

A330

Flight deck and systems briefing for pilots

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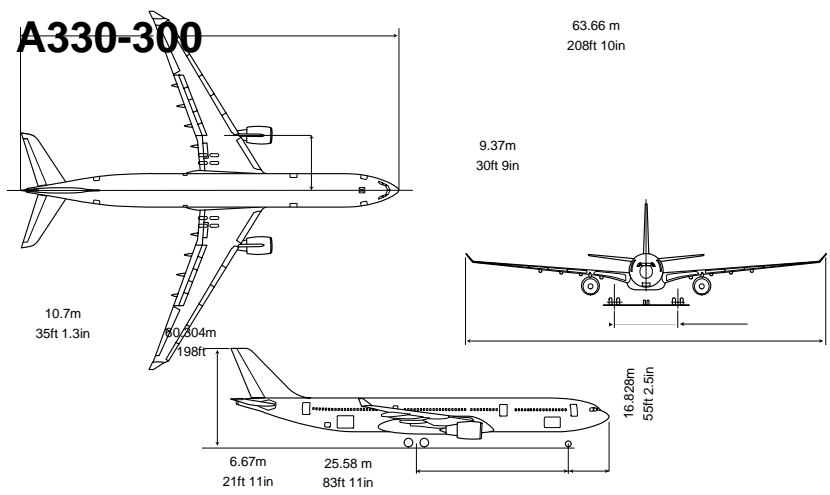
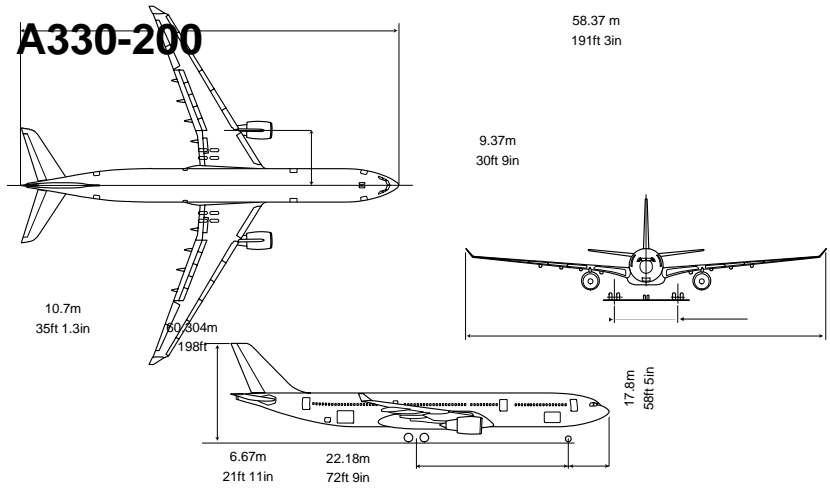
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RELEVANT AIRBUS DOCUMENTATION*

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10. **Automatic flight system**
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13. **Radio management and communication**
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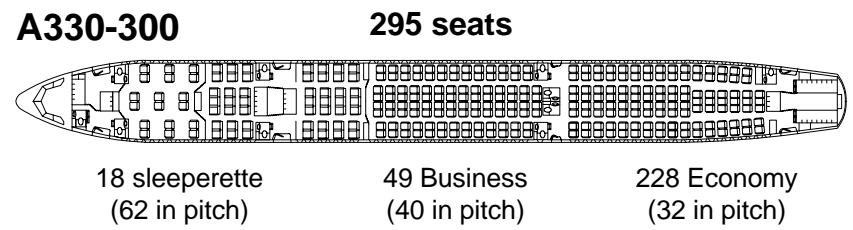
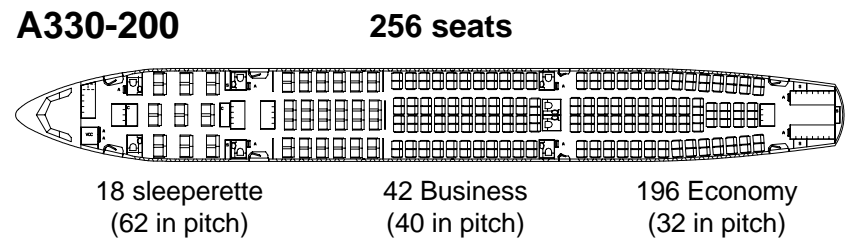


1. General

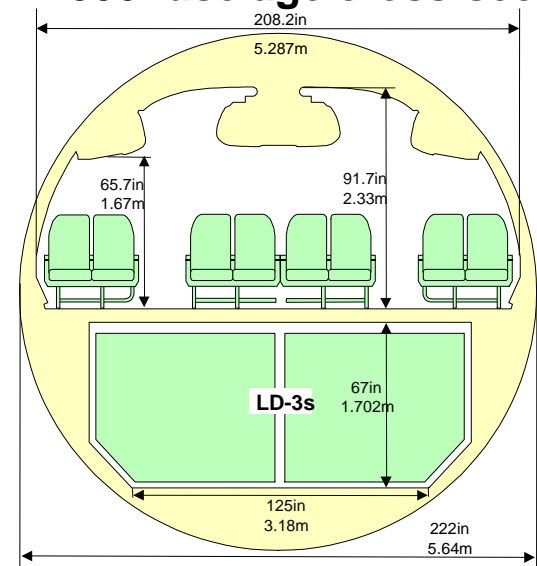
A330 general arrangement



Typical cabin layout



A330 fuselage cross-section



Passenger cabin

- True widebody spaciousness and adaptability

Lower cargo holds

- Large, efficient, fully compatible with existing worldwide air cargo system

Introduction

- The medium to long-range A330 is an all-new, wide-body, twin-engine, twin-aisle aircraft.
- The design combines high technology developed for the A320 and A340 with the wide experience gained from the A300 and A310 aircraft currently in world-wide service.

As with the A319, A320, A321 and A340, it will incorporate all of the following features :

- two-man crew operation with CRT displays
- electrically signalled flight controls
- sidestick controllers
- full authority digital engine control (FADEC)
- centralized maintenance system.
- Since it's introduction in December 1993 the aircraft is the most advanced medium to long-range airliner offering a major stride forward in airline profitability.
- Certification basis includes :
 - JAR 25 at change 13
 - JAR AWO at change 1 for CAT II and CAT III and autoland.
 - ICAO annex 16 chapter 3 for noise.

Basic data

	A330-200	A330-300
MTOW*	230 000 kg	217 000 kg
MLW	180 000 kg	179 000 kg
MZFW	168 000 kg	169 000 kg
Max fuel capacity	139 090 lit	97 170lit
Max operating altitude	41 100 ft	41 100 ft
Powerplants	GE CF6-80E1A4 70 000 lb	GE CF6-80E1A2 67 500 lb
	RR Trent 772 71 100 lb	RR Trent 768 / 772 67 500 lb / 71 100 lb
	PW 4168 68 000 lb	PW 4164 / 4168 64 000 lb / 68 000 lb
Design speeds Vmo/Mmo	330 kt CAS/0.86	330 kt CAS/0.86
Underfloor cargo	From 27LD3 to 3LD3 + 8 pallets + bulk 19.7 m3	32/33LD3/11 pallets + bulk 19.7 m3

* Max ramp weight 900 kg higher than MTOW

Aircraft design specifications

1. Design weights (see page 1.3)

2. Design speeds

$V_{MO} = 330$ kt CAS

$M_{MO} = 0.86$

$V_D = 365$ kt CAS

$M_D = 0.93$

$V_B = 260$ kt CAS

$M_B = 0.78$

V_{LO} (landing gear) extension
 retraction } **250 kt CAS**
 V_{LE} (Landing gear extended)

3. Slat and flap design speeds

Lever position	Function	Config. No.	Design speed V_{FE} kt (CAS)
0	Climb/cruise/holding	0	-
1	Holding	1	240
1	Take-off	1 + F	215
2	Approach	1*	205
	Take-off	2	196
3	Take-off/approach	3	186
Full	Landing	Full	180

4. Structural life (design aims)

The objectives for primary structure fatigue life are as follows based on average block time of 4 hours :

- design life goal 20000 flights
- threshold for initial inspection 8 750 flights

5. Landing gear

The design aim is 25000 cycles safe life operation in accordance with FAR and JAR.

6. Cabin pressure

Max nominal operational differential pressure	574 mb \pm 7 mb	8.33 psi \pm 0.1 psi
Actuating cabin pressure of discharge valve	610 mb \pm 7 mb	8.85 psi \pm 0.1 psi
Max relief valve overpressure	638 mb	9.25 psi
Max negative differential pressure	- 70 mb	1.00 psi

Aircraft design specifications

7. Fuel capacity

	A330-200		A330-300	
	Litres	US gallons	Litres	US gallons
Inner tank LH	42 000	11 095	41 904	11 070
Inner tank RH	42 000	11 095	41 904	11 070
Outer tank LH	3 650	964	3 624	957
Outer tank RH	3 650	964	3 624	957
Center tank	6 230	1 646	6 230	1 646
Trim tank	41 560	10 980	-	-
Total	139 090	36 745	97 286	25 700

8. Pavement strength

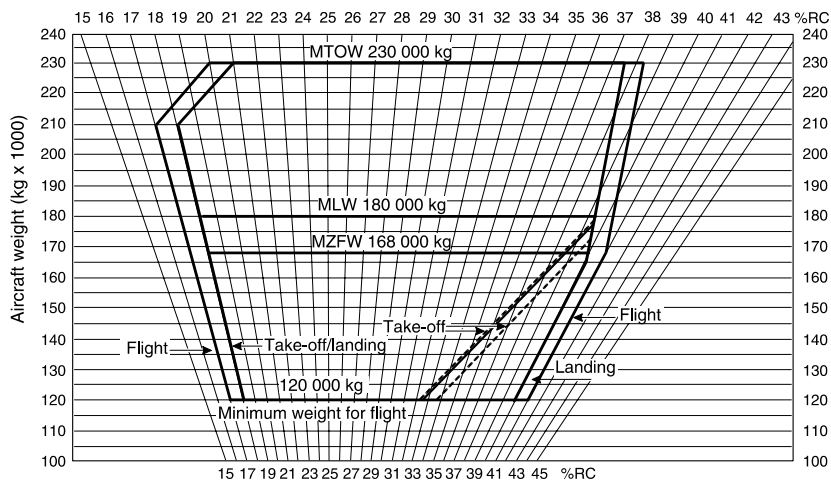
Max ramp weight and max aft CG.

	ACN							
	Flexible pavement				Rigid pavement			
	Cat A	Cat B	Cat C	Cat D	Cat A	Cat B	Cat C	Cat D
A330-200	61	66	77	105	52	61	73	85
A330-300	56	61	71	95	48	55	65	76

Tyres radial - main gear 1400 mm x 530 mm x R23
 - nose gear 1050 mm x 395 mm x R16

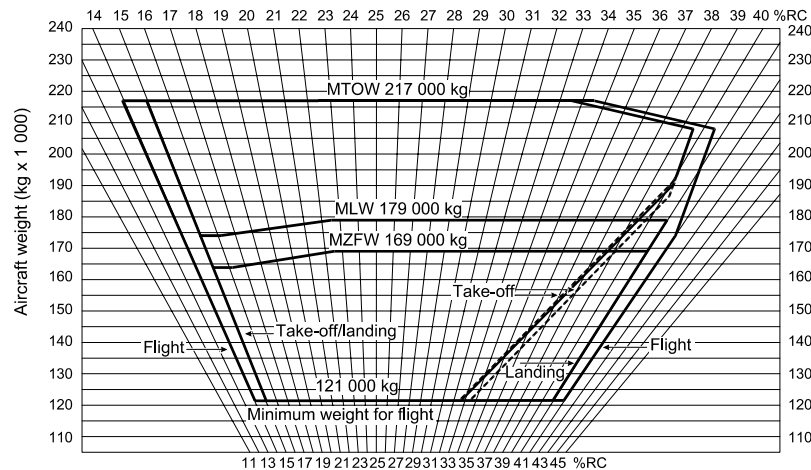
Weight and balance

A330-200 CG limits



Engines :
 - - - - R-R TRENT 772
 ——— PW4168
 - - - - GE CF6-80 E1A4

A330-300 CG limits



Engines :
 - - - - R-R TRENT 768
 ——— PW4164
 - - - - GE CF6-80 E1A2

A330 General

Ground manoeuvre capability

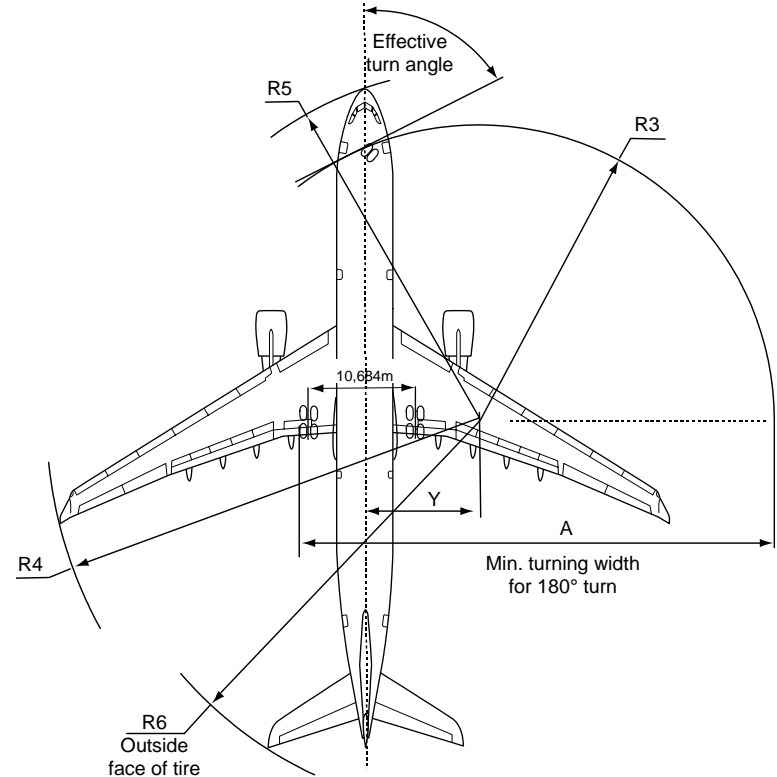
Minimum turning radius

Towing

The A330 can be towed or pushed up to a nosewheel angle of 78° from the aircraft centre line at all weights up to maximum ramp weight without disconnecting the steering.

Taxiing

Minimum turning radii (with tyre slip) and minimum pavement width for 180° turn are as shown.



A330-200

	Type of turn 1		Type of turn 2	
	Effective turn angle 78°		Effective turn angle 62.3°	
	Meter	(Feet)	Meter	(Feet)
Y	4.72	15.478	11.65	38.23
A	34.27	112.4	43.58	143.0
R3	23.24	76.26	25.62	84.06
R4	36.29	119.04	42.99	141.06
R5	29.26	96.07	31.20	102.37
R6	32.89	107.91	36.45	119.6

X = 22.19 m / 72.8 ft

Type of turn 1 : Asymmetric thrust differential braking (pivoting on one main gear)
Type of turn 2 : Symmetric thrust no braking

A330-300

	Type of turn 1		Type of turn 2	
	Effective turn angle 77.95°		Effective turn angle 64.5°	
	Meter	(Feet)	Meter	(Feet)
Y	5.342	15.53	12.10	39.7
A	38.13	125.1	47.16	154.7
R3	26.49	86.9	26.78	94.3
R4	36.96	120.9	43.36	142.3
R5	32.37	106.2	34.26	112.4
R6	34.60	113.5	38.01	124.7

X = 27.50 m / 90.23 ft

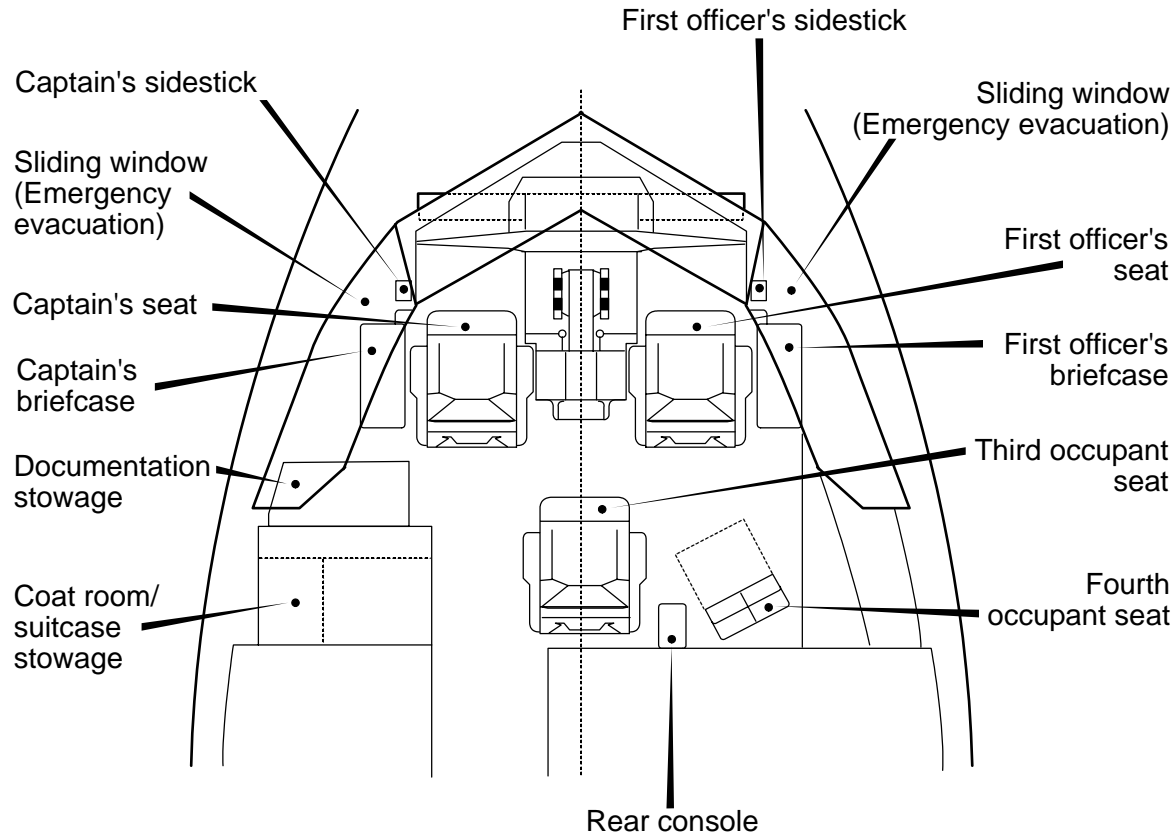


2. Flight deck layout

A330 flight deck layout

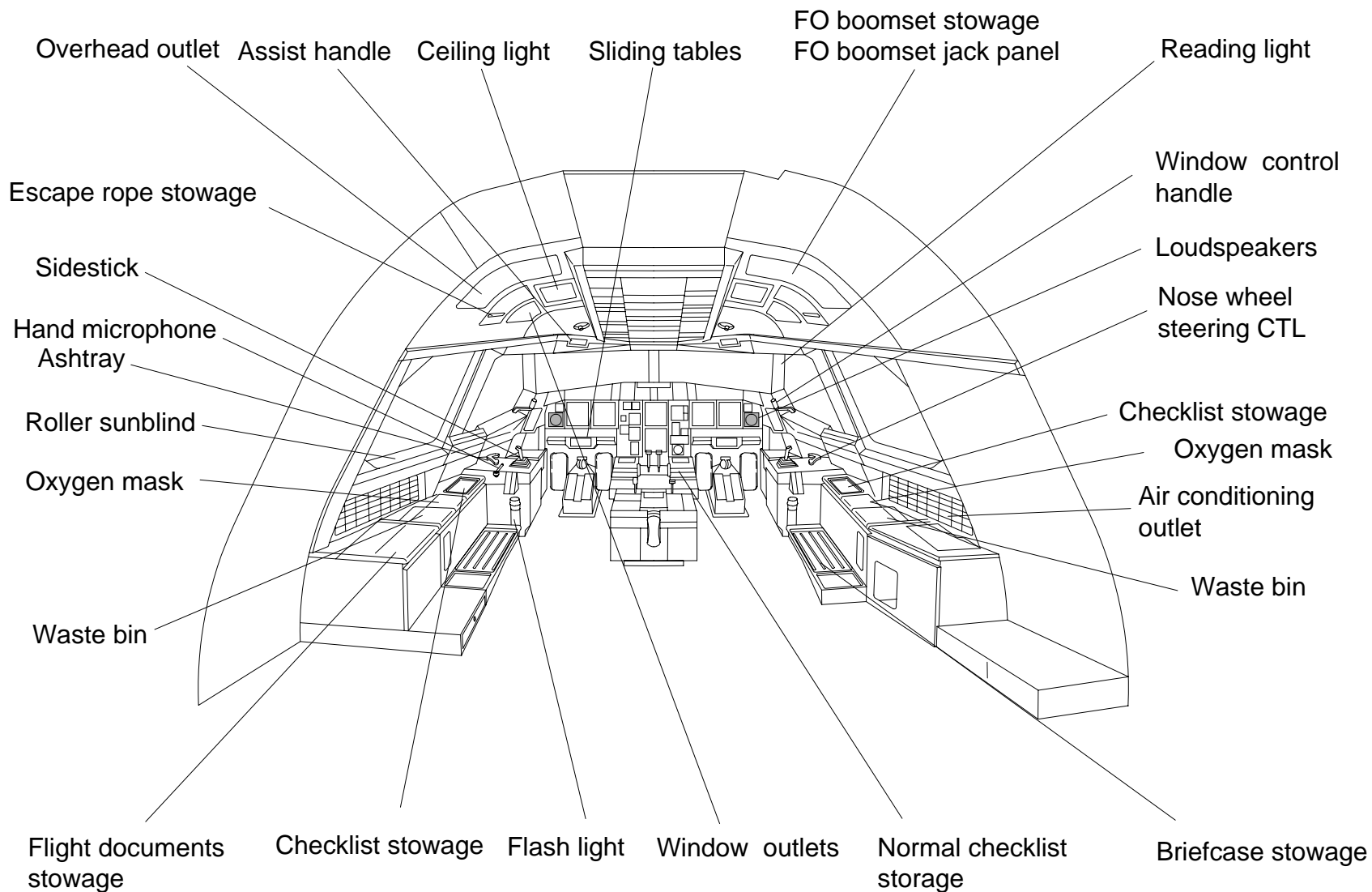
General provisions

- As the A330 is a medium long-range aircraft the cockpit offers full provision for a 3rd occupant seat as well as a folding 4th occupant seat.



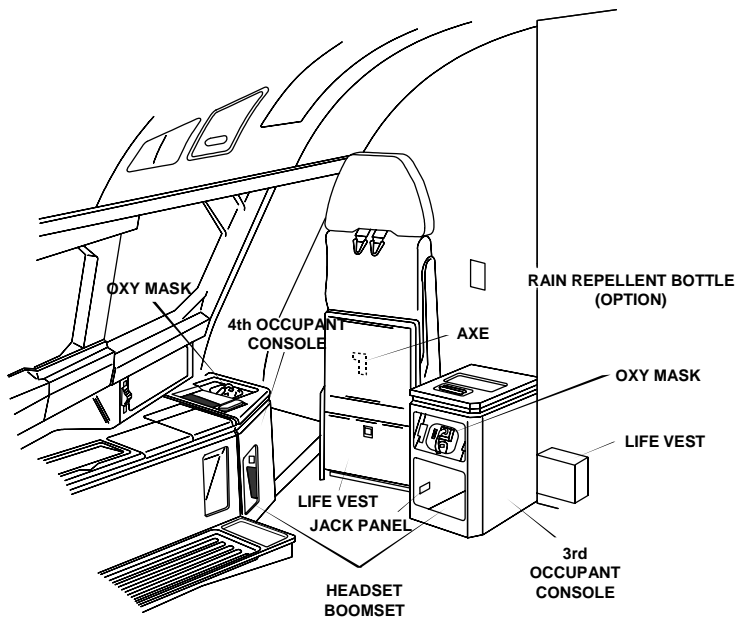
A330 flight deck layout

Forward view

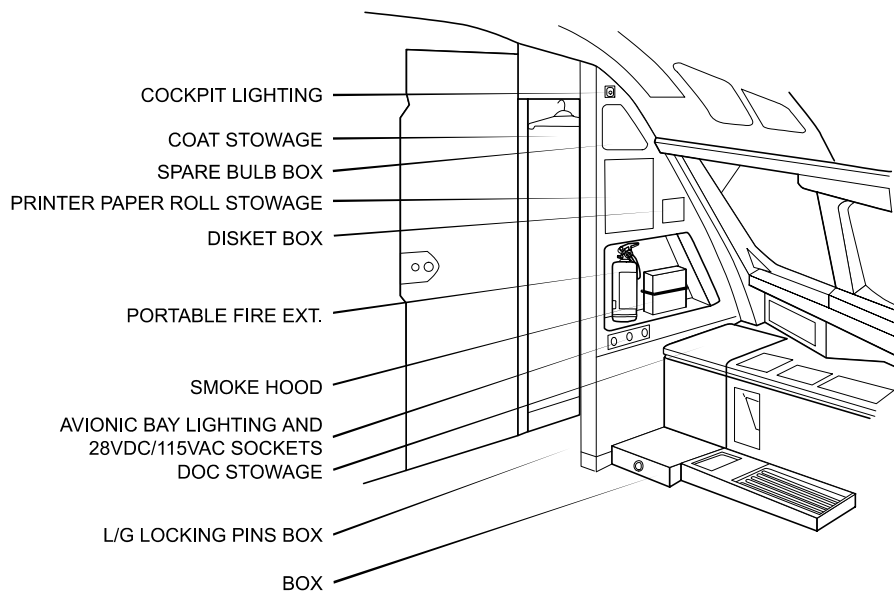


A330 flight deck layout

Rear view : right aft corner



Rear view : left aft corner



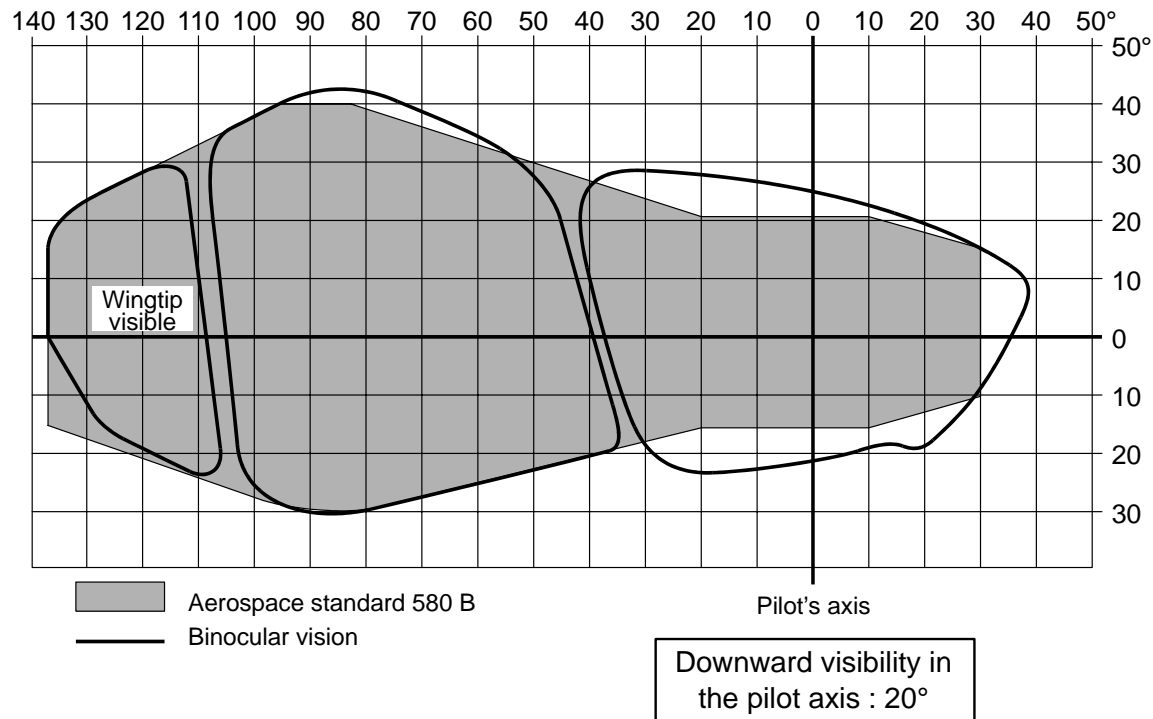
A330 flight deck layout

Pilots' field of vision

Visibility

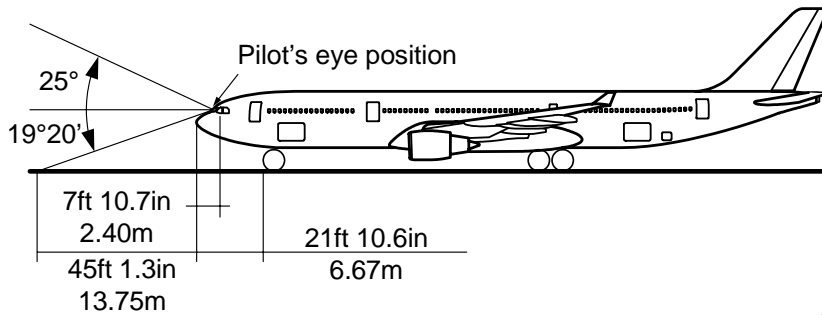
- Windows are designed to meet or exceed the Aerospace standard.
- Geometry :
 - windshield panels : flat glass
 - lateral windows : curved acrylic.

Pilots' vision envelope

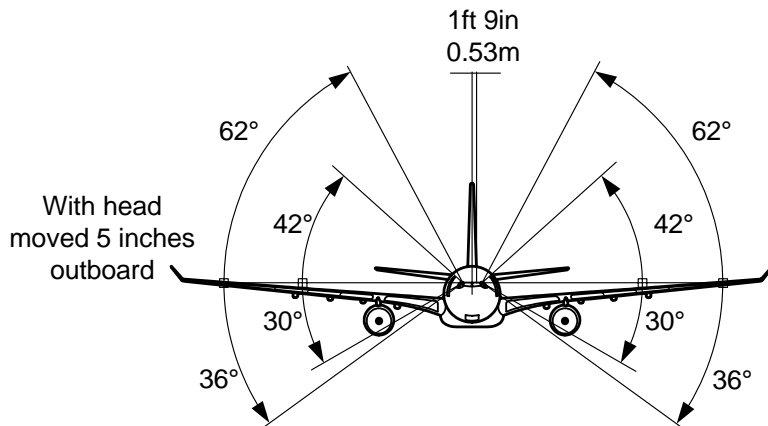
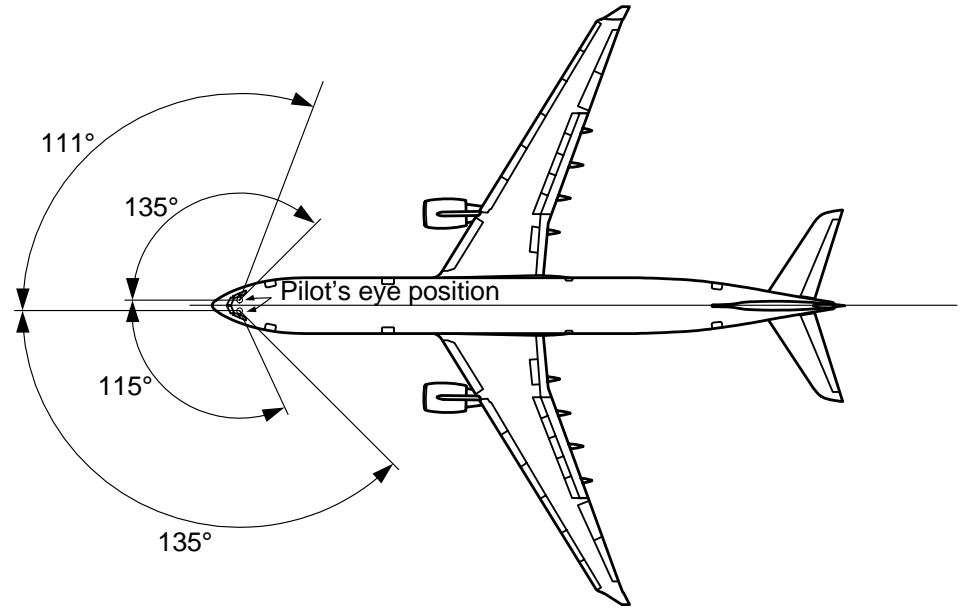


A330 flight deck layout

Pilots' field of vision



Max. aft vision
with head rotated
about spinal column

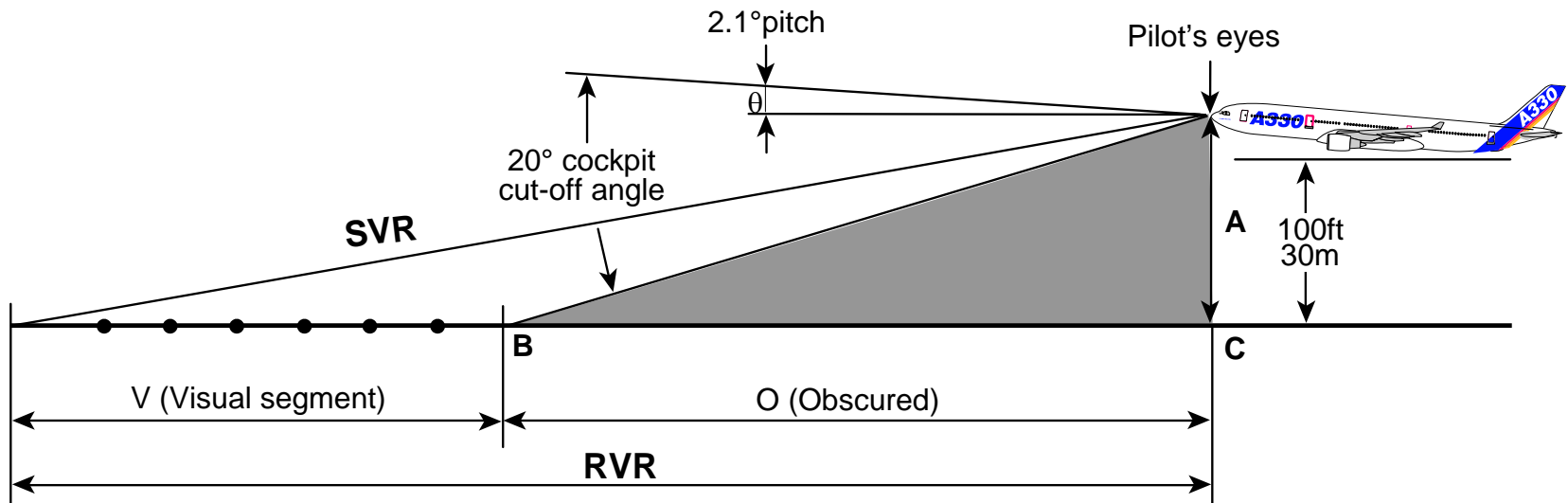


A330 flight deck layout

Pilots' field of vision - landing configuration CAT II DH = 100 ft

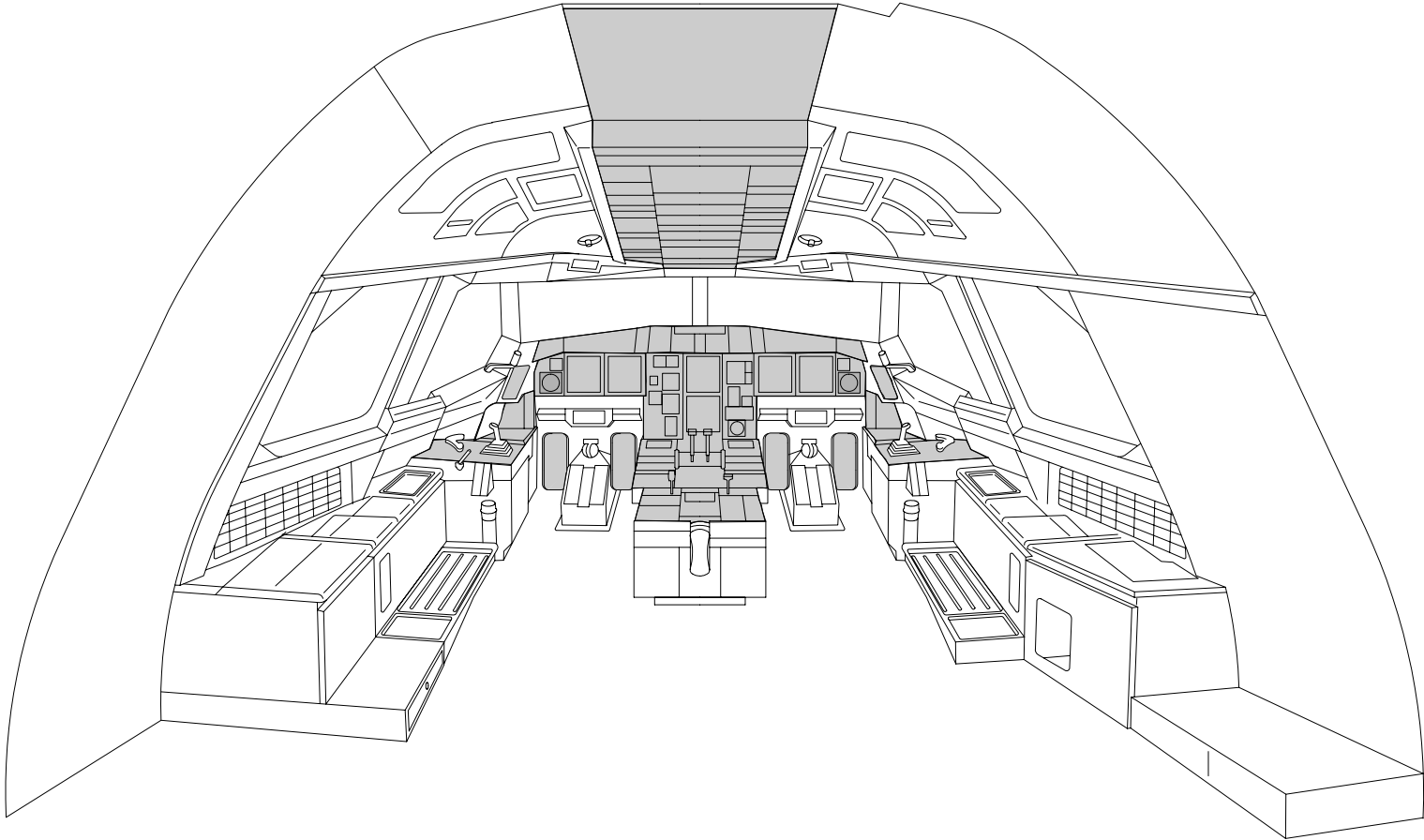
- This geometry improves external aircraft monitoring, thereby increasing safety standards.
 - Downward visibility in the pilot axis is 20° .
 - Wing tips are visible from respective pilot stations.

Aircraft	θ	A	V	O	RVR	SVR
A330-200 m (ft)	5°	39.7 (132)	120 (394)	150 (493)	270 (887)	273 (897)
A330-300 m (ft)	2.1°	38.2 (127)	120 (394)	120 (394)	240 (788)	243 (798)



A330 flight deck layout

Control and indication panels (shaded)



A330 flight deck layout

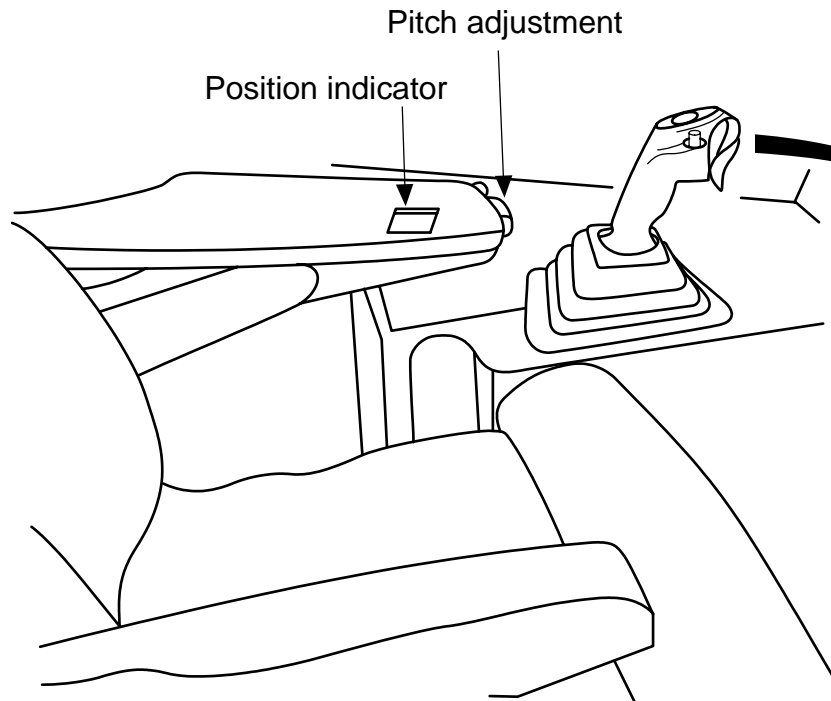
Main features

- The main features are common with those developed for the A320 and A340 families :
 - sidestick controllers which leave the main instrument panel unobstructed
 - six display units (**DU**) interchangeable, switchable and integrated into the same system architecture (EFIS/ECAM).
- The other features evolve directly from the concepts introduced with the A300/A310 family :
 - ergonomic layout of panels, synoptically arranged according to frequency of use (normal, abnormal, emergency) within easy reach and visibility for both crew members
 - philosophy of panels (e.g., “lights out” philosophy for overhead panel)
 - principles of presentation of information (“need to know” concept)
 - monitoring of systems through an Electronic Centralized Aircraft Monitor (**ECAM**)
 - coherent system of colour coding for EFIS, ECAM and panel lights.

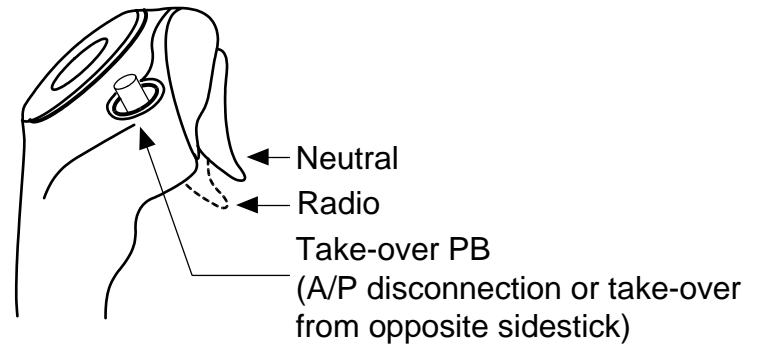
A330 flight deck layout

Sidestick arrangement

- Sidesicks are installed on the Captain's and First Officer's forward lateral consoles.
- A dual pivot adjustable armrest behind each sidestick to facilitate control is fitted on each seat, with position indicators.



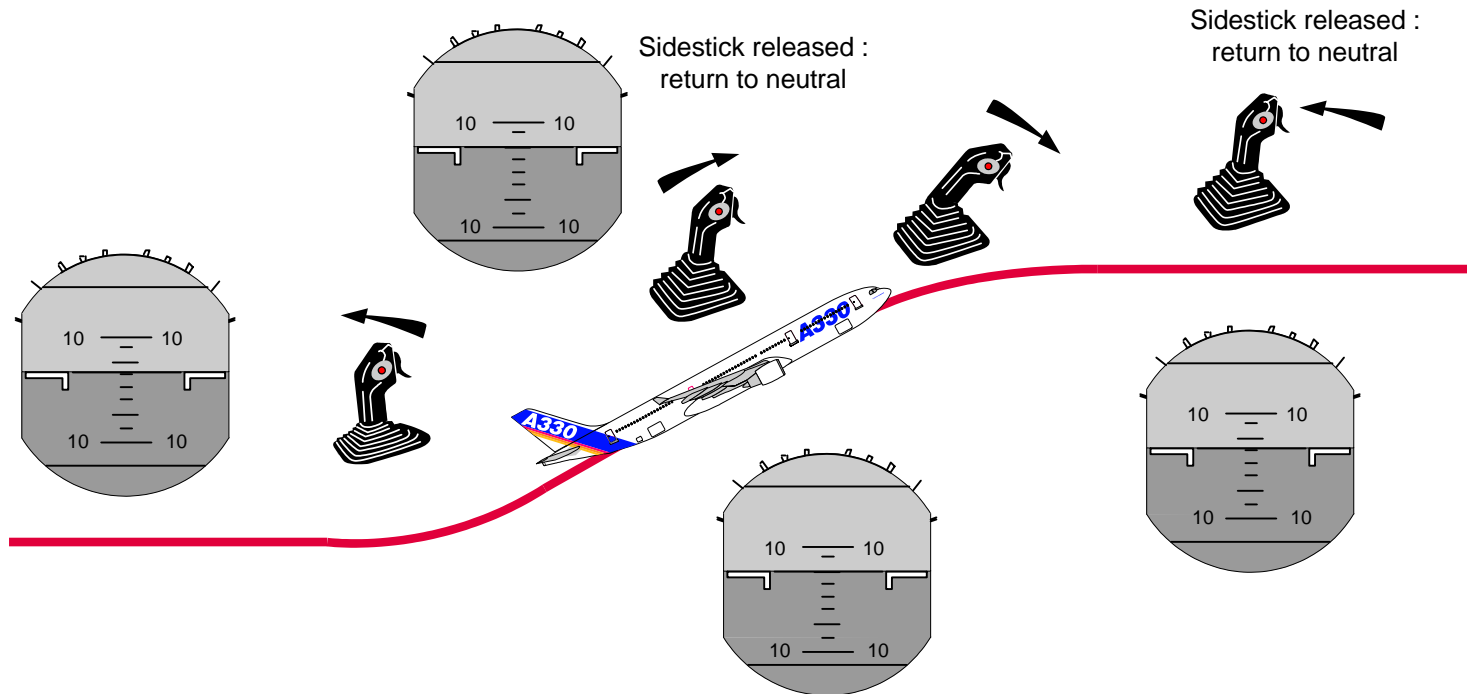
The handgrip includes two switches :
- A/P disconnect/sidestick priority push-button
- Push-to-talk button



A330 flight deck layout

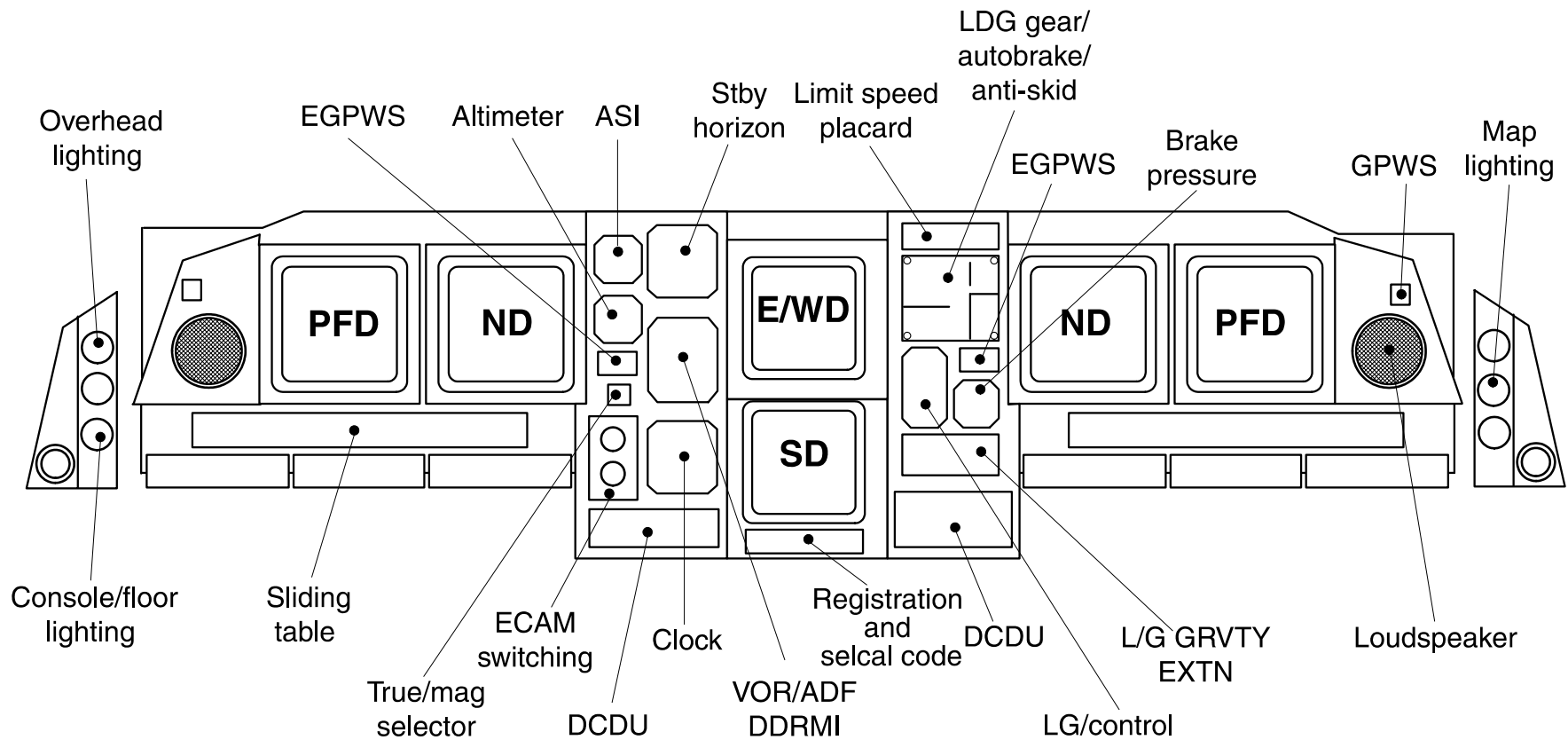
Sidestick operation

- Moving the sidestick results in “setting the aircraft trajectory” with a certain level of “g” for the requested manoeuvre depending on the amount of sidestick movement.
- Accuracy of movements is very precise since backlash and friction are negligible.
- Control of the flight path is performed by the Electronic Flight Control System (**EFCS**) which links the trajectory order with aerodynamic data to stabilize the aircraft and protect it from prohibited attitudes.



