Instrumentation

Sensors and Instruments:

Bar = 100000 pascal
Measure absolute pressure not differential
Bourdon tube —>high pressure: oxygen pressure, hydraulic pressure, engine oil pressure.
Bellow sensors —> medium pressure: Cabin differential pressure , manifold pressure.
Aneroid sensor —> low pressure: low pressure booster pump or air intake pressure.

Thermometers:
Mercury thermometer : -37 up to 356
Bimetallic thermometer : -50 up to 400
Thermocouple thermometer : -200 up to 2000 operate by Voltage release (thermocouple can only measure the temp difference that's why it's important to know the absolute temp of cold side). (**$E = K X T_h$**) (two dissimilar metals)

Fuel low temperature—> higher dielectric high temperature —> low dielectric
Capacitative fuel quantity measure fuel mass (C = e X a / d)

Float type gauge provide information that varies with temp.

Total fuel consumption can be calculated by integration the fuel consumption per hour.

Advantages of 3-phase AC tachometer (electrical):
Utilises a generator feeding synchronous motor turning a drag cup.
1- Not sensitive to line resistance.
2- Independent on aircraft power supply (rotational force of gear create electrical current).
3- multiple indicators can be supplied from one sensing moment.
————————————————————

- Speed indicating element is synchronous motor driving magnetic tachometer.
- Frequency is proportional to transmitter drive speed.

N1 gauge reads engine speed (percentage of the reference engine speed)
N1 itself is the speed of LP compressor or fan speed.
Electronic tachometer measure the electric impulse created by a notched wheel rotating in a magnetic field.

Thrust measurement:
The maximum percentage of N1 sometimes is more than 100%
Two main sources to calculate turbojet thrust; N1 and EPR (engine pressure ratio)
Torque = Newton X meter
Power = Torque X RPM
Power = Torque X Ω (angular velocity)
Axial force is proportional to the torque.
Oil Torque meter: Helically cut gears cause axial movement when power is transformed from one side to another.

Electronic Torque meter: measure the twist in output shaft of the engine.

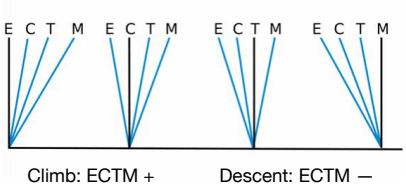
Synchroscope for a twin engine measure the difference in output frequencies of both alternators, so several engines can be set to same speed, reduce vibrations.
Synchroscope gives information about engine speed.

Vibration indicator receive signals from different indicators include vibration amplitude at given frequency.
Two types of sensors for vibration : Magnet, electric.
Filter vibration monitoring system : erase all data which is normal to the system and allow harmful data to go to the cockpit for the pilot to take actions.

Electrical requirement for alumel/chromel system is power for gauge lighting only.
Vibration indicate rotor imbalance.

Measurements of Air Data parameters:

RAM = SAT X (1+ 0.2 x(M^2 X Kr) or TAT = SAT X (1+ 0.2 M^2)
Vibrator in altimeter reduce the effect of friction in linkages.
Altimeter capsule has very low residual pressure inside and static pressure outside.
Airspeed indicator must be calibrated according to Saint-Venant, taking into account the air compressibility.
Striped needle in Airspeed indicator if installed, indicates V_{mo}/M_{mo} uses data from aneroid capsule.
VNE is speed you may only exceed in smooth air but not in dive.
VMO maximum operating speed, use EAS for calculating its value.



CAS = IAS + position + instrument error
EAS = CAS + compressibility correction
TAS = EAS + density error correction
TAS = CAS + compressibility error correction + density error correction

For constant CAS as you climb EAS decrease as density decrease as compensation and when you descent EAS increase as density increase.
$EAS = CASxK$ K: compressibility correction.
EAS depends on Mach number and its always equal or less than CAS.
Mach-meter is subjected to position error affected by (TAS)Mach number and AoA.
Air Data Computer ADC supply data to EFIS symbol generator, transponder, Auto Flight System and TCAS.
ADC collect data from static ports, pitot tube and **TAT** not OAT.

