDS ⇒ accelerate north, decelerate south)
  - if aircraft accelerates W⟷E, compass indicates apparent turn toward North
  - if aircraft decelerates W⟷E, compass indicates apparent turn toward South
  - N↕S no effect

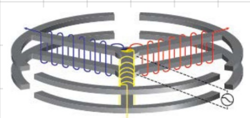
turning error because of vertical B-field

- Turning errors: (UNOS ⇒ undershoot North, overshoot South) (greatest at high latitudes/poles)
  - Aircraft turning through northerly heading, the pilot must undershoot
  - Aircraft turning through southerly heading, the pilot must overshoot

liquid swirls increases the effect

- Overshoot/undershoot by $\left(\frac{\text{bank angle} + \text{latitude}}{2}\right)$
- To remember if it's clockwise or anticlockwise:
  1) draw compass on a paper
  2) put pencil in direction of movement
  3) turn paper so that pencil points towards apparent turn
- Made aperiodic (dead beat) by keeping magnetic assembly mass close to compass pivot and damping wires
- Direct reading compass (DRC) → does not require power
- Maximum possible deviation errors are +- 10°

Flux Valve



- Detects electronically the horizontal earth magnetic field
- Used in a remote reading magnetic compass
- Heading information sent to error detector
- 2) information can be used as a "flux gate" compass or directional gyro
- 4) error in the value of magnetic field is less than 0.5%
- Sensor = 3 pick-up coil
- "free or slaved" switch decouples from flux valve

Flux Valve
Error detector
Amplifier
Torque motor

04 Gyroscopic Instruments 4

Gyroscope: basic principle
- Basic properties
  - rigidity in space
  - precession

  } high mass at periphery
- Drift = wander of the gyro axis in horizontal plane
  - Wander = $15 \cdot \sin(\text{latitude})$
- Two misaligned gyros → Transport wander

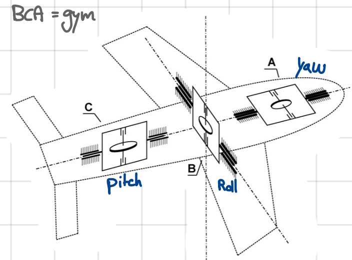
Turn indicator
- TL1

Artificial horizon
- AV2

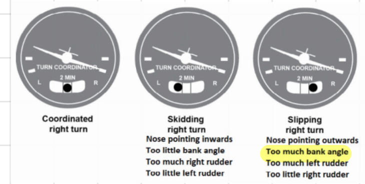
Directional gyro
- DH2

Errors
- Apparent wander
  - ↳ reduced by latitude
  - ↳ mvt gyroscopic pos. V axis seen by person standing
- gyro with vertical axis → only topple
- gyro with horizontal axis → drift and topple

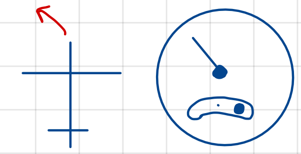
BCA = gym



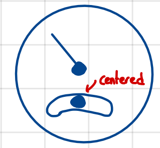
Rate-of-turn indicator - Turn coordinator - Balance (slip) indicator
- Rate 1 turn: 3°/second   bank angle = $\frac{TAS}{10} + 7$
- Turn indicator
  - Spin axis parallel to pitch axis and lateral axis uses rate gyro
  - Measure yaw rate for small angles
  - Displays the rate of change of heading
  - Inversly proportional to TAS



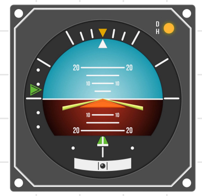
Taxiing on ground



"Yawing"



Attitude indicator (artificial horizon) ADI
AV2 Artificial horizon Vertical axis 2 degrees of freedom



- Roll attitude
- Pitch attitude
- Flight director
- Glide slope

turning errors in air driven artificial horizon

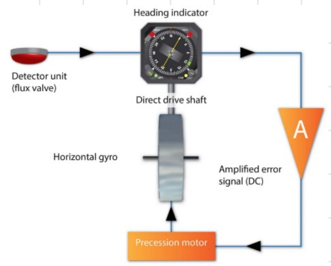
90°	Climb / under bank
180°	Climb / correct bank
270°	Climb / over bank
360°	Full correct