A330 flight deck layout

Main instrument panels



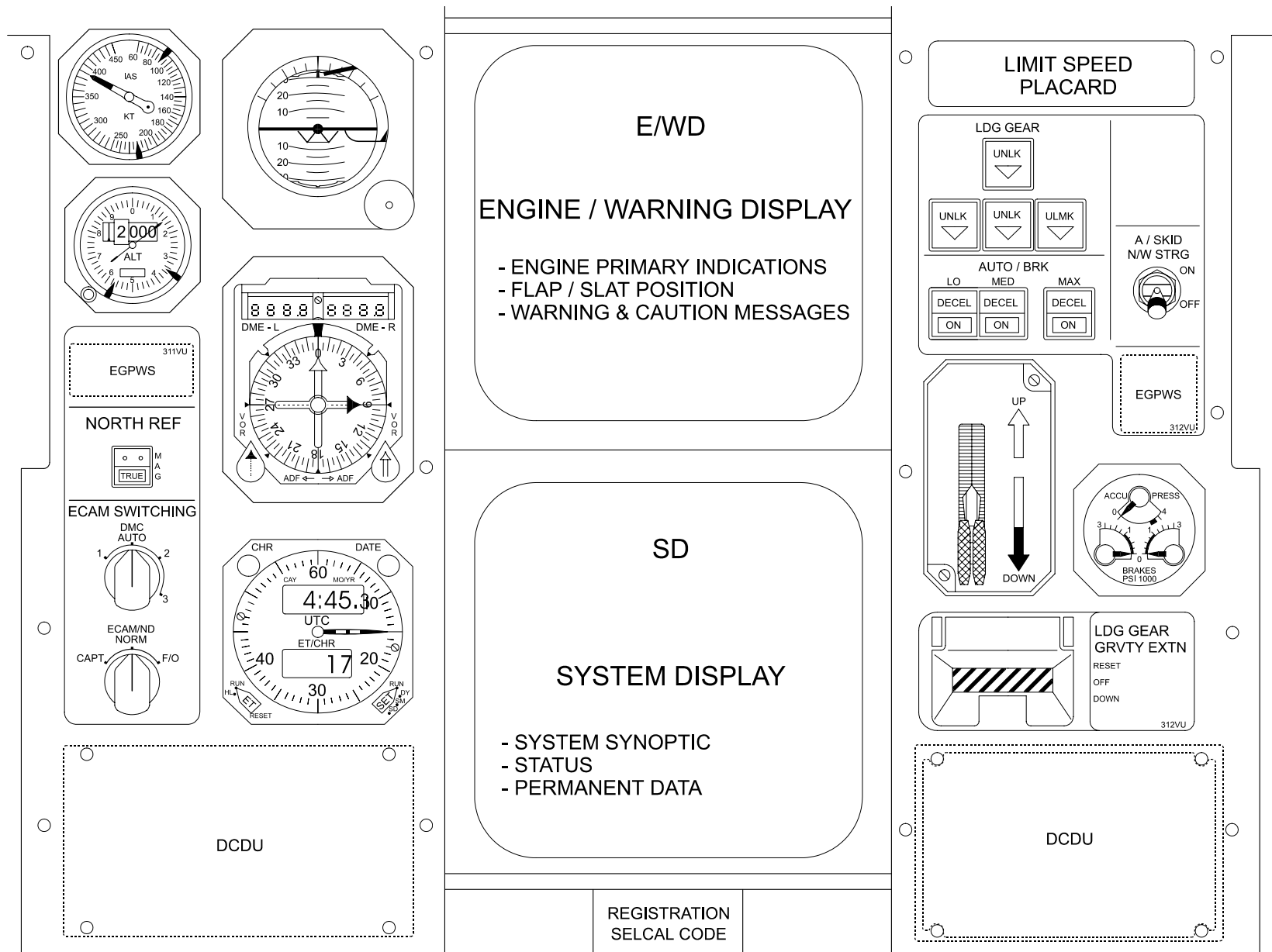
A330 flight deck layout

Captain and First Officer panels

- The CAPT and F/O panels are mirror images of each other :
both incorporate two side-by-side Display Units (DUs)
(7.25 in x 7.25 in) :
 - . a Primary Flight Display (**PFD**)
 - . a Navigation Display (**ND**).
- This arrangement provides :
 - better visibility on all DUs in normal configuration and in case of reconfiguration (PFD ND or ECAM ND)
 - the option to install a sliding table and a footrest in front of each pilot.
- **The PFD** includes the complete Basic T with :
 - attitude
 - airspeed/Mach (with all upper and lower limits)
 - altitude/vertical speed
 - heading
 - AFS status
 - ILS deviation/marker
 - radio altitude.
- **The ROSE** mode (ILS, VOR or NAV) : aircraft symbol in screen centre, with radar availability
 - **ARC** mode : heading up, horizon limited to a 90° forward sector, with radar availability
 - **PLAN** mode : north up, display centered on selected waypoint.
- **Engine display** : in case of a total DMC/ECAM failure, each pilot may display the ENG STBY page on his ND.

Note : In ROSE-NAV, ARC, and PLAN modes, MAP data from FMS is presented.

A330 flight deck layout



Main centre panel

The centre panel groups :

- two DUs, one above the other, which are interchangeable with the CAPT and F/O DUs :

- **Engine Display** (DU 1), showing :

- the main engine parameters (N1, EGT, N2 for GE engines ;
EPR, EGT, N1, N2 for PW engines ; (EPR, TGT, N1, N3 for RR engines)
- N1 (EPR) limit, N1 (EPR) command
- total fuel
- the flaps and slats position
- memo and warning

- **System Display** (DU 2) showing :

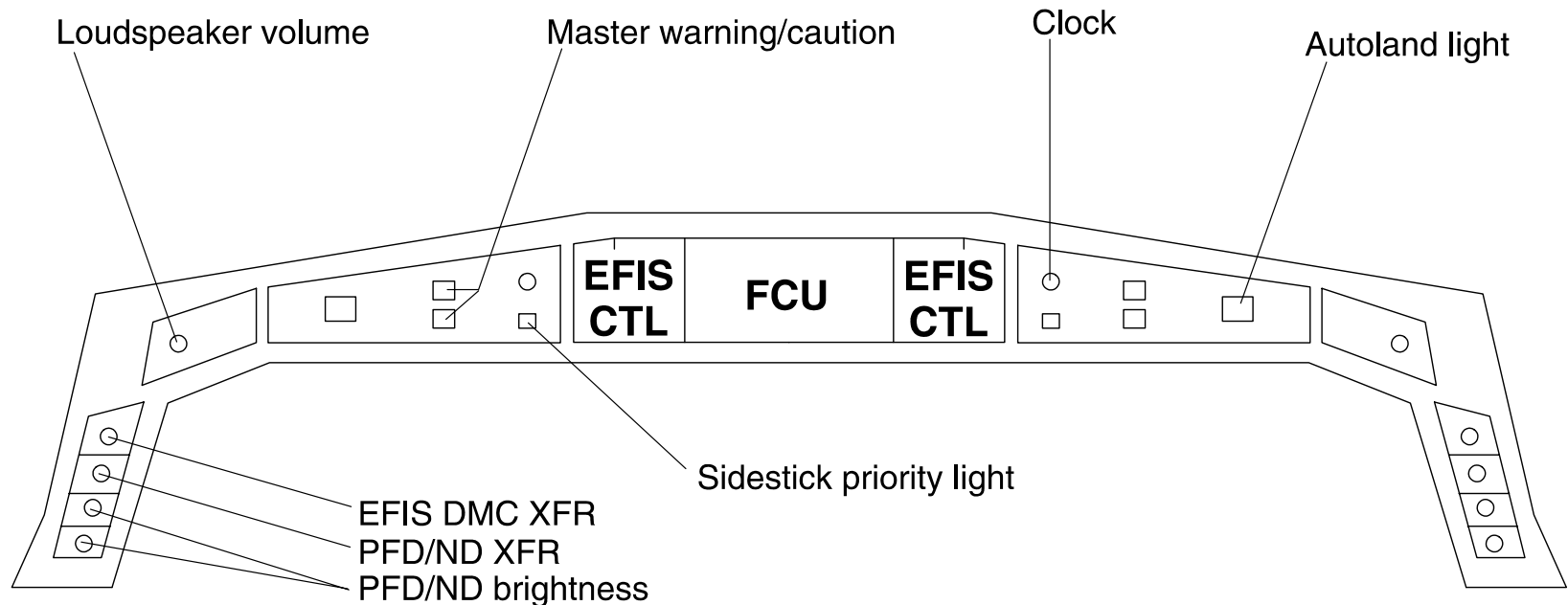
- an aircraft system synoptic diagrams page
- or the aircraft status (list of all operationally significant items)

- standby instruments
- landing gear control and indications (including brakes)
- clock.

A330 flight deck layout

Glareshield

- The Flight Control Unit (FCU) provides short-term interface between the Flight Management and Guidance Computer (**FMGC**) and crew for :
 - engagement of A/P, A/THR
 - selection of required guidance modes
 - manual selection of flight parameters SPD, MACH, ALT, V/SPD, HDG or track.
- The EFIS control panels for :
 - selection of desired ND modes (ROSE-ILS, -VOR, -NAV, ARC, PLAN, ENG) and ranges
 - selection of baro settings.
- The master warning, master caution, autoland and sidestick priority lights.

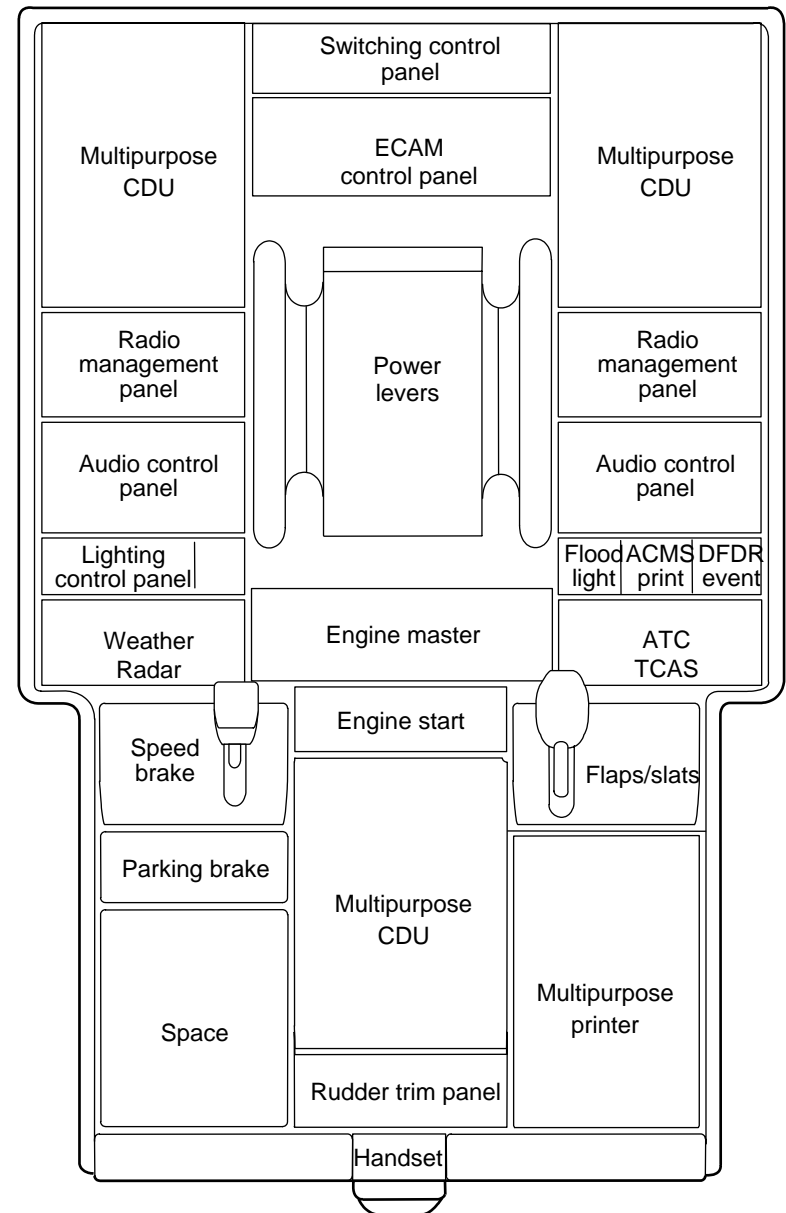


A330 flight deck layout

Central pedestal

In addition to the thrust levers and the engine control functions, the main features on the pedestal are :

- the Multipurpose Control and Display Units (**MCDU**) for flight management functions and various other functions such as data link, maintenance, etc.
- the Radio Management Panels (**RMP**) for tuning all radio communications and the radio navigation as a back-up to the normal operation through the Flight Management and Guidance Computers (**FMGC**).
- the electrical rudder trim
- the parking brake control
- the speedbrake and flap control levers.

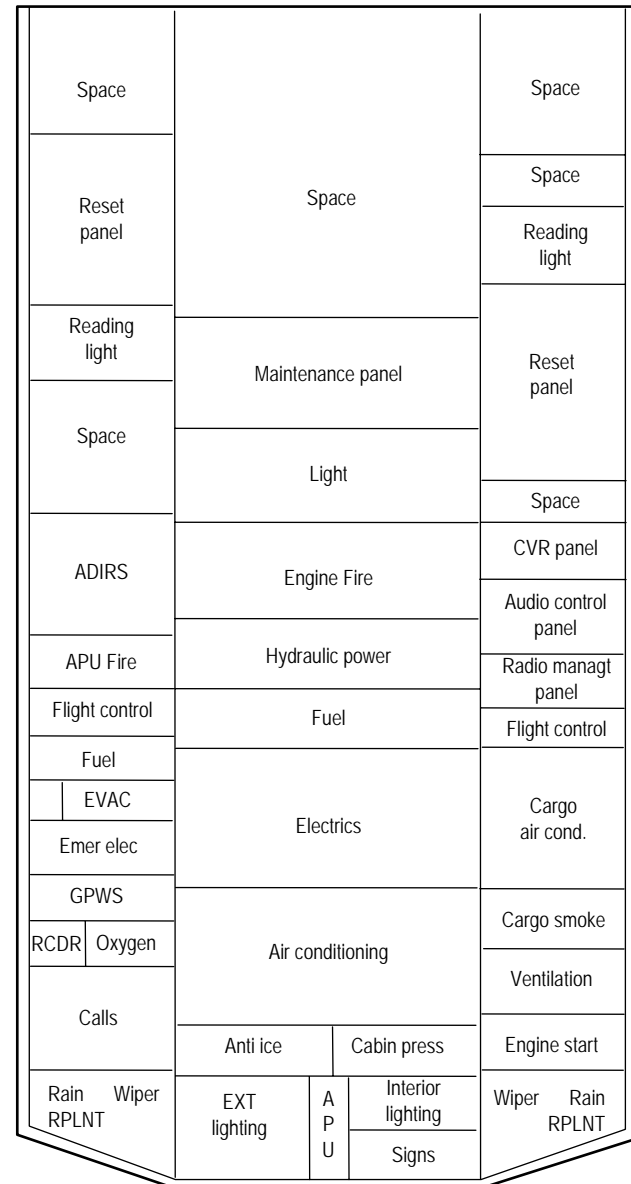




A330 flight deck layout

Overhead panel

- The overhead panel has a “single slope”.
- All controls on the overhead panel can be reached by either pilot.
- Two main zones are separated by protective padding.
 - **Forward zone :**
 - for most frequently used functions
 - for system controls : arranged in three main rows :
 - centre row for engine-related systems arranged in a logical way
 - lateral rows for other systems.
 - **Aft zone,** not used in flight, mainly for a small maintenance panel corresponding to some maintenance controls.
- The push-button philosophy is identical to that already applied on existing Airbus aircraft.





3. Electrical system

A330 electrical system

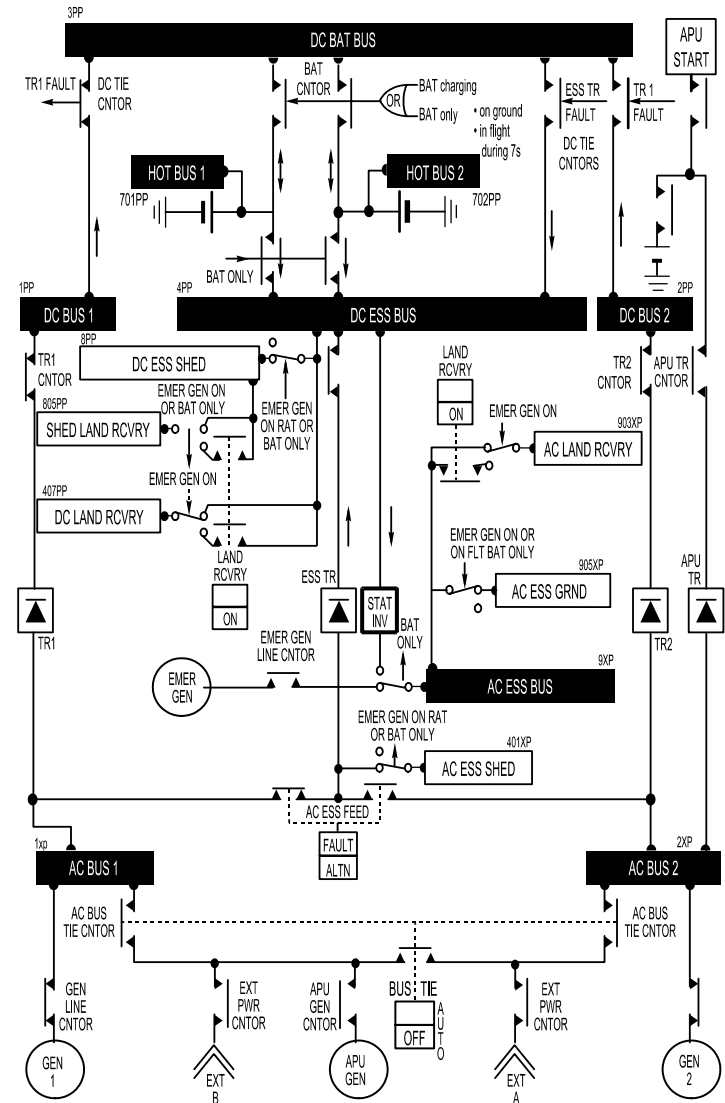
Electrical power generation

The electrical power generation comprises :

- Two engine-driven AC generators, nominal power 115 kVA
- One auxiliary power unit (APU) AC generator nominal 115 kVA
- One emergency generator (Constant Speed Motor /Generator or CSM/G), nominal power 8.6 kVA, hydraulically driven by the Green system.
- One static inverter fed by two batteries and working either on the ground or when CSM/G inoperative.
- Two ground connectors, power 90 kVA
- DC network supplied via two main Transformer Rectifier Units (200 A) and one essential (100 A).

A fourth TR (100 A) is dedicated to APU start or APU battery charging.

- Three batteries nominal capacity 37 Ah, 28 V each :
 - Two batteries used :
 - . in emergency configuration to feed some equipment during RAT deployment or when CSM/G not operating.
 - . On ground to provide an autonomous source.
 - One dedicated to APU start



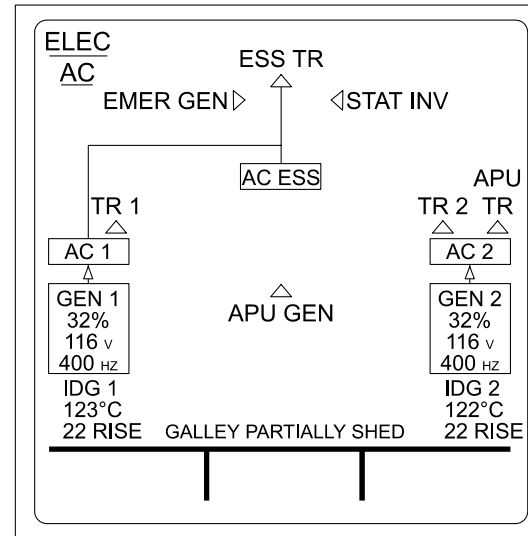
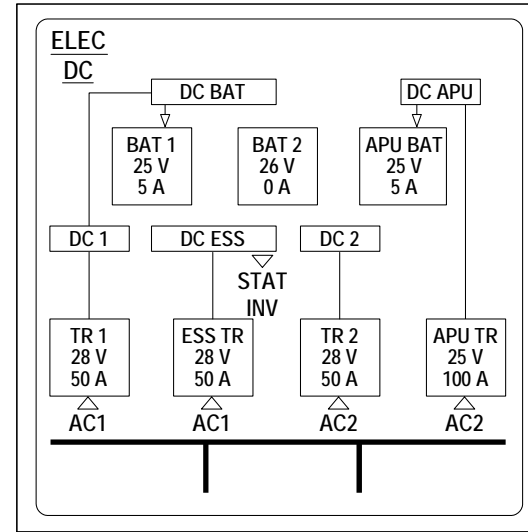
Distribution - normal configuration

AC distribution network

- In normal configuration, each engine-driven generator supplies its associated AC BUS.
- The AC ESS BUS is normally supplied from AC BUS 1.

DC distribution network

- In normal configuration, normal DC systems are split into two networks : DC BUS 1 in parallel with DC BAT BUS and DC BUS 2.
- Each DC network is supplied by its own TR.
- More specifically, ESS TR systematically feeds DC ESS BUS, which allows a better segregation between DC 1 and DC 2.
- Two batteries are connected to the DC BAT BUS via the Battery Charge Limiter (**BCL**).
- Each battery has its own HOT BUS bar (engine/APU fire squib, ADIRS, CIDS, PRIM and SEC computers, slide warnings, parking brake, etc).
- The third battery is dedicated to APU starting.



A330 electrical system

Distribution - abnormal configurations

Generator failure

- if one generator fails, another will automatically take over :
 - if APU operative, APU generator will take over
 - if APU generator not available, the other engine generator will take over.
- In case of total loss of all main generators :
 - the EMER GEN will deliver 8.6 kVA since the Green hydraulic system is still powered by engine-driven pumps

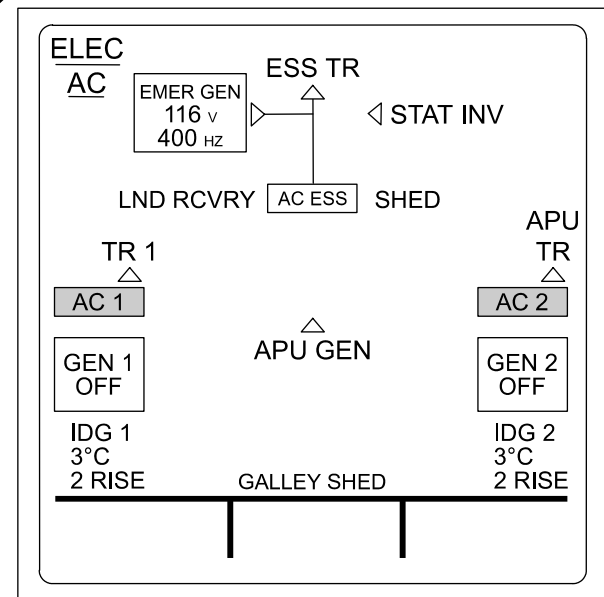
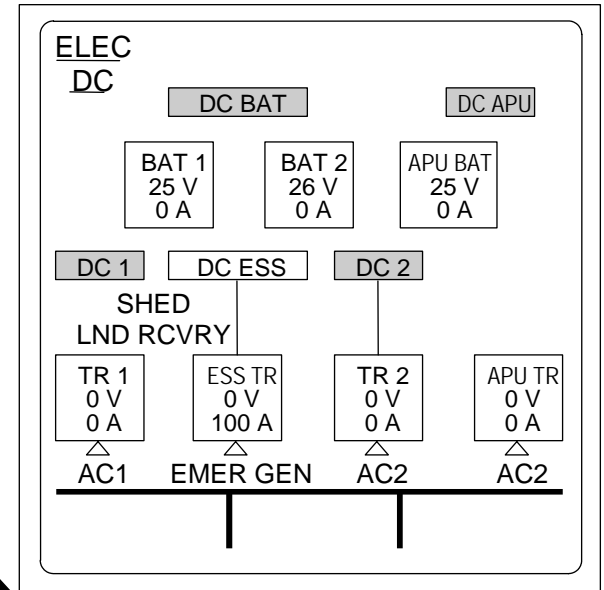
or

- In case of loss of all engines :
 - the EMER GEN will deliver 3.5 kVA since the Green hydraulic system is then powered by the RAT ; in this case the batteries take over when slats are extended.

TR failure

- if one TR fails, the other will automatically take over its corresponding DC network via DC BAT BUS,
- In case of double TR failure :
 - TR 1 and 2 : DC BUS 1 and DC BUS 2 are lost
 - TR 1 (or 2) and ESS TR : The remaining TR supplies DC BUS 1 + 2 and DC BAT BUS ; the DC ESS BUS is lost.

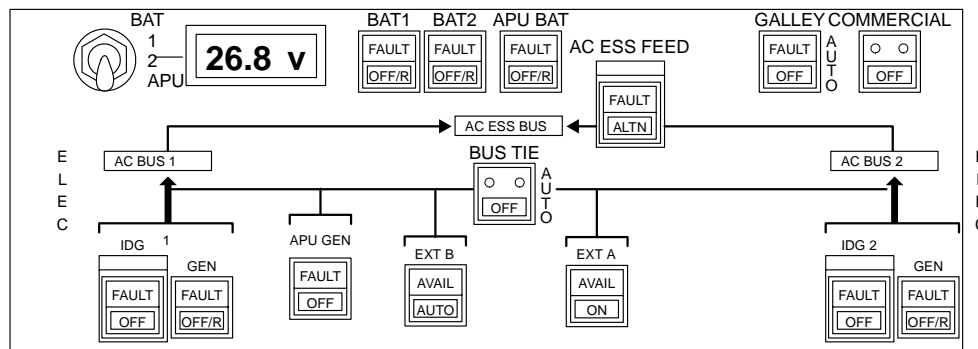
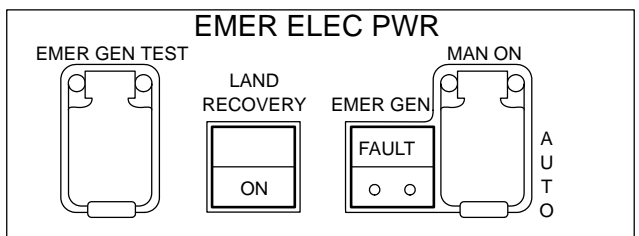
TOTAL LOSS OF ALL MAIN GEN



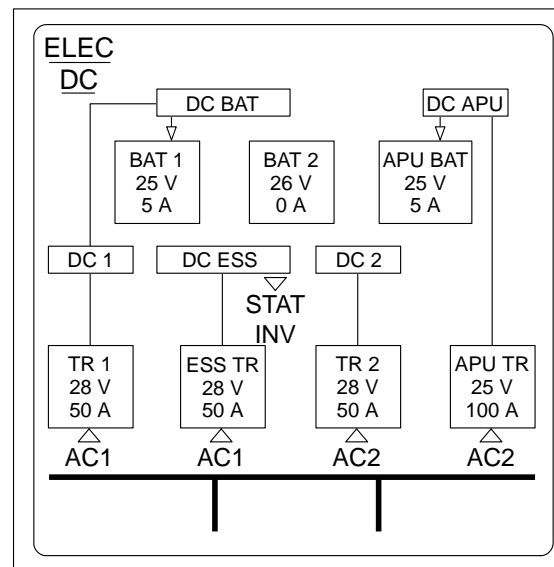
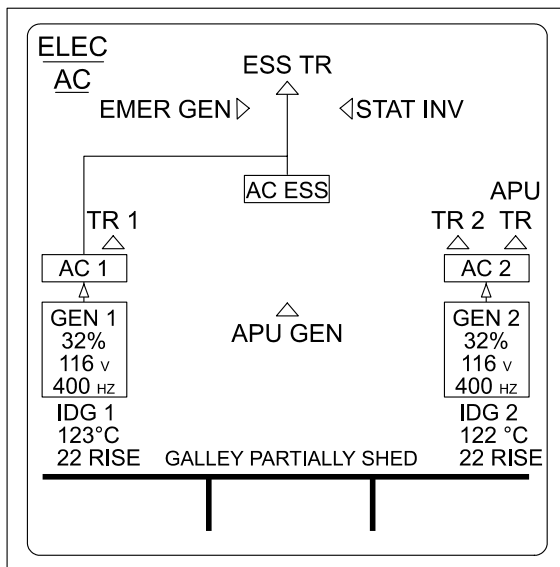
A330 electrical system

Control and display

Overhead panel



ECAM



Circuit - breaker monitoring

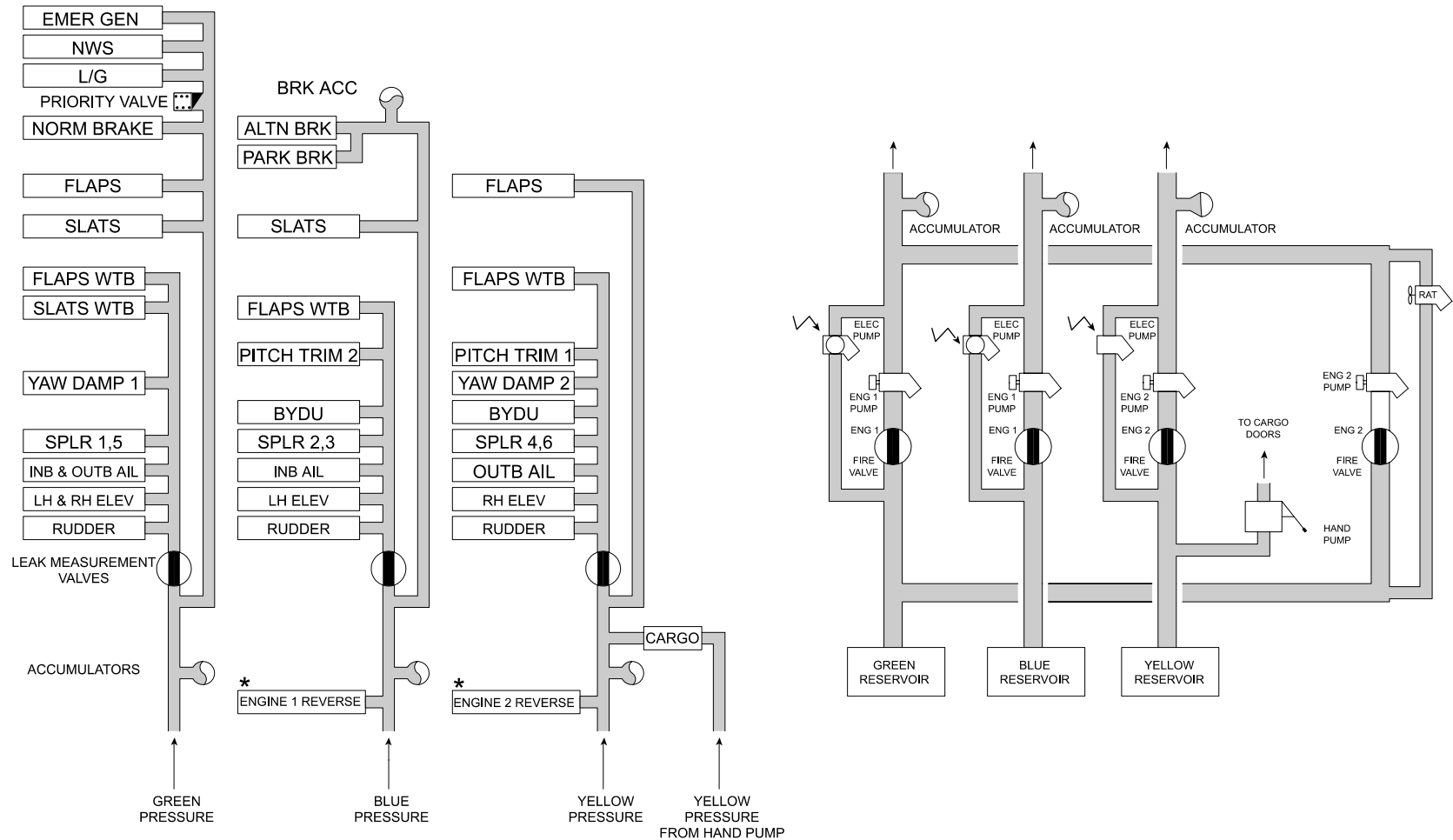
- Circuit-breakers are installed in the avionics bay area below the cockpit.
- Circuit-breakers are monitored by the CBMU (Circuit-Breaker Monitoring Units) which output the identification and status of each circuit-breaker.
- A specific C/B page is provided on the ECAM.
- Computer resets can be performed via system controls.

C/B		
ECMU1 VOLT SNSG	X1	4XM
SFCC1 NORM DCBUS AVAI	X3	10CW
HYD PUMP G ENG2	X44	4JG2
ANTI ICE ENG2	W2	2DN2
DU SWTG CAPT ND	S2	9WK1
HYD PUMP B ENG1	U15	1JB
ADIRU1 155VAC	C8	4FP1
ANTI ICE PITOT 1 OR 3	D10	4DA1
303PP	715VU	9PB
BUS 1/3 TIE CNTOR	X12	10PC1
ANTI ICE 1 OR 3 PHC	N21	2DA3
EXTRACT FAN AVNCS	J21	1HQ
ADIRU1 AOA1 26VAC	M80	5FP1
APU TR	5000VU	3PU3
SWTG FUEL BUS	W15	8PR
AUDIO ACP CAPT	A50	4RN1
AIR BLEED VLV ENG2	D12	3HA2
XFEED VLV ENG1 MOT1-2	C15	40E1



4. Hydraulic system

Architecture



* PW and RR engines only

A330 hydraulic system

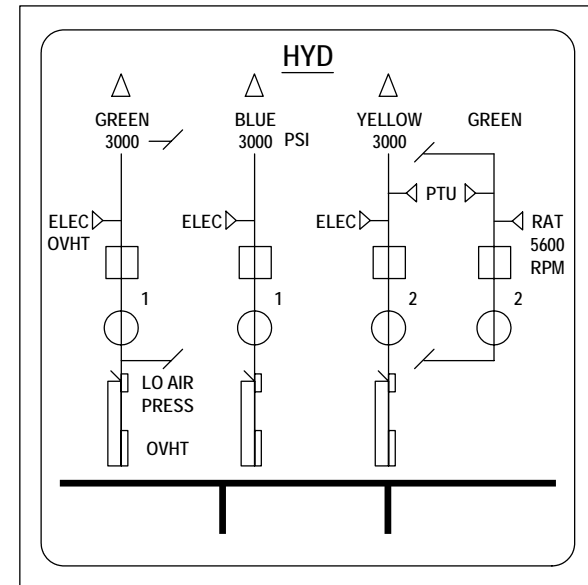
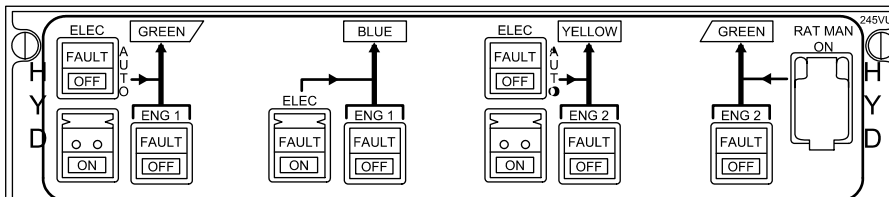
General

- Three fully independent systems : **Green, Blue, Yellow** (nominal pressure at 3000 psi).
- Normal operation :
 - four engine-driven pumps, two of which are for the Green system
 - three electrical pumps that can act automatically as back-up

They are managed by the **HSMU** (Hydraulic System Monitoring Unit) which ensures all autofunctions (electrical pumps, RAT, monitoring, etc) ; manual override is available on the overhead panel.

- one handpump on the Yellow system for cargo doors operation when no electrical power is available.

- Abnormal operation :
 - in the event of one engine failure, the Green electrical pump runs automatically for 25 seconds when landing gear lever is selected up.
 - in the event of engine 2 failure, the Yellow electrical pump runs automatically when flaps are not retracted.
 - In the event of both engine failure, RAT deployment will be automatically controlled by the HSMU to pressurize the Green system.





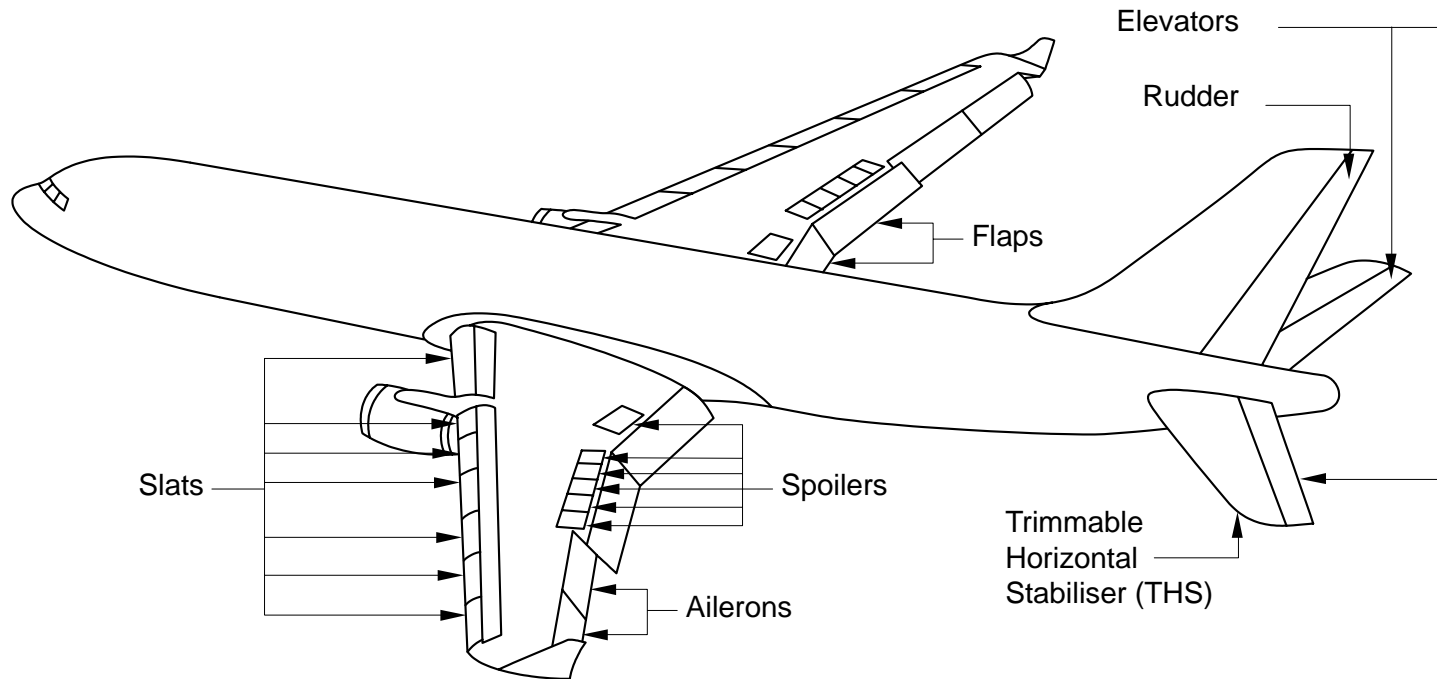
5. Flight controls

A330 flight controls - EFCS

Electronic Flight Control System (EFCS)

Surfaces :

- all hydraulically activated
- all electrically controlled
- mechanical back-up control :
 - rudder
 - Trimmable Horizontal Stabilizer



General

The A330 fly-by-wire system is being designed to make this new aircraft more cost effective, safer and more pleasant to fly, and more comfortable to travel in than conventional aircraft.

Basic principles

- A330 flight control surfaces are all :
 - electrically controlled
 - hydraulically activated
- Stabilizer and rudder can be mechanically controlled.
- Sidesticks are used to fly the aircraft in pitch and roll (and indirectly through turn coordination, in yaw).
- Pilot inputs are interpreted by the EFCS computers for moving the flying controls as necessary to achieve the desired pilot commands.
- Regardless of pilot inputs, the computers will prevent :
 - excessive manoeuvres
 - exceedance of the safe flight envelope.

A330 flight controls - EFCS

Computers

Electrical control of the main surfaces is achieved by two types of computers :

- three flight control primary computers (**PRIM**) which can process all three types of control laws (Normal, Alternate, Direct)
- two flight control secondary computers (**SEC**) which can process the Direct Control Law.

These computers perform additional functions including :

- speedbrakes and ground spoiler command
- characteristic speed computation (**PRIM** only).

High-lift devices are commanded by two Slat/Flap Control Computers (**SFCC**).

The **SFCCs** also command the aileron droop via the primary or secondary computers.

In order to provide all required monitoring information to the crew and to the Central Maintenance System (**CMS**), two Flight Control Data Concentrators (**FCDC**) acquire the outputs from the various computers to be sent to the ECAM and Flight Data Interface Unit (**FDIU**). These two FCDCs ensure the electrical isolation of the flight control computers from the other systems.

A330 flight controls - EFCS

Power sources

Electrical power supply

The flight control computers (primary, secondary and Flight Control Data Concentrator) are fed by various DC busbars.

This ensures that at least two flight control computers are powered in the event of major electrical power losses such as

- failure of two main systems or
- electrical emergency configuration (CSM-G) or
- battery-only supply.

	Normal		Emergency		
	AC	DC	AC ESS	DC ESS	HOT
Primary 1				X	X (BACK UP)
Primary 2		X			
Primary 3		X			
Secondary 1				X	X (BACK UP)
Secondary 2		X		X (BACK UP)	
FCDC 1				X (SHED)	
FCDC 2		X			

Power sources

Hydraulic power supply

Three hydraulic circuits (Green, Yellow, Blue) power the flight controls.

System circuit	Power source
Green	2 engine (N° 1 and 2) - driven pumps 1 electropump 1 RAT
Yellow	1 engine (N° 2) - driven pump 1 electropump
Blue	1 engine (N° 1) - driven pump 1 electopump

The distribution to the various control surfaces is designed to cover multiple failure cases.

Safety objectives

Safeguards were designed for protection against :

Loss of pitch control - extremely improbable ($<10^{-9}$)

Loss of elevators - extremely remote ($< 10^{-7}$)

Loss of roll control - extremely improbable

Permanent loss of THS - extremely improbable

Rudder loss or runaway - extremely improbable

In order to satisfy these objectives, the following architecture applies :

- electrical signalling for spoilers, elevators and ailerons
- electrical and mechanical signalling in parallel for rudder and THS.

A330 flight controls - EFCS

Dispatch objectives

The basic objective is to allow dispatch of the aircraft with at least **one** peripheral or computer failed in order to increase the dispatch reliability without impairing flight safety.

Systems	Dispatch situation
3 IRS 2 yaw rate gyros 3 PRIM 2 SEC	Maximum 1 inoperative or "off"
3 ADR	Maximum 1 inoperative or "off"
3 IR - 2 N _z accelerometers	Maximum 1 inoperative or "off"
2 FCDC	Maximum 1 inoperative or "off"
3 PRIM/2 SEC Electro hydraulic and electro actuators	Maximum 1 inoperative or "off" Maximum 1 inoperative if it is not connected to 2 computers No-go items are inboard aileron, elevator and yaw damper actuators.

Design principles

Two types of flight control computers :

- **PRIM** (two channels with different software for control/monitoring).
- **SEC** (two channels with different software for control/monitoring).
- Each one of these computers can perform two tasks :
 - process orders to be sent to other computers as a function of various inputs (sidestick, autopilot...)
 - execute orders received from other computers so as to control their own servo-loop.

The three primary or main computers (**PRIM**) :

- process all control laws (Normal, Alternate, Direct) as the flight control orders.
- One of the three PRIM is selected to be the master ; it processes the orders and outputs them to the other computers PRIM 1, 2 and 3, SEC 1 and 2) which will then execute them on their related servo-loop.
- The master checks that its orders are fulfilled by comparing them with feedback received ; this allows self-monitoring of the master which can detect a malfunction and cascade control to the next computer.
- Each **PRIM** is able to control up to eight servo-loops simultaneously ; each can provide complete aircraft control under normal laws.

The two secondary computers (**SEC**) :

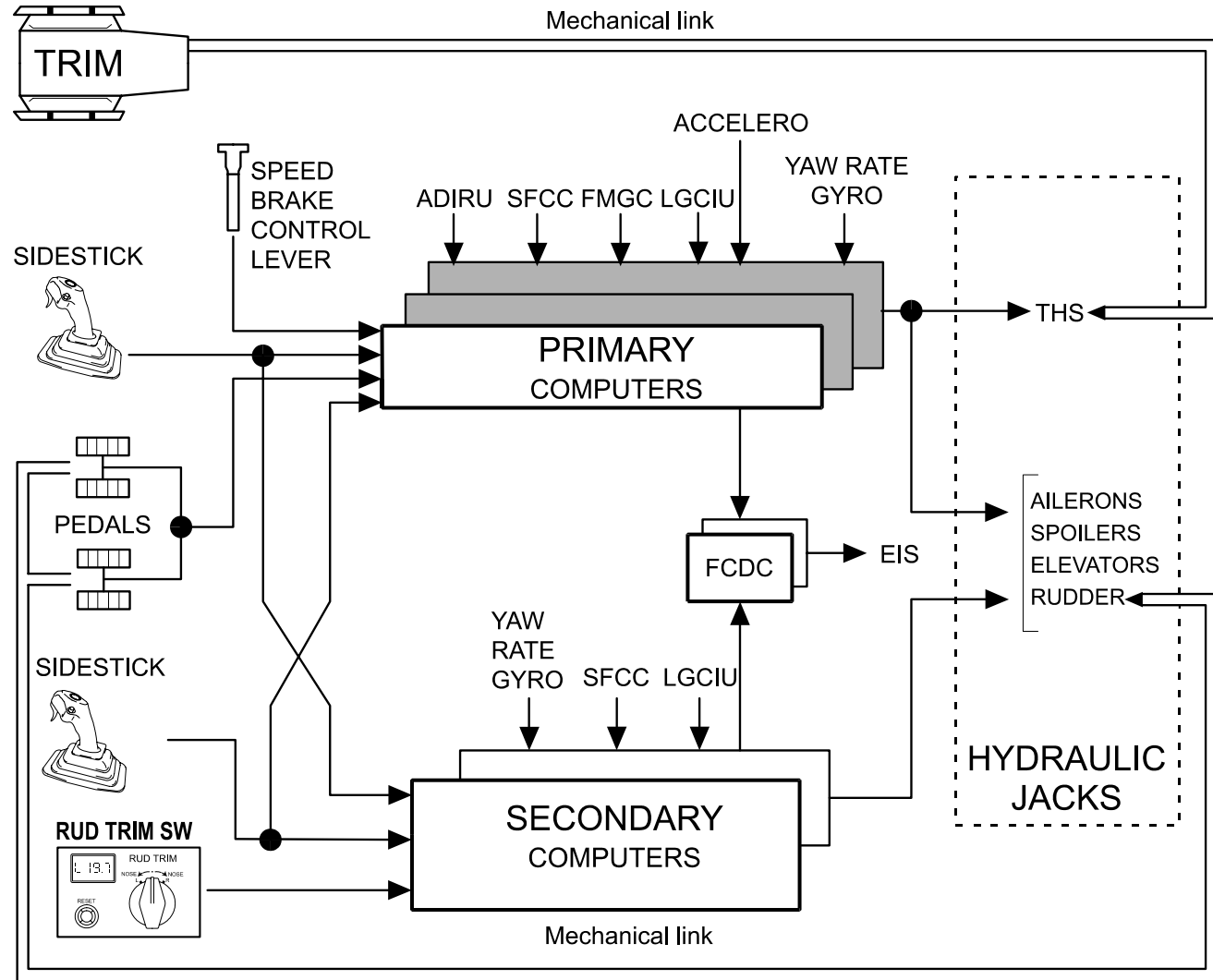
- are able to process direct laws only
- either SEC can be the master in case of loss of all primary computers
- each SEC can control up to 10 servo-loops simultaneously ; each can provide complete aircraft control.

Electrically controlled hydraulic servo-jacks can operate in one of three control modes depending upon computer status and type of control surface :

- **Active** : the servo-jack position is electrically controlled
- **Damping** : the servo-jack position follows the surface movement
- **Centering** : the servo-jack position is maintained neutral.