Mach-meter indication isn't affected with Temp. Mach = $(P_T - P_S)/ P_s$
Parallax is a reading error.

Magnetism - Direct reading compass and flux wave:

Attraction or repulsion between two magnets varies inversely with square of distance between the magnets.
Magnetic meridians is the horizontal component of magnetic lines of force.
Compass heading can be derived from magnetic heading by compass swinging curve in tabulated form known as compass deviation card.
Compass swinging is carried out to compensate compass deviation.
Turning errors is due to vertical component of earth magnetic field.
ANDS: Northern Hemisphere. SAND: Southern Hemisphere.
UNOS: under estimate north, over estimate south. (Bank angle + Latitude) / 2
Flux valve information is used in remote reading magnetic compass.
Inclination angle; Poles : 90 degrees Equator : 0 Degree
Magnetic Compensation: correct deviation. Calibration: determine residual deviation.
Direct reading magnetic compass error : due to north change depending on magnetic heading and bank angle.
Greatest magnetic force over equator.

Gyroscopic Instruments:

Apparent wander varies with latitude.
Two types of wander in terms of direction:
Drift : horizontal plane Topple : vertical plane
Gyro precess when force is applied 90 degrees to rotational axis or when forces are applied at the spinning rim at the same direction of axis of rotation.

Bank angle = (TAS/10) + 7
At constant bank angle of turn indicator reading is inversely proportional to TAS.
TL1 AV2 DH2
TL1 = Turn Indicator, Lateral axis, 1 degree freedom.
AV2 = Attitude indicator, Vertical axis, 2 degrees freedom.
DH2 = Directional Gyro, Horizontal axis, 2 degrees freedom. (Gyromagnetic compass)
Turn indicator measure the yaw rate for small bank angles.
Mechanical ADI relies on an electrical or vacum gyro !!!

In Air-Driven Indicators:
Acceleration :apparent climb and turn to right. Deceleration: apparent descent turn to left.
Turn through 90 degrees : apparent climb, under indication of bank.
Turn through 180 degrees : apparent climb, correct bank indication.
Turn through 270 degrees : apparent climb, over indication of the bank.
Turn through 360 degrees : both pitch and roll indicate correctly.

Solid state AHRS use piezo-electric gyroscope.
MEMS devices are used in AHRS and they are small in size & weight, low in cost, high accuracy.
MEMS used in Accelerometers, rate sensor gyroscope and magnetometers.

Apparent drift angle per hour = 15 X sin latitude {zero at equator and max at poles}
Apparent topple rate per hour = 15 X cos latitude {zero at the poles and max at equator}

Gyromagnetic compass:
FEAT : Flux valve - Error detector - Amplifier - Torque motor.
Flux valve: give direction of earth magnetic field, make gyro capable of self orientation.
Torque motor causes directional gyro unit to precess.

For transport wander : Add east, Subtract west.
In southern hemisphere earth drift to the left so we make gyro correction to the right.
Annunciator of remote indicating compass are used when checking the operation of slaving loop, synchronise magnetic and gyro compass.
Heading error is dependant on ground speed of aircraft, its true track and average latitude of flight
Gravity erector system is used to correct attitude indicator.
Gimbaling error: due to banked altitude.
Pendulous vanes are used with air driven artificial horizon (mechanical)
Electrical AH : tied to each vertical by two mercury level switches and two torque meters.

Internal navigation and reference systems (INS & IRS):

Schuler pendulum is used in the design of stabilised platform internal system.
Light illuminated beside the INS/IRS means there is a problem with AC supply and its been powered by battery.
ATT mode give provide attitude and heading.
Average position error on Internal Navigation system (INS) is 1.5 NM/ hr or more.
Stabilised platform inertial system require 3 rate gyro and 2 accelerometers.
Strapdown Inertial system 3 laser gyros and 3 accelerometers. Measure acceleration in trihedron fixed to aircraft trihedron. (Deals with Latitude only)
Ring laser gyro measure rotation about its sensitive axis.
Laser Gyro can measure rotation motion.
ADIRU (Air data computer integrated with IRS).
INS alignment : Vertical Axis & True North.