- four pendulous vanes

Directional gyro
DH2 → Horizontal spin axis, servo controlled in azimuth
- apparent wander = $15° \cdot \sin(\text{latitude})$ $\left[\frac{°}{h}\right]$
  - = 15° per hour at North pole
- Inaccuracy due to
  - Rotation of the Earth
  - Aircraft moving over the surface of the Earth
  - Mechanical defects
  - Gimbal mount of the gyro rings
  - Lateral and transversal aeroplane bank angles
- error from convergence of meridians = transport error

Remote reading compass system
DH2 → Horizontal spin axis, servo controlled in azimuth
- Levelling erection torque
- input signal from amplifier comes from error detector
- If gyro drifts → autopilot drifts
- Senses rather than seeks (more sensitive)
- Any heading pilot desires
- annunciator used to check operation of slaving loop

FEAT (Flux valve → Error detector → Amplifier → Torque motor)



Solid-state systems - altitude and heading reference system (AHRS)
- AHRS → piezo-electric gyro
  - ↳ Micro-electromechanical sensors technology MEMS
    - ↳ accelerometers
    - → rate sensors
    - → magnetometers
- Integrates Accelerometers, gyroscopes and magnetometers

05 Inertial Navigation 3

Basic principles

- if NAV of an INS inop and switch to ATT → output is attitude and heading
- local vertical alignement → accelerometers

IRS (Most recent technology)

- located close to CG and uses laser gyro to calculate accelerations
- IRS Strapdown 3 gyros, 3 accelerometers (in line with aircraft axes)
- Acceleration measured free from aircraft trihedron
- Ring laser gyro uses:
  - Ceruit glass
  - Cathode and Anode (to excite the lasing medium)
  - two laser beams/light waves frequency difference - beams rotating in opposite direction
  - Gyro measures rotation/angular movement only
  - measures rotation about sensitive axis

- INS
  - Old gyro platform (stabilized)
  - 3 gyros and 2 accelerometers (on the same platform)
  - Uses mechanical gyroscope and stand alone computer
  - After alignment output is rate correction to gyros

INS Alignement and operation

- Alignement (or gyro compassing) takes longer at high latitudes
  - ↳ 10 minutes at 60° lat
- laser gyro
  - is much more cumbersome
  - has a longer lifecycle
- OFF - ALIGN - NAV - ATT
  - The horizontal alignement precedes the unit orientation calculation
  - Battery test during alignement
  - ATT: provides altitude and heading
- Position updated only on the ground
- Incorrect entry of latitude is much more critical than wrong longitude
  - ↳ error in lat grows in time ↳ error in long stays constant
  - ↳ INS will not accept a 10° error in latitude
    will accept a 10° error in longitude
  - → IRS compares the computed latitude (with the one entered by pilot)
    - ↳ doesn't know longitude (does not compare longitude because he can't calculate it)
- IRS alignement:
  - IRS calculates the computed trihedron w/r to Earth
  - Uses Earth rotation and gravity
  - Can be aligned in ALIGN or NAV
- Stabilized platform inertial system is Azimuth controlled to True North and continuously gyro-erected
- North aligned by inputs from horizontal accelerometer and east gyro
- Errors in position 1-2 NM/h, 1.5 NM/h or more
- DSR TK/STS: Desired track and status to show great circles
- XTK/TKE: cross track distance and track error angle to check accuracy of IRU
- ADC (Air data computer)
  - supplies wind velocity, TAS
  - Can be reset in flight
- Output on ADIRU (Air Data Inertial Reference unit)
- Output from INS computer to platform → Rate correction to gyro
- Output from platform → acceleration N/S, E/W, attitude and true heading
- Input for IRS on CDU/MCDU

06 Aeroplane: Automatic Flight Control Systems 11

General

- Autopilot stabilizes aircraft around CG → Monitors movement of CG in three dimensions of space
- Self-induced oscillations
  - caused by anomalous interactions between pilot and aircraft
- Closed loop
  - Regulator processes the difference between target and corrected actual value according to control laws
  - Servo mechanism: closed loop control small power inputs to much larger output proportionally