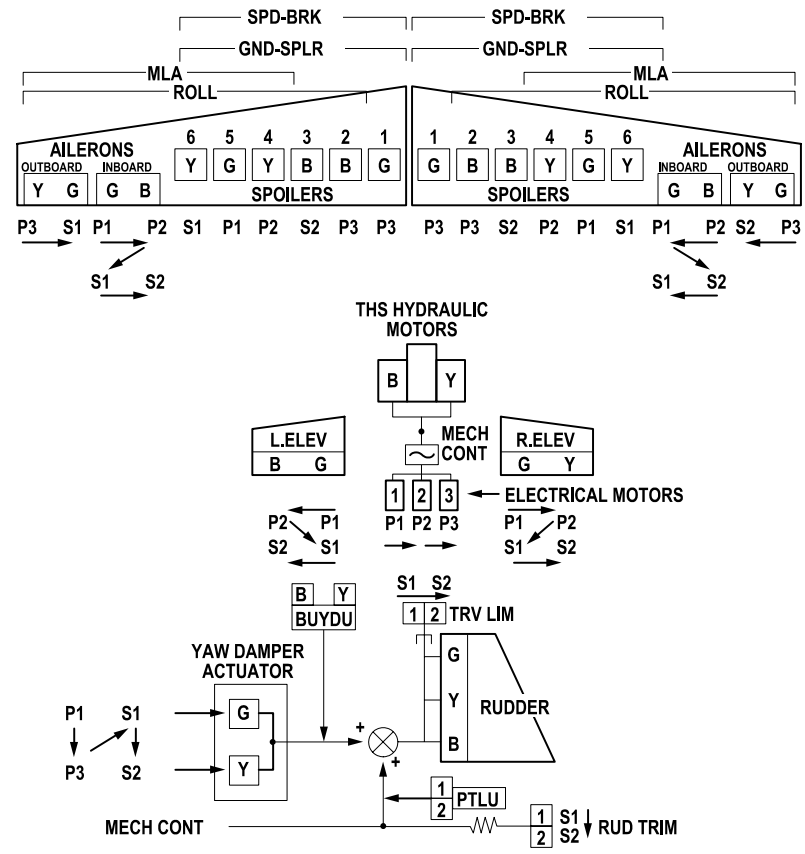
A330 flight controls - EFCS

Schematic diagram



A330 flight controls - EFCS

EFCS - Computers and actuators



P = PRIM computers S = SEC computers

→ Arrows indicate the control reconfiguration priorities

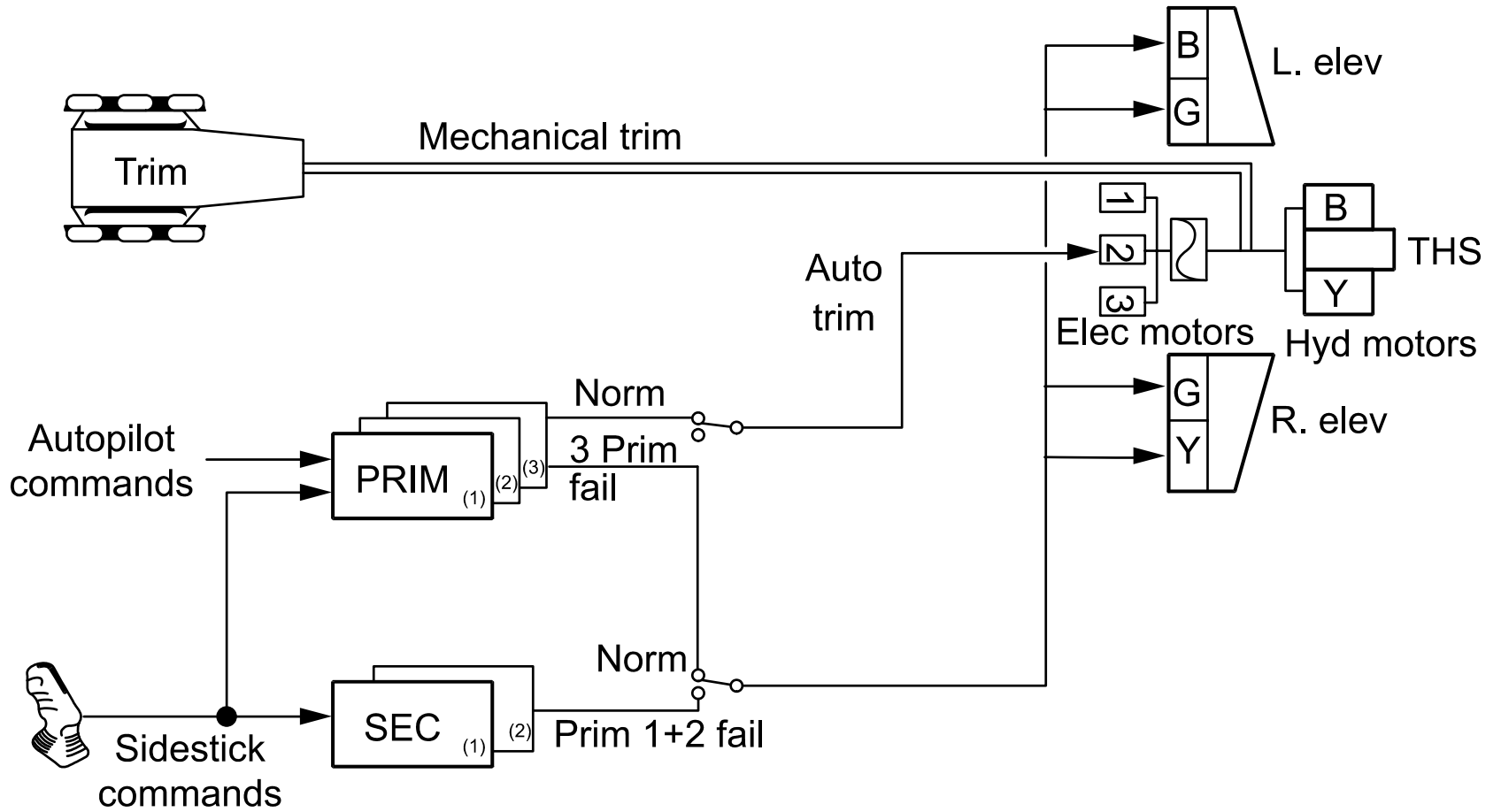
G	B	Y
---	---	---

 indicates the hydraulic power source for each servo control

MLA = Manoeuvre Load Alleviation
 BUYDU = Back Up Yaw Damper Unit
 PTLU = Pedal Travel Limit Unit

A330 flight controls - EFCS

Pitch control



Pitch control

Pitch control is provided by two elevators and the THS :

- elevator deflections 30° nose up - 15° nose down
- THS deflections 14° nose up - 2° nose down.

Each elevator is actuated by two independent hydraulic servo control units ;

L ELEV is driven by Green and Blue hydraulic jacks

R ELEV is driven by Green and Yellow hydraulic jacks

one servo control is in active mode while the other is in damping mode.

In case of a failure on the active servo-jack, it reverts to damping mode while the other becomes active.

In case of electrical supply failure to both servo-jacks of one elevator, these revert to centering mode which commands a 0° position of the related elevator.

Autoflight orders are processed by one of the primary computers.

Sidestick signals, in manual flight, are processed by either one of PRIM 1 and 2 or SEC 1 and 2

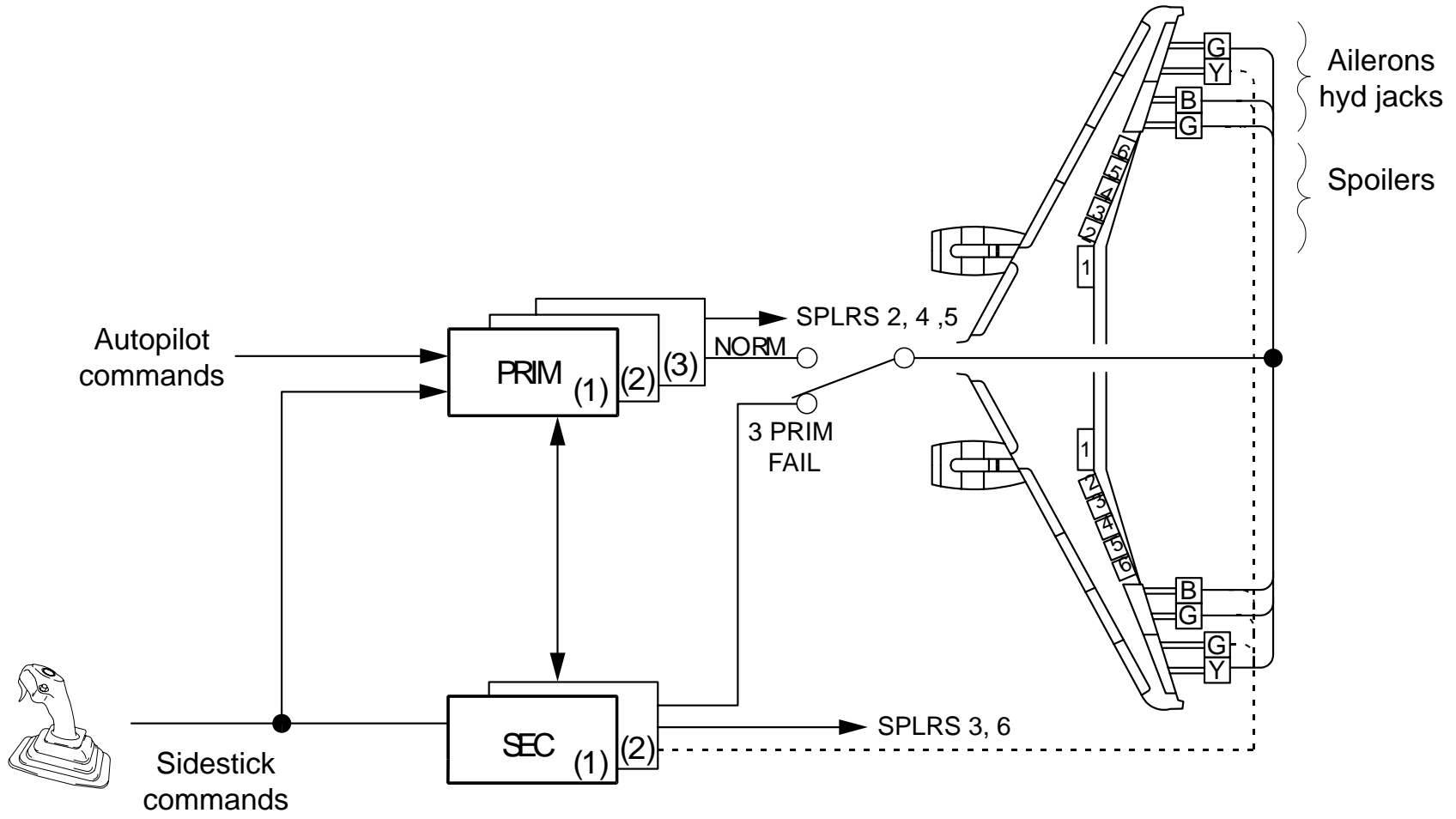
The THS is driven by two hydraulic motors supplied by Blue and Yellow systems ; these motors are controlled :

- either of the three electrical motors with their associated electronics controlled by one primary computer each
- or by mechanical command from control wheels located on the central pedestal.

The control wheels are used in case of major failure (Direct Law or mechanical back-up) and have priority over any other command.

A330 flight controls - EFCS

Roll control



Roll control

Roll control is provided two ailerons and five spoilers (2 to 6) per wing :

- aileron deflection is $\pm 25^\circ$
- spoiler max deflection is -35° . Deflection is reduced in CONF 2 and 3.

Each aileron is driven by two electrically signalled servo-controls which are connected to :

- two computers for the inboard ailerons (PRIM 1 or 2 and SEC 1 or 2)
- one computer for the outboard ailerons (PRIM 3, SEC 1 or 2)
- one servo-control is in active mode while the other is in damping mode.

In manual mode, above 190 kt the outboard ailerons are centered to prevent any twisting moment.

In AP mode or in certain failure cases the outboard ailerons are used up to 300 Kt. Each spoiler is driven by one electro-hydraulic servo-control which is connected to one specific computer.

In the event of a failure being detected on one spoiler, the opposite spoiler is retracted and maintained in a retracted position.

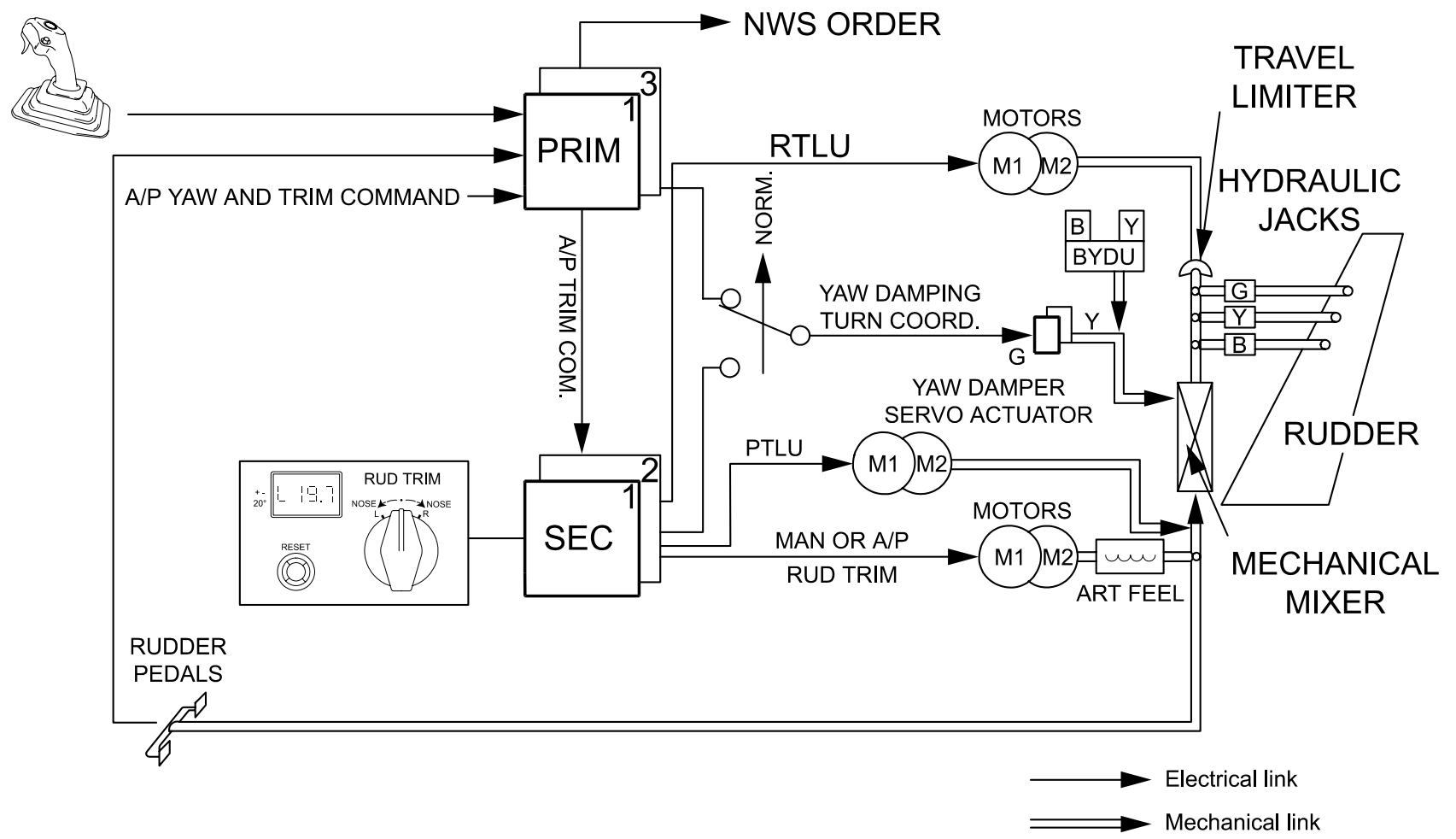
Autopilot orders are processed by one of the primary computers.

Sidestick signals, in manual flight, are processed by either one of the primary or secondary computers.

Note : If the RAT is deployed to provide Green hydraulic power, the outboard ailerons servo-controls revert to damping mode in order to minimize hydraulic demands.

A330 flight controls - EFCS

Yaw control



Yaw control

Yaw control is provided by one rudder surface :
- rudder deflection $\pm 31.6^\circ$.

The rudder is operated by three independent hydraulic servo-controls, with a common mechanical input. This mechanical input receives three commands :

- rudder pedal input
- rudder trim actuator electrical input
- yaw damper electrical input.

The mechanical input is limited by the Travel Limitation Unit (TLU) as a function of airspeed in order to avoid excessive load transmission to the aircraft. This function is achieved by the secondary computers.

The rudder trim controls the rudder pedal zero load position as a function of pilot manual command on a switch located on the pedestal (artificial feel neutral variation). This function is achieved by the secondary computers.

Yaw damper commands are computed by the primary or secondary computers

In case of total loss of electrical power or total loss of flight controls computers the back up yaw damper unit (BYDU) becomes active for yaw damping function.

Autoflight orders are processed by the primary computers and are transmitted to the rudder via the yaw damper servo-actuator and the rudder trim actuator.

Note : in the event of loss of both yaw damper actuators the yaw damping function is achieved through roll control surfaces, in which case at least one spoiler pair is required.

Left intentionally blank

Additional functions devoted to aileron and spoilers

Ailerons

Ailerons receive commands for the following additional functions :

- **manoeuvre load alleviation** : two pairs of ailerons are deflected upwards - 11° max to reduce wing loads in case of high “g” manoeuvre
- **lift augmentation** (aileron droop) : two pairs of ailerons are deflected downwards to increase lift when flaps are extended.

Spoilers

Spoilers receive commands for the following additional functions :

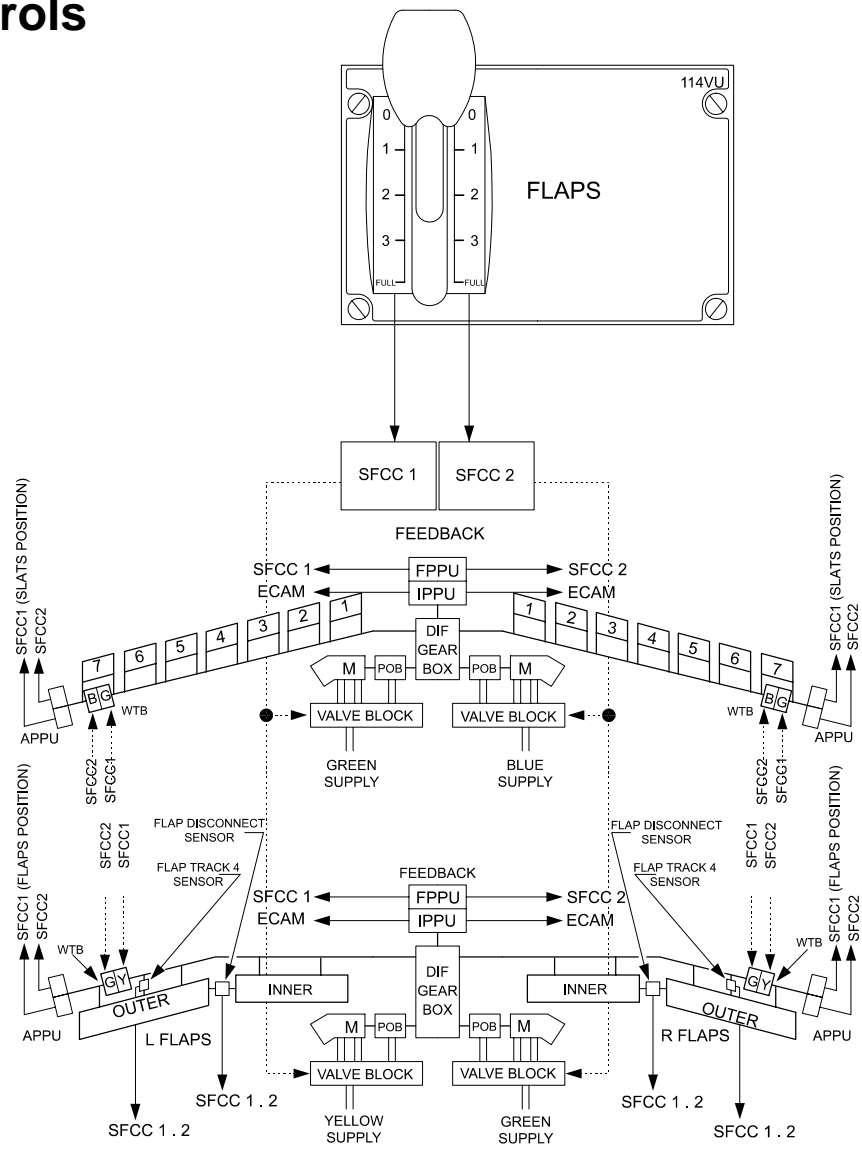
- **manoeuvre load alleviation** : spoilers 4, 5 and 6
- **Ground spoiler functions** : spoilers 1 to 6
 - - 35° max for spoiler 1,
 - - 50° max for spoilers 2 to 6
- **Speedbrake functions** : spoilers 1 to 6
 - - 25° max for spoiler 1
 - - 30° max for spoilers 2 to 6

Six spoilers and two pairs of ailerons perform these functions in following priority order :

- the roll demand has priority over the speedbrake function
- the lift augmenting function has priority over the speedbrake function
- if one spoiler surface fails to extend, the symmetrical surface on the other wing is inhibited.

A330 flight controls - EFCS

Slats/flaps controls

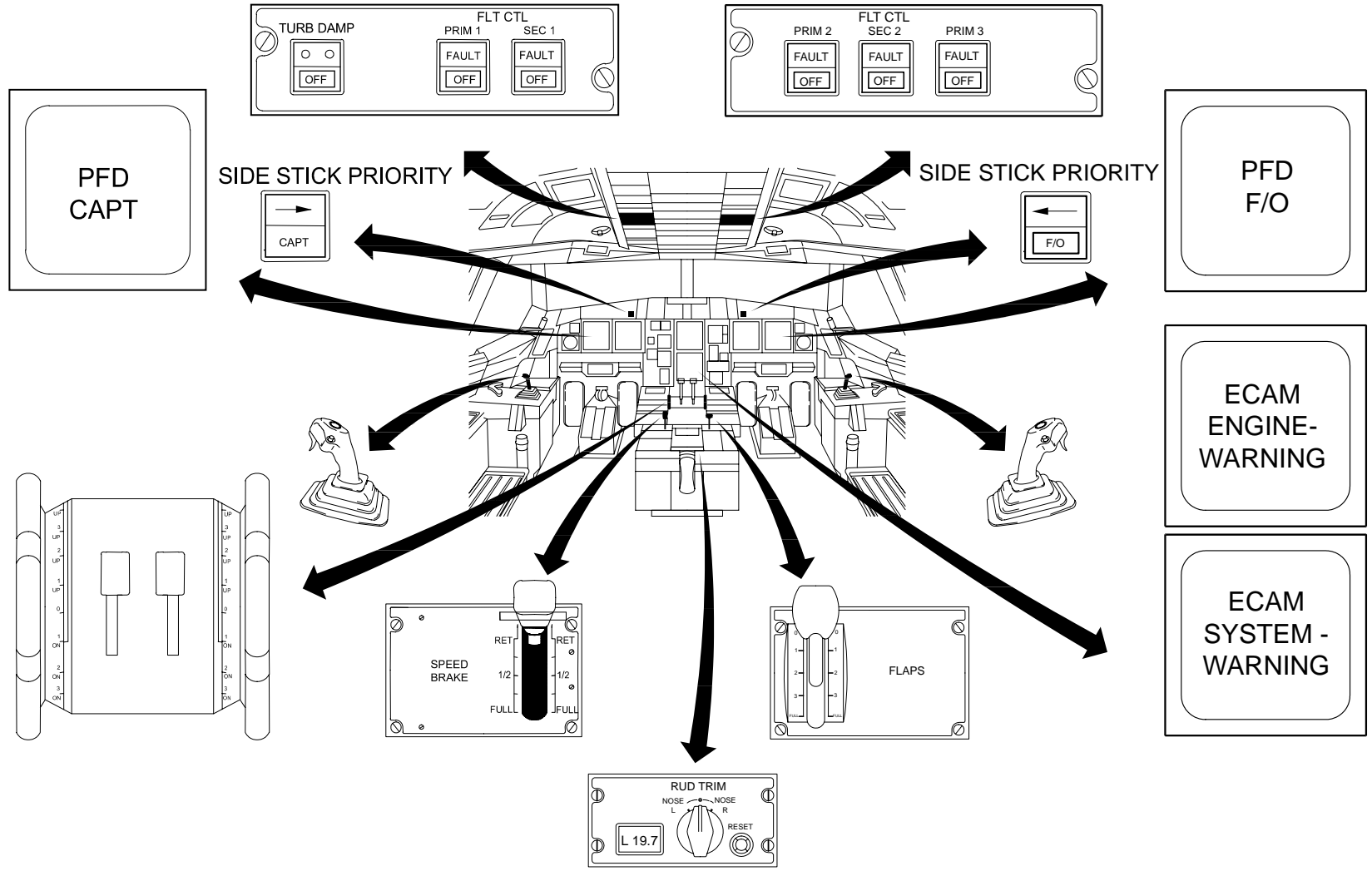


Slats/flaps

- High lift control is achieved on each wing by :
 - seven leading edge slats
 - two trailing edge flaps
 - two ailerons (aileron droop function)
- Slat and flaps are driven through similar hydromechanical systems consisting of :
 - Power Control Units (**PCU**)
 - differential gearboxes and transverse torque shafts
 - rotary actuators.
- Slats and flaps are electrically signalled through the SFCCs :
 - control lever position is obtained from the Command Sensor Unit (**CSU**) by the two SFCCs
 - each SFCC controls one hydraulic motor in both of the flap and slat PCUs.
- Aileron droop is achieved through the primary computers, depending on flap position data received from the **SFCC**.
- The SFCC monitors the slats and flaps drive system through feed-back Position Pick-off Units (**FPPU**) located at the PCUs and at the outer end of the transmission torque shafts.
- Wing Tip Brakes (**WTB**) installed within the torque shaft system, controlled by the SFCC, prevent asymmetric operation, blow back or runaway.
- A pressure-off brake provided between each hydraulic motor of the PCU and the differential gearboxes, locks the slat or flap position when there is no drive command from the SFCC.
- Flight Warning Computers (**FWC**) receive slat and flap position data through dedicated instrumentation Position Pick-off Units (**IPPU**) for warnings and position indication on ECAM display units.

A330 flight controls - EFCS

Controls and displays



Controls and displays

- **Overhead panel**

Pushbutton switches on the overhead panel allow disconnection or reset of the primary and secondary computers. They provide local warnings. Side 1 computer switches on left-hand side are separated from those of side 2 computers on right-hand side.

- **Glareshield**

Captain and First Officer priority lights, located in the glareshield, provide indication if either has taken the priority for his sidestick orders.

- **Lateral consoles**

Captain and First Officer sidesticks, located on the lateral consoles, provide the flight controls computers with pitch and roll orders. They are not mechanically coupled. They incorporate a take-over pushbutton switch.

- **Central pedestal**

- Speedbrake control lever position is processed by the primary computers for speedbrake control. A “ground spoiler” position commands ground deceleration (spoilers and ailerons).
- Rudder trim switch and reset pushbutton switch are processed by the secondary computers. The local rudder trim position indication is repeated on the ECAM FLT/CTL system page.
- Flap control lever position is processed by the SFCC. It allows selection of high-lift configurations for slats and flaps. Lever position indication is repeated in the “flap section” of the ECAM engine and warning display.
- Pitch trim wheels allow the setting of the THS position for take-off. They permit manual pitch trim control.

- **Main instrument panel**

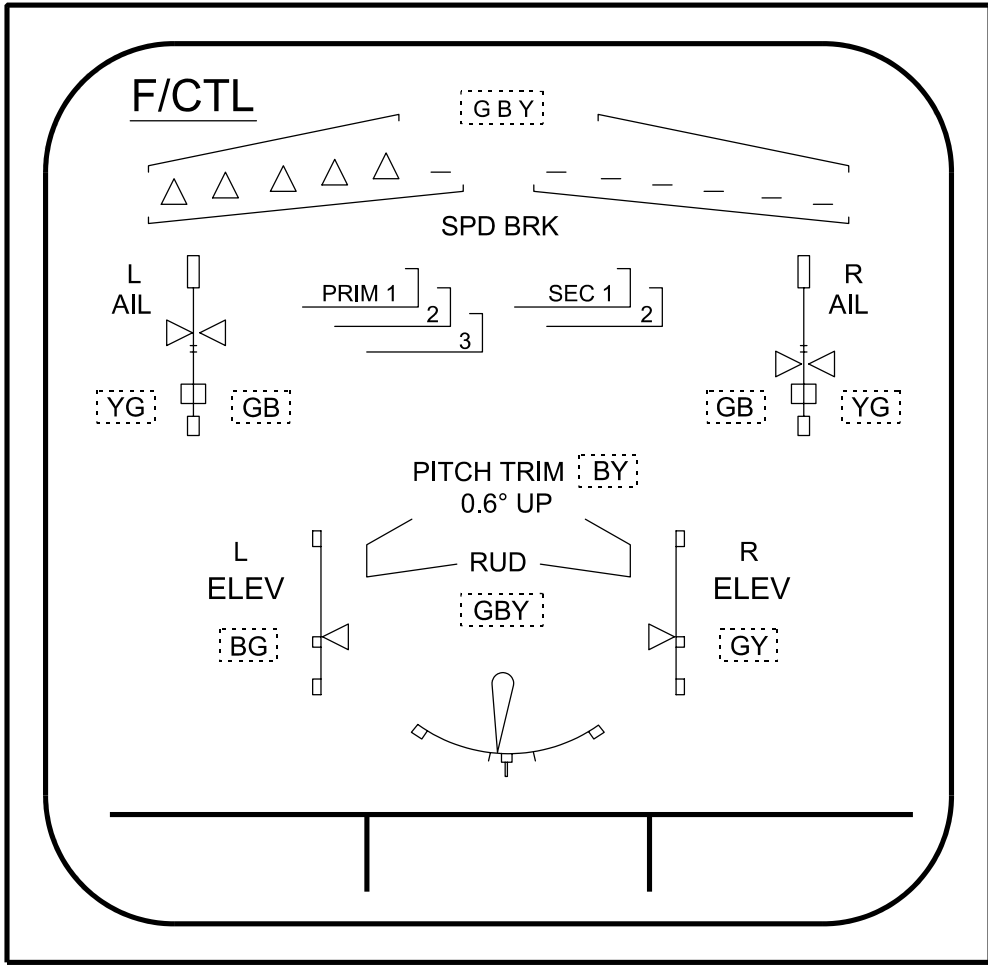
ECAM display units and PFDs present warnings and status information on the Flight control system. Permanent indication of slat and flap positions are given on the ECAM engine/warning display. Remaining flight control surface positions are given on the FLT/CTL system page which is presented on the ECAM system/status display.

- **Rudder pedals**

Interconnected pedals on each crew member’s side allow mechanical yaw control through the rudder.

A330 flight controls - EFCS

ECAM system page



A330 flight controls - EFCS

Control law introduction

- **Flight through computers**

Depending upon the EFCS status, the control law is :

- **Normal Law** (normal conditions even after single failure of sensors, electrical system, hydraulic system or flight control computer).

According to number and nature of subsequent failures, it automatically reverts to :

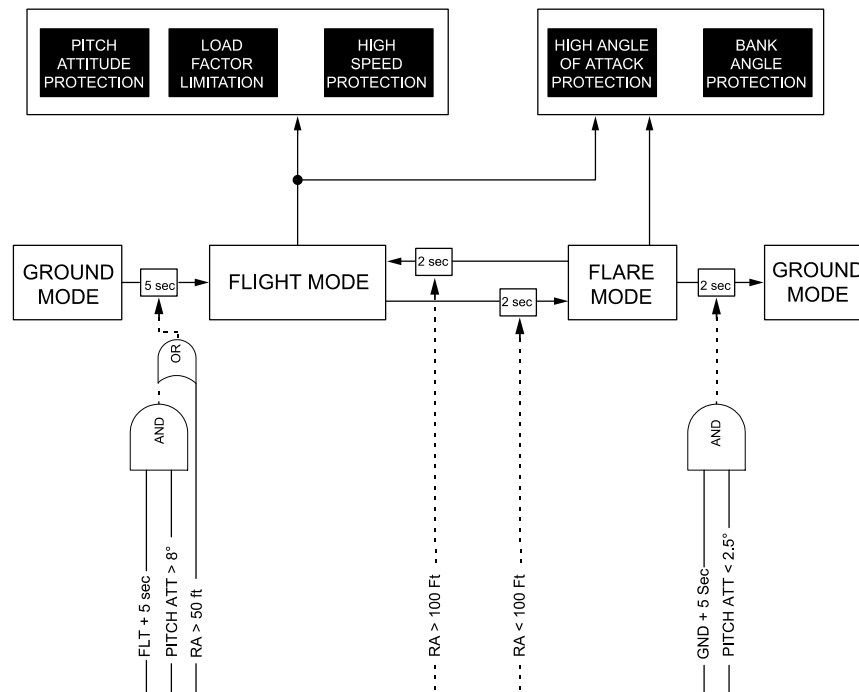
- **Alternate Law**, or
- **Direct Law**.

- **Mechanical back-up**

During a complete loss of electrical power the aircraft is controlled by :

- longitudinal control through trim wheel
- lateral control from pedals.

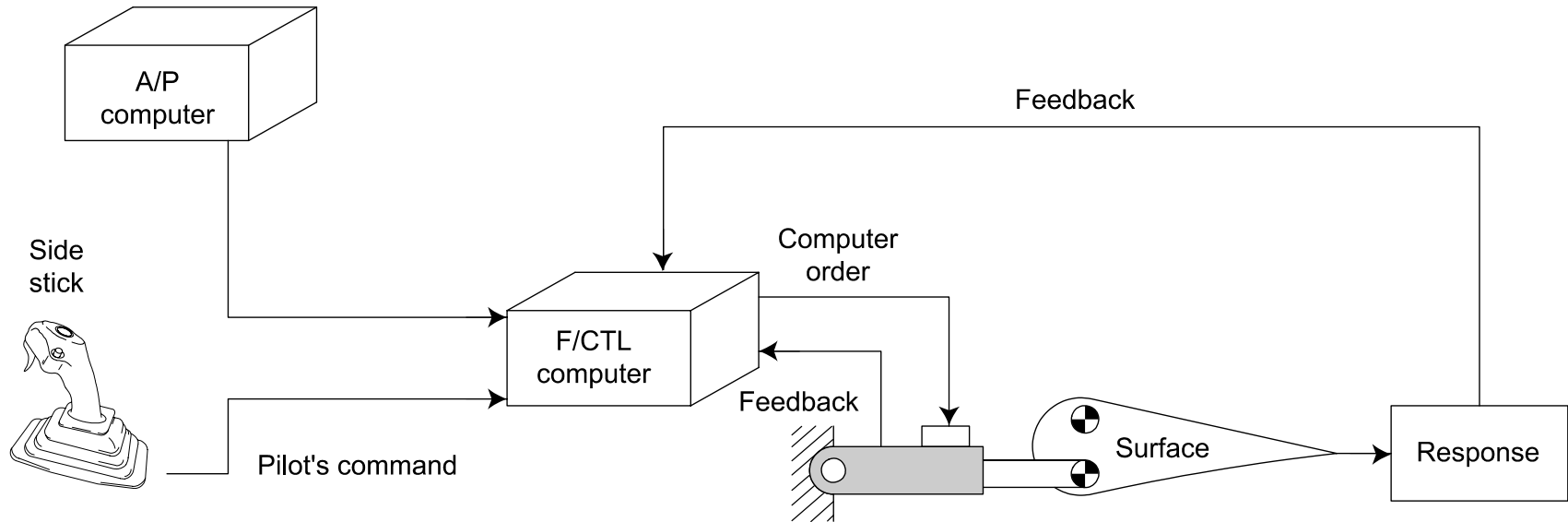
Overall Normal LAW schematic



A330 flight controls - EFCS

Normal Law - flight mode

Basic principle



• Highlights

- No direct relationship between sidestick and control surface deflection.
- The sidestick serve to provide overall command objectives in all three axes.
- Computers command surface deflections to achieve Normal Law objectives (if compatible with protections).

Normal Law - flight mode

Objectives

- **Pitch axis :**

Sidestick deflection results in a change of vertical load factor.

The normal law elaborates elevator and THS orders so that :

- a stick movement leads to a flight path variation
- when stick is released, flight path is maintained without any pilot action, the aircraft being **automatically trimmed**.

- **Lateral axis : Sidestick deflection results in initiating roll rate.**

Roll rate demand is converted into a bank angle demand. The Normal Law signals roll and yaw surfaces to achieve bank angle demand and maintain it - if less than 33° - when the stick is released.

Pedal deflection results in sideslip and bank angle (with a given relationship).

Pedal input - stick free - results in stabilized sideslip and bank angle (facilitates de-crabbing in crosswind).

- **Adaptation of objectives to :**

- **Ground phase : ground mode**

- . Direct relationship between stick and elevator available before lift-off and after touch-down.
- . Direct relationship between stick and roll control surfaces.
- . Rudder : mechanical from pedals + yaw damper function.
- . For smooth transition, blend of ground phase law and load factor (N_z) command law at take off.

- **Flight phase : flight mode**

The pitch normal law flight mode is a load factor demand law with auto trim and full flight envelope protection. The roll normal law provides combined control of the ailerons, spoilers 2 to 6 and rudder.

- **Landing phase : flare mode**

- . To allow conventional flare.
- . Stick input commands a pitch attitude increment to a reference pitch attitude adjusted as a function of radio altitude to provide artificial ground effect.

A330 flight controls - EFCS

Normal Law - flight mode

Engine failure or aircraft asymmetry

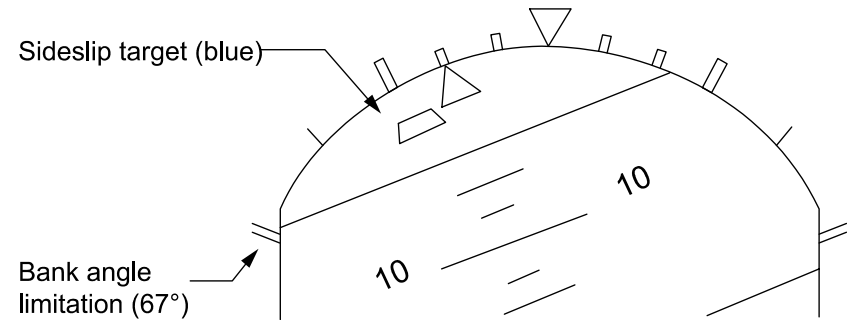
- By virtue of fly-by-wire controls and associated laws, handling characteristics are unique in the engine failure case :

- with no corrective action :

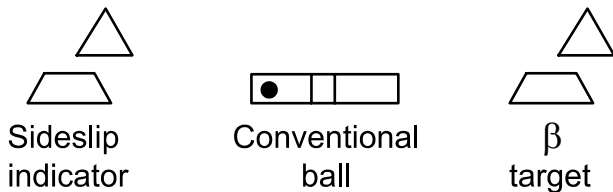
- stabilized sideslip and bank angle
- slowly diverging heading
- safe flight

- short-term recommended action :

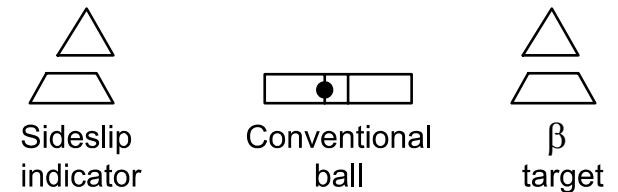
- zero sideslip or **sideslip target** (take-off) with pedals
- then stabilize heading with stick input
- steady flight with stick free and no pedal force (rudder trim).



No corrective action



Corrective action



- This feature is made possible since roll controls can be fully deflected with sidestick neutral.

The optimal pilot rudder application results in optimum climb performance.

Normal Law - flight mode

Main operational aspects and benefits

- Automatic pitch trim
- Automatic elevator to compensate turns up to 33° bank
- Aircraft response almost unaffected by speed, weight or center of gravity location
- Bank angle resistance to disturbance stick free
- Precise piloting
- Turn coordination
- Dutch roll damping
- Sideslip minimization
- Passenger comfort
- Reduced pilot, workload
- **Increased safety**

Normal Law - protections

- Protection does not mean limitation of pilot authority. Full pilot authority prevails within the normal flight envelope.
- Whatever the sidestick deflection is, computers have scheduled protections which overcome pilot inputs to prevent :
 - excessive load factors (no structural overstressing)
 - significant flight envelope exceedances :
 - speed overshoot above operational limits
 - stall
 - extreme pitch attitude
 - extreme bank angle.

Load factor protection

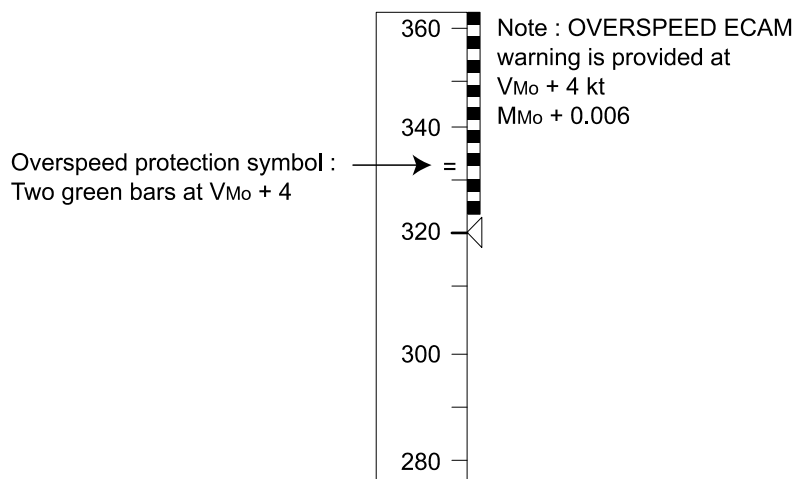
- **Design aim**
To minimize the probability of hazardous events when high manoeuvrability is needed.
- **Load factor limitation at :**
 - + 2.5 g, -1 g for clean configuration
 - + 2 g, 0 g when slats are extended.

Rapid pull-up to 2.5 g is immediately possible.

A330 flight controls - EFCS

High speed protection

- **Design aims**
To protect the aircraft against speed overshoot above V_{MO}/M_{MO} .
Non-interference with flight at V_{MO}/M_{MO} .
- **Principle**
When speed or Mach number is exceeded ($V_{MO} + 6 \text{ kt}/M_{MO} + 0.01$):
 - automatic, progressive, up elevator is applied (.1 g max)
 - pilot nose-down authority is reduced.
- **Results**
Maximum stabilized speed, nosed-down stick :
 $V_{MO} + 15 \text{ kt}$
 $M_{MO} + 0.04$



High angle-of-attack protection

- **Design aims**
 - Protection against stall
 - Ability to reach and hold a high CL (sidestick fully back), without exceeding stall angle (typically $3^\circ/5^\circ$ below stall angle) : good roll manoeuvrability and innocuous flight characteristics.
 - Elimination of risk of stall in high dynamic manoeuvres or gusts.
 - Non-interference with normal operating speeds and manoeuvres.
 - Load factor limitation maintained.
 - Bank angle limited.
 - Available from lift-off to landing.
- **Windshear protection**
Windshear protection is ensured by
 - SRS mode
 - speed trend indication
 - wind indication (speed and direction)
 - flight path vector
 - Windshear warning
 - predictive windshear function of weather radar (optional).

A330 flight controls - EFCS

High angle-of-attack protection

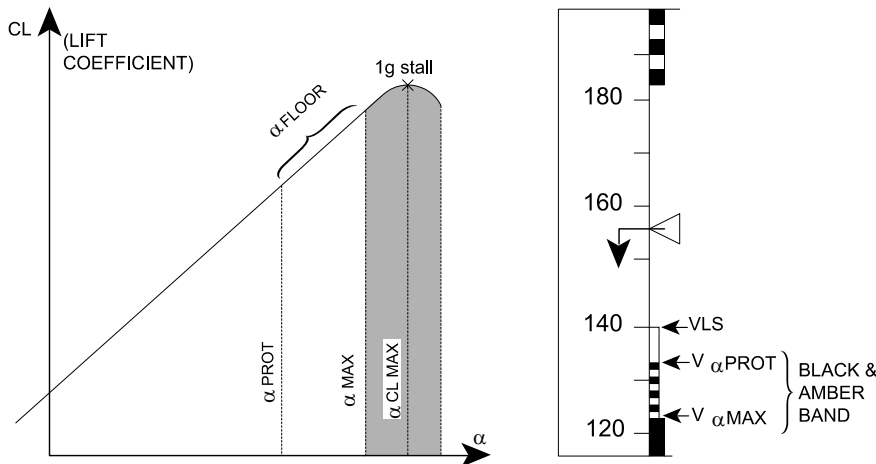
- **Principle**

When the AOA*) is greater than AOA prot, the basic objective defined by sidestick input reverts from vertical load factor to AOA demand.

- **Result**

- AOA protection is maintained if sidestick is left neutral.
- AOA floor results in GA power with an ensuing reduction of AOA.
- AOA max is maintained if sidestick is deflected fully aft.

Return to normal basic objective is achieved if the sidestick is pushed forward.



*) AOA = α

Pitch attitude protection

- **Design aim**

To enhance the effectiveness of AOA and high-speed protection in extreme conditions and in windshear encounter.

- **Principle**

Pilot authority is reduced at extreme attitude.

- **Result**

Pitch attitude limited :

- nose-down 15°
- nose-up 30°, to 25° at low speed

Bank angle protection

- When stick is released above 33° the aircraft automatically rolls back to 33°.
- If stick is maintained, bank angle greater than 33° will be maintained but limited to 67°.
- When overspeed protection is triggered :
 - . Spiral stability is introduced regardless of bank angle
 - . Max bank angle is limited to 45°.
- When angle-of-attack protection is triggered, max bank angle is limited to 45°.

Low energy warning

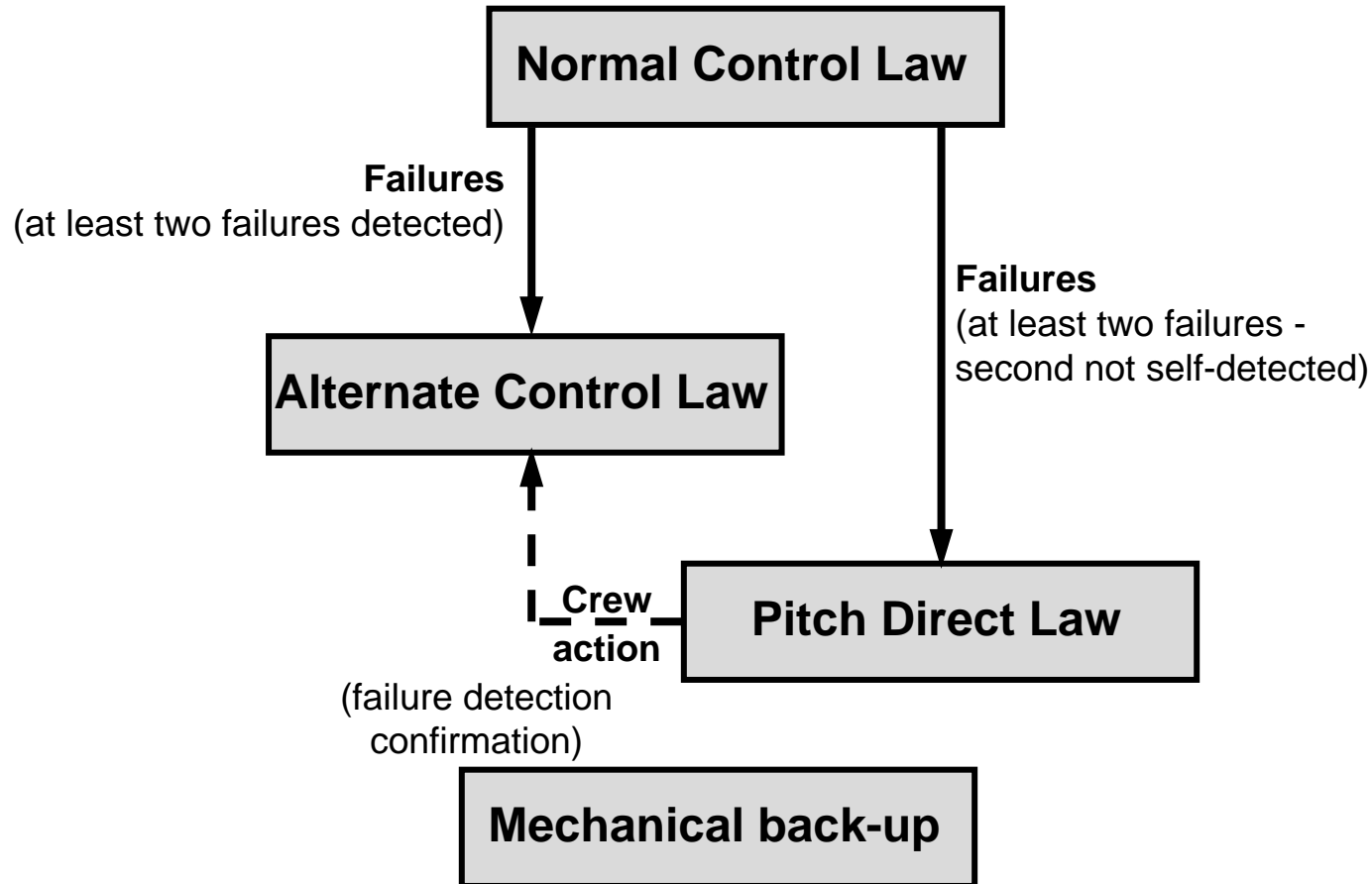
A low energy aural warning "SPEED SPEED SPEED" is triggered to inform the pilot that the aircraft energy becomes lower than a threshold under which, to recover a positive flight path angle through pitch control, the thrust must be increased.

A330 flight controls - EFCS

Reconfiguration control laws

No loss of Normal Law after a single failure.

Automatic reversion from **Normal Law** to **Alternate** or **Direct Law** according to the number and nature of subsequent failures.