Rate Integration Gyro is used in : Inertial attitude unit, inertial navigation unit.
IRS use Electrical system for operation.
Laser lock-in: happens at low rate turns, corrected by dither.
IRU measure acceleration and angular rates.

Aeroplane automatic flight control system:

Aircraft guidance are moving its CG in a predefined path (Outer Loop) : holding altitude, IAS or Mach and VOR radial.
Aircraft control is moving aircraft around its CG (Inner Loop) : pitching, yawing and rolling.
Closed loop system monitor controlled parameters, calculate an error and corrects it.
CWS is where the pilot has the ability to make inputs to autopilot by movement of normal control wheel.

When disengaging Autopilot smooth handing is provided by automatic pitch trim.
When engaging Autopilot smooth handing is provided with automatic synchronisation function,.
Lateral flight path mode: localiser intercept and track, track hold and FMS lateral navigation.
Flight director is presented in attitude indicator.
Flight director indicate optimum instantaneous path to reach selected radial.
FMA (flight Mode Annunciator) is the only reliable source to provide modes engaged in autopilot, and it provide auto landing capabilities.
FMS lateral navigation mode use the roll or heading command computed by FMS.
To hold vertical flight path : you have to hold .!!!!!

Trims - Yaw damper -Flight envelop protection:

Pitch trim:
1-permit the elevator always to be in neutral position with respect to horizontal stabiliser.
2- ensure the airplane is properly trimmed when the autopilot is disengaged.

Yaw dumber :
1- doesn't provide balanced turn.
2- sensing disturbance in yaw by rate gyro or accelerometer.
3- is rudder tuber to avoid dutch roll.
4- doesn't give feedback to the rudder pedals.

Flight Envelope Protection : prevents airplane to exceed specific limits by reversion mode
Over speed protection roll the aircraft wings level and it doesn't act on thrust setting.

Auto-thrust control system:

Auto-throttle can be : 1- active. 2- armed. 3- disengaged.
Auto-throttle for takeoff allow to hold N1 Speed , for landing allow to hold IAS.
Auto-throttle isn't used during engine start.
Auto-throttle is required in auto flight mode to control vertical axis.
Auto-throttle is controlled by mode command from flight crew or flight management computer.

Communication systems:

D-ATIS (Data link Automatic Terminal Information Service): is ATIS message received by data link.
D-ATIS can be provided by (SITA, ARNIC)

Communication Management Unit (CMU) is connected to HF, VHF, Satcom, MCDU(Multipurpose Control Display Unit) and FMS.
ATC clearances can be received by datalink applications: Departure, Oceanic.
Best way of communication in North Pole is HF Communication.
Up link communication from ground to airplane, Down link communication from airplane to ground.
SATCOM transmissions : no line of sight and disturbed by ionospheric conditions.
FANS (Future Air Navigation System) relies on **GPS** developed by ICAO.
CPLDC is a FANS application of transmitting datalink formatted messages between the Pilot and ATC controller.
Log on in FANS mode is establishing air/ground connection to verify if datalink can be performed.
Route where FANS-1/A concept is used require specific RNP (Required Navigation Performance) capabilities.

ADS is FANS application consists in sending automatically aircraft surveillance to air traffic controller.

Flight Management System (FMS):

FMC (flight Management Computer): uses (GPS, Navigation radios, IRS, LOC and DME) for updating position.
Most common doesn't include Localiser and its only in the airport (my idea about its availability)

FMS —> 28 days. (4D and Navigation assistance).
FMS database include (Airports, Airways and Nav-aids), Magnetic variation information is stored in IRS memory.

Performance factor of FMS can take in consideration aircraft age.
FMC mainly decided into two sources : Aeroplane Performance and Navigation.
Performance factor (Positive/Negative) must be applied for better fuel burn prediction from the FMS.
Cost Index = Airplane Operating Cost / Fuel Cost.
Cost Index zero: maximum range airspeed, minimum trip fuel. (ignore trip time).
High Cost Index cares about time : use highest airspeed and high fuel trip.
FMS require RTA (Required Time of Arrival) to provide a speed target to satisfy a time entered in flight plan waypoint.