Autopilot system

- CWS (Control wheel steering)
  - Controlled with control column
  - Consider as target the current pitch and roll angle (altitude at that moment)
- TCS (Touch Control Steering)
  - Temporary manual flying while the autopilot is still engaged
- Inner loop
  - Stabilization function
    - Wing, Yaw, Pitch } W Y P
- Outer loop: Guidance/command/path
  - MACH/IAS/V-Speed
  - Altitude
  - VOR
  - Glide slope intercept and track
  - monitors movement of CG in three dimensions of space
- Synchronisation (prevents jerking when engaging AP)
  - Can prevent engagement of autopilot if INOP
- Altitude hold takes pressure from static source (independent from barometric setting)
- VOR cone of confusion → temporarily maintains a heading
- V/S (Vertical speed) and FPA (Flight Path angle)
  - both follow trajectory but use different reference
  - VS altitude gain per time
  - FPA altitude gain per ground distance
- During a climb: V/S engaged and ALT armed
- Mixed mode: for vertical path → pitch attitude to avoid tail-strike and localizer for RWY centreline
- LNAV: autopilot uses roll or heading command computed by FMS
- Component of an AP:
  - Computer
    - Uses CAS, Altitude, Vertical speed, heading, altitude
  - Actuators
  - Mode control panel, Altitude reference system, ADC (Air Data Computer) } input
  - Mode announciator panel (not an input)
- Disconnect AP:
  - Push/Pull sidestick hard
  - A/P button
  - Takeover button
- Initial phase:
  - New trajectory is obtained via a change in altitude to achieve desired parameter
- Capture phase
  - Given rate of change of trajectory maintained to achieve parameter without undershooting
- Hold phase (tracking)
  - AP maintains parameter without any change
- Localizer interception
  1) at constant heading (HDG mode) until capture point
  2) at capture point changes from HDG to VOR/LOC, capture by radio deviation signals

Flight Director System FDS Design and Operation

- Flight Directors (FD) are presented on the ADI (Attitude Director Indicator)

Aeroplane: Flight Annunciator FMA

- AFCS (Automatic Flight Control System)

Vertical guidance mode

- wing level hold
- altitude hold
- IAS or Mach hold
- GS intercep and track
- FMS vertical navigation
- Flight path angle hold

Stabilisation mode

- pitch angle hold
- bank angle
- wing level hold

Lateral guidance mode

- localiser intercept and hold/track
- track hold
- FMS lateral navigation
- heading hold

Autoland

- Fail passive
  - 2 AP
  - No significant deviation from flight path or out-of trim
  - If failure, can't autoland
- Fail operational hybrid
  - Consists of primary fail-passive and independent HUD for manually landing
- Fail operational/active
  - 3 AP
  - If failure, can still autoland
- Semi-automatic: disengages at DH
- Does not need barometric altimeter, only auto pilot, autothrottle and radio altimeter
- Single autopilot: Go around is manual
- Dual autopilot: Go around pitches up automatically
- Failure of AoA sensor → ADC affected
- In case of AP failure → continue as Pilot monitoring

08 Trims - Yaw Damper - Flight Envelope Protection 3

Trim systems

- Automatic pitch trim
  - Prevents snatching on disengaging A/P
- Mach trim system
  - prevent Mach tuck (nose down) by offering a pitch up moment
  - Active when centre of pressure move rearward above a certain Mach number

Yaw Dampers

- Avoids Dutch roll
- Acts on the rudder without moving the rudder pedals (no feedback)
- Requires a rate gyro
- Is not designed to provide a balanced turn
- Activates if derivative of yawing rate is not zero (basically yawing rate is not constant)
- Yaw damper filter: detects roll rate that initiate Dutch roll (i.e. not normal turn)

Flight envelope protection (FEP)

- Purpose
  - Autothrust protection
  - Reversion modes
- Stall protection
  - Overspeed protection
    - produce an automatic pitch-up signal
  - Rolls the aircraft wings level
  - Does not act on thrust