Alternate Law

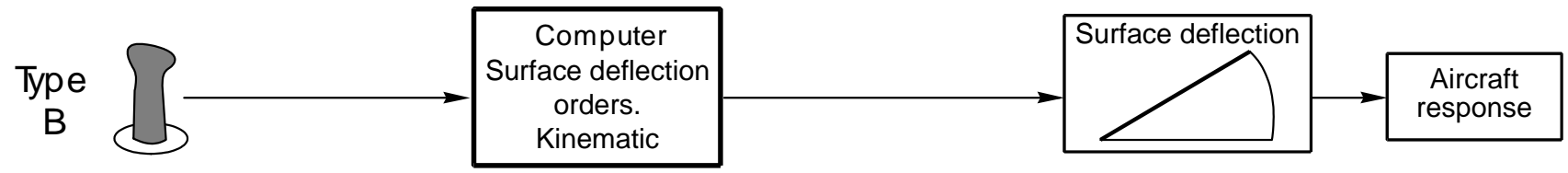
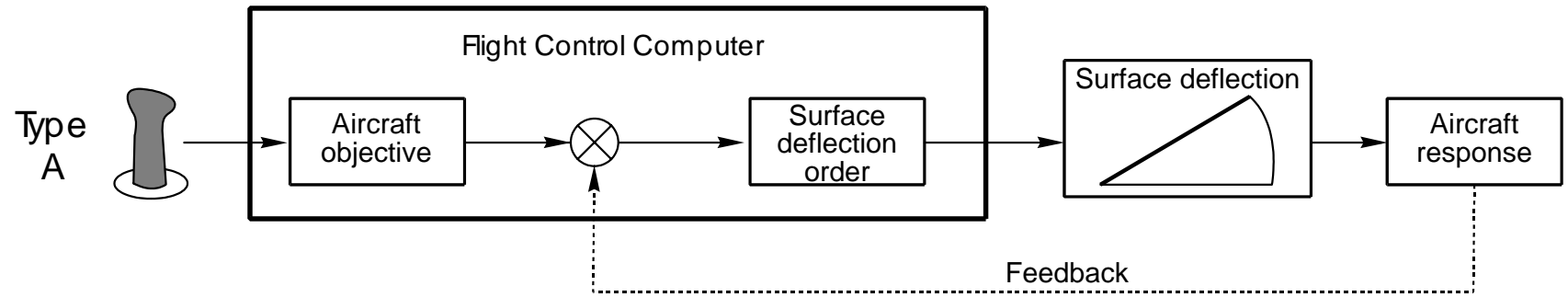
- **Probability objective** : 10^{-5} /flight hour (10^{-3} under MMEL).
- No change for **ground, take-off** and **flare** mode compared to Normal Law.
- **Flight mode** :
 - **Pitch axis** : as per Normal Law with limited pitch rate and gains depending on speed and CONF.
 - **Roll/yaw axes : Depending on failure** :
 1. The lateral control is similar to normal law (no positive spiral stability is introduced).
 2. Characterized by a direct stick-to-roll surface relationship which is configuration dependent.
- **Protections** :
 - pitch attitude : lost
 - high speed : replaced by static stability
 - high angle of attack : replaced by static stability (Vc prot. Law)
+ aural stall warning when $\alpha > \alpha_{sw^*}$
 - low energy : lost

Direct Law

- **Probability objective** : 10^{-7} /flight hour (10^{-5} under MMEL).
- No change for **ground mode** and **take-off mode** compared to Normal Law.
- **Flight mode** : Maintained down to the ground
 - in all three axes, direct relationship between stick and elevator/roll control surfaces which is center of gravity and configuration dependent.
- **All protections are lost**
Conventional aural stall and overspeed warnings are provided as for Alternate Law.
- Main operational aspect :
 - **manual trimming** through trim wheel.

A330 flight controls - EFCS

Control law reconfiguration summary

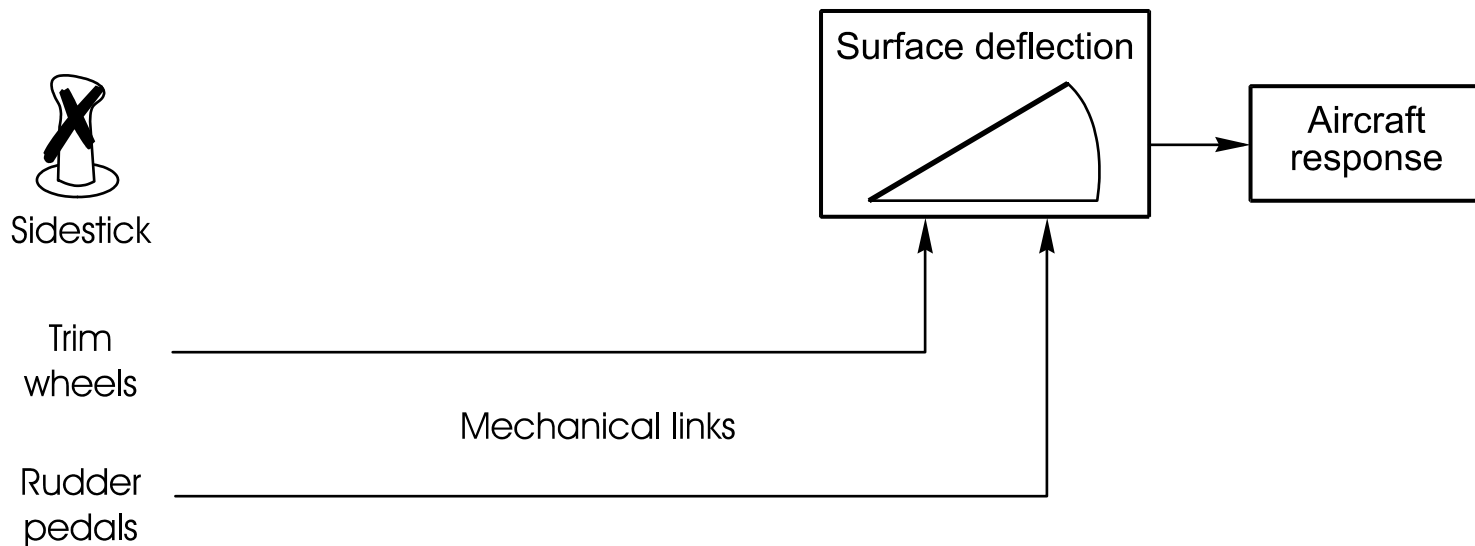


Control law	Pitch	Lateral
Normal	Type A	Type A
Alternate	Type A	Type A/B
Direct	Type B	Type B

A330 flight controls - EFCS

Mechanical back-up

- To sustain the aircraft during a temporary complete loss of electrical power.
- Longitudinal control of the aircraft through trim wheel. Elevators kept at zero deflection.
- Lateral control from pedals. Roll damping is provided by the Back up Yaw Dumper Unit (BYDU).
- Message on PFD **MAN PITCH TRIM ONLY** (red).

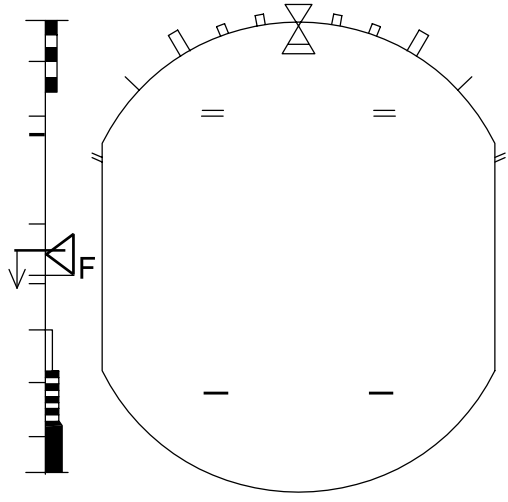


A330 flight controls - EFCS

Control law status information

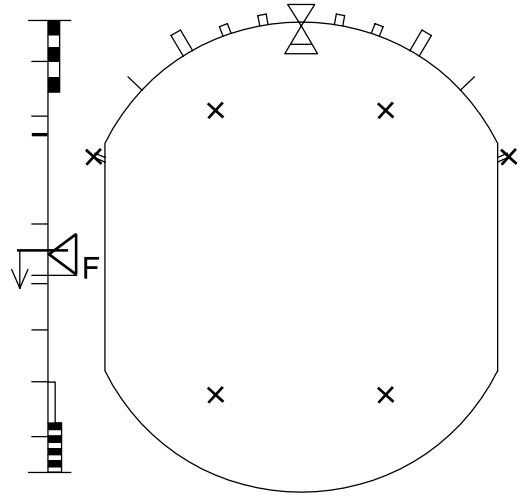
Besides ECAM messages, the pilot is permanently informed of control law status on PFD.

Normal Law
Normal FMA indications



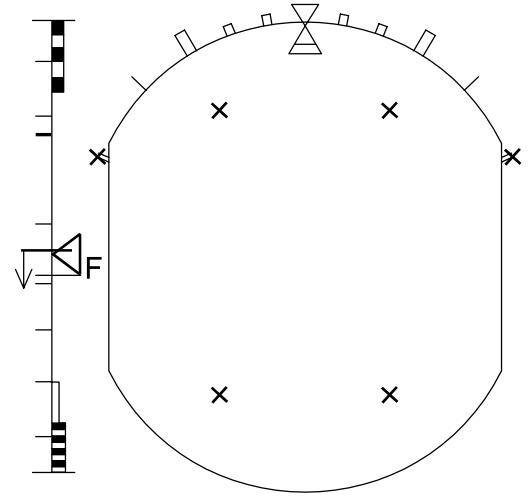
Pitch attitude protection
Bank angle protection

Alternate Law
Normal FMA indications



+ Audio warning
+ ECAM messages
with
limitations, if any

Direct Law
Normal FMA indications +
USE MAN PITCH TRIM

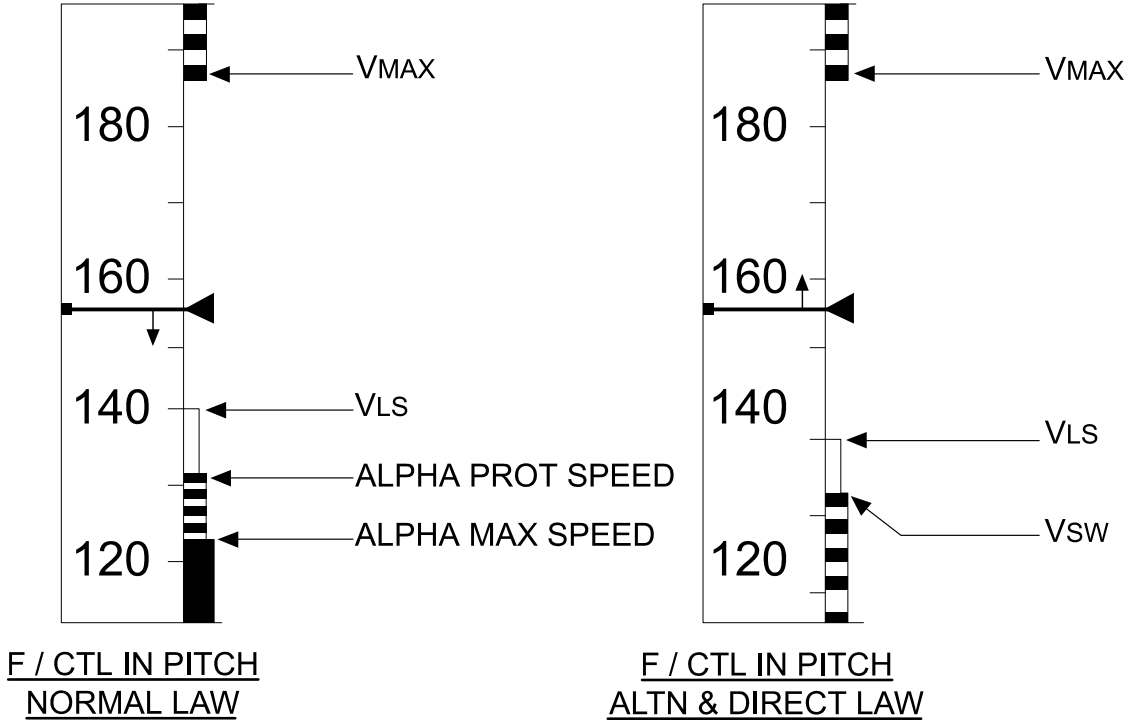


+ Audio warning
+ ECAM messages
with
limitations, if any

A330 flight controls - EFCS


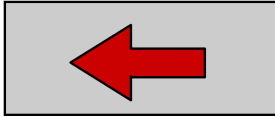

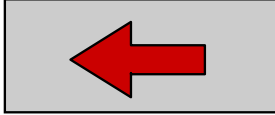
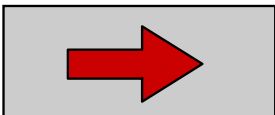
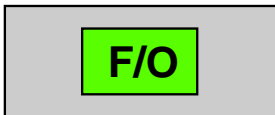
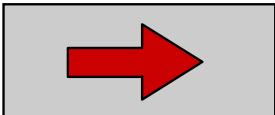

Control law status information

Crew information : PFD speed scale



A330 flight controls - EFCS

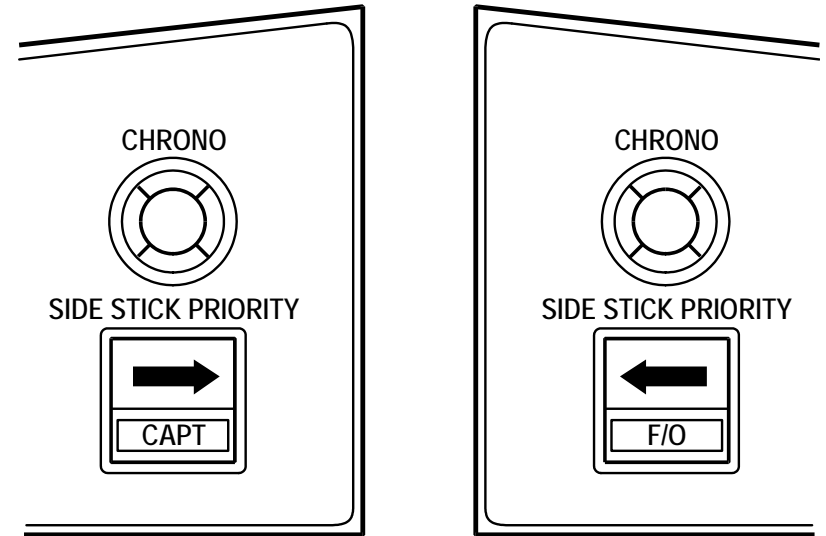
Priority display logic

Captain's side		First Officer's side	
Sidestick	Annunciation	Annunciation	Sidestick
Take-over button depressed	 Green	 Red	Sidestick deflected
Take-over button depressed	 "Light off"	 Red	Sidestick in neutral
Sidestick deflected	 Red	 Green	Take-over button depressed
Sidestick in neutral	 Red	 "Light off"	Take-over button depressed

A330 flight controls - EFCS

Priority logic

- Normal operation : Captain and First Officer inputs are algebraically summed.
- Autopilot disconnect pushbutton is used at take-over button.
- Last pilot who depressed and holds take-over button has priority ; other pilot's inputs ignored.
- Priority annunciation :
 - in front of each pilot on glareshield
 - ECAM message
 - audio warning.
- Normal control restored when both buttons are released.
- Jammed sidestick :
 - priority automatically latched after 30 seconds
 - priority reset by depressing take-over button on previously jammed sidestick.





6. Landing gear

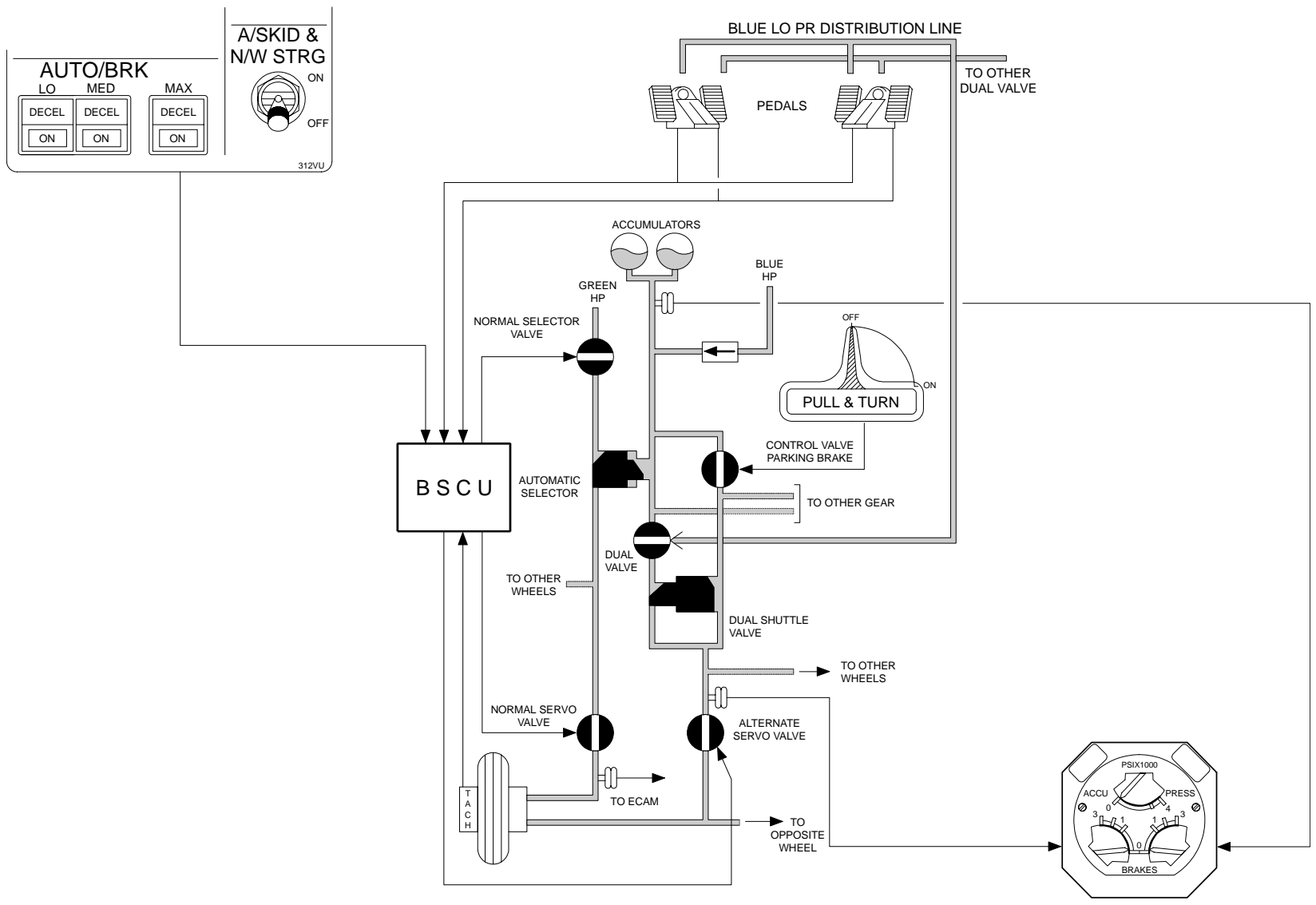
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A330 landing gear

Main features

- Conventional landing gear with single bogie nose gear and double bogie main landing gear with direct-action shock absorbers.
- The main landing gear is also provided with a shock absorber extension/retraction system.
- The main gears retract laterally ; nose gear retracts forward into the fuselage.
- Electrically controlled by two Landing Gear Control/Interface Units (**LGCIU**).
- Hydraulically actuated (Green system) with alternative free-fall/spring downlock mode.
- Alternating use of both LGCIUs for each retraction/extension cycle. Resetting the landing gear control lever results in transition to the other LGCIU.
- Elimination of gear lever neutral position through automatic depressurization of landing gear hydraulic supply at speeds above 280 kt.
- Elimination of microswitches by use trouble-free proximity detectors for position sensing.

A330 landing gear





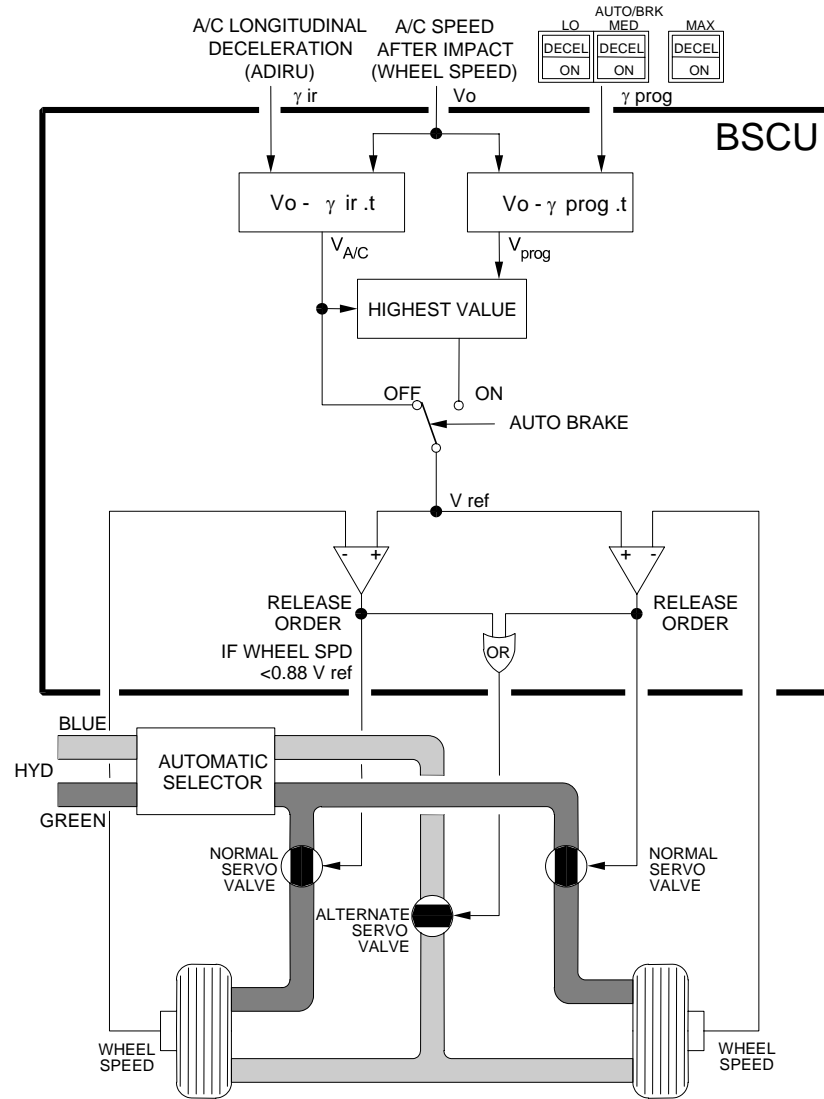
A330 landing gear

Braking system

- Carbon disc brakes are standard.
- Normal system (Green hydraulic system supply) :
 - electrically signalled through antiskid valves
 - individual wheel antiskid control
 - autobrake function
 - automatic switchover to alternate system in event of Green hydraulic supply failure.
- Alternate braking system with antiskid (Blue hydraulic system supply) :
 - electrically signalled through alternate servovalves
 - hydraulically controlled through dual valve
 - individual wheel antiskid control
 - no autobrake function.
- Alternate braking system without anti-skid (Blue hydraulic system supply or Blue brake power accumulator) :
 - hydraulically controlled by pedals through dual valve
 - brake pressure has to be limited by the pilot referring to the gauges.
 - no autobrake function
 - no antiskid system
- Parking brake (Blue hydraulic system supply or Blue brake power accumulator) :
 - electrically signalled
 - hydraulically controlled with brake pressure indication on gauges.
- The Braking and Steering Control Unit (**BSCU**) is digital dual-channel double system (control and monitoring) computer controlling the following functions :
 - normal braking system control
 - anti-skid control (normal and alternate)
 - autobrake function with LO, MED, MAX.
 - nosewheel steering command processing
 - brake temperature signal processing
 - monitoring of all these functions.

A330 landing gear

Antiskid system schematic



Braking principle

Antiskid system

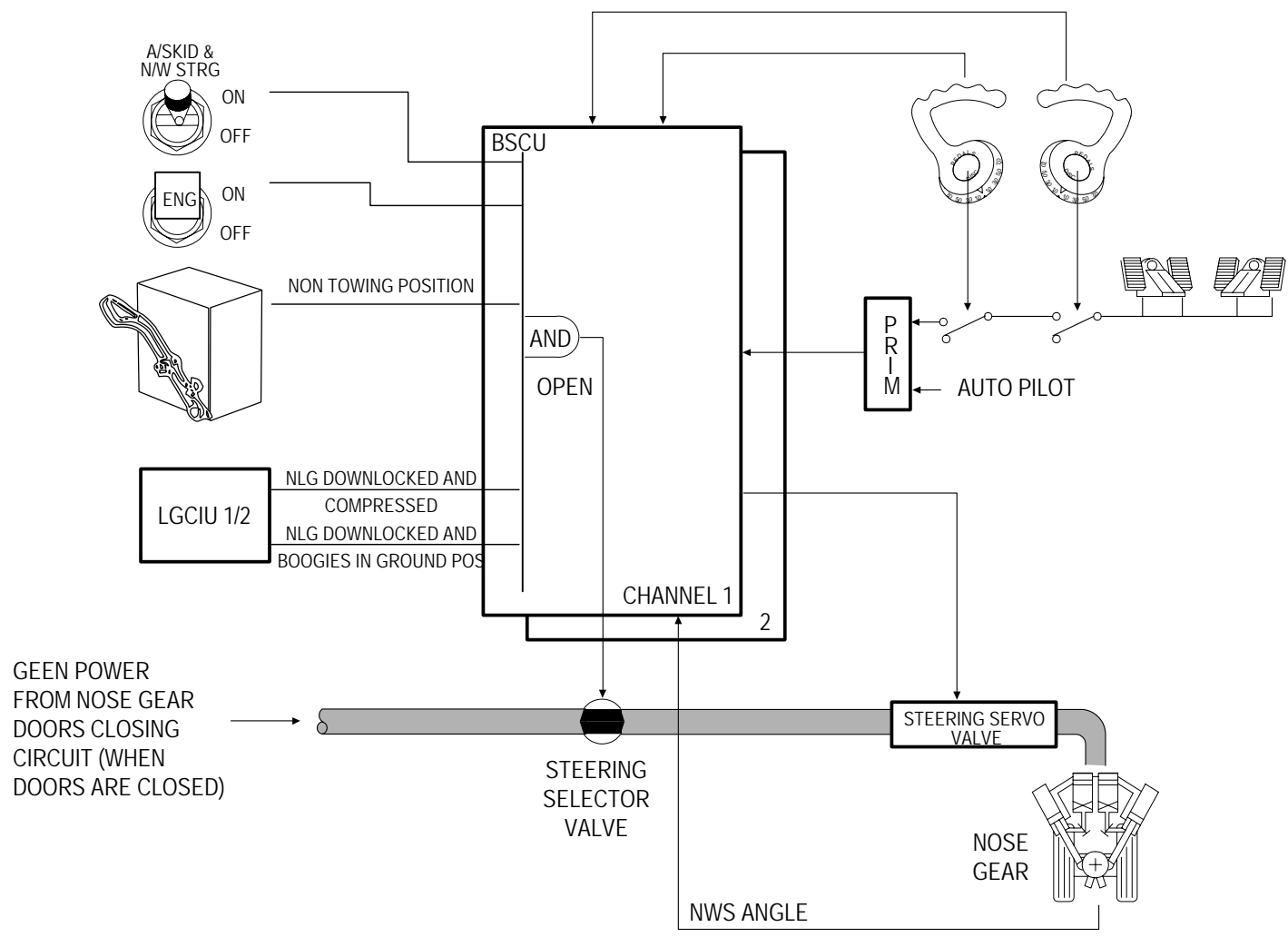
- From touchdown, aircraft speed is computed based on touchdown speed (wheels) and integrated deceleration (ADIRS). This reference speed is compared with each wheel speed to generate a release order for closing the normal servovalve in case of skid exceeding 16%.
- Brake pedal orders open this servovalve which is also modulated by anti-skid closing signals.

Autobrake system

- From touchdown, a specific speed is computed based on touchdown speed (wheels) and programmed deceleration (low, medium, max). This programmed speed is compared with each wheel speed to generate a release order for closing the normal servovalve to meet selected deceleration.
- If the reference speed exceeds programmed speed (contaminated or iced runways), the former will take over for the antiskid to modulate the normal servovalve.

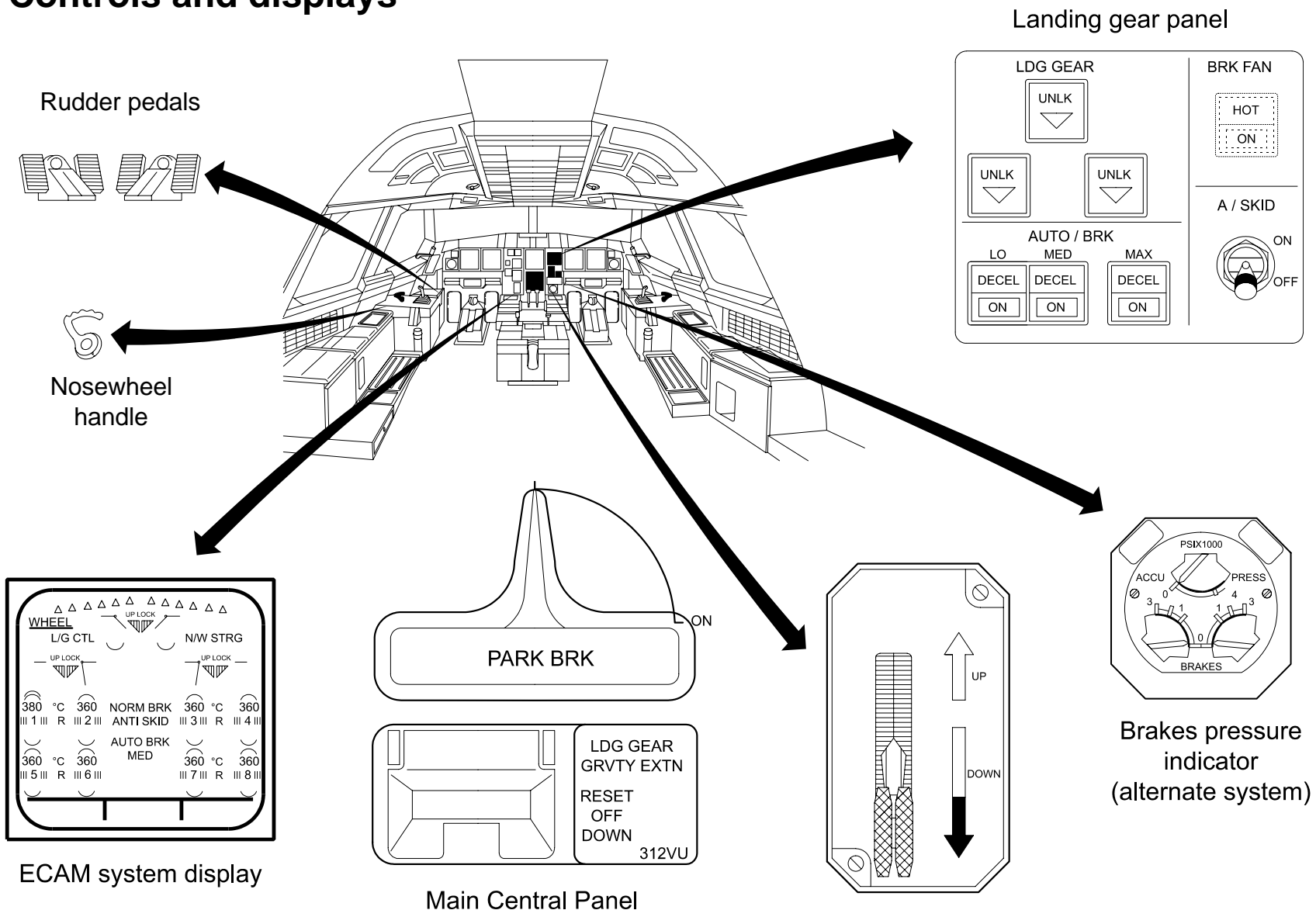
A330 landing gear

Nose gear steering principle



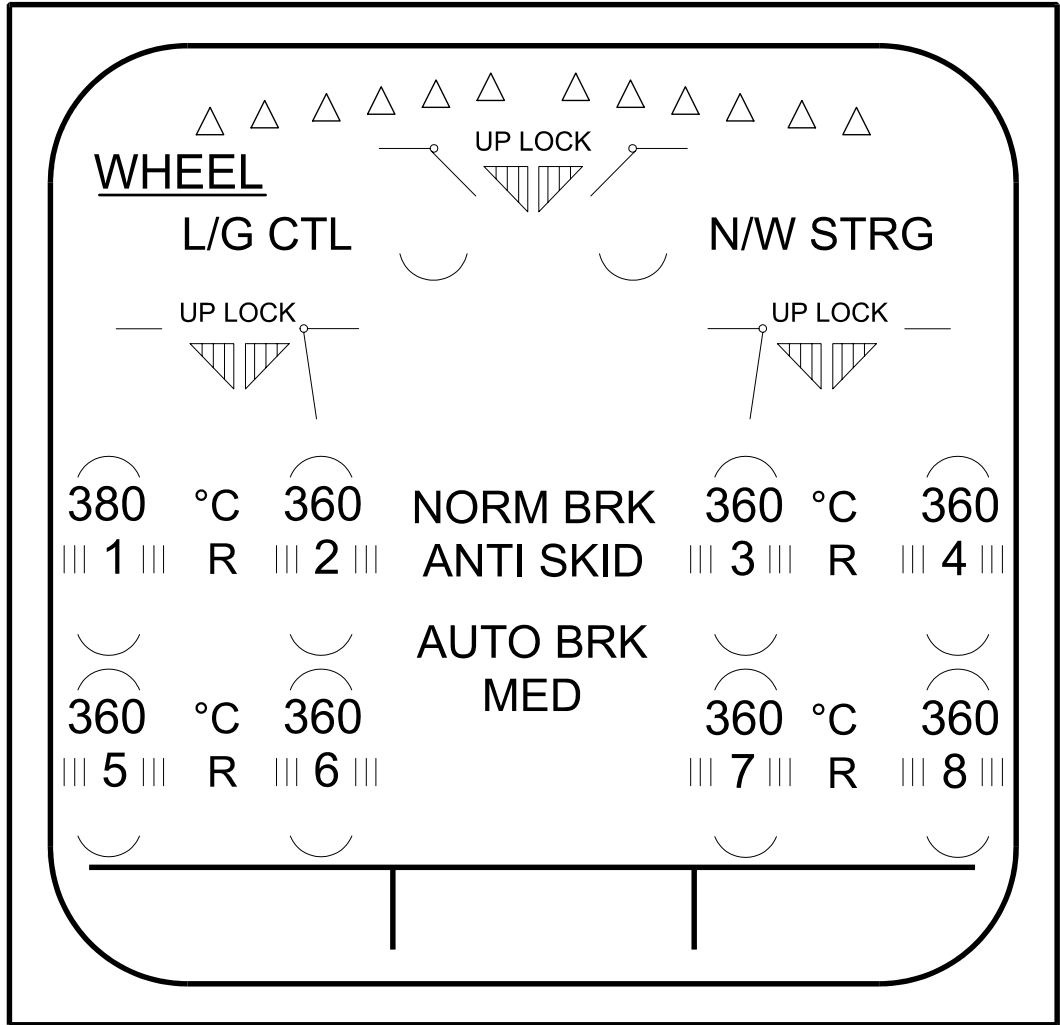
A330 landing gear

Controls and displays



A330 landing gear

ECAM system page





7. Fuel system

A330 fuel system

Basic layout

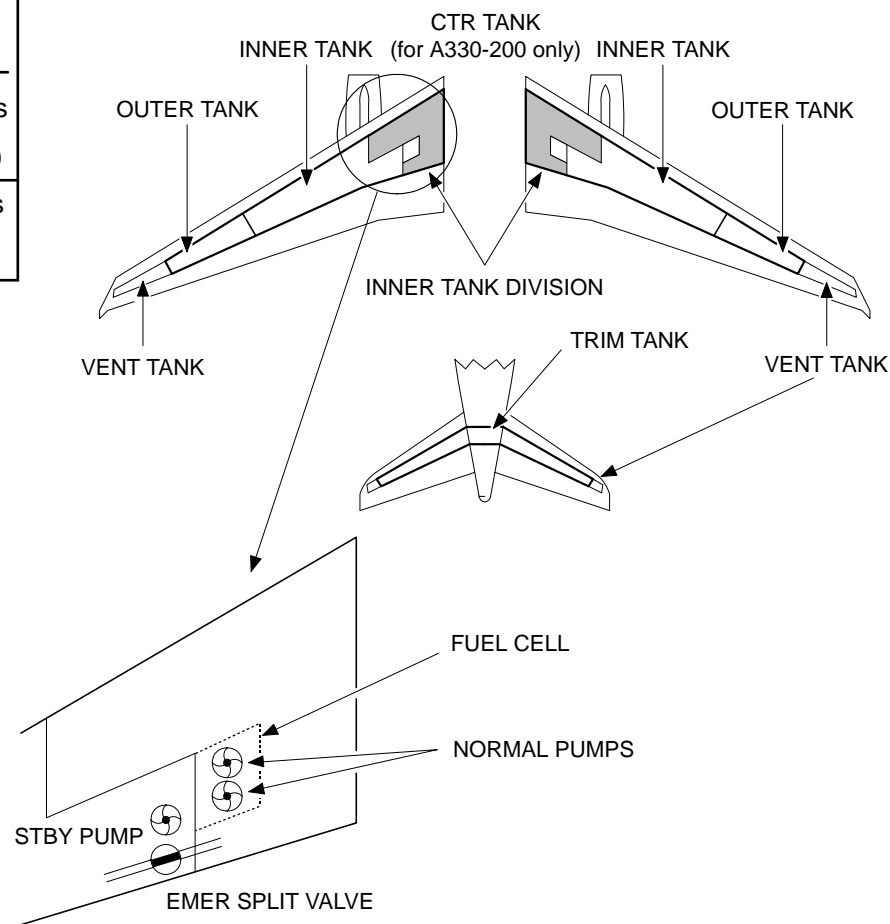
• Total fuel capacity

	Outer tanks	Inner tanks	Center tank	Trim tank	Total
A330-200	7300 litres (5730 kg)	84 000 litres (65940 kg)	41650 litres (32625 kg)	6230 litres (4890 kg)	139090 litres (109185 kg)
A330-300	7248 litres (5690 kg)	83808 litres (65790 kg)	/	6230 litres (4890 kg)	97 286 litres (76 370 kg)

• Ventilation

- Each wing tank and the tail tank is separately vented through its associated vent tank.
- These vent tanks are open to the atmosphere via flame arrestors and NACA inlets.
- Location of ducts and float valves is designed to ensure free venting over appropriate attitude ranges during refueling and normal ground and flight manoeuvres.
- Pressure relief outlets protect the inner tank from over- or under-pressure in case of failure or blockage of the vent system or pressure refueling gallery.

Tank arrangement



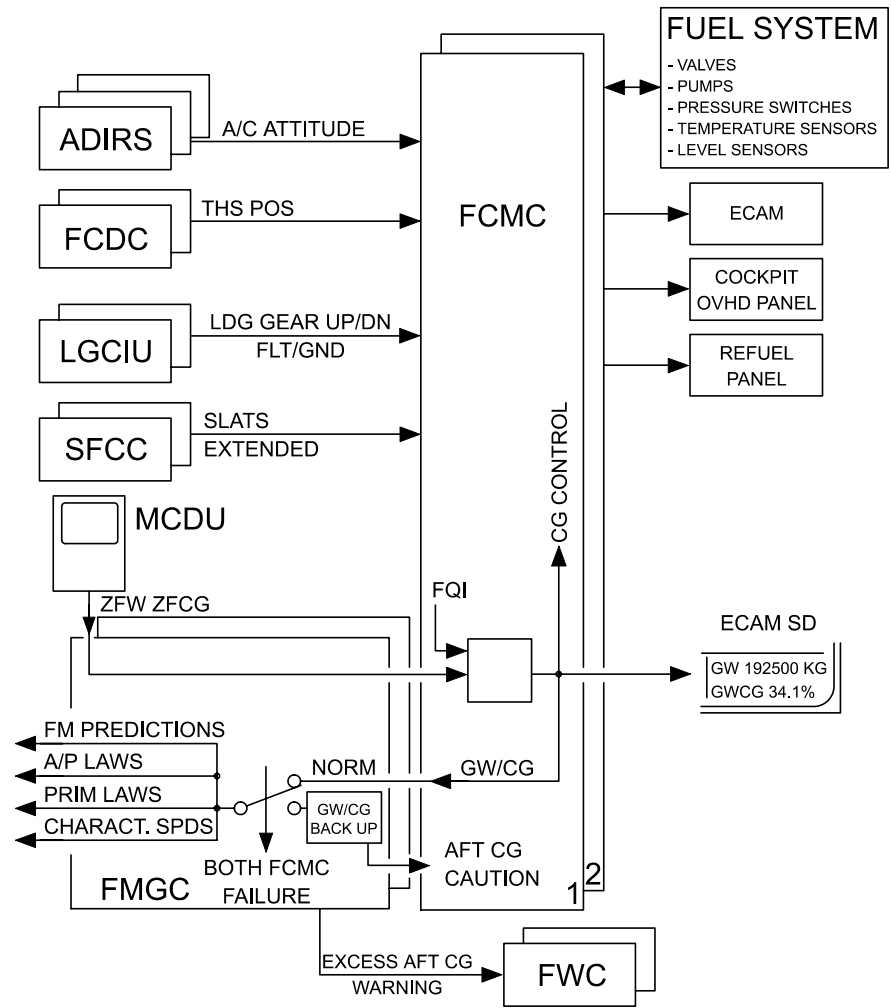
A330 fuel system

Control and monitoring

The Fuel Control and Monitoring System (FCMS) controls the fuel system automatically

Two identical Fuel Control and Monitoring Computers (FCMC) provide :

- fuel transfer control
- aircraft gross weight and center of gravity calculation based on zero fuel weight and zero fuel center of gravity entered by the crew.
- center of gravity control
- refuel control
- fuel quantity measurement and indication
- level sensing
- fuel temperature indication
- signals to FADEC for IDG cooling control.



Engine feed

- In normal operation, each engine is independently supplied by two continuously operating booster pumps located in a dedicated collector box.

In the event of a pump failure, a standby pump automatically comes on line.

Collector boxes are maintained full by a jet pump transfer action using booster pump pressure.

In cruise conditions, a single booster pump is able to supply flow to both engines.

- A cross-feed valve allows the engine on either wing to be supplied from the opposite one.
- Supply of fuel to each engine may be shut off by an engine LP valve driven by a double motor actuator. It is controlled by either the ENG FIRE pushbutton or the ENG master lever.
- Automatic transfer of fuel from the outer tanks is performed by gravity. This occurs when trim tanks have been emptied and when either inner tank reaches 3500 kg.

Outer tank fuel transfer valves are used to cycle the inner tanks contents between 3500 and 4000 kg. These valves are closed when outer tanks are empty for 5 minutes.

- Transfer to inner tanks can be manually selected through the OUTFR TK XFR pushbutton.

When selected ON, the outer tanks fuel transfer valves, outer and inner inlet valves are controlled OPEN.

- **For A330-200 only :**

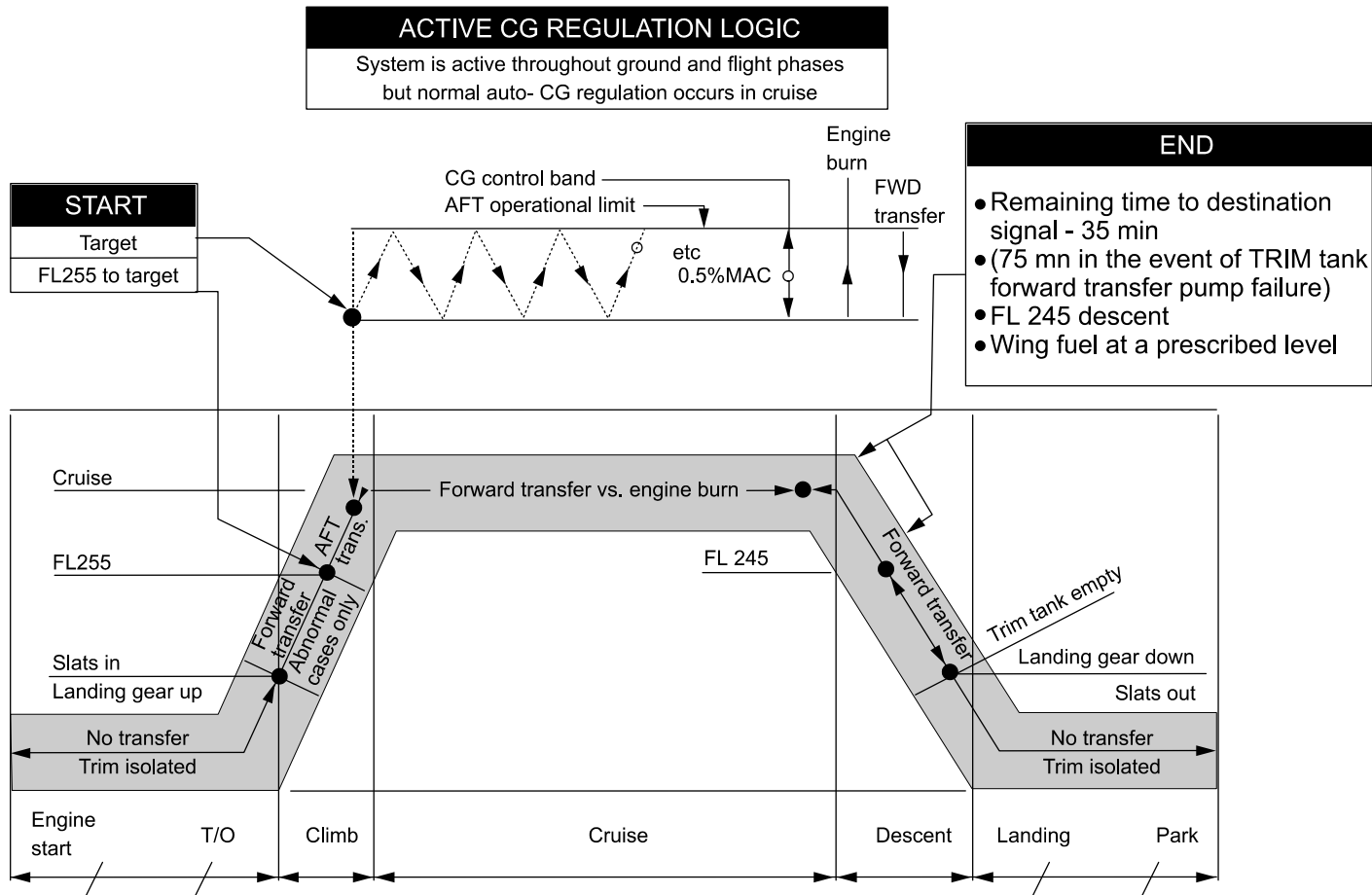
With fuel in the center tank, both CTR TK pumps are running and the inner inlet valves are used independently to cycle their respective inner tank contents between underfull and high level (Underfull is set at approximately 2000 kg below high level).

When the center tank is empty, the pumps are automatically shut off, and both inner inlet valves close.

Jettison system (on A330-200 only - optional)

- The jettison pipe is connected to the refuel gallery in each wing. A dual actuator jettison valve is fitted.
- Fuel is jettisoned from the centre and inner tanks simultaneously. All normal and STBY pumps are running and a forward transfer into center tank is initiated.
- The aircraft weight will be reduced at a rate of not less than 70 tonnes/hour.
- Jettison is stopped when :
 - the crew deselects the jettison pushbutton
 - both level sensors dedicated to jettison become dry
 - a signal from the FCMC indicates that the remaining fuel on board reaches a value previously defined by the crew via the FMGS MCDU (option : Preselection of gross weight after jettison).
 - sum of both inner quantity reaches 10 000 kg.

Centre of Gravity control band relative to operational flight envelope



CG control

- Automatic CG control begins in climb at FL 255 and stops in descent at FL 245 or when FMGS time to destination is below 35 minutes (or 75 minutes if the trim tank transfer pump fails).

- **Aft transfer**

- * **A330-200**

- Fuel for trim tank aft transfer is provided by the center tank when it contains fuel or by the inner tanks when the center tank is empty.

- * **A330-300**

- The inner tanks provide fuel for trim tank aft transfer through the engines feed pumps.

Aft transfer is terminated for example when computed CG = target CG - 0.5%, or when an inner tank reaches the low level.