FMS vertical guidance function require (Airspeed and Flight path angle)(Pitch Angle&speed target).
Radio Nav system is accurate in DME range.
Inertial position may be obtained whatever the position on earth.
Fuel Management performed by FMC (not reliable) helps the crew to estimate remaining fuel.!!!
FMS lateral offset can be entered manually on FMC CDU.
FMS temperature compensation provide compensated altitudes for temperatures different from ISA along vertical approach profile.

FMS vertical navigation management based on the bar altitude input from the air data system.
FMS navigation between two waypoints use Great Circle Arc.
FMS LNAV output is a roll angle or a heading target.
FMS provide guidance for (RNAV, VOR and ~~NDB~~) **not** ILS.
FMS provide automatic switching of Radio Navigation Frequency. Its choice is based on suitability of the available signal in terms of geometry and strength.

If Radio Updating isn't available a warning will appear on MCDU showing "IRS NAV ONLY".
FMS for fuel prediction take into account(one engine inoperative & Current wind and resulting GS).
FMC least accurate position is on Top Of Descent.
FMS is approved for Localiser approach if Localiser signals can be used by FMS.
FMS is approved to provide guidance for **non-precision approach**.
Dead Reckoning (DR) is a backup navigation mode to compute FMS position where the other navigation sensors are no longer operating, use (heading & TAS).

FMS cross track (XTK) is abeam distance error to the left or right from desired flight plan leg to the aircraft position.
FMS Flight Plan or LEG page **displays (speed distance track)** but ~~not position(Long/Lat)~~
FMS doesn't display magnetic variation, it's data are stored for internal calculations.
FMS has both alerting and advisory message.

Alerting System & Proximity System:

Purpose is to Alert in case of failures.
Priority for flight warning system: Stall, Windshear, GPWS,TCAS.
Stall Warning receive info about: 1-AoA. 2-Airplane configuration (slats/flaps)
Stall warning on large airplane appears in form of control stick vibration simulating natural buffeting.
Low Altitude Radio Altimeter uses centimetric wavelength, (4200 - 4400)MHZ, SHF Super High Frequency, measure **frequency difference**, 2500 feet range. In last 500 feet accuracy (+/-2 feet)
High Altitude Radio Altimeter uses decimetric wavelength.
Radio Altimeter supplies data to: TCAS, GPWS, Automatic Landing System.

GPWS (Ground Proximity Warning System):

Send The Drunk To Go Buy Wine:
Sink - Terrain - Don't Sink - Too Low - Glide slope - Bank angle - Windshear
Too Low : too low terrain, too low flaps, too low gear.
Inputs of GPWS : ADC - CAS - Glide Slope -Radio Altimeter - Flap and Landing gear configuration.
Red: 2000 above airplane. Yellow: 1000 above Green: below about 500-1000.
Black: below 2000 from airplane altitude. Magenta: No Data for GPWS.
If computed aircraft position become less accurate, EGPWS will operate as basic GPWS which doesn't display terrain on Nav display.
For GPWS: Alert : 30 - 60 seconds Warning: 20 - 30 seconds

ACAS/ TCAS principles of operation:

TCAS interrogation signal is sent from TCAS and time is measured until a response is received from the transponders of the other aircraft, bearing is done by directional antenna.
TCAS is based on time.
TCAS II uses: 1- configuration (gear/flap). 2- pressure altitude. 3-height from radio altimeter.
Non threat : white / blue empty diamond.
Proximate traffic : white/blue full diamond.
Threat/ Intruding Traffic advisory : yellow.
Threat/ Resolution advisory : red solid square.
TCAS II gives avoidance in vertical plane only.
Mode A is minimum to produce traffic advisory , for resolution advisory you need mode C (minimum) or S to be able to determine altitude.
TCAS resolution advisory doesn't take into account stall margin.
If active transponder fails TCAS can't operate normally.
TCAS can't resolve the problem automatically with autopilot, it needs pilot action.
TCAS can be displayed in its own screen or combined with EFIS or weather radar screen.
Upper antenna is separate from transponder antenna and its directional for surveillance.
Traffic Advisory (Po**T**ential threat) **R**esolution Advisory (Se**R**ious threat)