09 Autothrust 4

- Ground/TO roll = hold N1
- Flight = hold N1/IAS
- Approach/Climb (with VSI) = Hold IAS
- Can hold:
  - IAS
  - MACH
  - N1, EPR
- Autothrottle not used for engine start (FADEC does that)
- Engine thrust controlled by autothrottle in response to mode commands from crew or FMC
- THRUST mode: thrust set to computed thrust using performance database
- N1 adjusted automatically as aircraft climbs
- In climb holding vertical speed, autothrottle can be operated in SPEED mode

10 Communication System 2

Voice communication, data-link transmission

- SATCOM (Avex: no lign of sight, no variable quality by ionosphere)
- ACARS (Aircraft communications, addressing and reporting system)
  - On-board and ground units: ATC/AOC
  - Transmits via HF (slow), VHF or SATCOM (fast)
- Data-link messages:
  - Departure clearance
  - Oceanic clearance
  - D-ATIS (Data link Automatic Terminal Information Service)
  - Printer connected to external bus
- North pole communication: HF frequency

Future air navigation systems (FANSs)

- ICAO concept used in FANS airspace over the oceans to allow for smoother traffic flows
- Uses SATCOM
- ADS (Automatic dependent surveillance)
  - ↳ Automatically sends position and altitude of an aircraft to other nearby aircrafts
  - ↳ Periodic, on demand and on event
  - ↳ MAYDAY → high periodic rate
- FANS-1/A: require specific RNP capabilities

11 Flight Management System (FMS) / Flight Management and Guidance System (FMGS) 6

Design

- FMS provides continuous automatic navigation guidance and performance management
- XTK (cross track error) → abeam distance error, left or right from desired flight plan leg
- Dual FMS
  - ↳ if one fails → operative FMS takes over
- 4-D (time)
- Normal FMS operation → master, slave with synchronization through common bus

FMC databases

- Performance and navigation database
  - ↳ calculate perf. including drag and thrust
  - ↳ no obstacles
  - ↳ no terrain cell
  - → no ATC frequencies

If update database:
→ data entered will be deleted

- Place bearing / Place bearing (PBX)

- Inputs using 5 alphanumeric → navigation facility, reporting points and airway designator
- Performance factor: ⊕ or ⊖ factor intended to adjust the predicted rate of fuel flow
- Magnetic variation info stored in each IRS memory
- The FMS doesn't take into account the MEL items

Operations, limitations

- FMS inputs ← IRS, Air Data Computer, GPS, VOR, DME, LOC

Cost index $CI = \frac{\text{operating cost}}{\text{fuel cost}}$

CI = 0 results in max range airspeed

- primary method for radio position → DME/DME
- FMS VNAV based on → baro altitude input from ADC
  - ↳ output command: pitch angle and target speed
- Fuel management → helps but should not be considered an accurate and reliable source
  - ↳ if wrong fuel indication → FMS needs to be reinitialized

GPS lost → loss of integrity monitoring (RAIM) and RNP APCH capability

- Least precise at top of descent
- DME 0.3 NM
- Kalman filtering used in navigation computer

FMS guidance
- → RNAV
- → VOR/DME, VOR } non-precision approaches
- → NDB

Human-machine interface (control and display unit (CDU) / multifunction control and display (MCDU))

- MCDU inserted data represented as white text in the scratchpad
- IDENT
- POS IDENT
- FMS LEG page
  - → True track
  - → Distance to waypoints
  - → Remaining fuel prediction
  - → Distance
  - → Time prediction
  - → Altitude constraint or prediction
  - → Speed
  - → ~~Position (long/lat)~~

- → Bearing/Distance
- → Bearing/Bearing
- → Along track displacement
- → Latitude and Longitude

Messages
1) FMC ALERTING
2) FMC ENTRY ERROR
3) FMC ADVISORY

12 Alerting Systems, Proximity Systems 8

General

1) Red warning lights → immediate action
2) Amber caution lights → immediate awereness
3) Green Safe operation advisory light → crew awereness required and subsequent crew action may be required

Flight warning system (FWSs)

Priority
1) Stall
2) Windshear
3) GPWS
4) TCAS

Advisory messages on the ECAM

Stall Warning System (SWSs)

- based on measuring AOA, Configuration (slats/flaps) and speed (CAS)
- opening on wing leading edge connected to duct
- unique stall sound
- required margin to stall 5Kts or 5% of CAS whichever is greater
- FBW → inhibits and limits pilot inputs