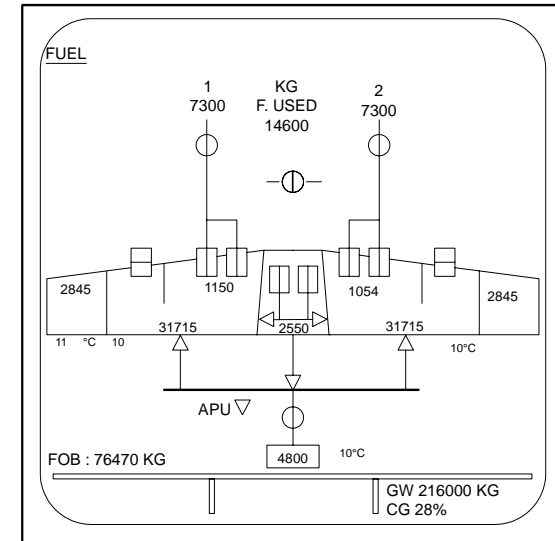
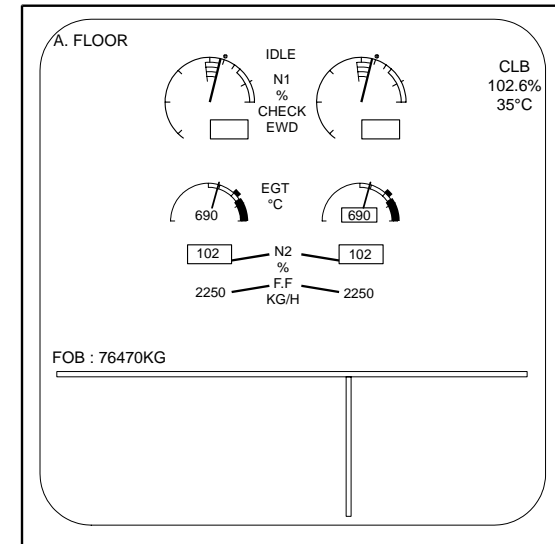
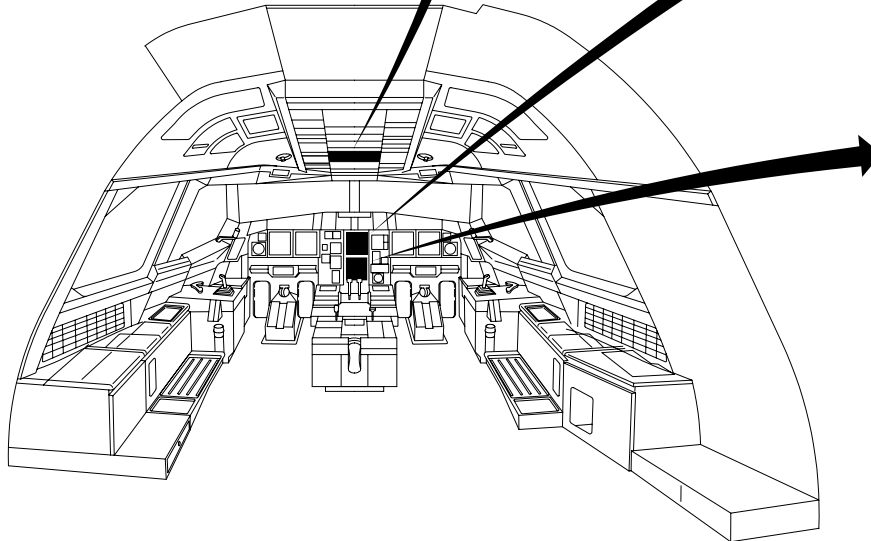
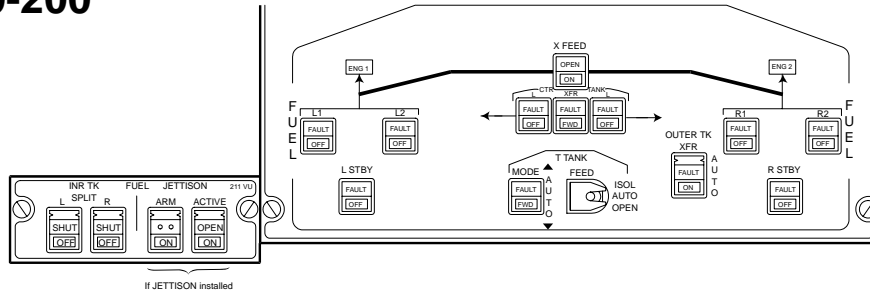
- **Forward transfer**

- Forward transfer is required for example when computed CG = target CG.
- Fuel transfer from the trim tank to the inner tanks is performed by the trim tank forward transfer pump through the trim pipe isolation valve.
- On the A330-200, forward transfer is directed to the center tank when it is not empty.
- Forward transfer is terminated when computed CG = target CG - 0.5%.

A330 fuel system

Controls and displays

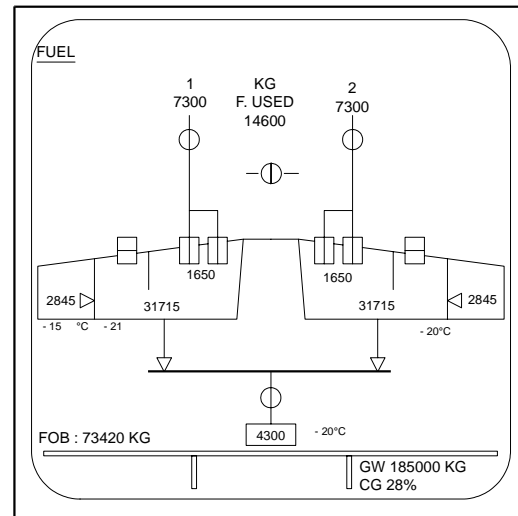
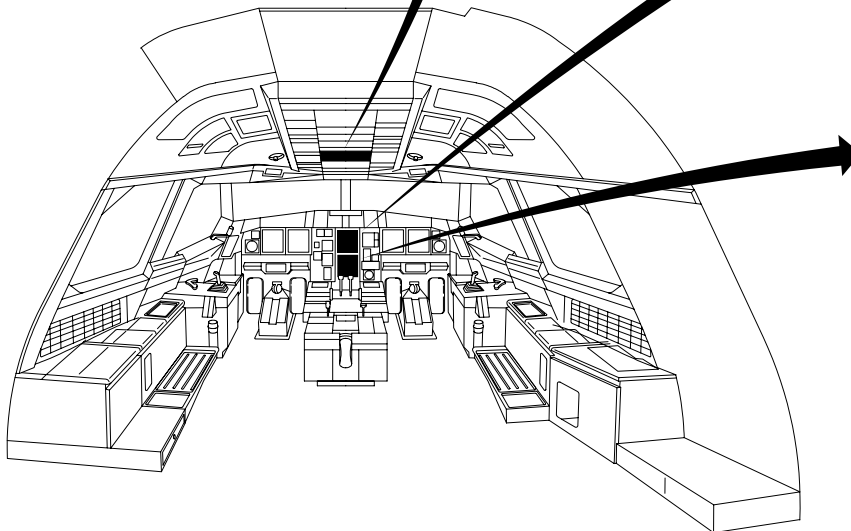
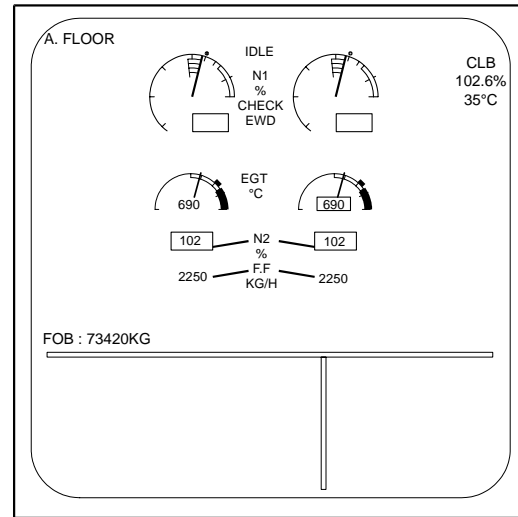
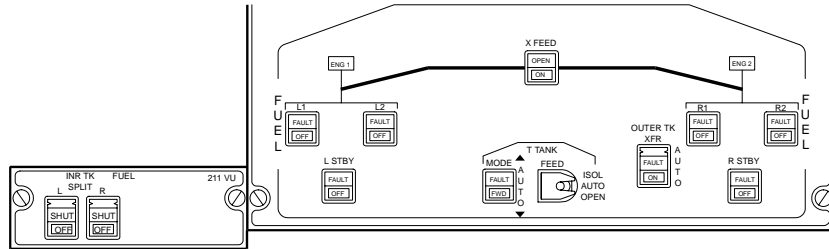
A330-200



A330 fuel system

Controls and displays

A330-300



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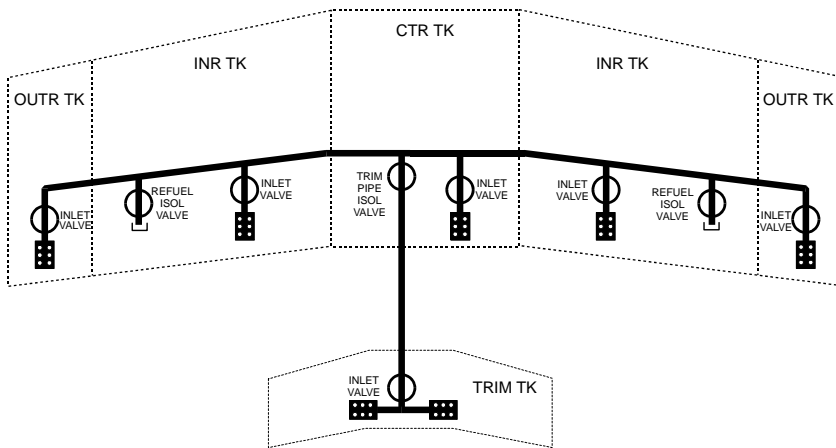
Control and indication

- No crew action is required for normal operation except initiation and termination.
- Indications :
 - fuel data (quantity, temperature) are available from a Fuel Quantity Indication (**FQI**) system
 - Fuel quantity is permanently displayed on upper ECAM DU
 - Fuel system synoptic on lower ECAM DU is displayed according to ECAM logic
 - low level warning is totally independent from FQI.
- Abnormal operations :
 - Fuel feed sequence may be operated manually
 - cross-feed valve may be operated manually
 - forward and (some) inter tank transfers may be initiated manually
 - gravity feed is possible.

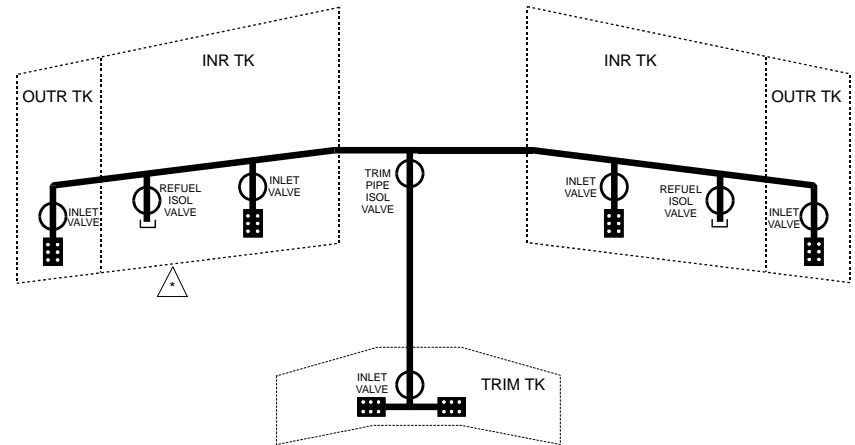
A330 fuel system

Refueling system

A330-200



A330-300



Refueling

- Two 2.5 inch couplings are installed in the leading edge of the right wing and of the left wing (optional on the A330-300), enabling all tanks to be filled from empty in some :
 - 33 minutes on the A330-200
 - 25 minutes on the A330-300 or 35 minutes if the left wing refueling point is not installed.
- An isolation valve is provided between couplings and the refueling gallery.
- A refueling inlet valve is provided for each tank, allowing distribution to a diffuser to reduce turbulence and avoid electrostatic build-up.
- An automatic refueling system controls the refuel valves to give preselected fuel load and correct distribution.
- Refueling/defueling is controlled from an external panel, located in the fuselage fairing under the RH belly fairing, and can be carried out with battery power only.
 - Optional : Refueling can be controlled from the cockpit
- Gravity refueling can be achieved by overwing refueling points
- Defueling is accomplished by means of fuel pumps and for the outer and trim tanks, via transfer valves.



8. Engine controls

A330 engine controls

FADEC

- Thrust control is operated through Full Authority Digital Engine Control (FADEC) computers which :
 - command the engines to provide the power best suited to each flight phase
 - automatically provide all the associated protection required :
 - either in manual (thrust lever)
 - or in automatic (autothrust) with a fixed thrust lever.
- Engine performance and safety improvement over current hydromechanical control system.

Simplification of engine/aircraft communication architecture.

Reduction of crew workload by means of automatic functions (starting, power management).

Ease of on-wing maintenance.

- The system design is fault-tolerant and fully duplicated, with 'graceful degradation' for minor failures (i.e. sensor failures may lose functions but not the total system).

The engine shut-down rate resulting from FADEC failures will be at least as good as today's latest hydromechanical systems with supervisory override.

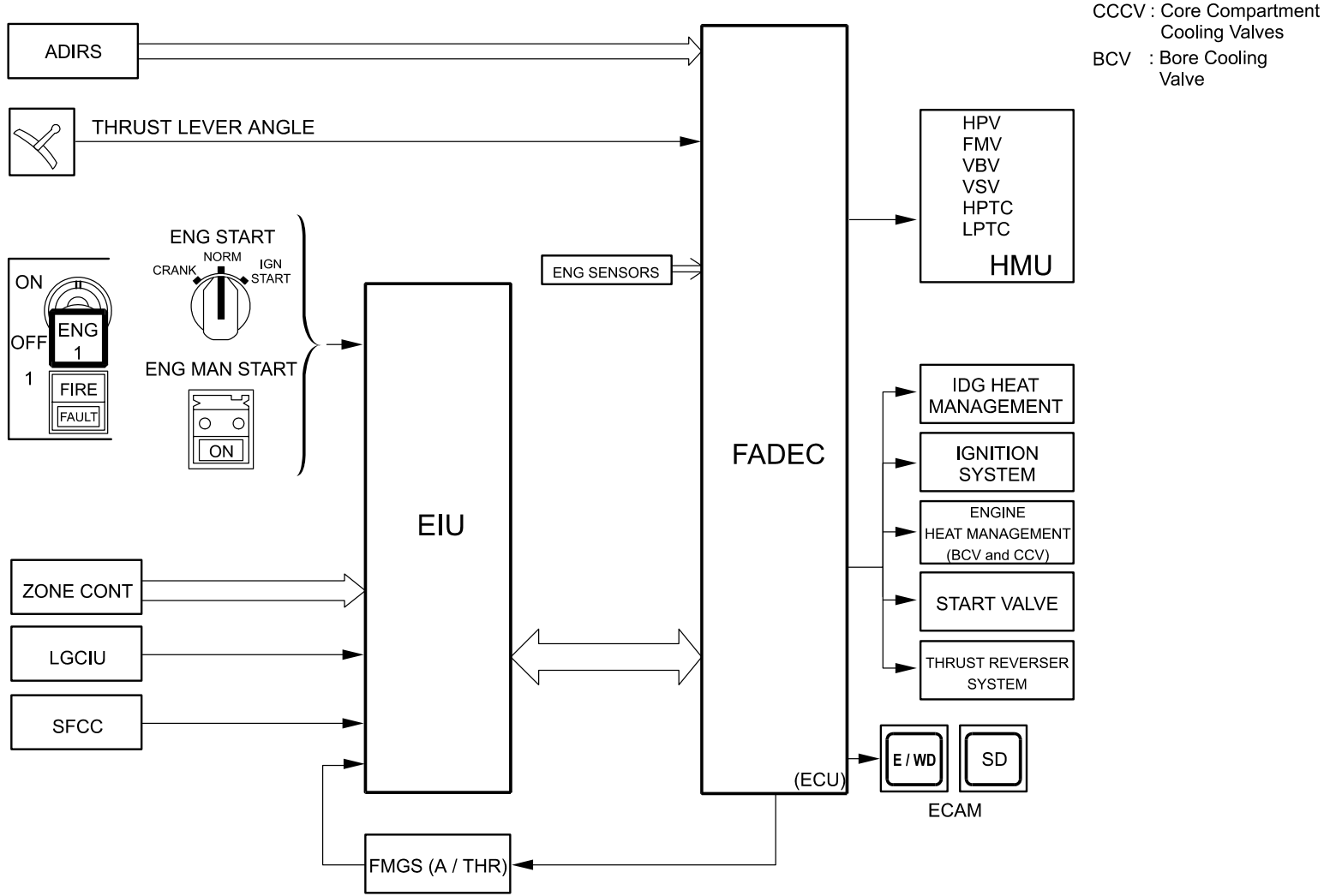
- FADEC also called Engine Control Unit (ECU for GE engines) or Engine Electronic Controller (EEC for PW and RR engines) is a fully redundant digital control system which provides complete engine management. Aircraft data used for engine management is transmitted to the FADEC by the Engine Interface Unit (EIU).

Each engine is equipped with a fan-case-mounted FADEC supporting the following functions :

- gas generator control
- engine limit protection
- engine automatic starting
- engine manual starting
- power management
- engine data for cockpit indication
- engine condition parameters
- reverser control and feedback
- fuel used computation
- fuel recirculation control (RR engines)
- FADEC cooling (RR engines)

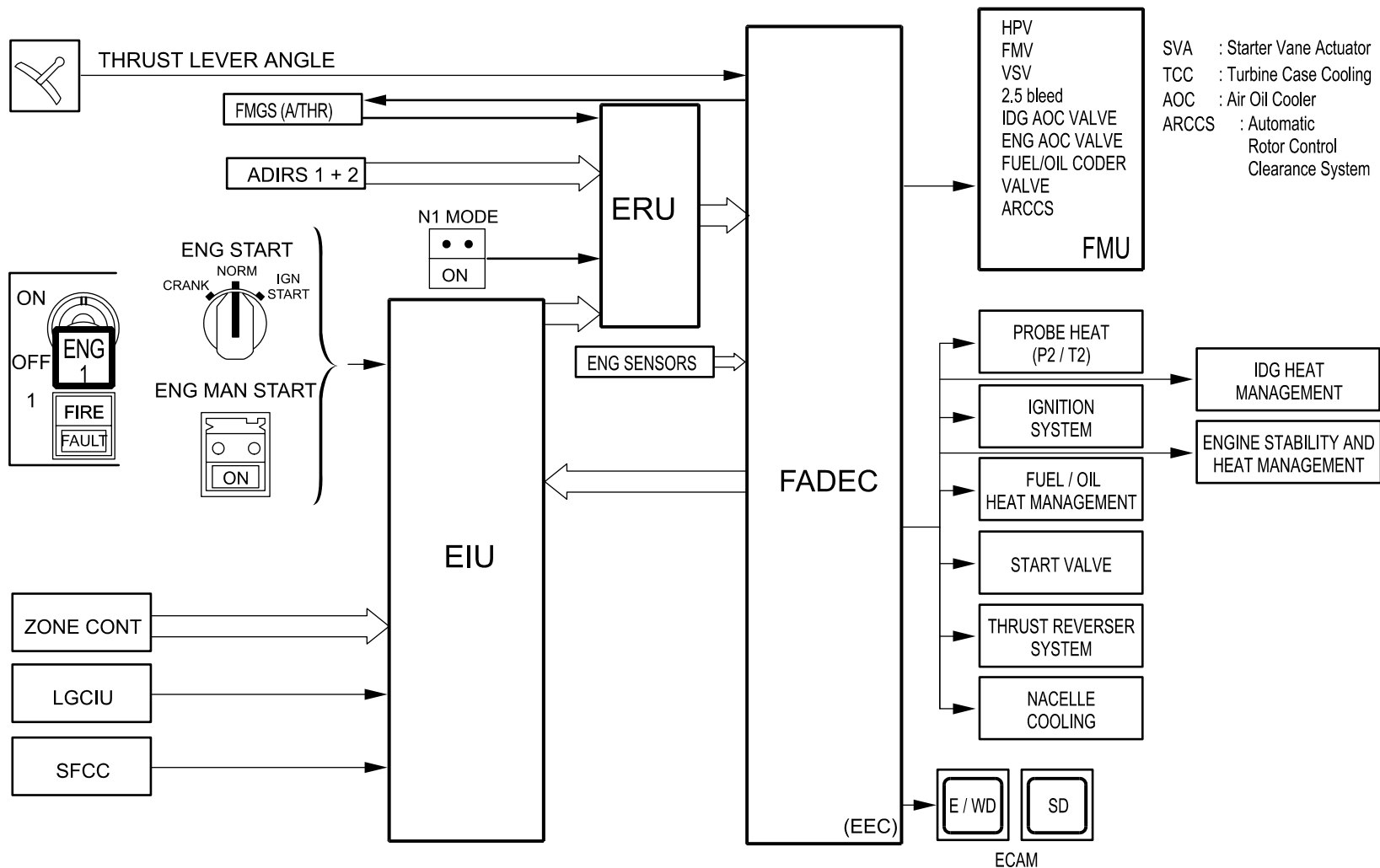
A330 engine controls - GE CF6-80E1A

FADEC architecture



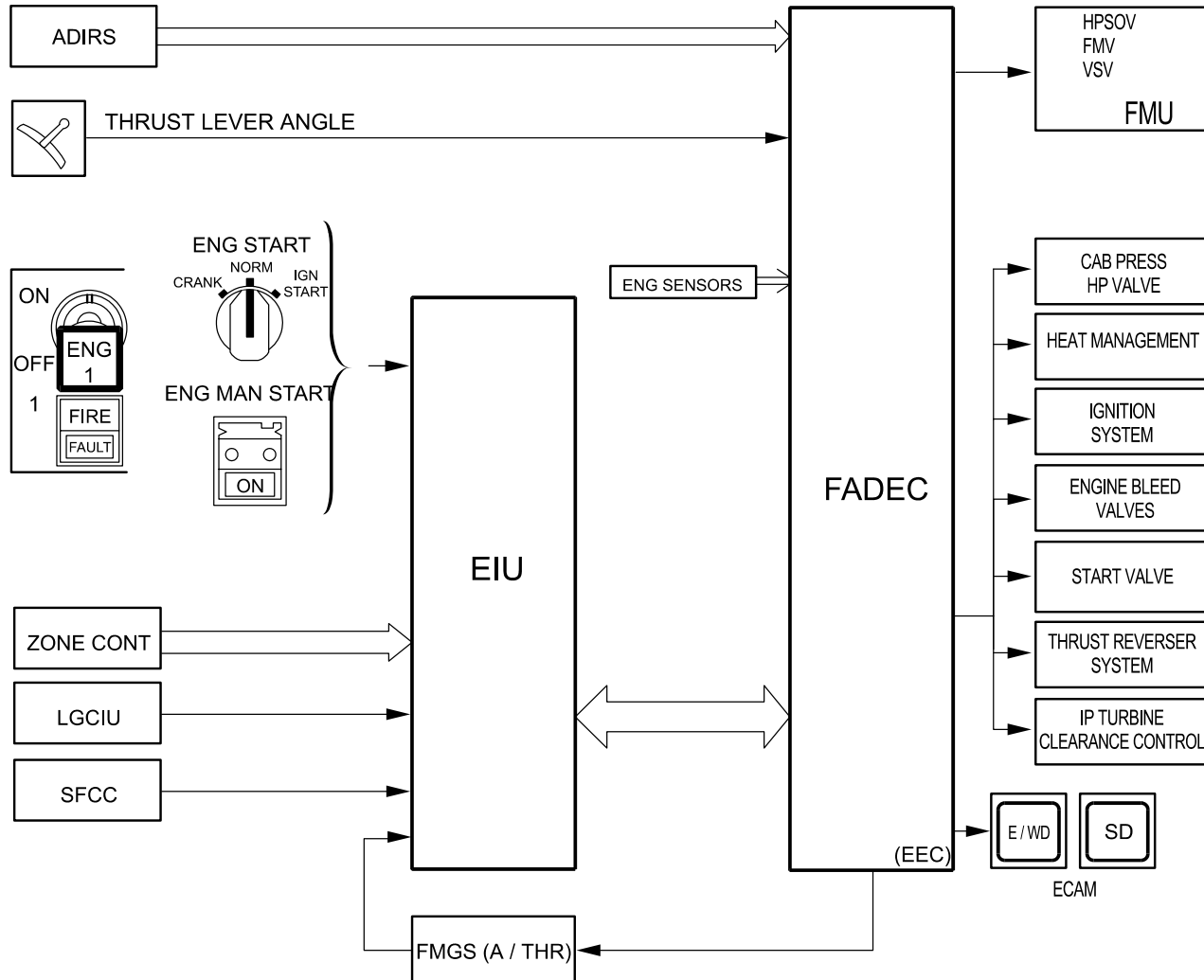
A330 engine controls - PW4164

FADEC architecture



A330 engine controls - RR Trent

FADEC architecture



FADEC and EIU

One FADEC located on the engine with dual redundant channels (active and standby) each having separate 115 VAC aircraft power sources to provide engine starting on ground and in flight.

Additional features

Dedicated FADEC alternator provides self power above :

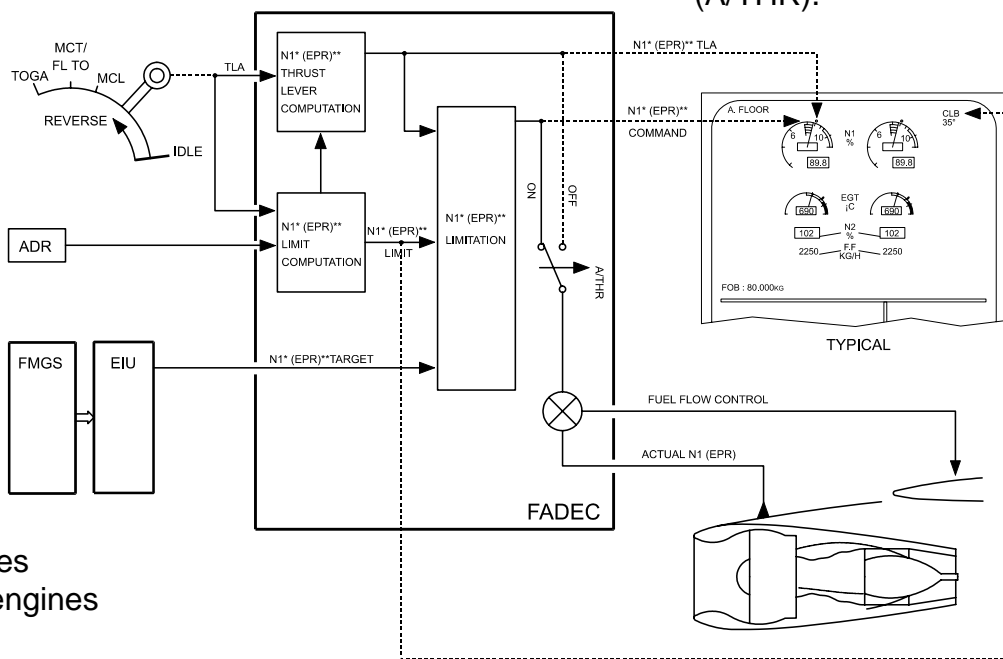
- 12% N2 for GE engines
- 5% N2 for PW engines
- 8% N3 for RR engines

- Dual redundancy for electrical input devices (ADIRS 1 + 2, TLAs, engine parameters).
- Dual redundancy for electrical part of control actuator.
- Simplex system for hydromechanical parts of the control.
- Fault tolerance and fail-operational capability.
- High level of protection against electromagnetic disturbance.
- Interface between the FADEC system and the other aircraft systems mainly performed by the EIU through digital data buses.
- One EIU per engine located in the avionics bay.
- Care taken to preserve system segregation for safety and integrity.

A330 engine controls

Thrust control system

- Engine thrust control is provided by the FADEC 1 and 2 controlling engines 1 and 2 respectively.
- Thrust selection is performed by means of :
 - thrust levers when in manual mode,
 - A/THR function of the FMGS when in automatic mode, but limited to the value corresponding to the thrust levers position.
- Limit thrust parameters are computed by the FADEC.
- Since there is no mechanization of the thrust levers (no servomotor) any thrust lever displacement must be performed manually.
- According to the thrust lever position the FADEC computes :
 - thrust rating limit
 - N1* (EPR)** when in manual mode
 - N1* (EPR)** which can be achieved in automatic mode (A/THR).

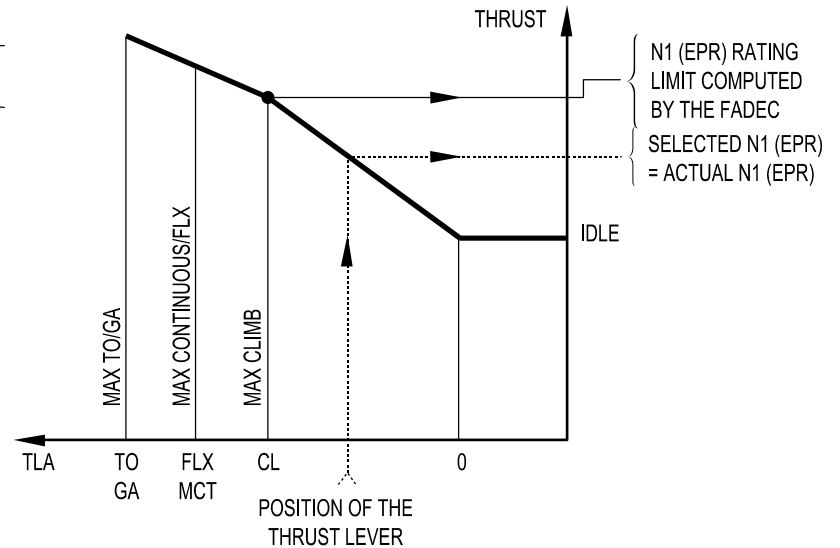
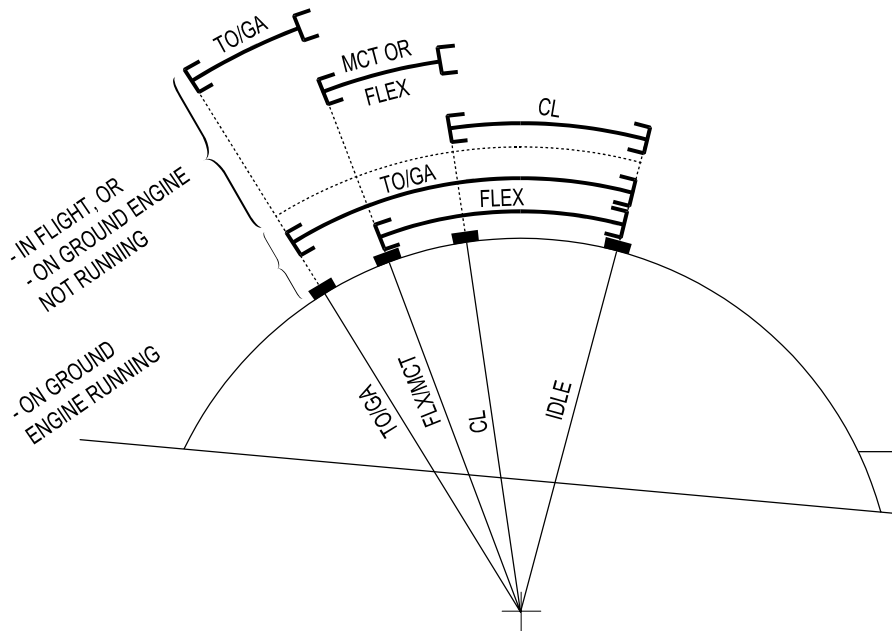


* for GE engines
** for PW, RR engines

A330 engine controls

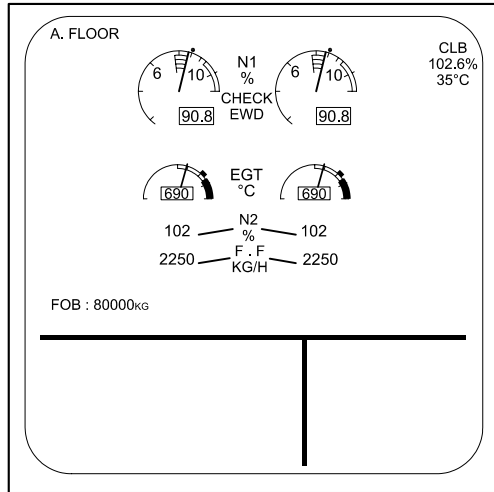
Thrust control operations

N1 (EPR) RATING LIMITS:

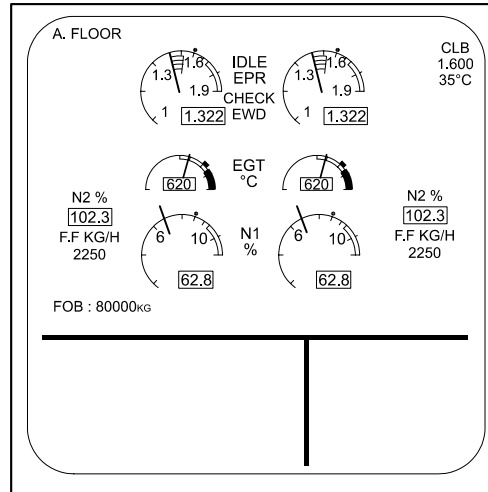


A330 engine controls

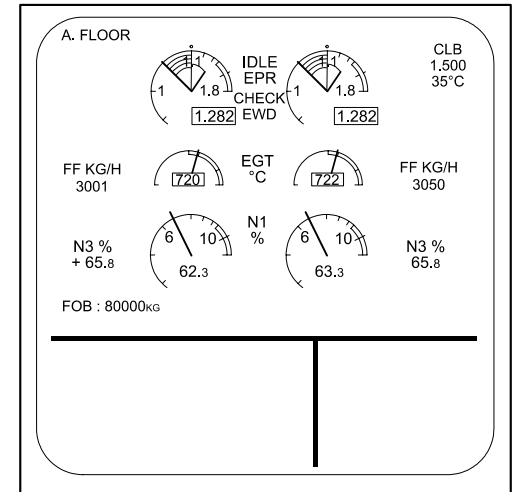
Indications on ECAM upper DU



GE engines



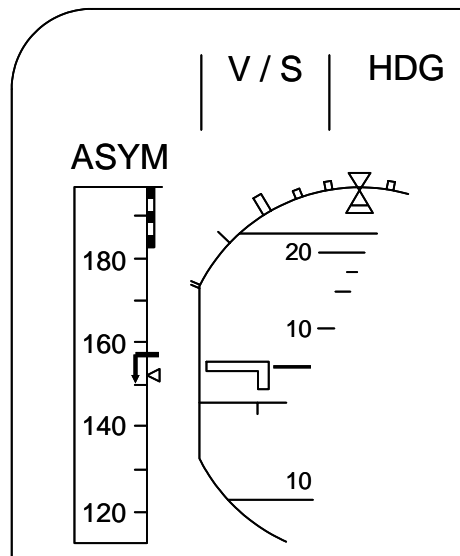
PWE engines



RR engines

Indications on PFD : FMA

- Following indications may appear on the PFD flight mode annunciator, in the upper left corner : (examples only)
- ASYM : One thrust lever not in CL detent.
- CLB : Flashing when aircraft is above thrust reduction altitude and thrust levers are not retarded to CL.
- MCT : Flashing in case of engine failure if the non-affected thrust levers are not set at MCT.
- A-FLOOR : When thrust is at MTO and an alpha-floor condition is encountered.



Thrust reverser

- Reverser deployment selection is performed through conventional reverser controls.
- Automatic maximum reverse power limitation versus ambient conditions with full aft throttle position.
- Display of reverser status on ECAM upper DU.





9. Auxiliary power unit

A330 auxiliary power unit

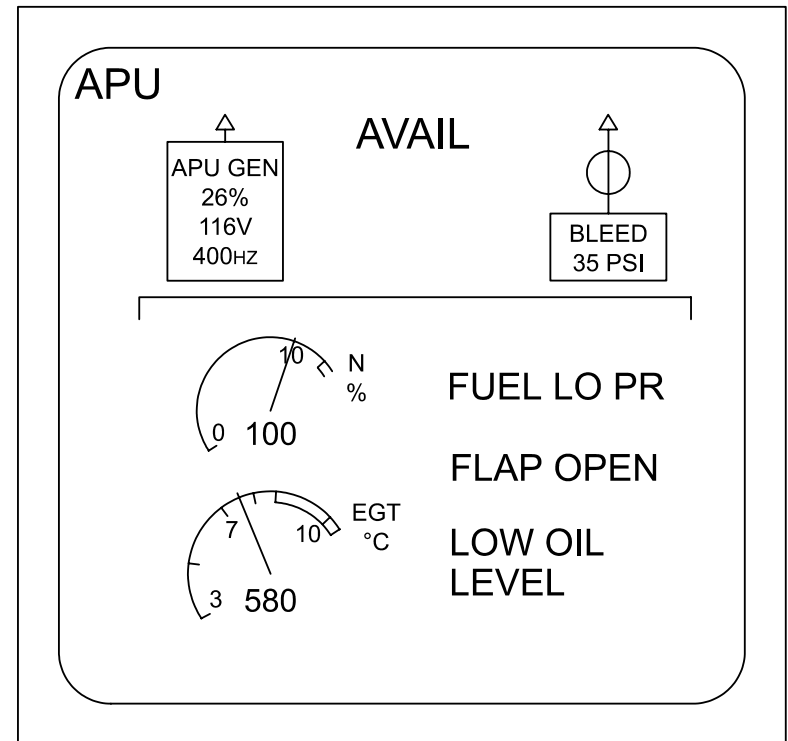
General principles

- **On ground**, the APU makes the aircraft self-contained by :
 - providing bleed air for starting engines and for the air conditioning system
 - providing electrical power to supply the electrical system.
- **In flight**, provision of back-up power for the electrical system, the air conditioning system and engine start.
- The APU can be started using either dedicated battery, external power or normal aircraft supply.

The normal flight envelope does not impose any limitations for starting except when batteries are supplying starting power.

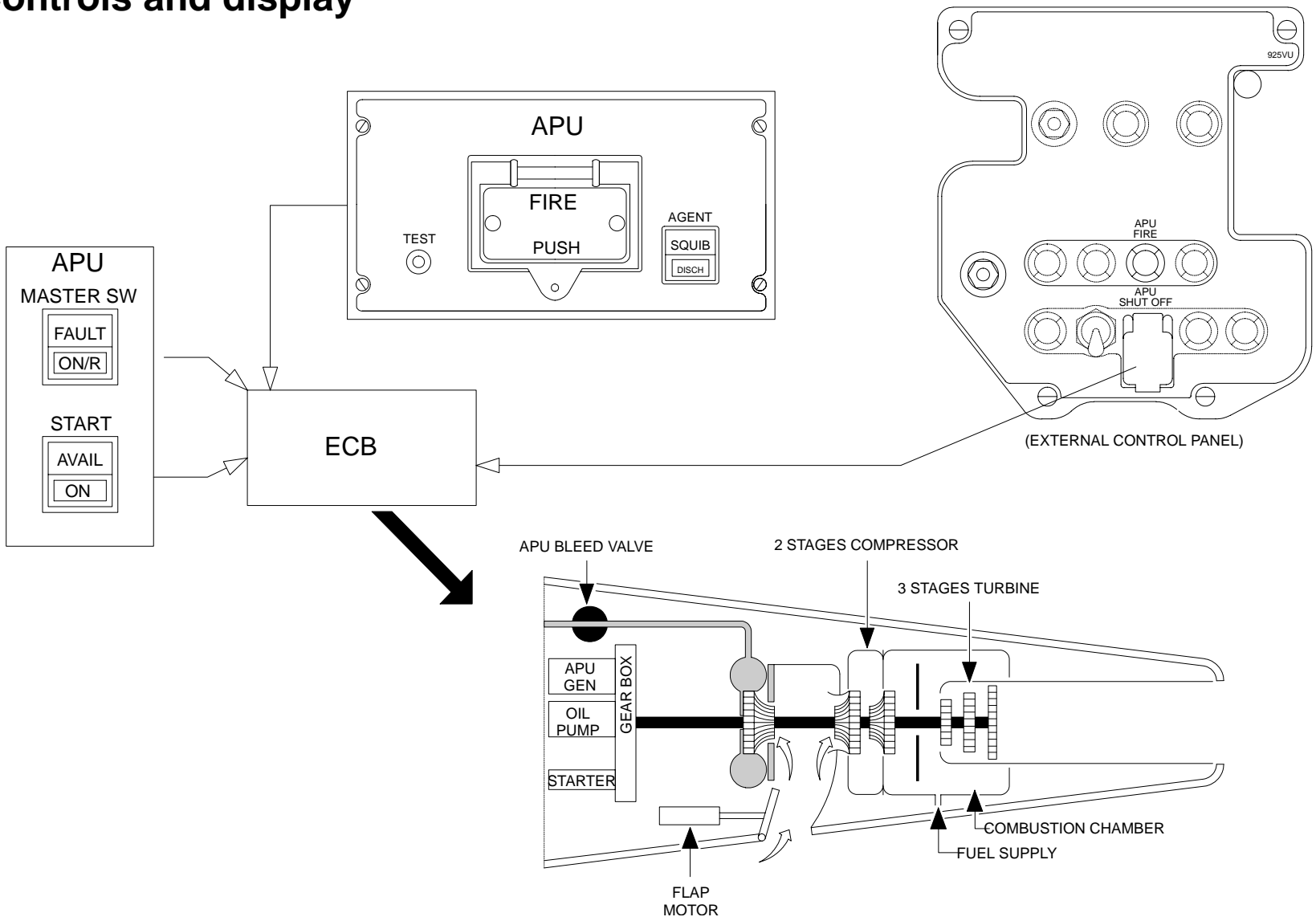
- The APU is automatically controlled by the Electronic Control Box (**ECB**) which acts as a FADEC for monitoring start and shut-down sequences, bleed air and speed/temperature regulation.
- Control and displays are located :
 - on the overhead panel for APU normal operation and fire protection
 - on the ECAM for APU parameter display
 - on the external power control panel next to the nose landing gear
 - on the REFUEL/DEFUEL panel for APU shut-down.

System display



A330 auxiliary power unit

Controls and display

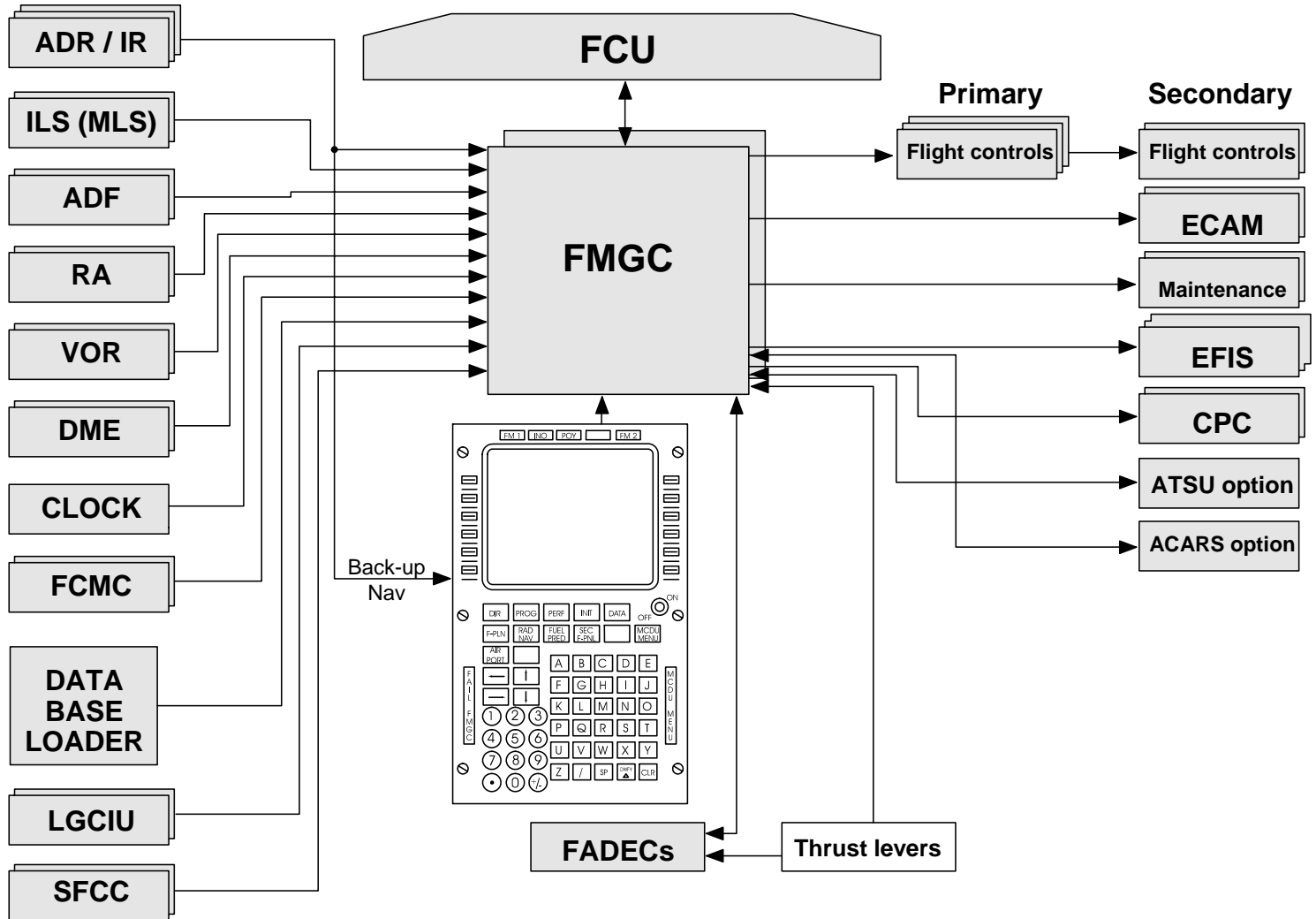




10. Automatic flight system

A330 automatic flight system

Architecture block diagram



A330 automatic flight system

Architecture components

Unit	Number per aircraft	Comments
FMGC	2	FMGEC 1 includes AFS/FIDS*
FCU	1	Includes three independent channels
MCDU	3	Colour display
A/THR instinctive disconnect switches	2	One for CM 1 and one for CM 2
AP take-over switches	2	One for CM 1 and one for CM 2
North reference switches	1	For EIS and MCDU display
FM source switch	1	For EIS display

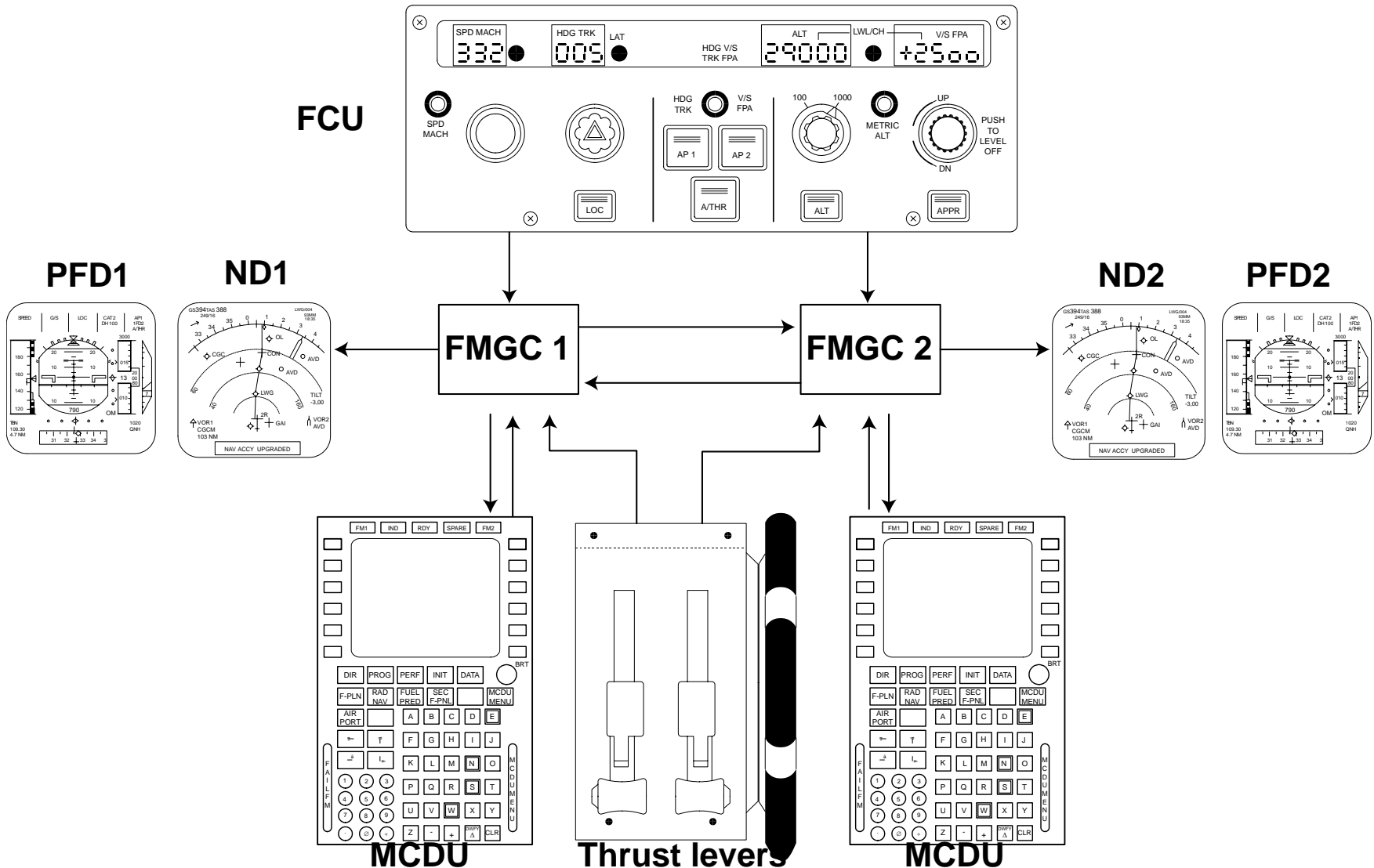
* Fault isolation and Detection System

OBRM (On-board Replaceable Modules)

- Solid-state memory modules plugged into the front face of the computer.
- Cost and logistic improvement for software changes.
- Software change can be achieved *in situ* using a common replaceable module reprogrammer.

A330 automatic flight system

Flight Management Guidance and Envelope System (FMGS) crew interface



FMGS - AFS/FMS integration

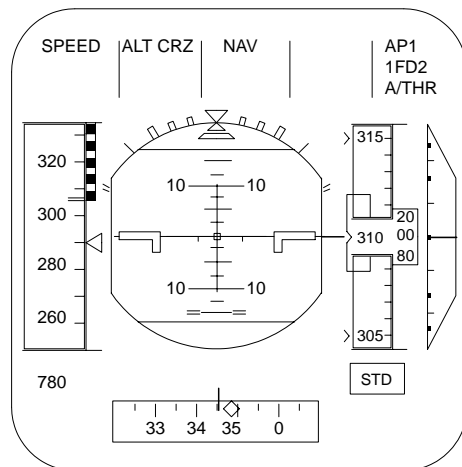
- Composed of two computers (**FMGC**) including a management part (**FM**), a flight guidance (**FG**) and a flight envelope part (**FE**), this pilot interactive system provides :
 - flight management for navigation, performance prediction and optimization, navigation radio tuning and information display management,
 - flight guidance for autopilot commands (to EFCS), flight director command bar inputs and thrust commands (to FADECs)
 - flight envelope and speed computation.
 - The FMGS offers two types of guidance achievable by AP/FD :
 - “**managed**” : guidance targets are automatically provided by the FMGS as a function of lateral and vertical flight plan data entered in the Multipurpose Control and Display Units (**MCDU**).
 - “**selected**” : guidance targets are selected by the pilot on the glareshield Flight Control Unit (**FCU**).
- Selected guidances mode always have priority over the managed guidance modes.