Integrated Instruments - Electronic Displays:

Armed mode: white
ILS glide slope use Pointer with scale.
EFIS consists: symbol generator, display units, control panel, remote light sensor.
Navigation Display (ND) : Magnetic heading, track, course related info, **TAS, GS**.
PFD : altitude capture,**Radio altitude**, TCAS resolution advisory, autopilot and flight director mode, autothlrothle mode.
Decision Height (based on radio altimeter) : flash when you reach it , exceeding it makes colour changes from white to yellow, when you reach MDA (minimum decision altitude) altitude is based on barometric value.
ND is a mode selectable flight progress display.
EFIS shows current fuel flow of each engine.
Active waypoint appears in magenta or blue.

ECAM (Electronic Centralised Aircraft Monitoring System): in system failure:
1- Lights up appropriate push-buttons on the overhead panel.
2- Triggers an aural warning.
3- Display the relevant diagram on the system display.

EICAS (Engine Indicating and Crew Alerting System) : provide engine data on the upper part and monitor systems on the lower parts such as hydraulics, pneumatics and electrics.
To chose system on EICAS you have to select it manually.
Electronic display unit can show commanded N1 , **not commanded EGT**.

Maintainance, Monitoring and Recording Systems:

CVR (Cockpit Voice Recorder) consists of : Microphone and Recorder in compliance with shock and fire resistance standards. Doesn't have independent battery nor a flight data recorder.
CVR preserve the conversation for 30 minutes of operation.

FDR (Flight Data Recording) ; EVENT button allow to mark the record and enable this event to be found rapidly.
FDR Record flight data on last 25 hours, 30 minutes for cockpit voice.
FDR store data on memory chip or magnetic tape.
FDR doesn't contain area microphone.

ACMS (Airplane Condition Monitoring System) : use datalink without crew notification.

Digital Circuits and Computers:

MT Multitasking : Software concern, on same processing unit.
MP Mutliprocessing : Hardware concern, two or more CPU are used in same computer.
Bus : transfer data between computer component.
Parallel bus simultaneously provide data.
Control Unit: control data flow, co-ordinate activities.
Binary number : read from AE.
RAM characteristics : 1- Rapid access. 2- Volatile. 3- Read and write access.
'Von Neumann Arch' type holds data + instructions. Connected to CPU include: arithmetic ALU (basic operation) and control unit. It contain as well single separate storage structure.
Optical disc use laser beam to read data.
Software are stored on ROM.

Certification :
Operation system (Charts & Company info) :No certification.

Electronic documentation : EUROCAE.
ATSU: ED-12B, DO178B.
Flight controls : highest certification level A.

Software Failure: A: Catastrophic. B: Hazardous. C: Major. D: Minor.
Assembly Language is translated into machine codes and thereafter can be read by machine fast & easy, used to solve execution performance issues.

After exam notes

Interception of localiser take place at constant heading.
Max operating speed Vmo is expressed in CAS or EAS however its calculated from EAS.
Power = work done/ time
Capacitor type measure fuel according to change in condensers.
CG lies below pivot point in order to reduce magnetic inclination.
IRS measure in relation to aircraft axis.
Control Law: Computer Input deviation and output control deflection signals.
Autopilot system contain: Actuators, mode control panel, mode annunciator panel.

Fuel flow data information is stored in performance database.
Torque can be determined by measuring change in phase between the Torque shaft and reference shaft.

FMS lateral Navigation is performed based on the bare altitude input from Air data system (ADS).
Autothrotle can hold IAS and Mach number not TAS.
Automatic trim control on Pitch axis only.

Q=C x U

ADC output is : barometric Altitude, Mach number, CAS, TAS, SAT.
Magnetic dip angle is between compass needle and the local horizontal.

Ratio-meter type temp indicator carries carries out a measurement independent of the supply voltage.