Stall protection

- Stick pusher
  - ↳ warns + protect of stall without pilot action requirement

Overspeed warning

- if exceeding V_{MO}/M_{MO} → Reduce power to idle, → Give a nose-up input } issue a warning

Take-off warning

- aural warning only
- Stabilizer, trim or parking brake out of position
- No trigger: → low brake pressure, → elevator

Altitude alert system

- warns if: → approaching pre-selected altitude
  - → deviation above or below pre-selected altitude

Radio Altimeter

- if RA failure → affected systems are Autothrust and EGPWS
- Supplies TCAS, GPWS and Autoland
- Two antennas → 1 Transmitter, 1 Receiver
- Frequency band SHF 4.2 - 4.4 GHz, frequency modulated
- Limitation: works up to 2500ft
- +- 2ft or 2% whichever is greater between 0-500ft and 5% above 500ft
- Low alt RA: Centimetric
- High alt RA: Decimetric

GPWS

- Receives data from
  - → CAS
  - → Landing gear + flaps
  - → Radio altimeter
  - → GS deviation
  - → ADC

→ Aural alert, Aural Warning

depending on PAX #
- Turboprop
- piston
- jet

- generates at least one alarm to which a visual alarm can be added
- TAWS/EGPWS (helicopter HTAWS) → terrain ahead
  - Terrain Awareness Warning System
  - Enhanced GPWS
  - → Aural alert, Aural Warning, Terrain on ND
- Uses RA, 3D database, baro alt, IRS, GNSS, ILS, FMS
- If position is less acurate: the terrain display on the ND will be affected only
- Caution alert: 40 to 60 seconds before hitting terrain
- Warning alert: 20 to 30 seconds before hitting terrain
- Does not give predictive windshear
  - ↳ but windshear yes

Mode 1: "Sinkrate, Sinkrate":
- excessive descent

Mode 2: "Terrain, Terrain"
- excessive terrain closure

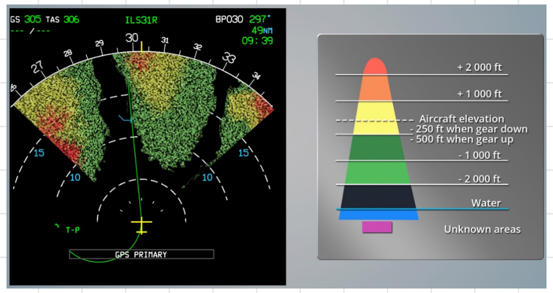
Mode 3: "Don't Sink" repetive only
- altitude loss after take-off

Mode 4a/b: "Too low Gear/flaps"
"Too low Terrain"

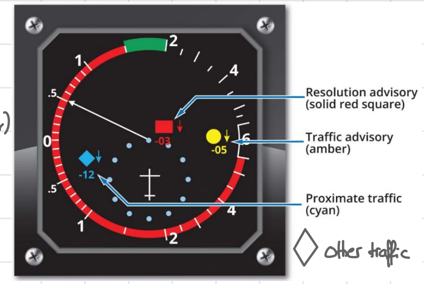
Mode 5: "Glideslope"

Mode 6: "Bank angle + Callout"
- Mode 6A DH "Minimums, minimums"

Mode 7: "Windshear"



ACAS / TCAS



TCAS II

- upper and lower antennas are directional (separated from transponder)
- preventive resolution advisory RA
  - ↳ only advises to avoid deviation from corrent vertical rate
  - → requires no change
- avoidance resolution
  - → only in the vertical plane
- REVERSAL → "Climb, climb now" after a "Descend"
- Anti-collision logic based on Time

Transponder

- if transponder with no altitude reporting → "traffic advisory" only
- if no transponder → no protection / not work
- Mode A for TA
- Mode C for RA
- Mode S for coordinated RA
- operates on the secondary radar principle

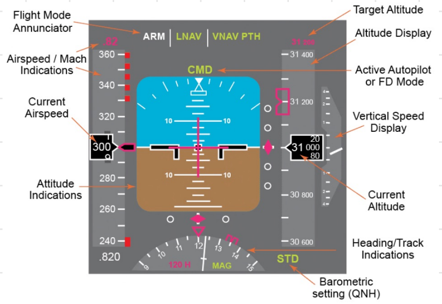
13 Integrated Instruments - Electronic Displays 4