A330 automatic flight system

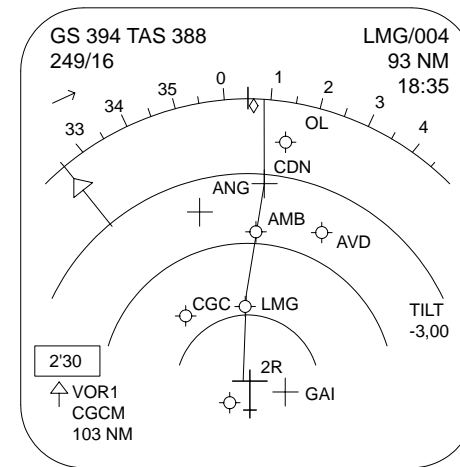
FMGS Crew interface

- Three MCDUs (only two at a time) on the central pedestal provide a long-term interface between the crew and the FMGCs in terms of :
 - flight plan definition and display
 - data insertion (speeds, weights, cruise level, etc.)
 - selection of specific functions (direct to, offset, secondary flight plan).
- One FCU on the central glareshield provides a short-term interface between the crew and the FMGCs.
- Two thrust levers linked to the FMGCs and FADECs provide autothrust or manual thrust control selection to the crew.
- Two PFDs and two NDs provide visual interface with flight management and guidance-related data such as :
 - on PFD :**
 - FMGS guidance targets
 - armed and active modes
 - system engagement status
 - on ND :**
 - flight plan presentation
 - aircraft position and flight path
 - navigation items (radio aids, wind).

PFD



ND



General functions

- **Guidance function**

Fail operational architecture*
Operation
Modes

- **Autothrust**

Operation
Modes

AP/FD and A/THR mode relationship



- **Flight envelope**

Envelope protection ----- (windshear, aft CG detection)
Speed computation

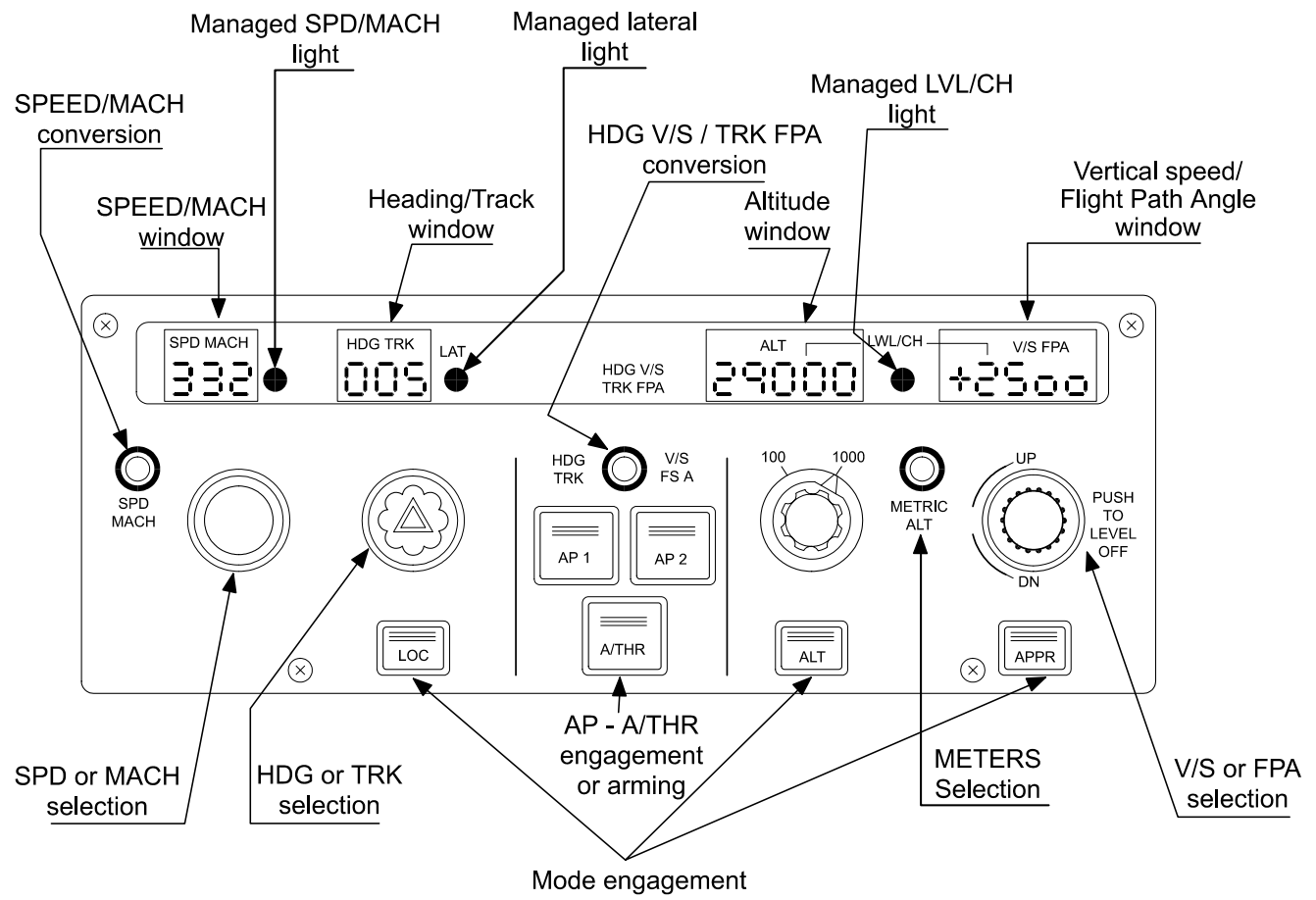
- **Flight management**

Functional architecture
Navigation
Flight planning functions ----- (assembly , fuel management, lateral revision)
Optimisation performance ----- (speed/altitude, prediction)
Vertical profile

* Fail operational refers to a single failure of a system which does not modify the aircraft's flight path.

A330 automatic flight system - guidance function

Flight Control Unit (FCU)



Control knob philosophy

Pull + rotate = selected guidance (pilot input via FCU)
 Push = return to managed guidance (via FMS)



A330 automatic flight system - guidance function

AP/FD modes

Available modes

Guidance	Managed mode	Selected mode
Lateral	NAV B/C*, B/C, LOC*, LOC RWY RWY TRK GA TRK ROLL OUT	HDG - TRK
Vertical	SRS (TO and GA) CLB, DES ALT G/S*, G/S FINAL DES FLARE	OP CLB, OP DES V/S - FPA ALT*, ALT
Speed	FMGC reference ECON, Auto SPD, SPD LIM	FCU reference

Mode engagement (or arming as long as engagement conditions are not met).

- By pushbutton action (located on the FCU) LOC - APPR - ALT, AP1 - AP2 - A/THR.
- By action on the thrust levers. On the ground, setting the thrust levers to the TO/GA or FLEX/TO detents leads to AP/FD mode engagement (SRS/RWY). During approach, setting the thrust levers to TO/GA engages go-around mode.
- By action on the FCU selection knobs (speed selection knob, HDG/TRK selection knob, altitude selection knob, V/S-FPA selection knob).
 - Push action engages managed mode
 - Pull action engages selected mode - e.g speed or Mach selected mode pushed in flight engages managed speed profile (usually ECON).



A330 automatic flight system - guidance function

AP/FD operation

- The aircraft can be operated in 'selected guidance' with flight references selected by the crew, or in 'managed guidance' with references computed by the system.
- If the AP/FD controls a vertical trajectory the A/THR controls the target SPEED/MACH.
If the AP/FD controls a target speed, the A/THR controls the thrust.
- Selected guidance always has priority over managed guidance, which means that the PF may select a speed, lateral or vertical path at any time ; actions are acknowledged on the FCU itself and on the FMA (Flight Mode Annunciator).
- Selected guidance or managed guidance is available for SPEED/MACH control, LATERAL guidance and LEVEL CHANGE execution.

Lateral modes

NAV : lateral navigation

- Lateral track is defined by the FMGC according to the flight plan introduced in the system.

LOC : LOC axis capture and track

- LOC is armed if LOC pushbutton is pressed ; LOC capture replaces NAV.

HDG/TRK

- Selection of HDG/TRK references is obtained by turning the dedicated switch located on the FCU.
- HDG/TRK is engaged by pulling on lateral selector ; HDG/TRK value can be selected before or after pull action.
- Heading track preselection is possible on ground before take-off, in flight as from 30 ft height.



A330 automatic flight system - guidance function

Vertical modes

Level changes [managed guidance (CLB, DES), selected guidance (OP CLB OP DES)].

- In CLB/DES modes vertical path is maintained as defined by the FMGC, taking into account the flight plan constraints inserted in the system at the clearance altitude selected on the FCU.
- OP CLB (OP DES) mode allows the aircraft to climb or descend uninterrupted toward FCU selected altitude, maintaining a TARGET SPEED (managed or selected) with a fixed given thrust. ALT constraints are ignored.

Altitude hold

- It is active if aircraft reaches FCU altitude, intermediate flight plan altitude constraints when ALT pushbutton is depressed on FCU or when V/S is set to zero.

V/S/FPA

- V/S/FPA is engaged by pulling on V/S/FPA selector. V/S or FPA value can be selected before or after a pull action.

Common modes

- Approach**
- ILS available
 - GLIDE capture and track
 - FLARE
 - LAND
 - ROLL OUT

- ILS not available, RNAV approach selected on MCDU :

- LATERAL guidance on the F-PLN
- VERTICAL guidance and descent allowed down to MDA.

- Take-off**
- SRS
 - with engines running $V_2 + 10$ holding
 - with one engine out V_A (1) holding if $V_A > V_2$
 V_2 holding if $V_A < V_2$.

(1) V_A = aircraft speed when the engine failure occurs.

- RWY :
 - Track hold or LOC centerline hold.

- Go-around**
- SRS (as take-off).

- GA TRK hold.



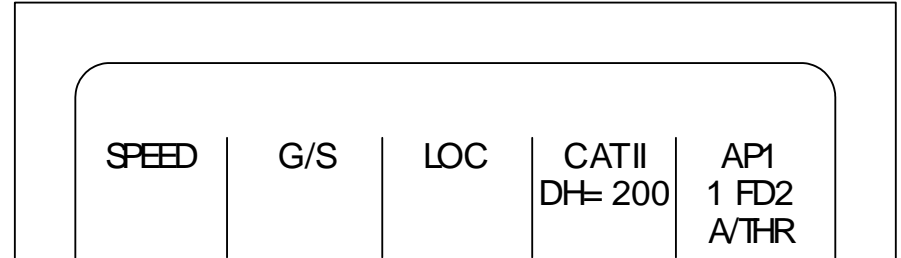
A330 automatic flight system - autothrust function

AP/FD and A/THR mode relationship

1st case

AP/FD pitch mode controls a vertical flight path (V/S or G/S or FINAL) then A/THR mode will control the target speed/Mach.

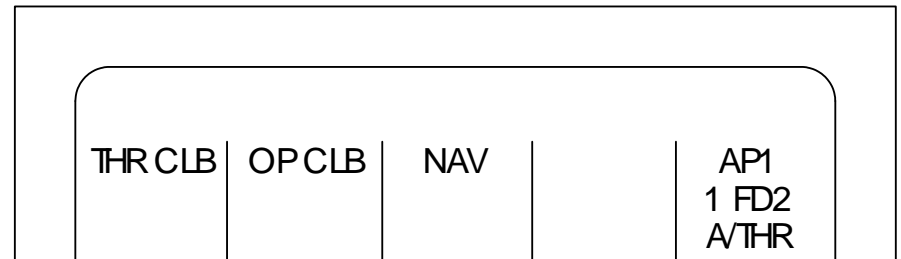
e.g. if AP/FD V/S mode is selected
A/THR is in SPEED mode



2nd

AP/FD pitch mode controls the target speed/Mach then A/THR mode will control the thrust

e.g. if AP/FD open CLB mode is selected
A/THR is in THR CLB mode





A330 automatic flight system - autothrust function

AP/FD and A/THR SPD/MACH modes

In SPD/MACH managed mode

- Is engaged by pushing the FCU SPD selector knob.
- AP/FD or A/THR holds the SPEED/MACH as provided by the FMS.
- Speed preset for next flight phase is available by entering preset value on the MCDU ; speed preset becomes active at flight phase change.
- Crossover altitude is automatically provided.

SPD/MACH selected mode

- Is engaged by pulling the FCU SPD selector knob.
- Crossover altitude is automatically provided.
- Manual SPD/MACH selection is available to the pilot via the SPD/MACH conversion push-button.

AP/FD and A/THR SPD/MACH modes

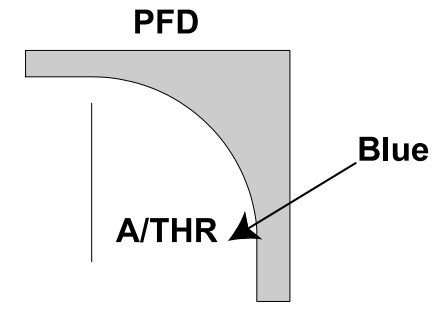
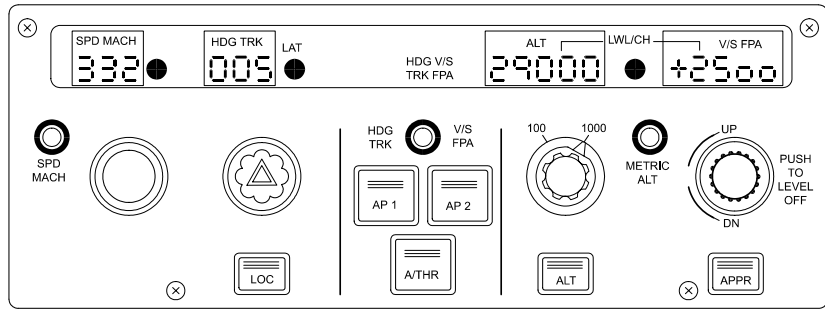
SPEED/MACH managed or **selected** may either be controlled by AP/FD pitch mode or A/THR mode. The reasons for this are as follows.

- An AP/FD pitch mode may control a flight or an indicated airspeed - but not both at the same time.
- Thus, if the pitch mode (elevator) controls a flight path, (G/S or V/S) the A/THR controls the IAS, but if the pitch mode controls a speed (OPEN CLB/OPEN DES) then the A/THR will control a thrust.

Consequently, AP/FD pitch mode and A/THR are linked so that, if no AP/FD engaged, A/THR can be active in SPD/MACH mode.

A330 automatic flight system - autothrust function

A/THR operation - A/THR can be armed, active or de-activated



By pressing A/THR push button switch

By moving TLA in T O/G A or FLEX T O gates

Alpha floor activation

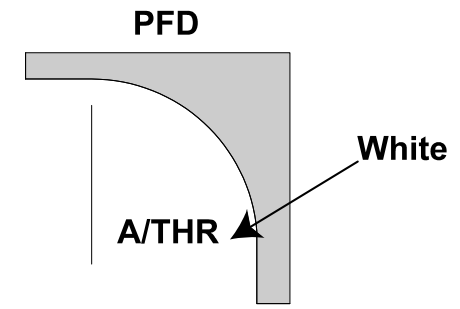
AUTOTHRUST ARMED

A/THR ACTIVE

ARMED

ACTIVE

At least one TLA above MCT :
Thrust = f (TLA pos.)



No TLA above MCT :
Max thrust = f (TLA pos.)



A330 automatic flight system - autothrust function

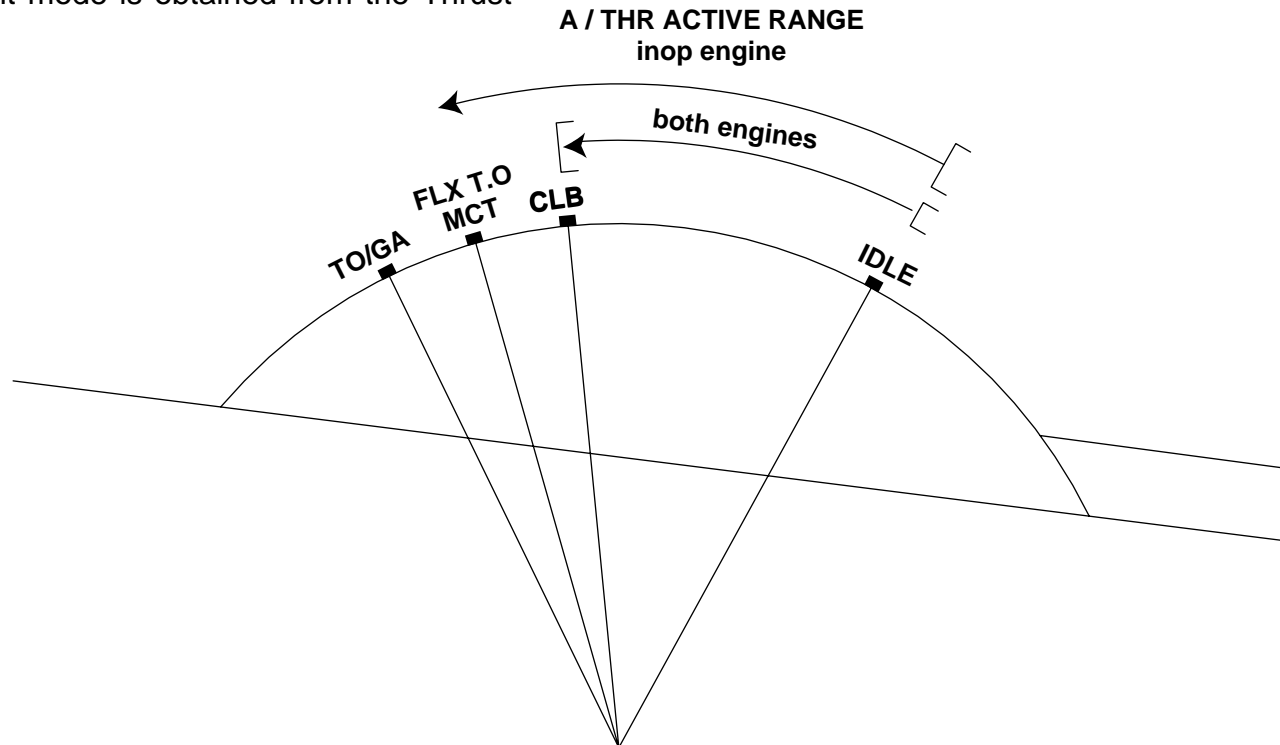
A/THR main features

Each engine thrust is electrically controlled by the associated FADEC (FULL Authority Digital Engine Control) which is fully integrated in the autothrust system.

The A/THR function is computed in the FMGC.

The FADECs receive A/THR commands directly from the AFS via an ARINC 429 bus.

Selection of thrust limit mode is obtained from the Thrust Lever Angle (TLA).





A330 automatic flight system - autothrust function

A/THR mechanisation

The thrust levers can only be moved manually by the pilot.

Take-off

Thrust mode selection

- On ground TO limit mode is automatically selected at power up.
- FLX/TO limit mode is selected by setting a FLX/TO temperature on the MCDU (TO page).

Take-off is performed :

- in limit mode, by manually setting the thrust lever to TO/GA detent.
- in FLX/TO limit mode, by manually setting to FLX/TO/MCT detent.

Notes :

- In both cases, this manoeuvre also engages FD TO mode (SRS RWY if ILS selected).
- The lowest FLX/TO thrust is limited to CL thrust.

Cruise

Thrust levers must be set :

- to be CLB detent
- to the MCT detent (engine failure case).
- The A/THR modes become active according to AP/FD mode selection.

Approach

Thrust levers must be set to CLB (or MCT engine failure case) detent :

- ATS SPD mode is active

Go Around

GA mode engagement is achieved by setting the thrust levers to TO/GA detent ;

(A/THR armed ; GA thrust is applied via the FADEC).

This manoeuvre also engages AP/FD GA mode.

Alpha floor

If the alpha floor function is activated, A/THR increases the thrust to the GA thrust limit.



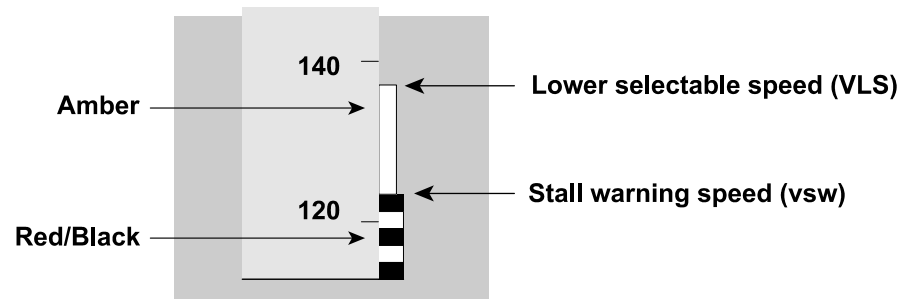
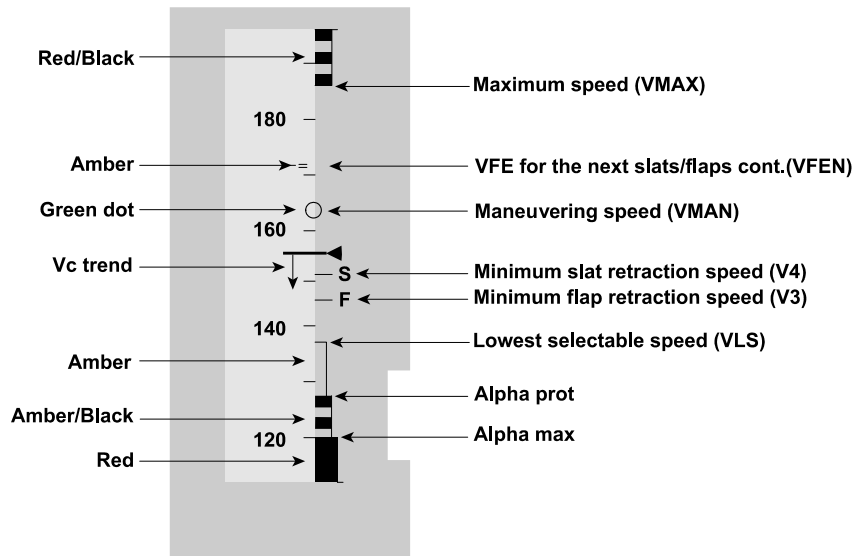
A330 automatic flight system - autothrust function

Flight envelope protection

Flight envelope protection is achieved by generating maximum and minimum selectable speeds, windshear warning and stall warning. Also computed as part of this protection are the maneuvering speed and the flap and slat retraction speeds.

The alpha-floor signal is computed by the flight control computers.

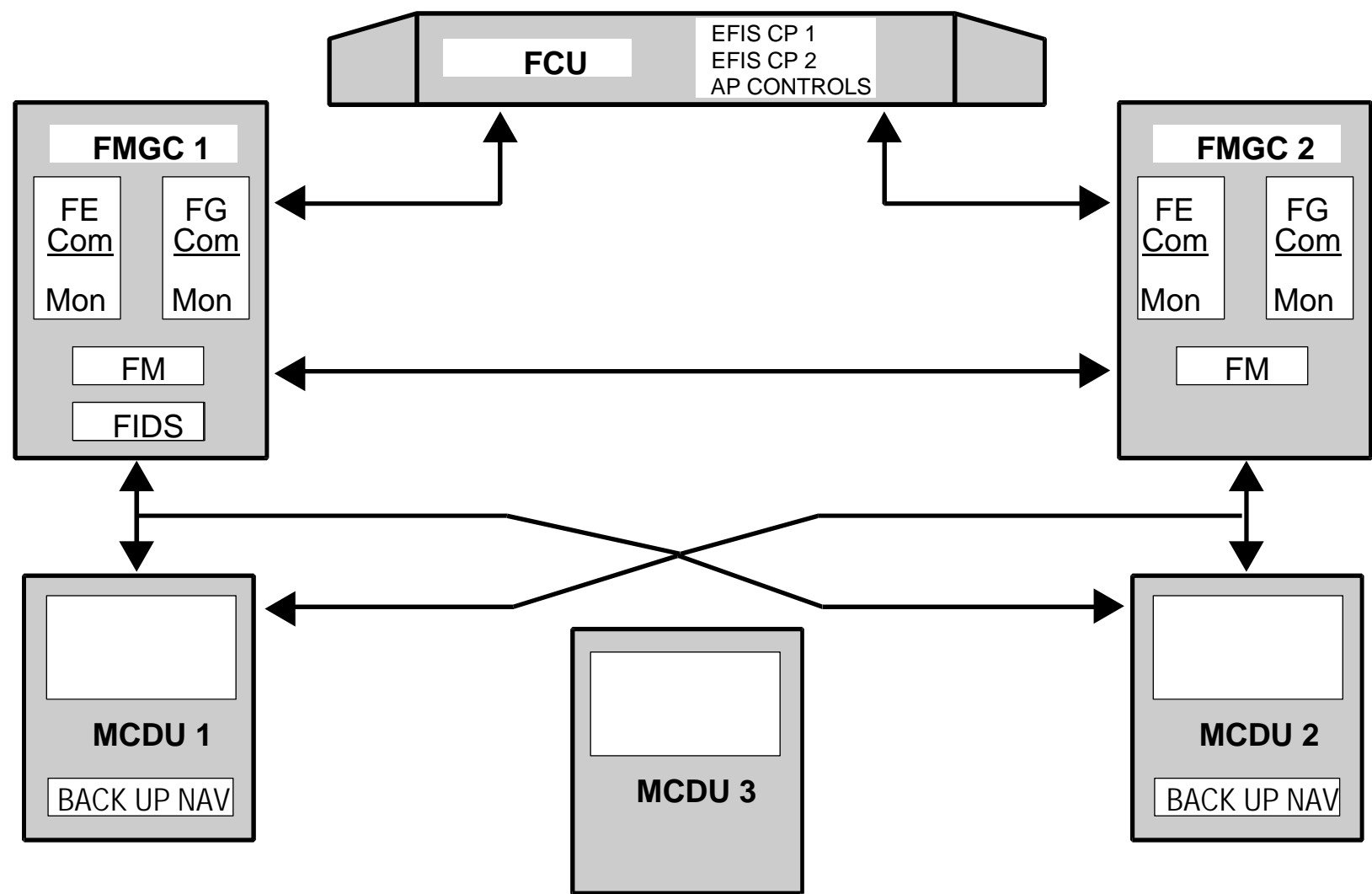
Speed computation (PFD scale)





A330 automatic flight system - flight management

General architecture

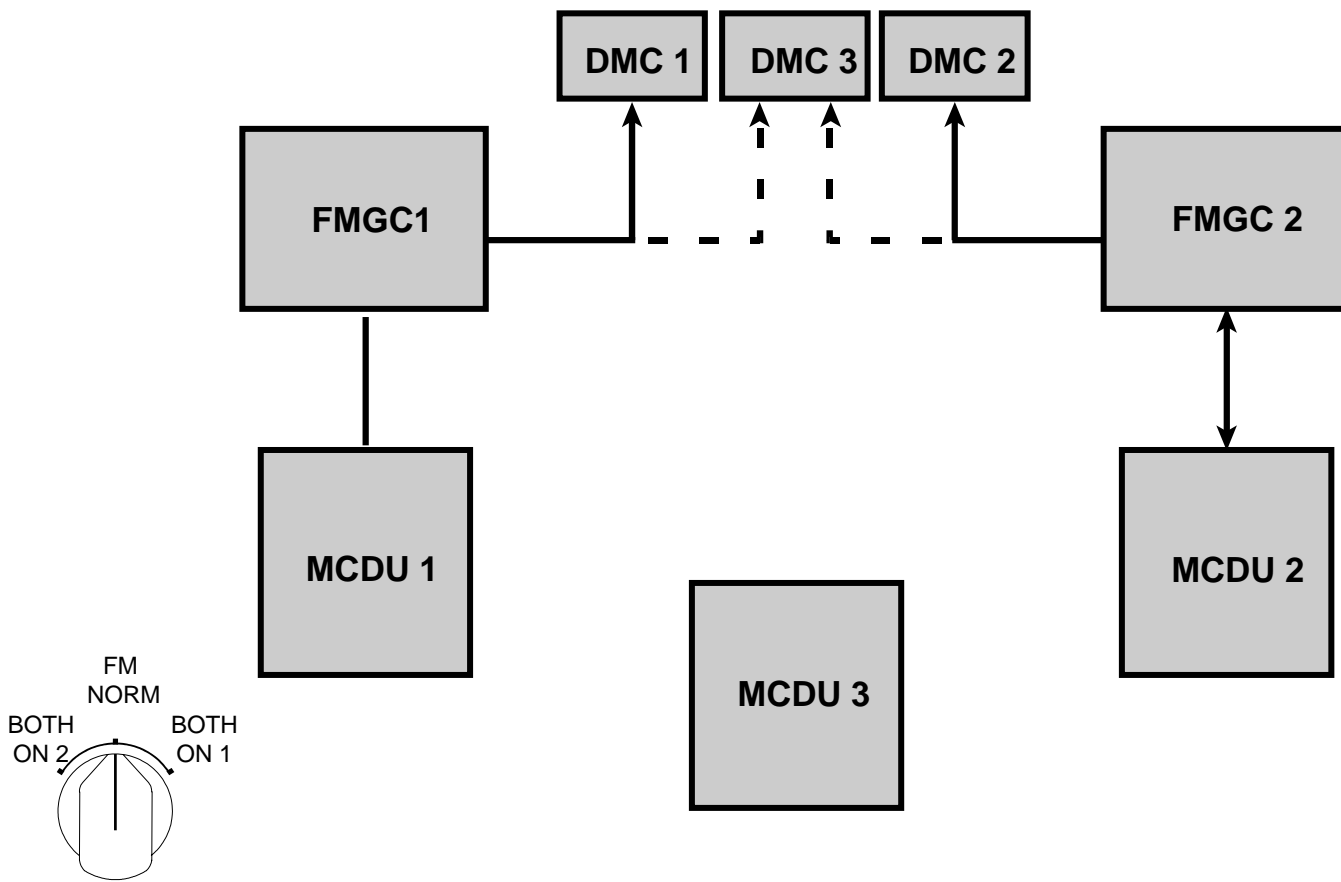


MCDU 3 switchable for FM function in case of MCDU 1 or 2 failure



A330 automatic flight system - flight management

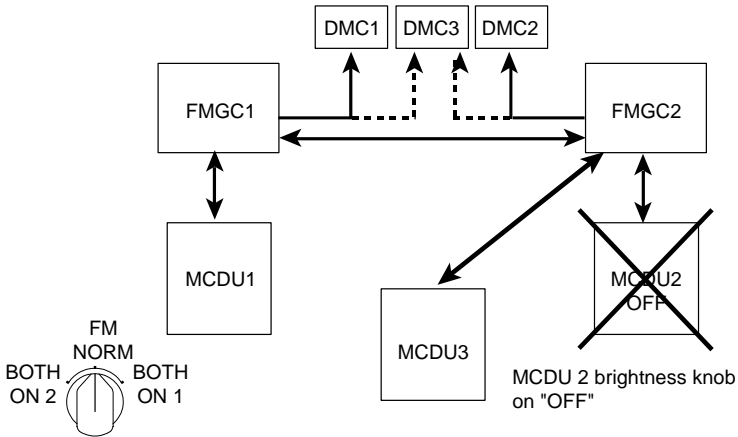
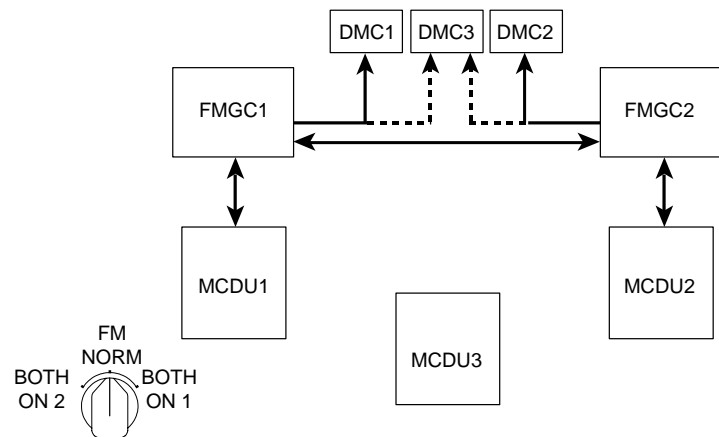
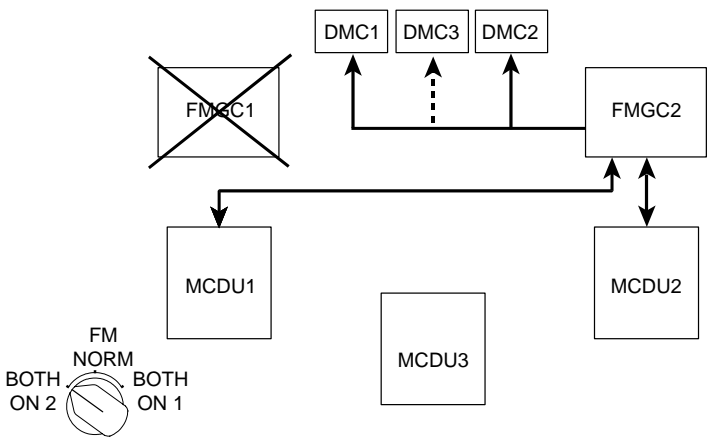
Functional architecture - Normal configuration



A330 automatic flight system - flight management

Functional architecture - One FMGC failed

Functional architecture - Normal configuration





A330 automatic flight system - flight management

Two FMGCs associated to two MCDUs provide a redundant configuration

- Normal mode operation : **dual mode**

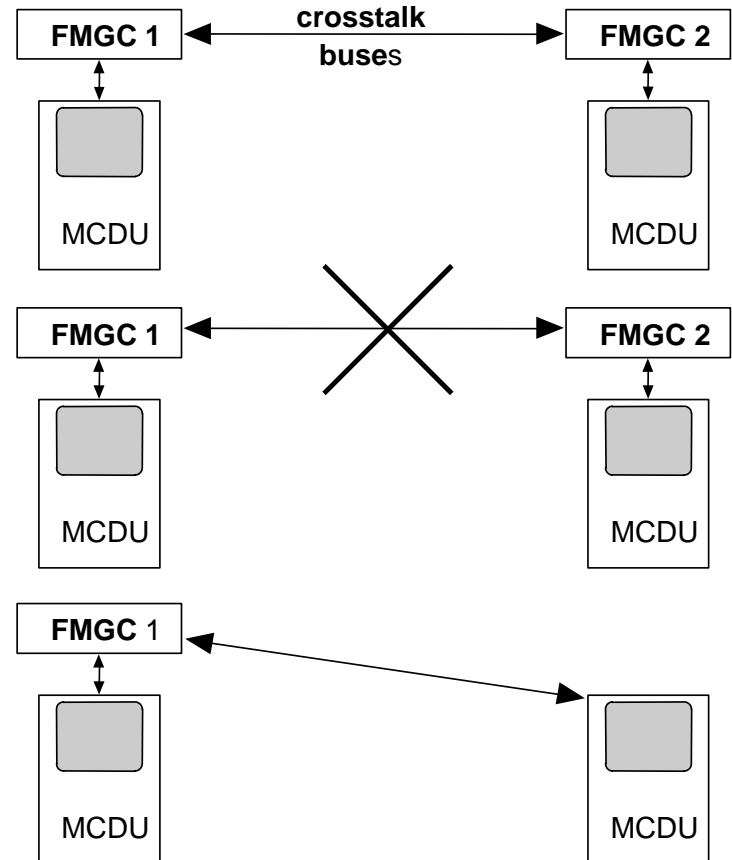
- Each FMGC makes its own computation.
- One FMGC is **master** - the other one is **slave**.
- Both FMGCs are synchronized.
- Both MCDUs act independently (entries are automatically transmitted on the other MCDU and applied to both FMGCs).

- **Independent mode**

- Automatically operative if mismatch occurs between FMGCs.
- Independent operation of FMGC with associated MCDUs.
(Data insertion and display related to the side concerned).
- One FMGC remains master.

Single mode

- One FMGC fails.
- Either MCDU can be used to enter or display data related to the remaining FMGC.

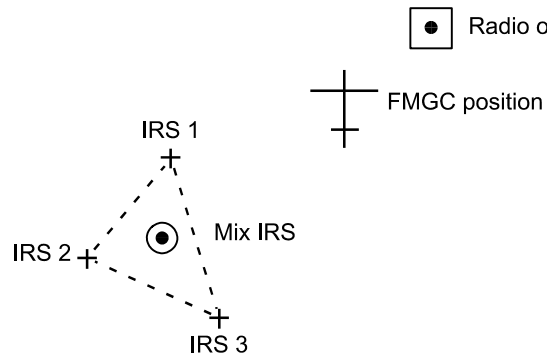


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A330 automatic flight system - flight management

Position indication



Mix IRS = mean weighed average position of the 3 IRS positions

GPIRS = GPS position integrity verified against IRS position

POSITION MONITOR				SELECTED NAVAIDS				
1L	FMGEC 1	4610.2N/00618.3E		1R	VOR/ DME	AUTO	DESELECT	1R
2L	FMGEC 2	4610.2N/00618.8E		2R	<GEN	115.20	()*	2R
3L	RADIO	4610.1N/00618.2E		3R	VOR/DME	115.10		3R
4L	MIX IRS	4609.7N/00618.0E		4R	<TOP	115.40		4R
5L	IRS 1	IRS 2	IRS 3	5R				5R
6L	NAV 0.4	NAV 0.2	NAV 0.4	6R	<RETURN			6R
			SEL					
	←FREEZE		NAVAIDS>					

To see the navaids used for radio position



A330 automatic flight system - flight management

MCDU

1	5	10	15	20	25
		ECON	DES		AI101
CRZ		OPT		REC MAX	
.....			FL390	
2L	REQD	DIST	TO	LAND	= 70NM
3L	DIR	DIST	TO	DEST	= 89NM
	< REPORT				
4L		BRG / DIST			
	 /.....	TOE]	
5L	UPDATE AT				
	[]	*	
6L	VOR 1 /	FREQ	ACY	FREQ /	VORZ
	ATH /	114.4	HIGH	117.2 /	DDM

1L

2L

3L

4L

5L

6L

1R

2R

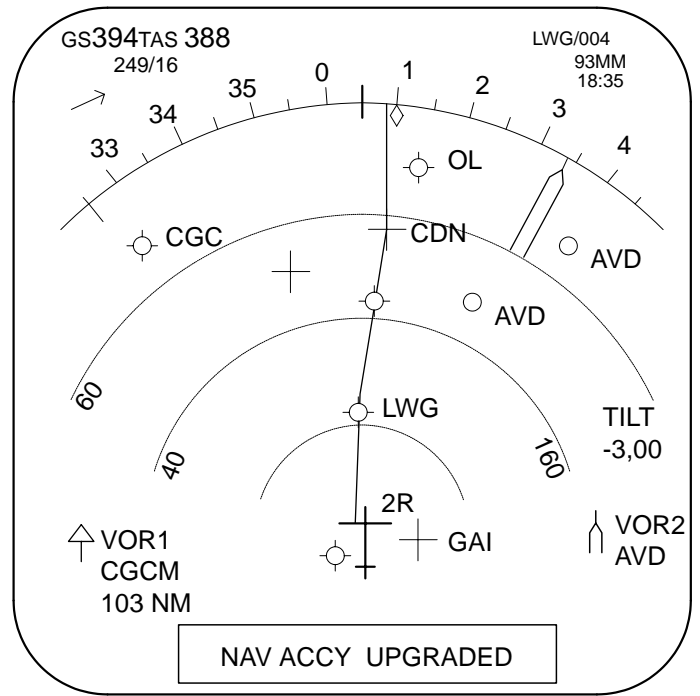
3R

4R

5R

6R

ND





A330 automatic flight system - flight management

Lateral navigation

- Position computation

- Before flight, the three IRSs are aligned on airfield or gate position (manually or via database).
- At take-off, the position is automatically updated to the runway threshold.
- In flight, position updating is computed using radio nav aids (DME, VOR, ILS and GPS when available).

The FMGC position is a blend of IRS and radio position. On a medium-term basis the FM position will tend towards the radio position, if any drift occurs.

- Navigation mode selection

- If the aircraft is equipped with GPS primary, the FMGC uses the GPIRS position in priority (IRS-GPS mode).
- if the GPIRS position is not available or if the aircraft is not equipped with GPS primary, depending upon availability of nav aids and sensors, FMGC automatically uses the best navigation means to compute the most accurate position :

IRS - DME/DME
IRS - VOR/DME
IRS - ILS/DME
IRS only.

- The FMGC position is associated with a high or low criterion which is based on an Estimated Position Error (**EPE**).

This EPE depends upon the flying area (en route, terminal, approach) and is permanently compared to Airworthiness Authorities Accuracy Requirements (AAAR).

If $EPE > AAAR$, then LOW is displayed on MCDU and the position must be cross-checked with raw data (ADF/VOR needles, DME reading).

Each time HIGH (or LOW) reverts to LOW (or HIGH) the message NAV ACCUR DOWNGRAD (or UPGRAD) is displayed on NDs and MCDUs.



A330 automatic flight system - flight management

Radio navigation

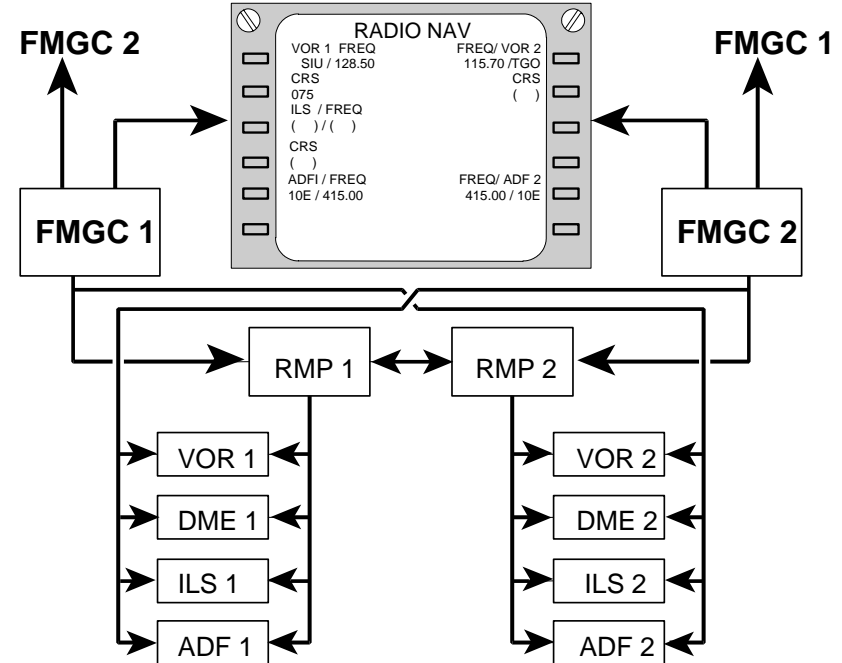
Each FMGC tunes its own side radio nav aids except when in single operation :

- one VOR, one ILS, one ADF (if belonging to the F-PLN) and five DMEs may be auto tuned at the same time.
- manual tuning always has priority over autotuning.
- autotune priority rules are done according to FMGS logics ;

for example :

- VOR autotune (frequency course) priority is :
 - manual tune
 - specified navaid for approach
 - radio position computation
 - display purpose logic.
- Five DMEs can be scanned simultaneously
 - one DMEs for display purpose
 - two DMEs for radio position computation when in DME/DME mode
 - one DMEs for VOR/DME position computation when in VOR/DME mode
 - one DME is linked to ILS/DME.

Radio navigation architecture





A330 automatic flight system - flight management

Navigation and flight planning

Navigation

- Aircraft position determination.
- Aircraft position referenced to the flight plan.
- Automatic VOR/DME/ILS/ADF selection.
- Automatic guidance along flight plan from take-off to approach.
- IRS alignment.
- Ground speed and wind computation.
- Polar navigation.
- Optimum radio and inertial sensor mixing.
- Provision for GPS and MLS.

Flight plan stringing

- Flight plan definition by company route or city pair.
- Departure and arrival procedures including associated speed/altitude/time constraints.
- Standard flight plan revision (offset, DIR TO, holding pattern, alternate flight plan activation, etc.).
- Additional flight plan revisions linked to long-range flights (DIR TO mechanization, AWY stringing).
- Secondary flight plan creation similar to primary flight plan.
- Definition of five cruising levels on the flight plan.
- Extension of the data base capacity.

A330 automatic flight system - flight management

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A330 automatic flight system - flight management

Back-up NAV function

- A back-up source of navigation is available in the MCDU 1 and the MCDU 2, to cover failure cases.
- No data base is available in the MCDUs. The FM F-PLN is permanently downloaded in the MCDUs (from the FMS to which the MCDU is linked) and the back-up NAV is selectable on MCDU menu page if FM source is on 'normal' position.
- The following features are provided.
 - Lateral revision using :
 - . 'direct to' (DIR TO) modification
 - . clearing of discontinuity
 - . waypoint deletion
 - . waypoint lat/long definition and insertion.
 - F-PLN automatic sequencing.
 - Track and distance computation between waypoints.
 - IRS position using one ADIRS (onside or ADIRS 3, according to pilot selection).
 - F-PLN display on ND with crosstrack error.



A330 automatic flight system - flight management

Flight plan aspects

- Flight plan optimisation through the performance database :
 - optimum speeds.
 - optimum and maximum recommended altitudes.
 - optimum step climb.
 - Advisory functions :
 - fuel planning.
 - optimum altitude and step climb.
 - time/distance/EFOB to en route diversion airfields.
 - Fuel vertical guidance related to flight plan predictions, from initial climb to approach.
- The computation are based on :
- flight conditions (multiple cruise levels, weights, center of gravity, meteorological data).
 - cost index given by the airline.
 - speed entered on the FCU or given in the flight plan.
- Performance predictions :
 - time, altitude, speed at all waypoints.
 - estimated time of arrival, distance to destination.
 - estimated fuel on board at destination.
 - energy circle.



A330 automatic flight system - flight management

Vertical profile

• Take-off

SRS control law maintains $V_2 + 10$ up to thrust reduction altitude where max climb thrust is applied. $V_2 + 10$ is held up to acceleration altitude (ACC ALT).

• Climb

Energy sharing is applied for acceleration (70% thrust) and for altitude (30% thrust) from ACC ALT up to first climb speed. Max climb thrust is kept - altitude and speed constraints are taken into account.

• CRZ

Steps may exist and/or may be inserted.

• Descent

Top of Descent (T/D) is provided on ND.

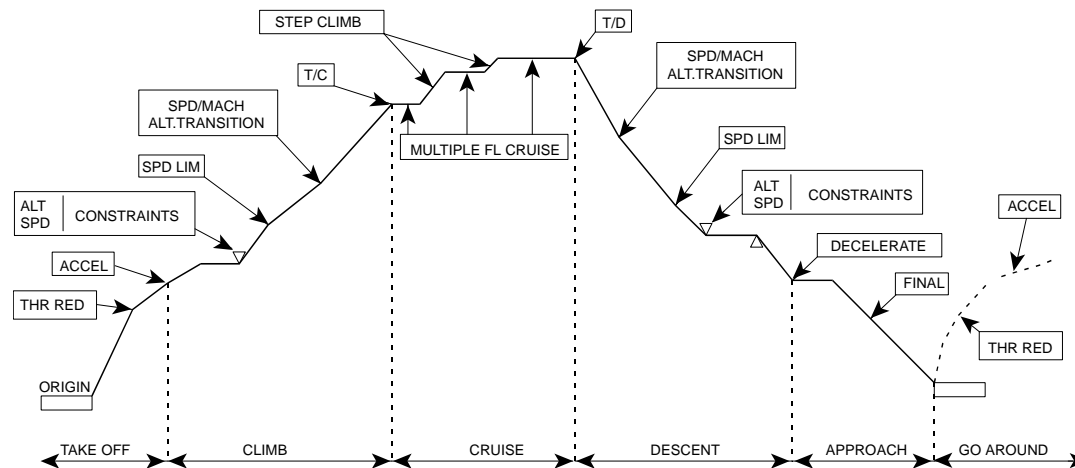
From T/D down to the highest altitude constraint, ECON descent speed is held by the elevator and IDLE thrust by the A/THR. If this status can no longer be held or maintained, geometric segments will be followed between the constraints.

• Approach

From DECEL point, a deceleration allows configuration changes in level flight.

Approach phase is planned to reach approach speed at 1000 ft above ground level.