Electronic display units

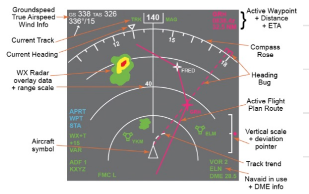
- LCD → requires low energy
  - → limited black levels
  - → poor viewing angles

CRT → massive heat

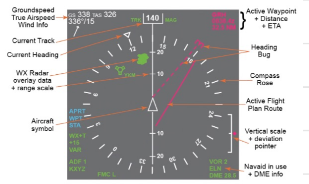
Electronic flight instrument systems (EFISs)



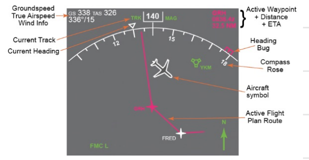
Map mode (MAP):
The MAP mode displays the plan view of the aeroplane's position relative to the FMC flight plan and/or FMC database waypoints or navaids. The map background (along with the route and navaid symbols) moves relative to the fixed airplane symbol. Display is referenced to the current track at the top of the screen. Displayed information includes aircraft heading, track, route of flight, trend vectors, wind direction and velocity, distances, ETAs, navaids, waypoints, airports, VOR/ADF bearings, weather radar display, etc...



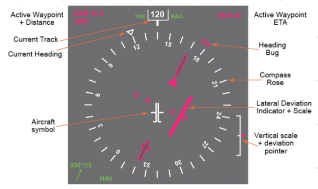
Centre Map mode (CTR MAP):
The CENTER MAP mode provides the same data as the MAP mode with the exception that the airplane symbol is located at the center of the display so that map data behind the airplane is within the viewing are.



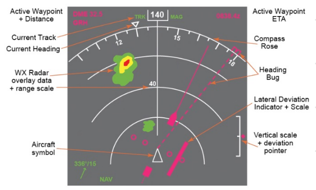
Plan mode (PLAN):
PLAN mode is the only EFIS mode orientated to the True North (TN is always at the top of the screen). The PLAN mode is a map display which may be used to view the FMC flight plan route, either in total in case of a short route, or in waypoint-by-waypoint method for a longer route.



Full-rose Navigation (FULL NAV):
The NAV mode is used when a conventional display (HSI-type) is desired to display deviation information from the FMC active route. In addition to the FMC route course deviation information (needle) the distance to the active waypoint is displayed, along with ETA. Wind direction and velocity + system source annunciation (NAV) is also displayed.
The display in NAV mode is orientated with reference to the current aircraft track.



Expanded-rose Navigation (EXP NAV):
The expanded NAV mode displays effectively the same information as the FUll-rose NAV mode, however only a segment of ± 45° either side of the current track is displayed on the compass rose. In the expanded mode it is possible to display the WX radar overlay.



- DH → radio altitude
- MDH → baro alt

Engine parameters, crew warning, aircraft system, procedure and mission display system

ECAM = Electronic Centralised Aircraft Monitor

EICAS = Engine-Indicating and Crew-Alerting System

EFB

- not covered by MEL
- Type A software → does not affect flight safety
- Type B software → impact safety (minor)
  - ↳ EFB

- Class: Integrated and separated EFB
- Hardware: Installed and portable

HUD (Heads UP display), SVS (synthetic vision system) and EVS (Enhanced Visual System)

- declutter → removes the altitude and speed tapes
- SVS shows Terrain and ground features

14 Maintenance, Monitoring and Recording System 1

Cockpit Voice Recorder (CVR)

- doesn't need to record cabin attendants
- no event switch

Flight Data Recorder (FDR)

- Records 25 hours (← after 1998) of flight data, 30 min of cockpit voice
- memory chip or magnetic tape
- Recording capacity and operational requirement
- Event button

Maintenance and monitoring system

- Record system status for company investigation

15 Digital Circuits and Computer 1

- CPU interacts with memory via address bus, data bus, control bus
- Transfer data via data bus (serial bus)
- Software on (REPROM, EEPROM) read only memory
- Level A Catastrophic