Flight plan - vertical definition

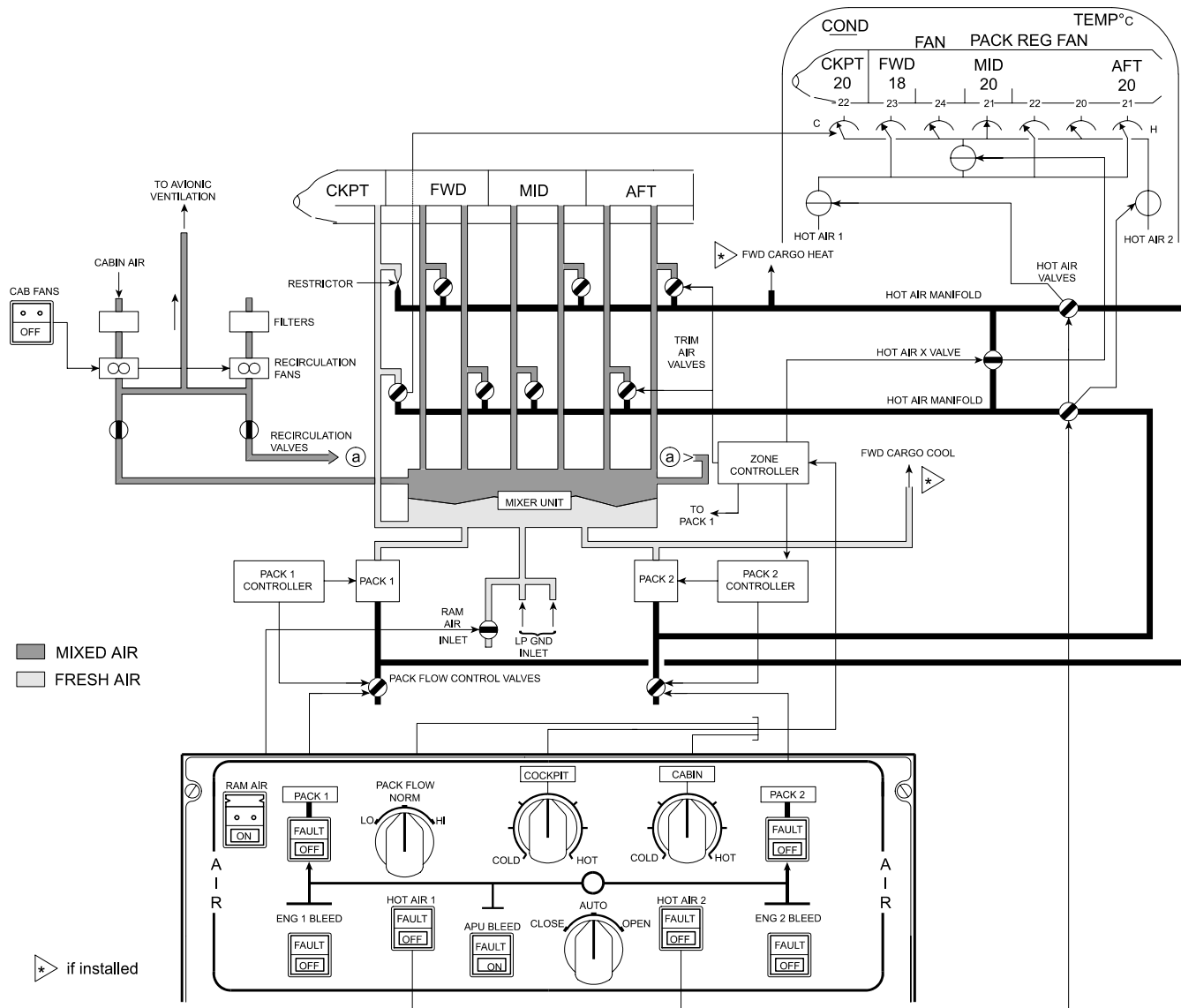




11. Environmental control system



A330 environmental control system





A330 environmental control system

Air conditioning

The hot compressed air is cooled, conditioned and delivered to the fuselage compartments and then discharged overboard through two outflow valves.

Fresh air can also be supplied to the distribution system through two low-pressure ground connections. A ram air inlet supplies emergency air to fuselage if there is a complete failure of the air generation system during flight. A mixing manifold, mixes fresh air with cabin air.

The cabin air that enters the underfloor area, is drawn through recirculation filters by fans. The recirculation fans then blow the air through check valves to the mixing manifold. The flight deck is supplied by fresh air only.

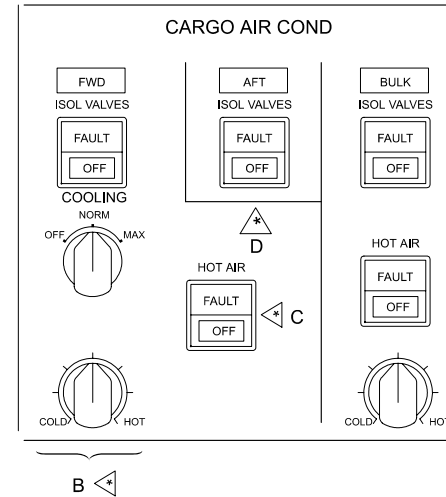
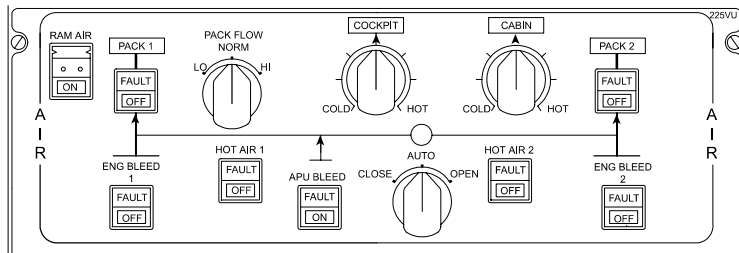
Hot bleed air is tapped downstream of the pack valves. The air flows through two hot air valves which control the pressure of the hot trim air going into two hot air manifolds.

To control the temperature in the different upper deck zones, the quantity of trim air added is controlled through the cockpit and cabin temperature control system. Hot air is delivered to the air supply ducts through the related zone trim air valves. The trim air valves are controlled through the temperature requirements of each zone and duplicated for cabin zone flexibility.

The trim air system has several features to ensure that no substantial comfort degradation occurs in case of trim air valve or hot air valve failure ; a hot cross-bleed valve is installed between the two hot air manifolds and will open to maintain trim air supply to all riser ducts in the event of hot air failure (blocked closed). Moreover, in the event of trim air valve failure (blocked open) and/or duct overheat, as the shut-off valve is normally closed and there are two riser ducts per cabin zone, only half of each zone will lose its trim air supply. The flight deck is permanently supplied by a constant restricted trim air flow in addition to the normal controlled trim air supply.

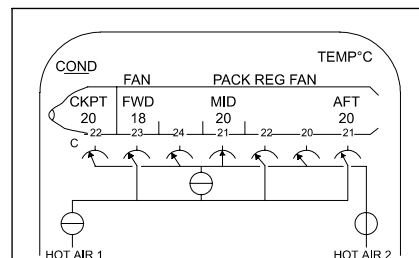
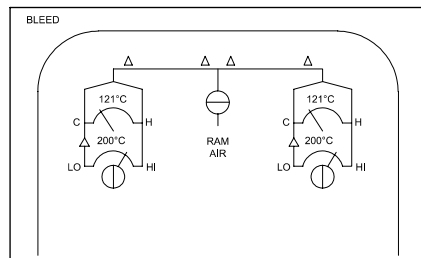
A330 environmental control system

Air conditioning - Air bleed



- A ▷ BULK CARGO HEATING
- B ▷ FWD CARGO VENTILATION AND HEATING
- C ▷ FWD CARGO TEMP PRESELECTION
- D ▷ AFT CARGO VENTILATION

▷ if installed



ENGINE

1530	FUSED	1560	VIB(N1)
	KG		0.8 T 0.9
11.5	OIL	11.5	VIB(N2)
	QT		1.2 T 1.3

AIR LDG ELEV AUTO 2500FT
ΔP 7.5 PSI

CKPT	FWD	MID	AFT	
23	24	23	24	°C
	22		23	

CAB V/S
40500FT/MIN
CAB ALT
7500 FT

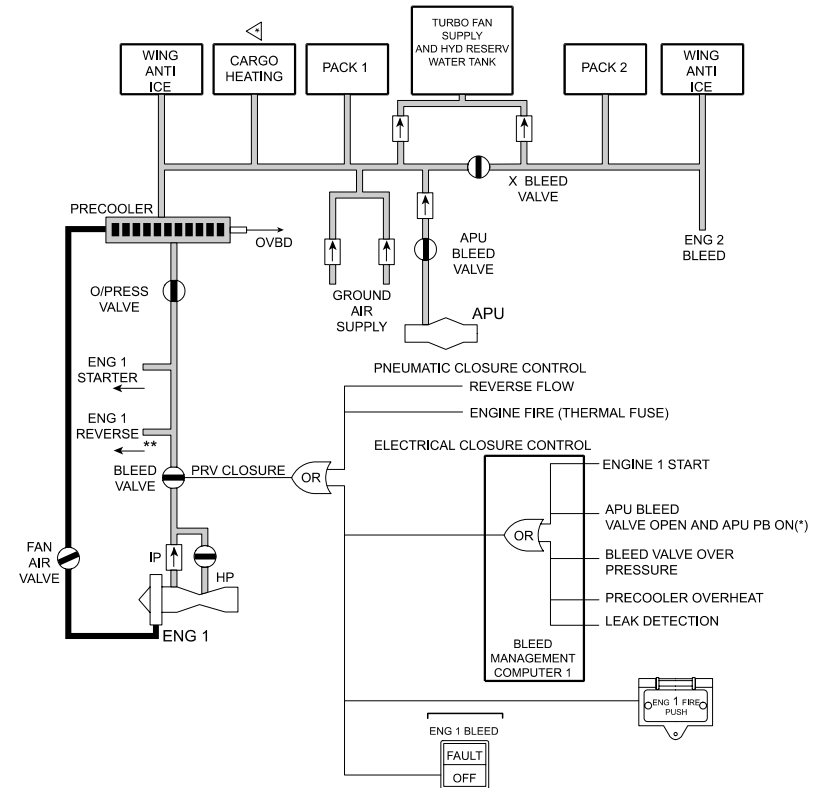
TAT -51°C	23 H 56	GW 170300 KG
SAT -36°C		GWCG 37.5%



A330 environmental control system

Pneumatic

- Pressurized air is supplied for air conditioning, air starting, wing anti-ice, water pressurization and hydraulic reservoir pressurization.
- System operation is electrically by Bleed Monitoring Computers (**BMC**), and is pneumatically controlled.
- A leak detection system is provided to detect any overheating in the vicinity of the hot air ducts.



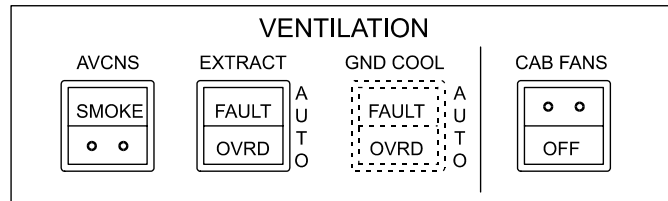
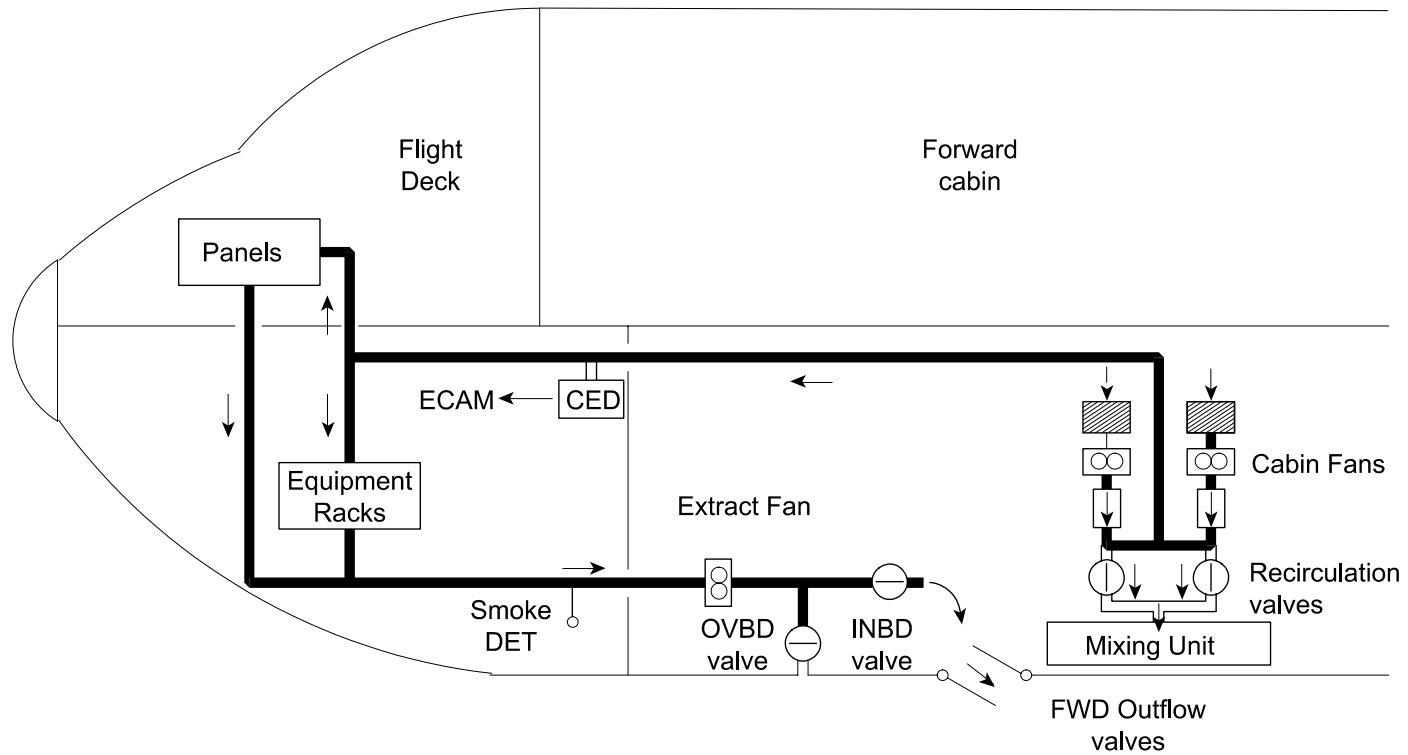
(*) For engine 2 the bleed valve closure due to APU bleed valve open will occur only if the x bleed valve is not selected close.

(**) For GE engines only

◁* if installed

A330 environmental control system

Avionics ventilation





A330 environmental control system

Ventilation

• Avionics ventilation

Provides ventilation and cooling of avionics and electronic equipment under digital control (AEVC) and without any crew intervention.

- Cabin fans provide air blown to the avionics compartment.
- Extract fan (continuously on) blows air through the overboard valve (on ground), or the under-floor valve (in flight).
- Manual control opens the overboard valve (fan failure or smoke removal).

• Pack bay ventilation

Provided to maintain a mean temperature compatible with the structure constraints. In flight, air is fed from outside through a NACA air inlet. On ground, air is blown by a turbofan which is carried out by the air bleed system.

• Battery ventilation

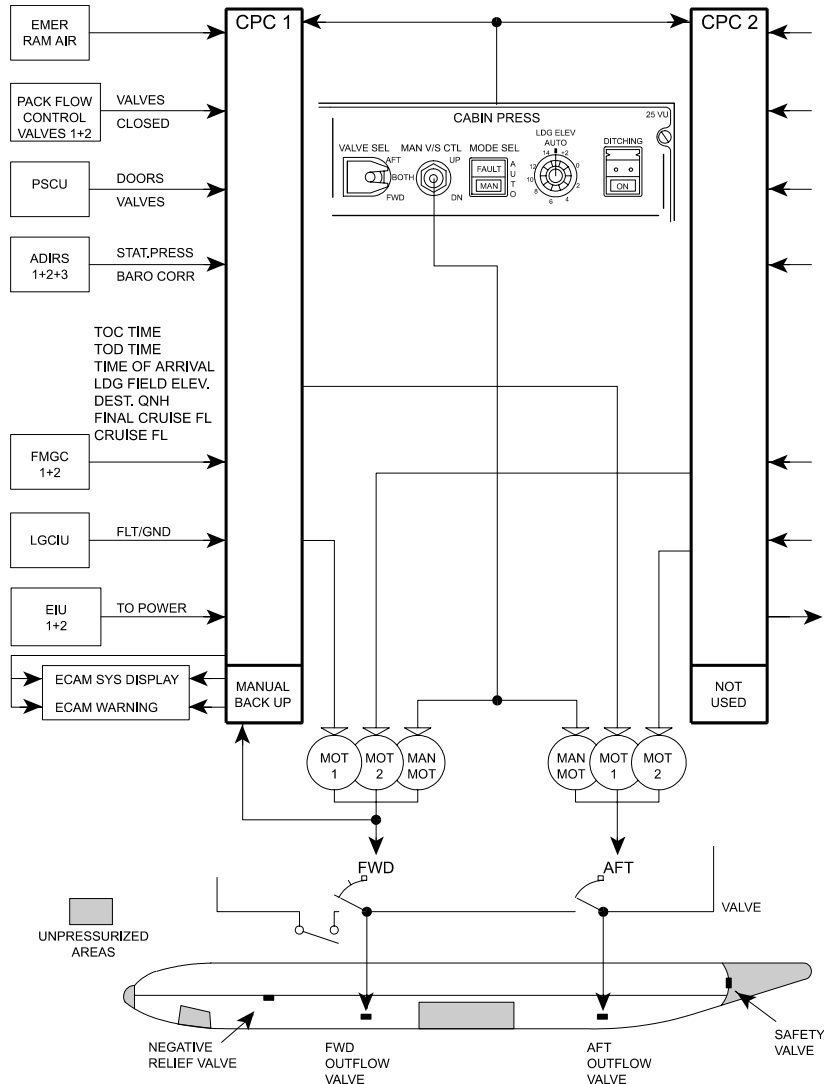
Provided by ambient air being drawn around the batteries and then vented directly outboard via a venturi.

• Lavatory and galley ventilation

Provided by ambient cabin air extracted by a fan and exhausted near the outflow valves.

A330 environmental control system

Cabin pressure control



CRUISE

ENG

F. USED		
4260	KG	4250
17.5	QT	18.0
0.9	N1	1.2
0.6	N2	0.9

AIR

LDG ELEV AUTO 2500 FT
D P 7.5 PSI

CKPT	FWD	MID	AFT	CAB V/S
23	24	23	24	500 FT/MN
				CAB ALT
				7500FT

TAT -51°C	GW 205300 KG
SAT -36°C	23 H 56
GWCG 37,5 %	

PRESS LDG ELEV MAN 500 FT

Δ P

PSI

8.3

V/S

FT/MN

1150

CAB ALT

FT

8000

SYS 1 SYS 2 SAFETY

MAN FWD AFT

VENT EXTRACT SAFETY VALVE

PACK 1
PACK 2



A330 environmental control system

Pressurization

- The pressurization control system operates fully automatically.
- Dual system with automatic switchover after failure. Alternative use for each flight. Two outflow valves are operated by one of three independent electric motors. Two of these are associated with automatic controllers.
- In normal operation, cabin altitude and rate of change are automatically controlled from FMGC flight plan data :
 - cruise flight level, landing field elevation, QNH
 - time to top of climb, time to landing.
- In case of dual FMGC failure, the crew has to manually select the landing field elevation. The cabin altitude varies according to a preprogrammed law.
- In case of failure of both pressurization system auto-controllers, the manual back-up mode is provided through the third outflow valve motor.



12. Electronic instrument system

A330 electronic instrument system

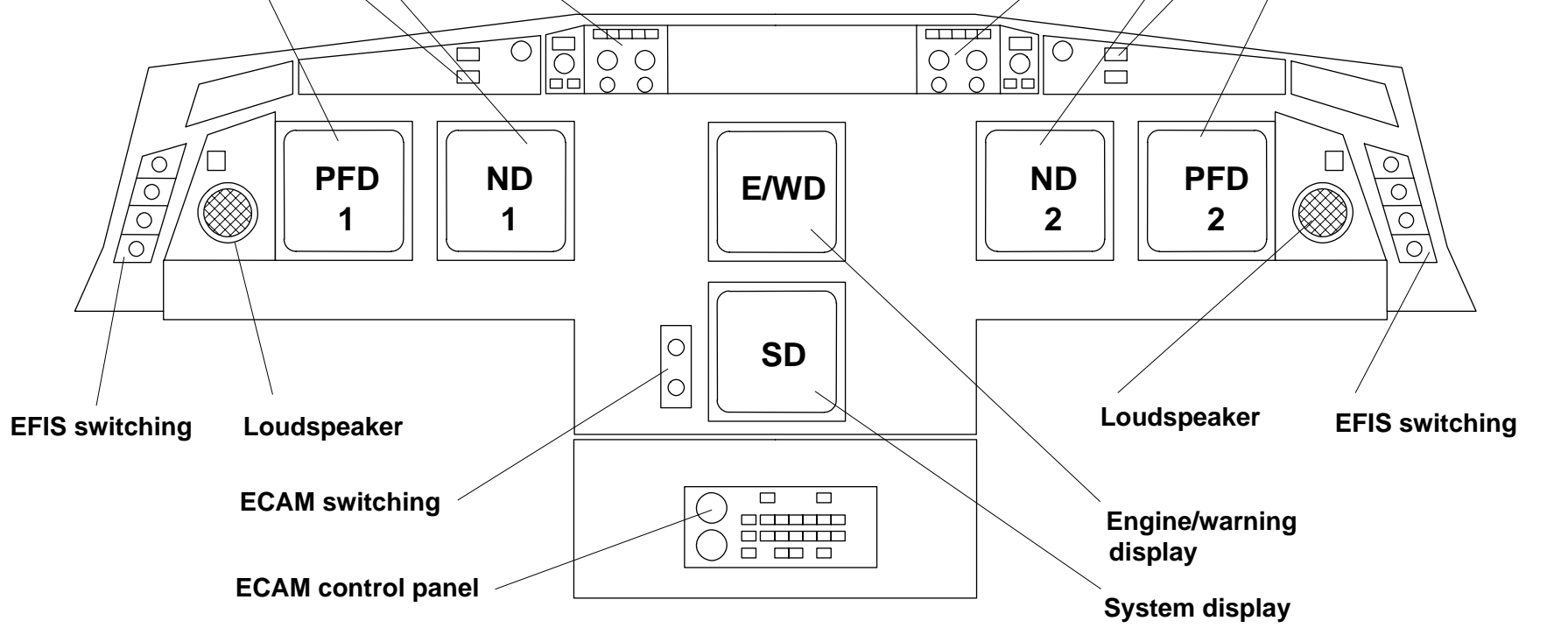
Cockpit arrangement

Captain :

- EFIS control panel
- Navigation display
- Master warning and caution lights
- Primary flight display

First Officer :

- EFIS control panel
- Navigation display
- Master warning and caution lights
- Primary flight display





A330 electronic instrument system

General

The Electronic Instrument System (EIS) performs a **display** function for :

- **flight operation.** EFIS (Electronic Flight Instrument System) on each crew member instrument panel :
 - 1PFD (Primary Flight Display)
 - 1 ND (Navigation Display)
- **system operation.** ECAM (Electronic Centralized Aircraft Monitor)

On the centre instrument panel for both crew members :

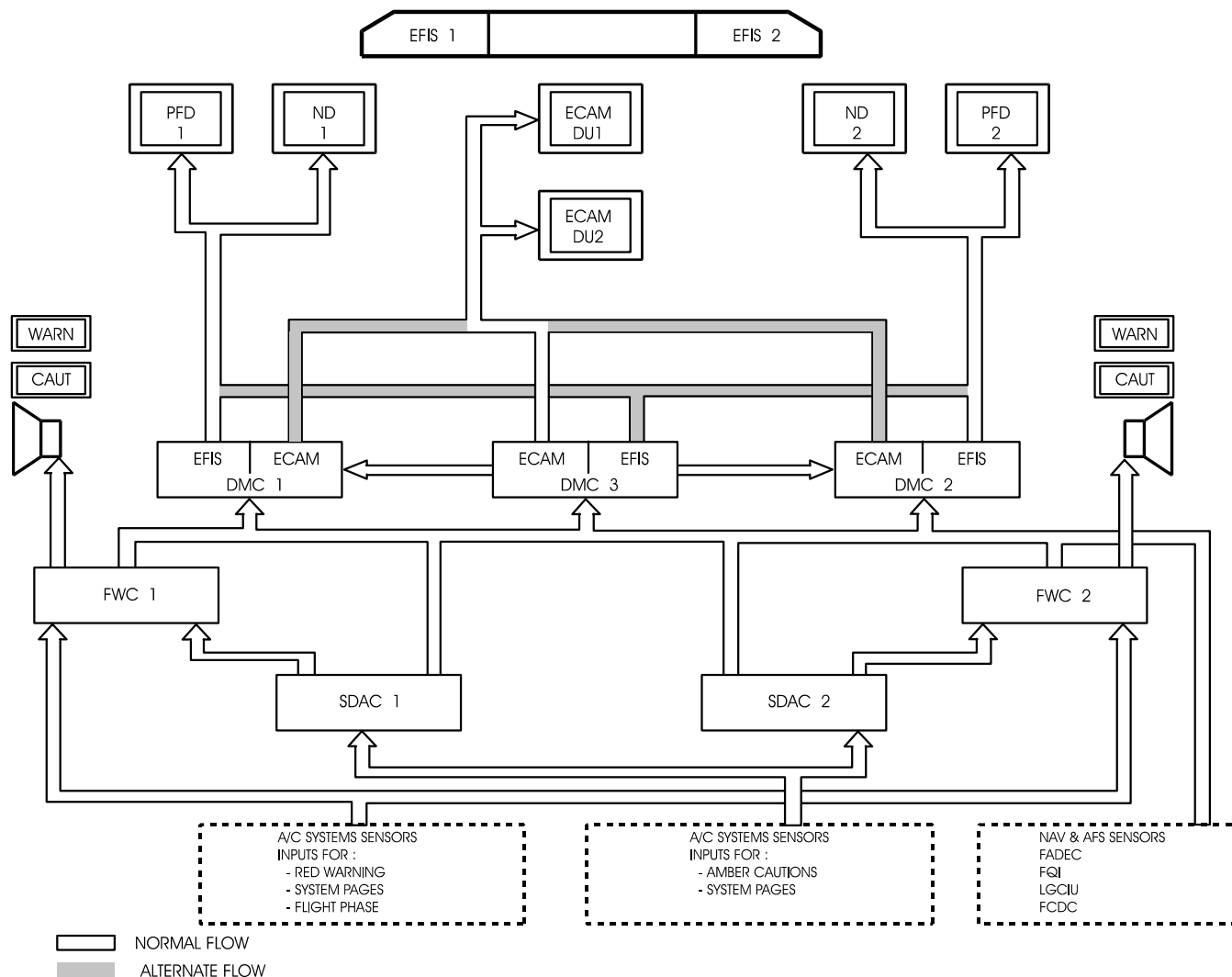
- 1 E/WD (Engine/Warning Display)
- 1 SD (System Display)

The crew remains in the INFORMATION/ACTION loop at all times and is able to CHECK and OVERRIDE the automation (if necessary).



A330 electronic instrument system

EFIS / ECAM architecture





A330 electronic instrument system

Components

- **DU** (Display Unit) → **Display function**
 - Six identical full-colour DUs
 - 7.25in x 7.25in case size
 - Symbol generator resident in DU
- **DMC** (Display Management Computer) → **Acquisition and processing functions**
 - Three identical DMCs
 - Each DMC has two independent channels : EFIS/ECAM
 - Each DMC is able to drive all six DUs with four independent formats (PFD ; ND ; E/WD ; SD).
- **SDAC** (System Data Acquisition Concentrator) → **Acquisition of system data for transmission to FWC and DMC**
 - Two identical SDACs
 - The SDACs are connected to the DMCs and FWCs
- **FWC** (Flight Warning Computer) → **Acquisition and processing of :**
 - Two identical FWCs
 - Each FWC is connected to all DMCs.
 - Alert messages
 - Memos
 - Aural alerts
 - Flight phases
 - Auto callout



A330 electronic instrument system

Architecture

- **Fully redundant EIS architecture**

Partitioned DMCs (three EFIS functions/three ECAM functions) to drive the six DUs.

- Full reconfiguration capability.
- Independence between EFIS and ECAM switching.

- **Benefits**

- Dispatchability.
- No operational degradation when a DMC fails or some external computers fail (ADIRS, FWC, SDAC, etc.)

Availability objectives

- Departure with one DMC and one DU failed all functions remain available :

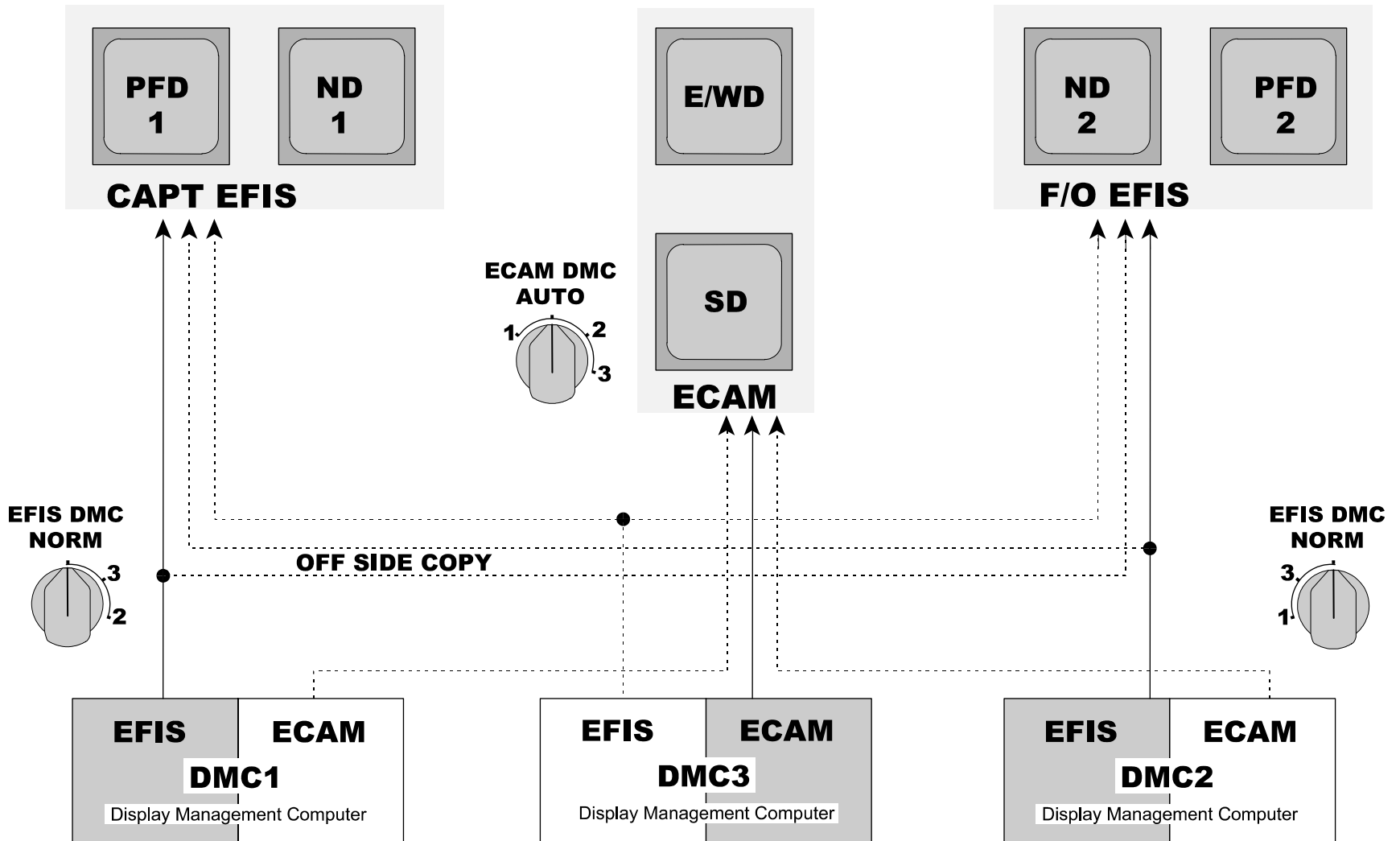
- EFIS 1
- ECAM
- EFIS 2

- After two failures (normal operation) or one failure (MEL operation) the following functions remain available :

- EFIS 1 or 2
- ECAM
- Copy of remaining EFIS on the opposite side.

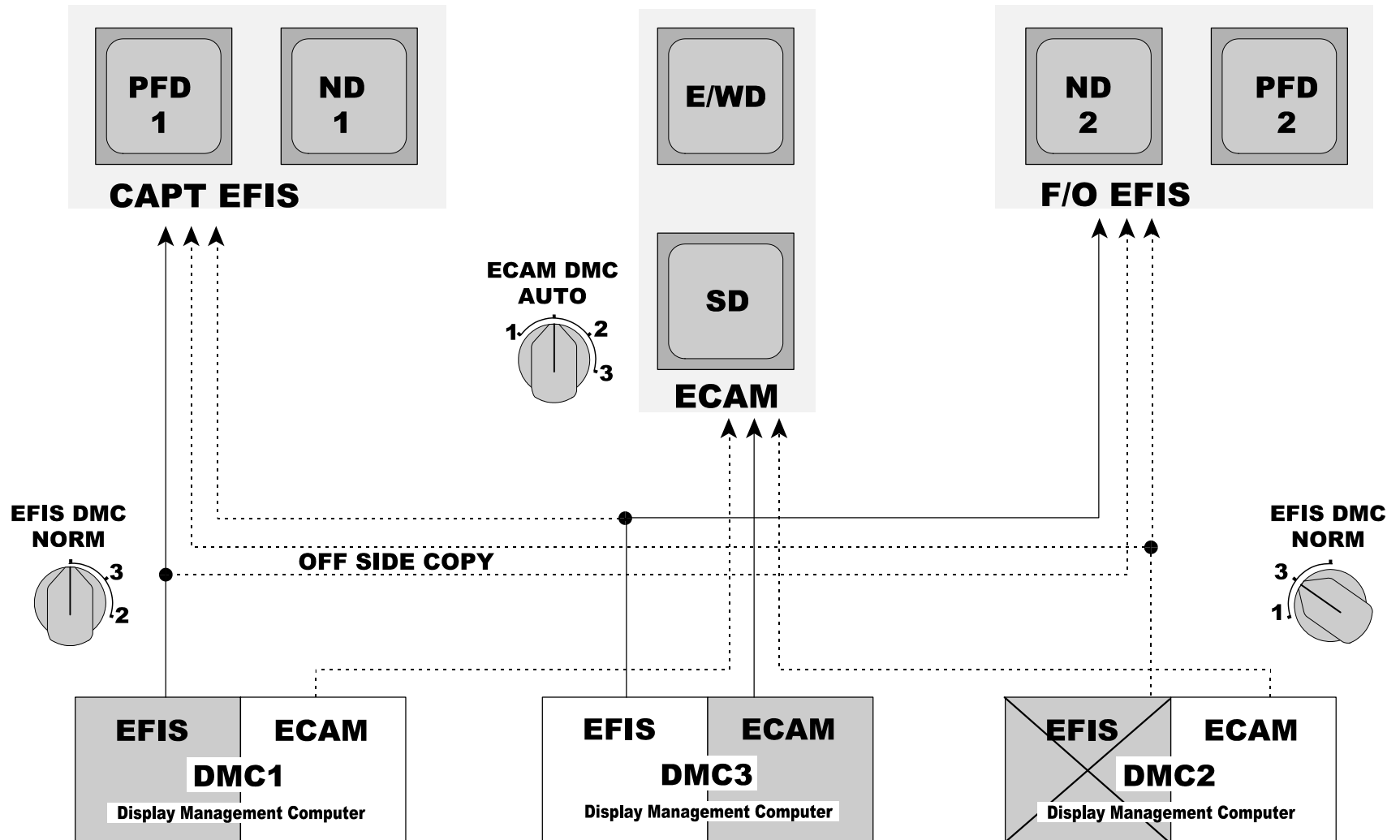
A330 electronic instrument system

Reconfiguration possibilities - Architecture



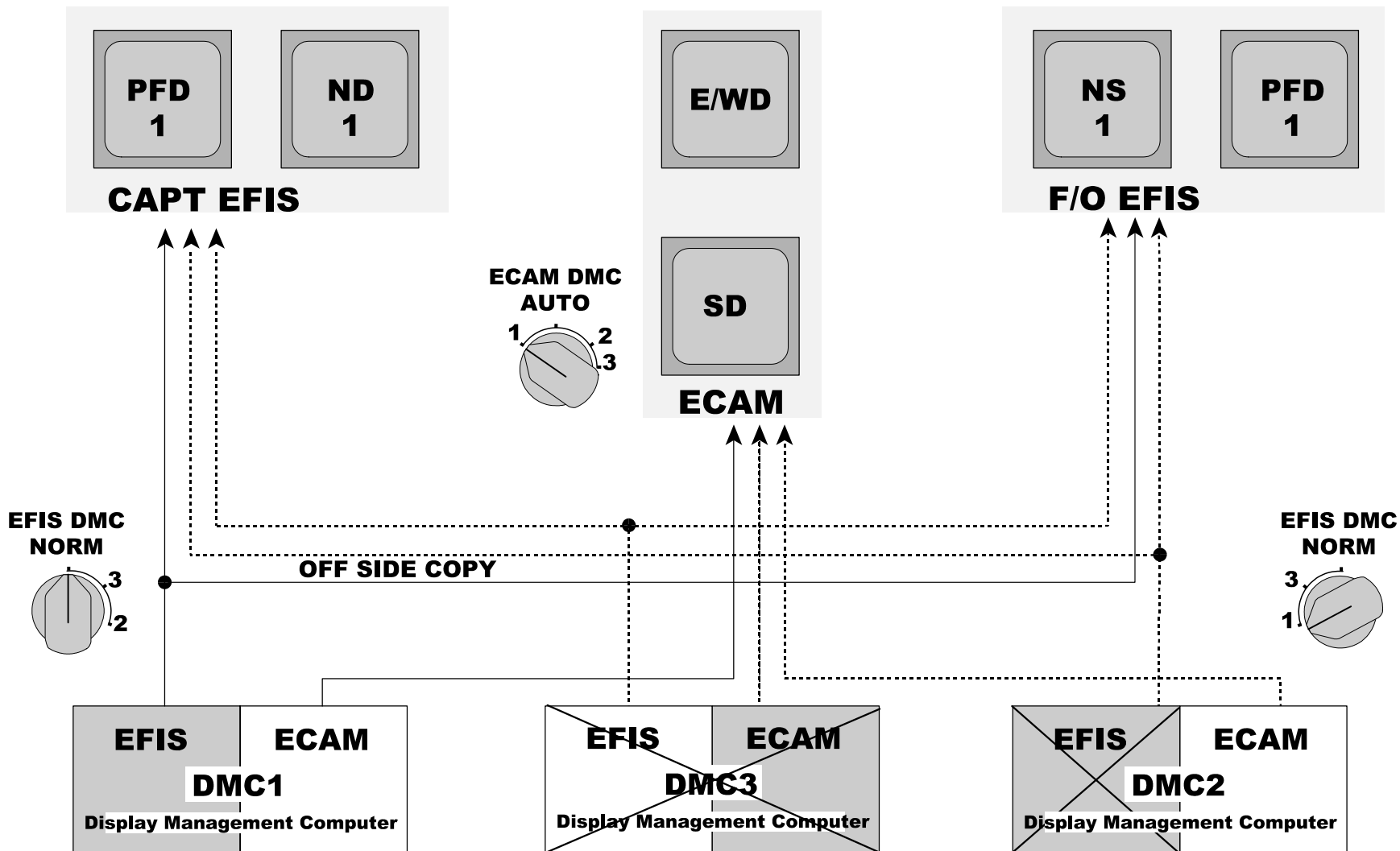
A330 electronic instrument system

Reconfiguration - F/O on EFIS DMC3



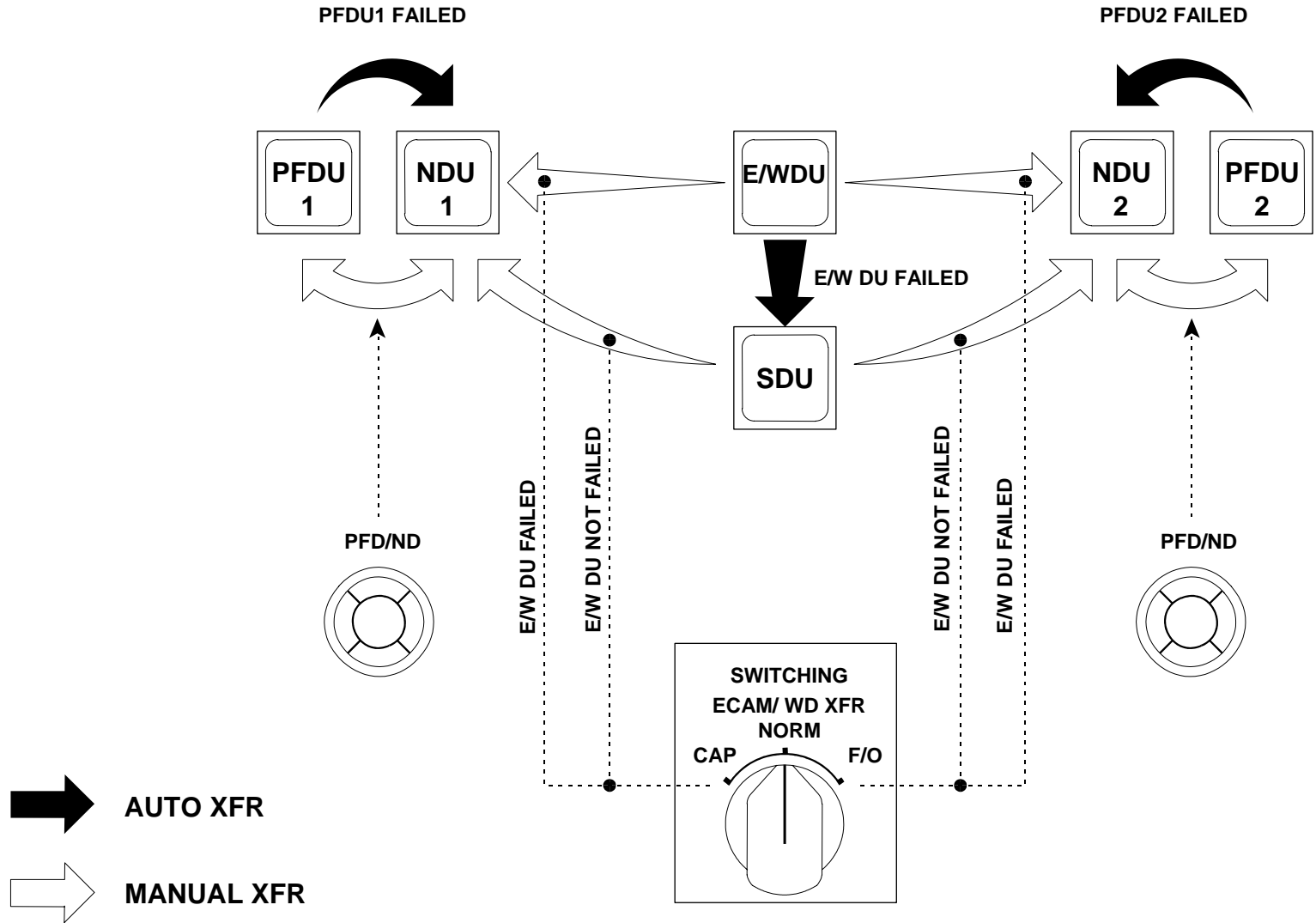
A330 electronic instrument system

Reconfiguration - ECAM on DMC1 + F/O on EFIS DMC1



A330 electronic instrument system

DU reconfiguration





A330 electronic instrument system - EFIS

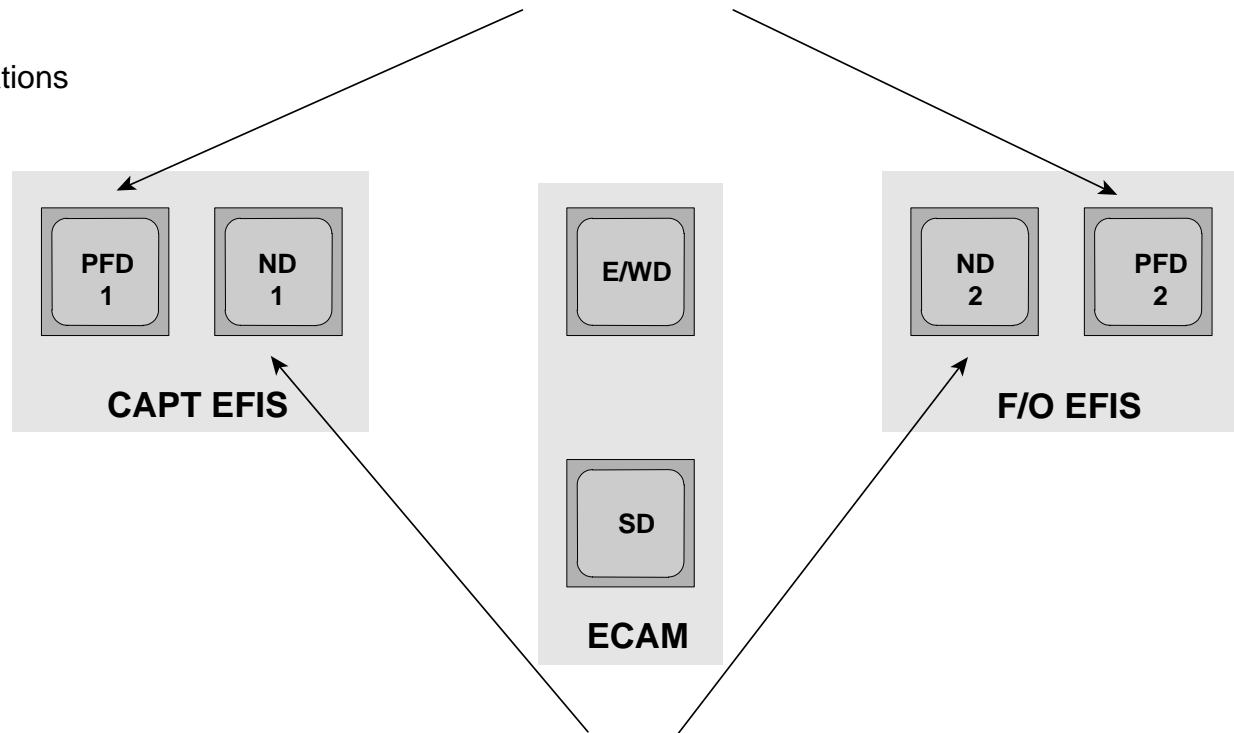
The **EFIS** (Electronic Flight Instrument System) is used for flight operation.

The two **PFDs** (Primary Flight Displays) provide **short-term flight information** :

- aircraft attitude
- air speed
- altitude and vertical speed
- heading and track
- autoflight information
- vertical and lateral deviations
- radio NAV information.

The two **NDs** (Navigation Displays) provide **medium-term flight information** :

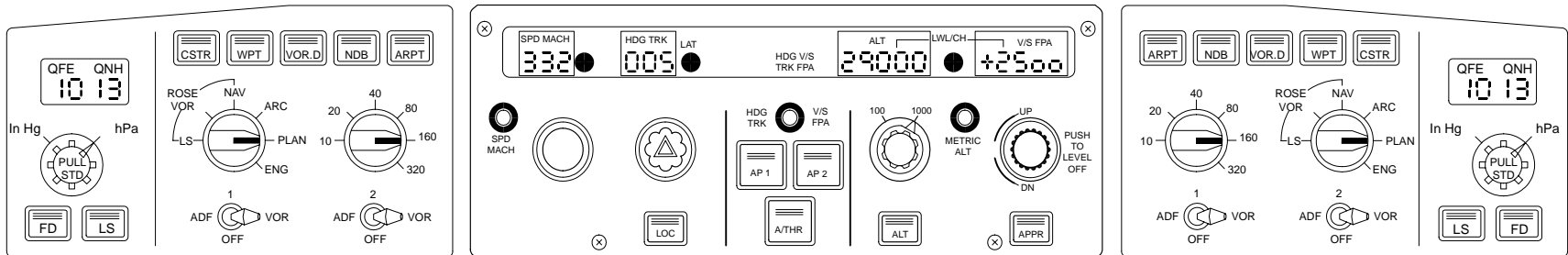
- location of the aircraft with respect to navigation aids : FMS flight plan and map data
- weather radar information.



A330 electronic instrument system - EFIS

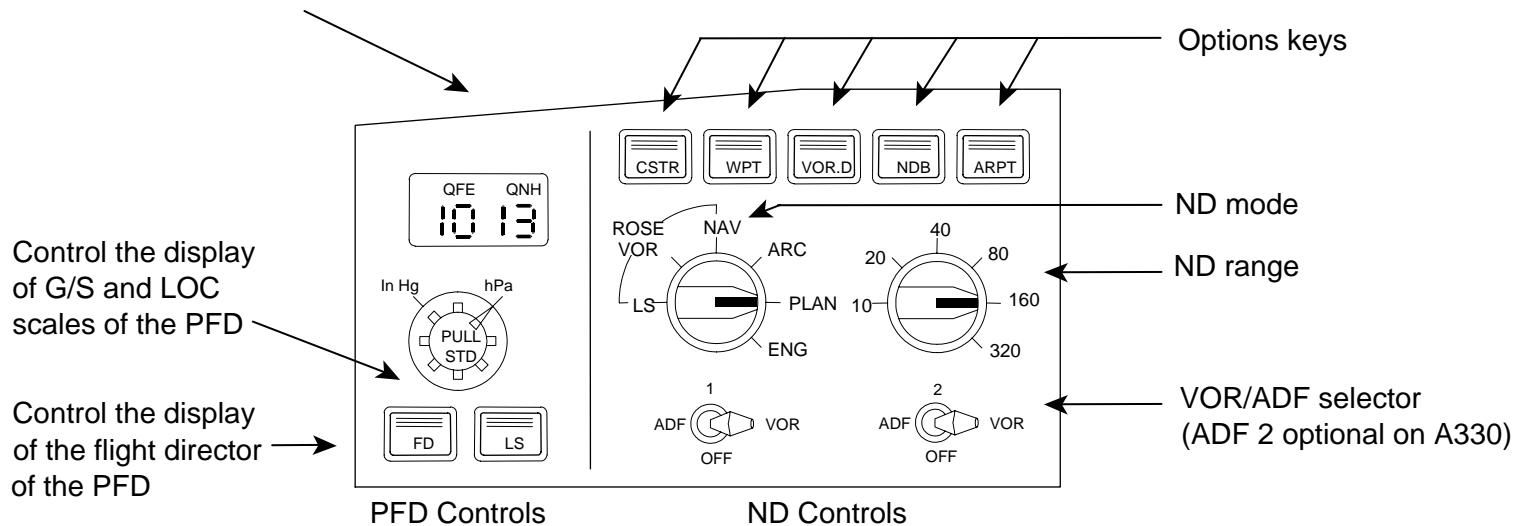
Control panels

The capt and F/O control panels are part of the FCU (Flight Control Unit)



Capt. EFIS control panel

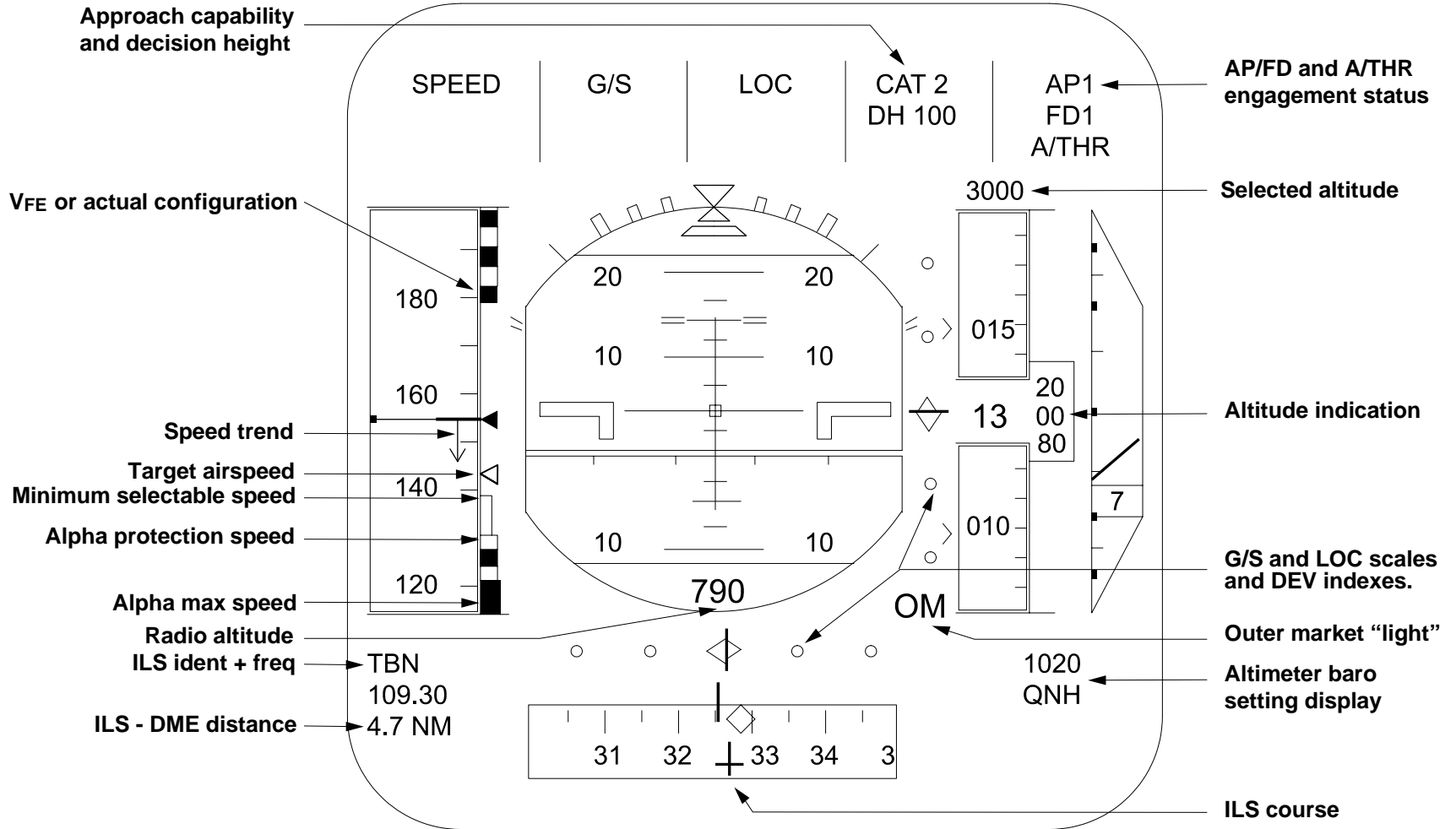
F/O EFIS control panel





A330 electronic instrument system - EFIS

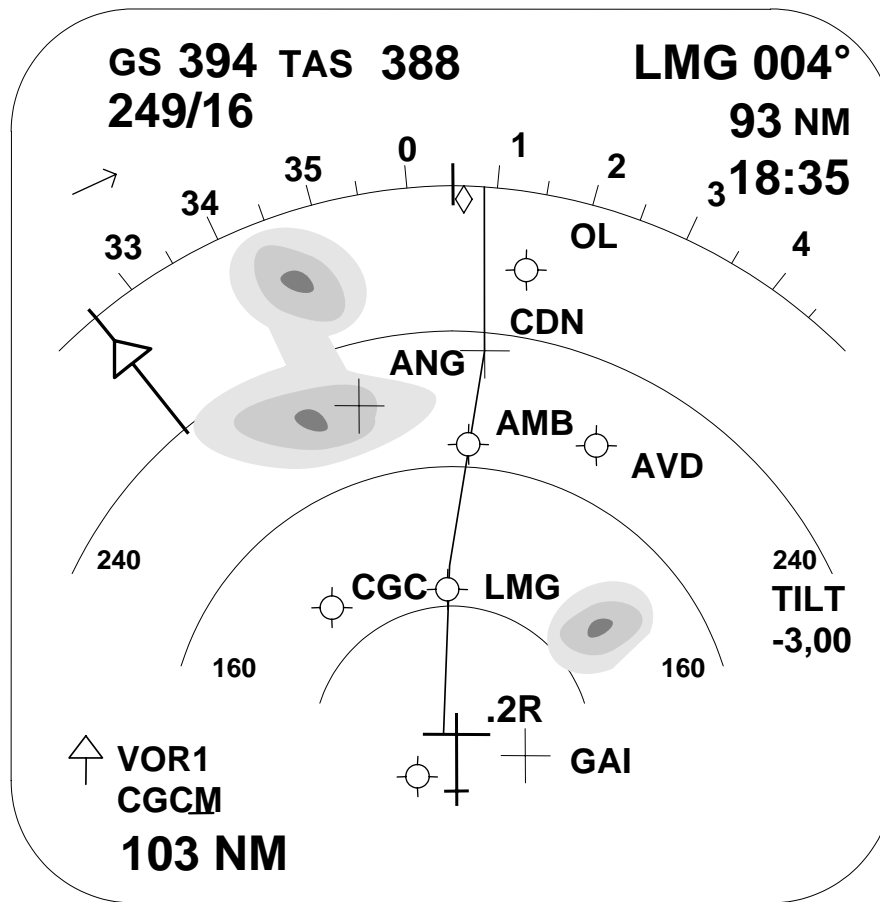
PFD - Approach





A330 electronic instrument system - EFIS

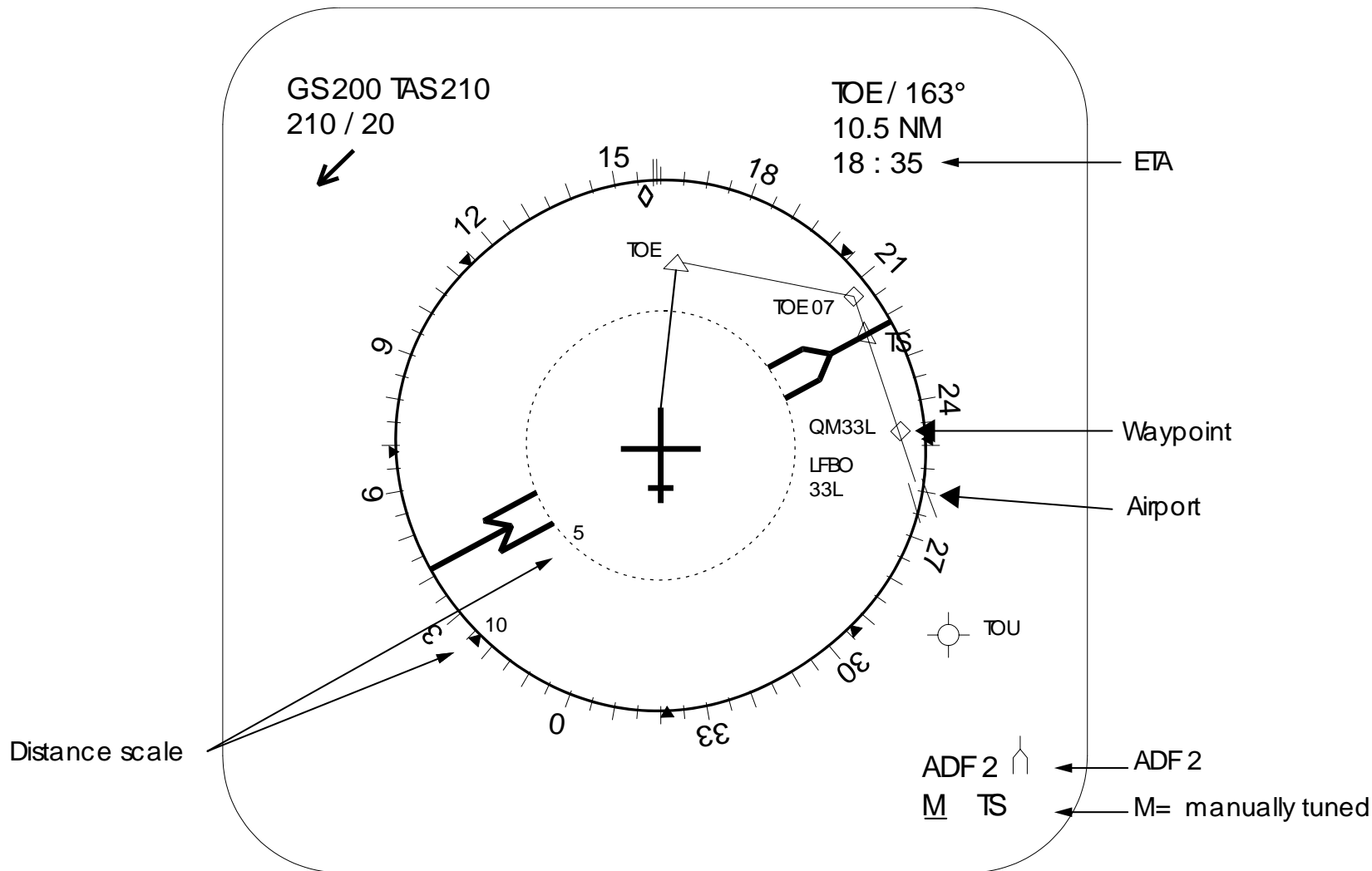
ND - ARC mode





A330 electronic instrument system - EFIS

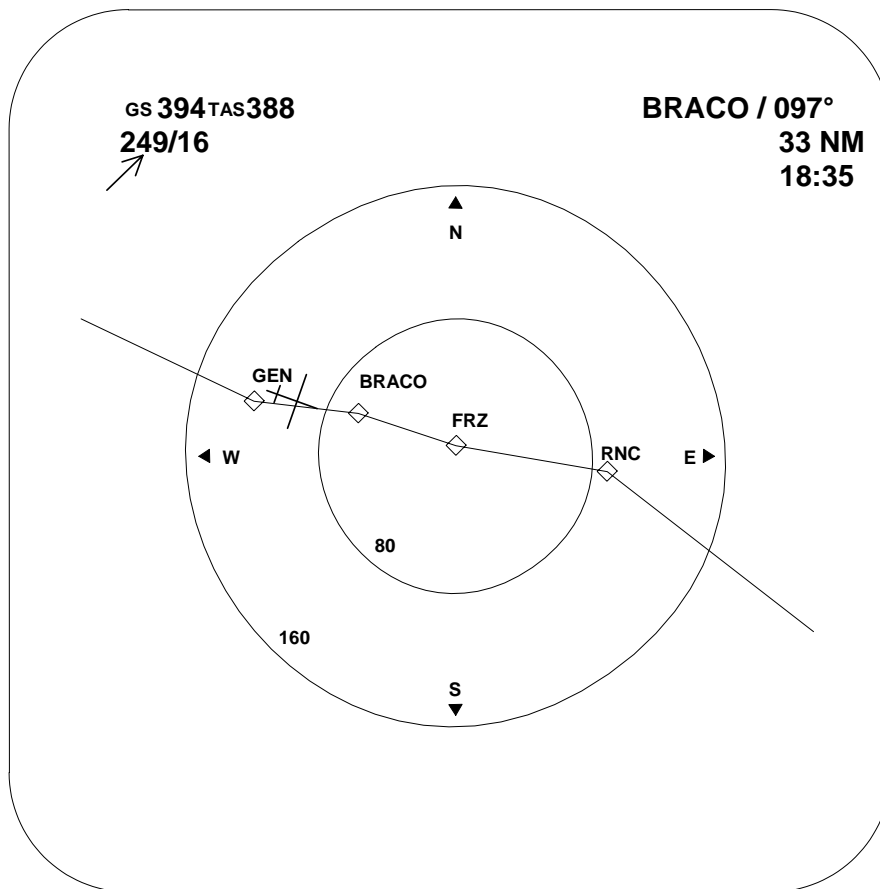
ND - ROSE/NAV mode





A330 electronic instrument system - EFIS

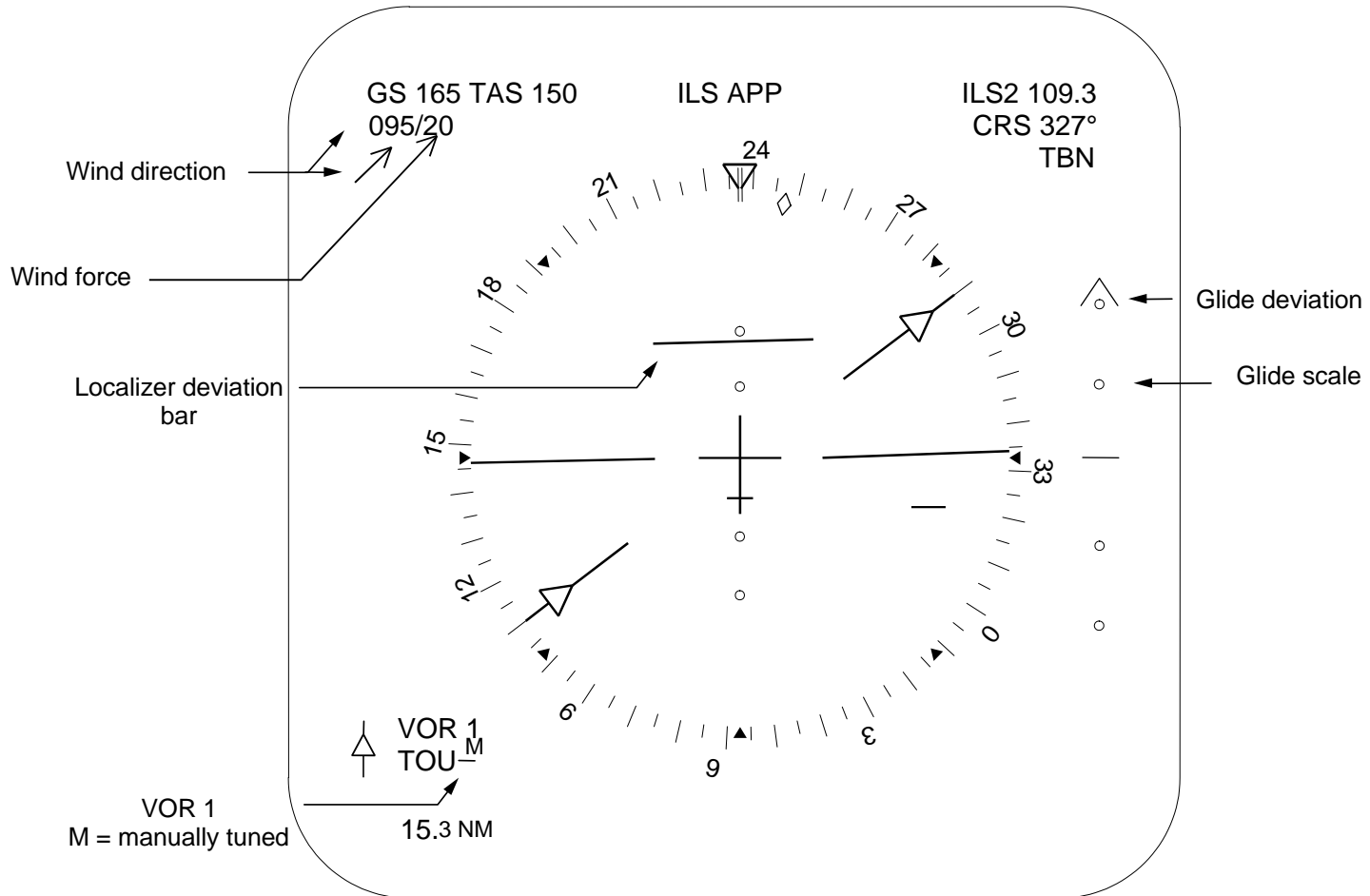
ND - PLAN mode





A330 electronic instrument system - EFIS

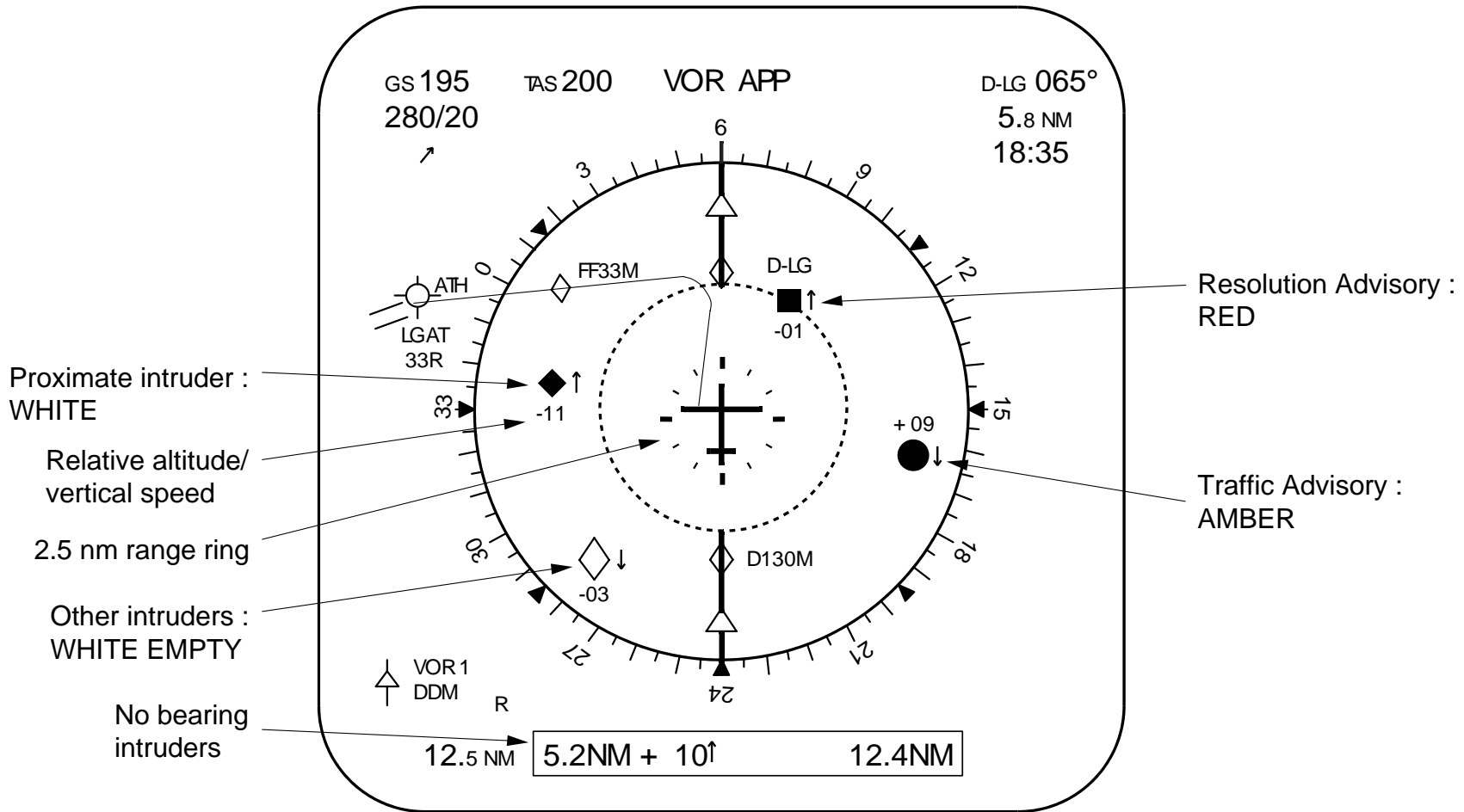
ND - ROSE/ILS mode





A330 electronic instrument system - EFIS

ND - TCAS (optional)





A330 electronic instrument system - ECAM

Arrangement

- ECAM (EFIS) colour symbology

- Warnings : **RED** for configuration or failure requiring immediate action.
- Cautions : **AMBER** for configuration or failure requiring awareness but not immediate action.
- Indications : **GREEN** for normal long-term operations.
WHITE for titling and guiding remarks.
BLUE for actions to be carried out or limitations.
MAGENTA for particular messages, e.g. inhibitions.

- ECAM displays arrangement

Upper DU

- Engine primary indication
- Fuel quantity information
- Slats/flaps position
- Warning/Caution or Memo messages.



Lower DU

- Aircraft system synoptic diagram or status messages.




A330 electronic instrument system - ECAM

Audible warning definition

WARNING SIGNAL	CONDITION	DURATION	SILENCING
CONTINUOUS REPETITIVE CHIMIE	RED WARNINGS	PERMANENT	Depress* MASTER WARN It
SINGLE CHIME	AMBER CAUTION	1/2 sec.	
CAVALRY CHARGE	A/P DISCONNECTION BY TAKE OVER pb	1.5 sec	Second push on TAKE OVER pb
	A/P DISCONNECTION DUE TO FAILURE	PERMANENT	Depress MASTER WARN It or TAKE OVER pb
CLICK	LANDING CAPABILITY CHANGE	1/2 sec (3 pulses)	
CRICKET + "STALL" message (synthetic voice)	STALL	PERMANENT	NIL
INTERMITTENT BUZZER	SELCAL CALL	PERMANENT	Depress RESET key on ACP
BUZZER	CABIN CALL	3s	NIL
	EMER CABIN CALL	3s REPEATED 3 TIMES	NIL
	MECH CALL	As long as outside pb pressed	NIL
	ACARS  CALL or ALERT	PERMANENT	Message reading on MCDU or Depress MASTER CAUT
C CHORD	ALTITUDE ALERT	1.5 sec or PERMANENT	new ALTITUDE selection or depress MASTER WARN pb
AUTO CALL OUT (synthetic voice)	HEIGHT ANNOUNCEMENT BELOW 400 FT	PERMANENT	NIL
GROUND PROXIMITY WARNING (synthetic voice)	UNSAFE TERRAIN IN CLEARANCE FORESEEN	PERMANENT	NIL
"WINDSHEAR" (synthetic voice)	WINDSHEAR	REPEATED 3 TIMES	NIL
"PRIORITY LEFT" "PRIORITY RIGHT" (synthetic voice)	A/PTAKE OVER pb	1 sec	NIL
"RETARD" (synthetic voice)	THRUST LEVER NOT IN IDLE POSITION FOR LANDING	PERMANENT	THRUST LEVER
TCAS  (synthetic voice)	TRAFFIC OR POTENTIAL COLLISION	PERMANENT	NIL

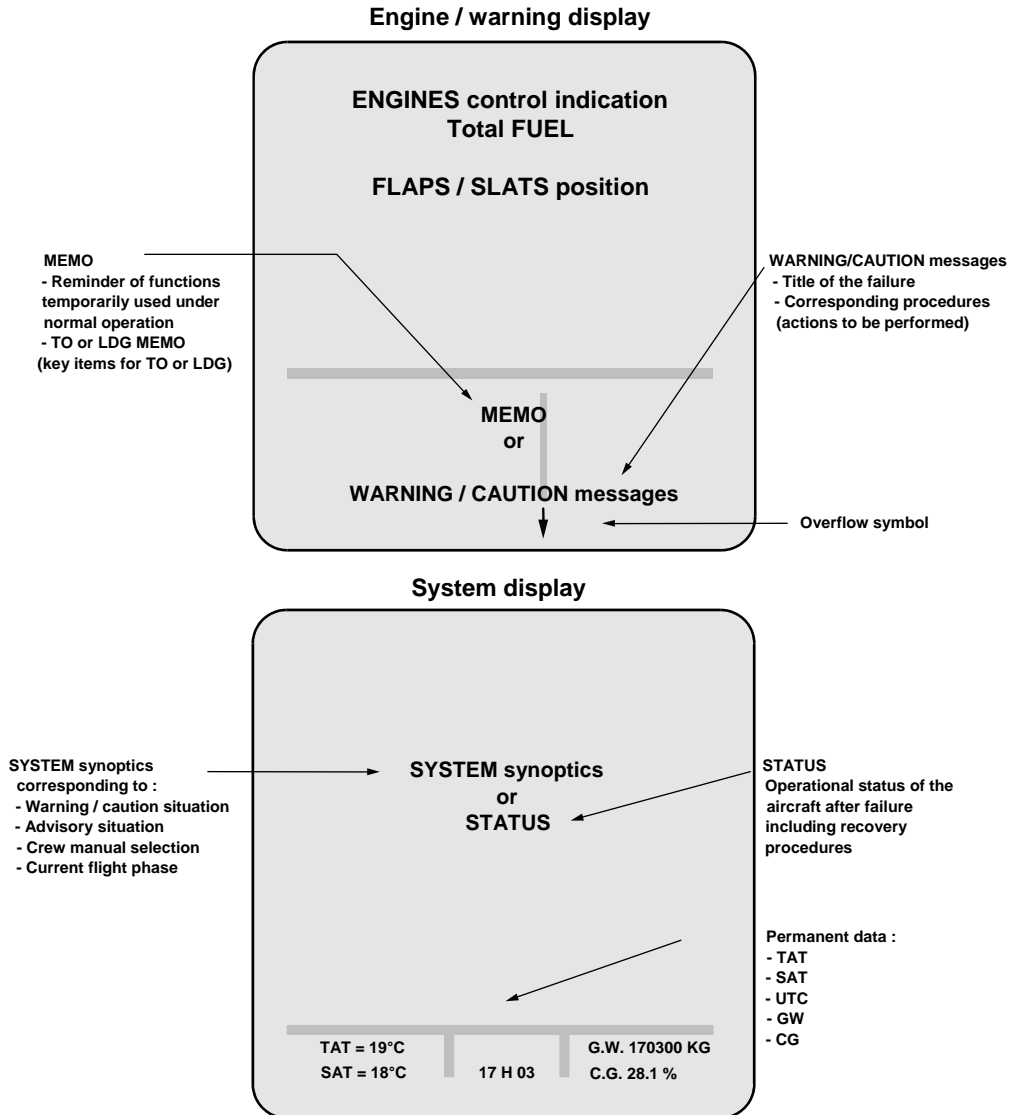
* All aural warnings may be cancelled by depressing the EMER CANC pb on ECAM control panel or the MASTER WARN It except for some warnings like overspeed or L/G not down.

 If option is installed



A330 electronic instrument system - ECAM

Display unit

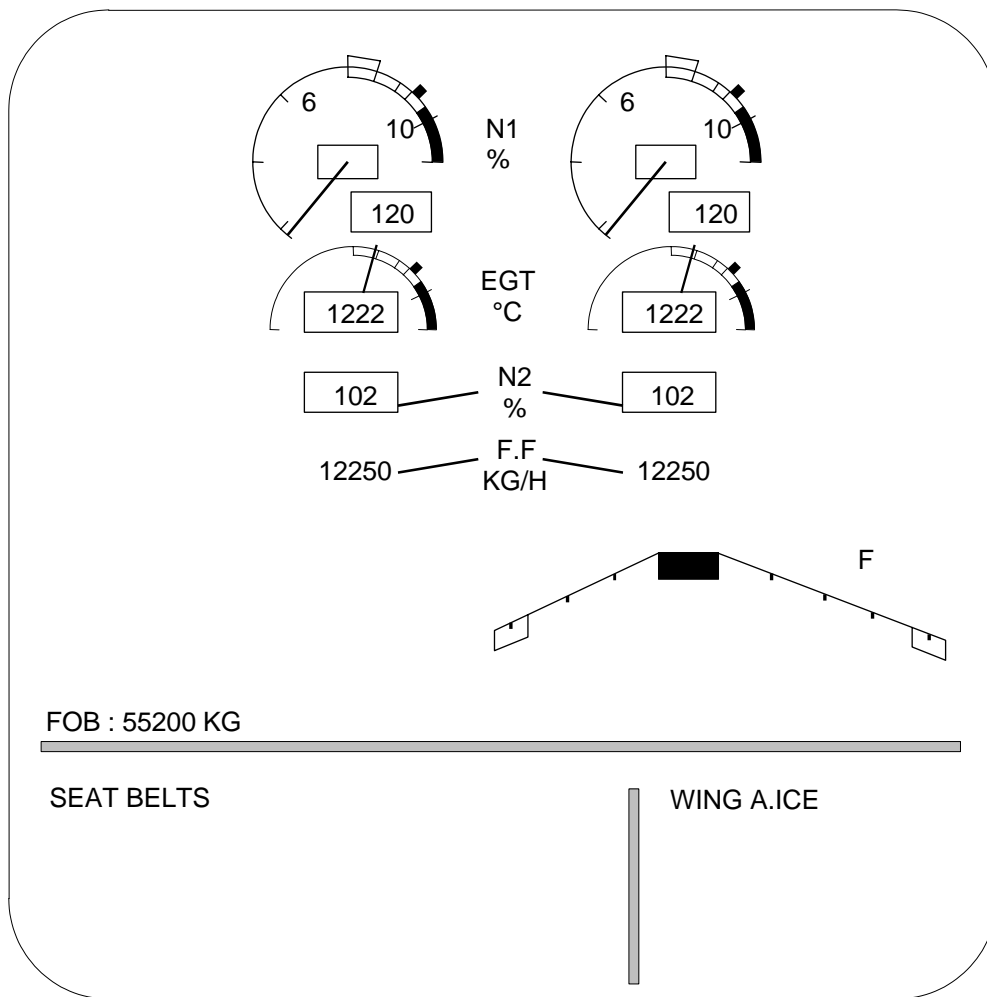




A330 electronic instrument system - ECAM

E/WD - engines

Typical



ECAM UPPER DISPLAY (E/WD)

ENGINE CONTROL PARAMETERS
FUEL QUANTITY INDICATION
- FLAPS/SLATS POSITION

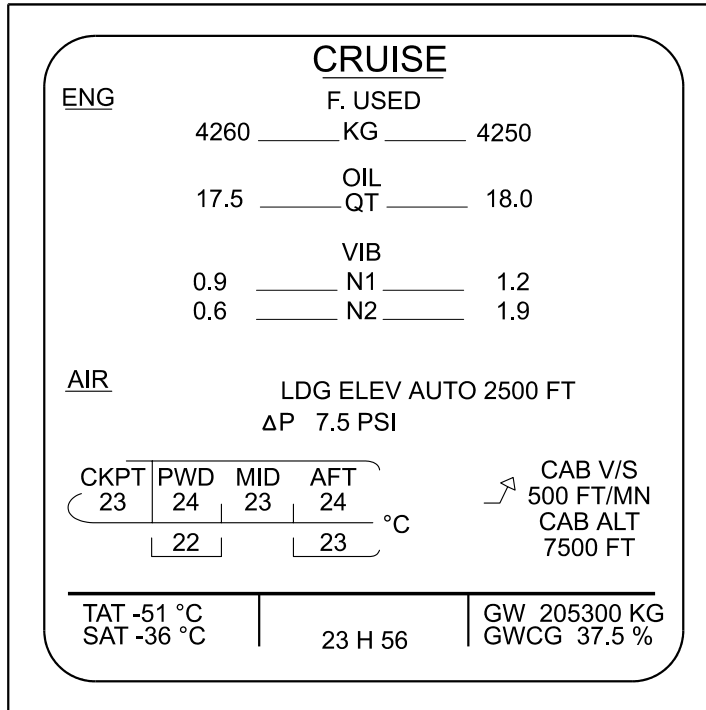
- MEMO INFORMATION



A330 electronic instrument system - ECAM

S/D - A330 cruise page

ECAM LOWER DISPLAY (SD)



System pages

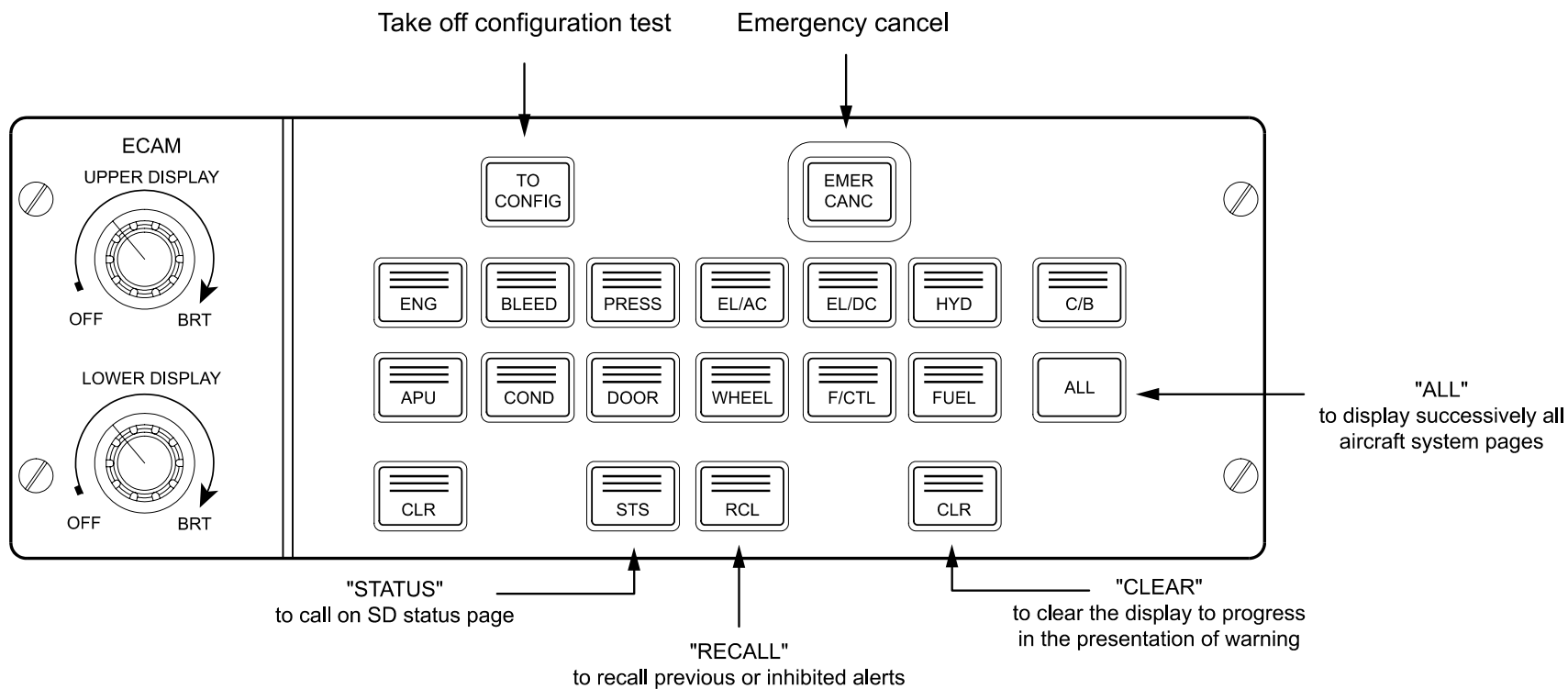
14 system pages can be displayed :

- BLEED (Air bleed)
- COND (Air conditioning)
- PRESS (Cabin pressurization)
- ELEC AC (AC electrical power)
- ELEC DC (DC electrical power)
- C / B (Circuit breakers)
- F / CTL (Flight controls)
- FUEL (Fuel)
- HYD (Hydraulic)
- APU (Auxiliary power unit)
- ENGINE (Secondary engine parameters)
- DOOR / OXY (Doors / oxygen)
- WHEEL (Landing gear, braking, ground spoilers, etc.)
- CRUISE (Cruise)



A330 electronic instrument system - ECAM

Control panel



Note : In the event of complete failure of the ECAM control panel electronics, the CLR, RCL, STS, EMER CANC and ALL remain operative since the contacts are directly wired to the FWCs/DMCs.



A330 electronic instrument system - ECAM

Operating modes

- **Four modes of ECAM system pages presentation :**

NORMAL mode : automatic flight phase related mode :

- MEMO on E/WD
- most suitable system page on SD.

MANUAL mode : use of the ECAM control panel

- any of the system pages may be called-up on SD by pressing the corresponding selector keys of the ECAM control panel.

ADVISORY mode : parameter trend monitoring

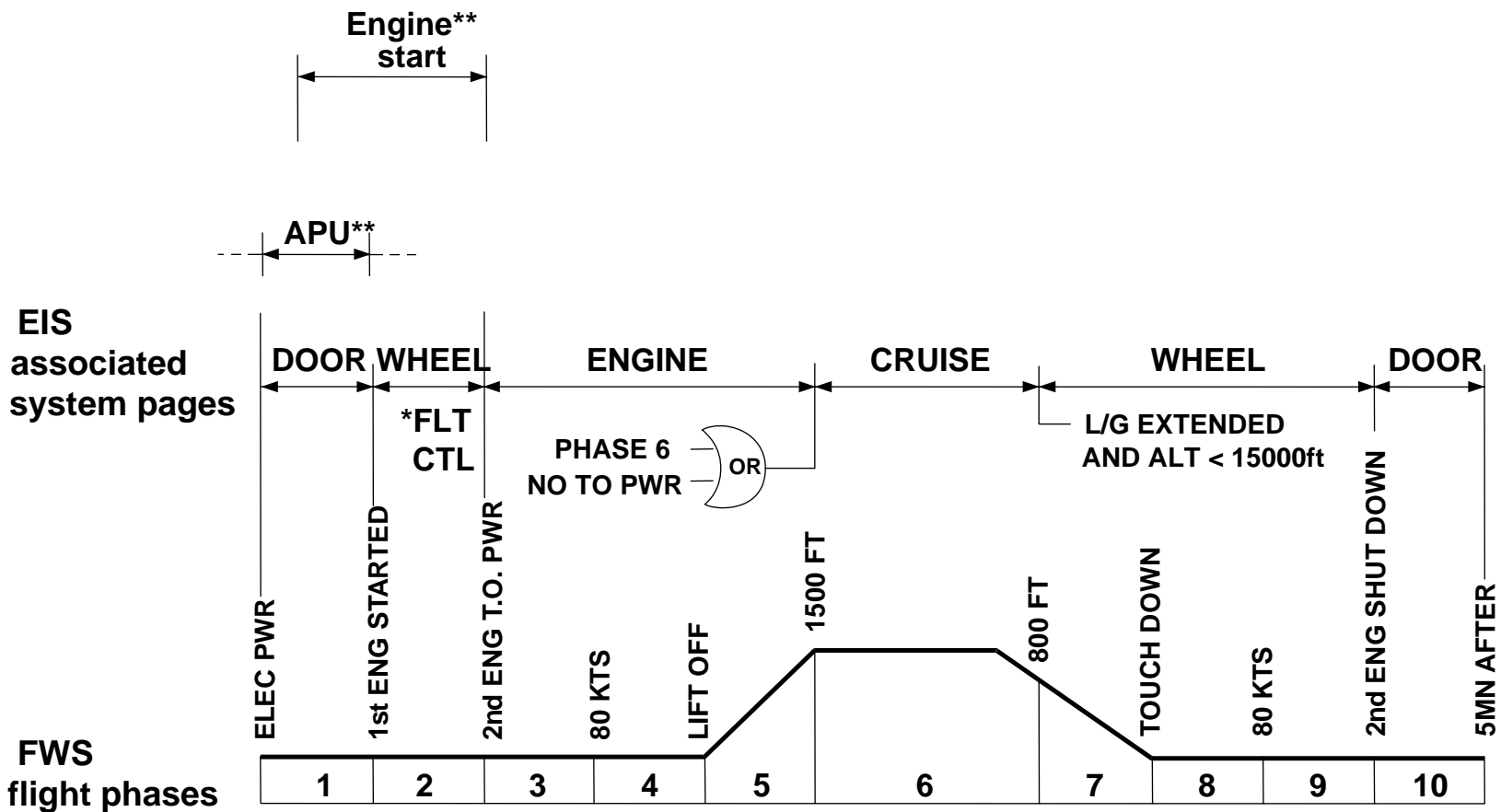
- corresponding system page on SD with affected parameter pulsing.

FAILURE RELATED mode :

- Failure indication and abnormal/emergency procedures on E/WD
- affected system synoptic on SD.

A330 electronic instrument system - ECAM

Automatic flight phase



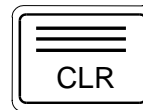
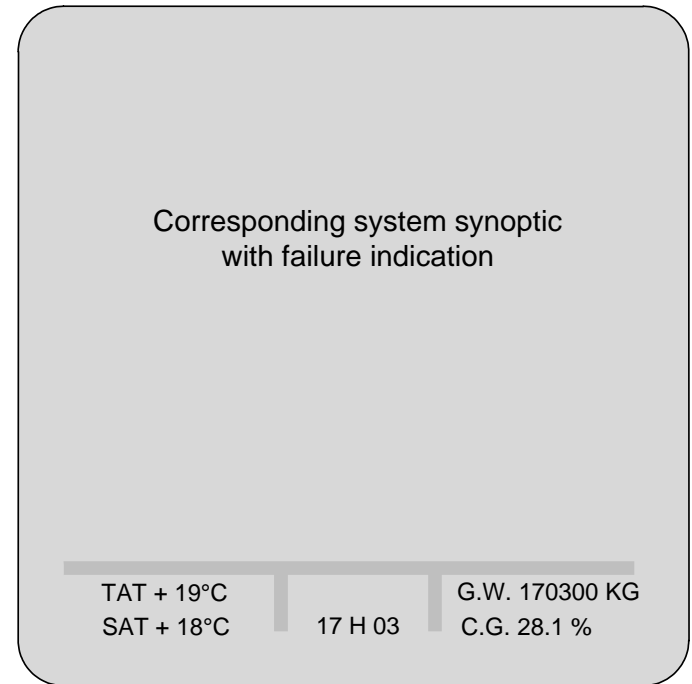
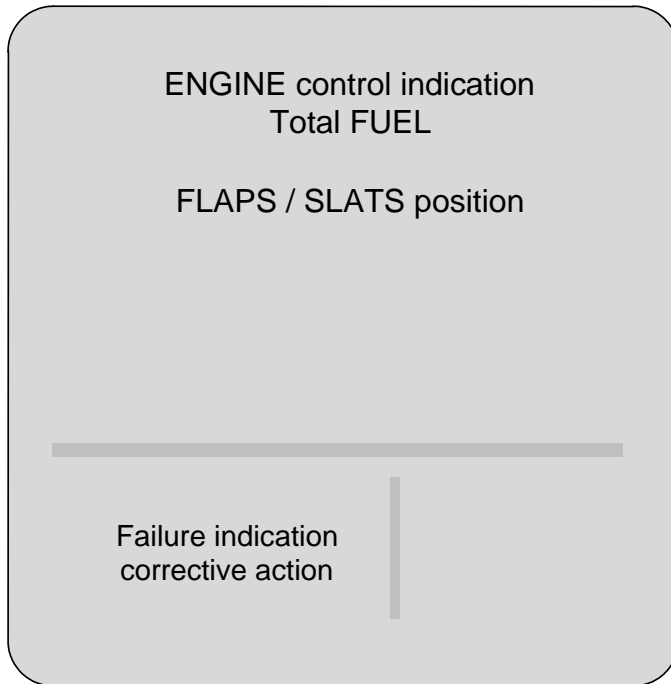
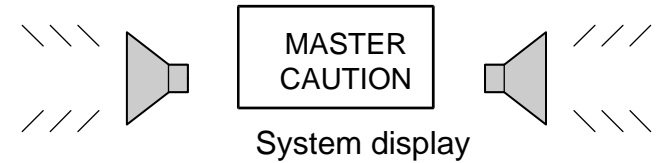
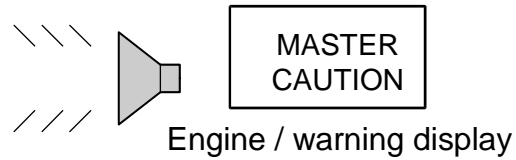
* FLT CTL page replaces wheel page for 20 seconds when either sidestick is moved or when rudder deflection is above 22°.

** APU page or ENG START page automatically displayed during start sequence.



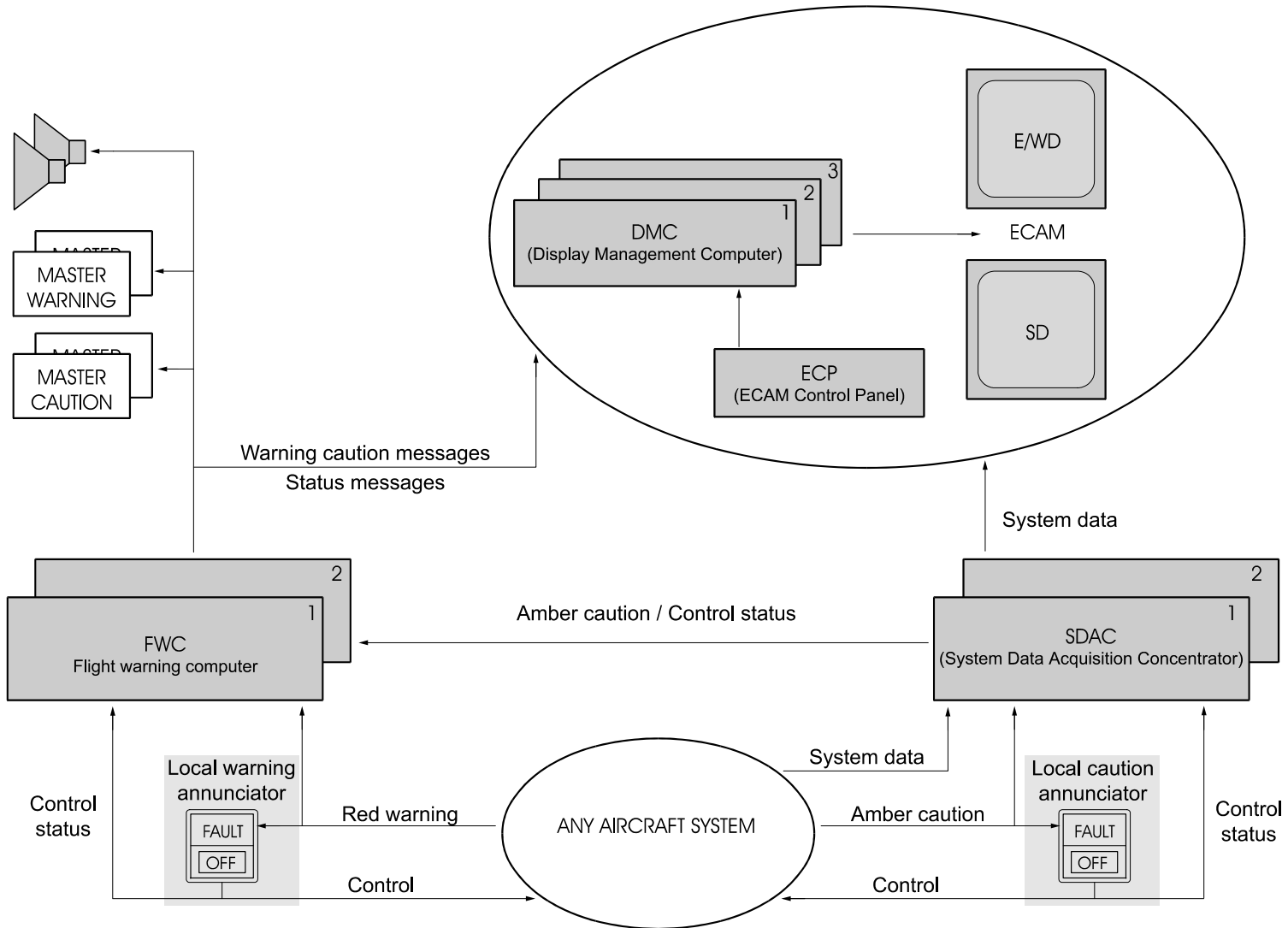
A330 electronic instrument system - ECAM

Failure-related mode



A330 electronic instrument system

Architecture - Flight Warning System (FWS)





A330 electronic instrument system

- The FWS performs **(in real time)** the **computation** and **management of central warnings and cautions**
 - **Warning/caution hierarchical classification** (level 3 : red warning, level 2 : amber caution, level 1 : simple caution) and **priority rules**.
 - **Warning/caution inhibitions**.
 - **Operational failure categorization** : independent failure, primary failure, secondary failure.
- The FWS directly activates the crew attention getters (aural and visual) and uses the EIS (ECAM : E/WD and SD) to display the warning/caution messages.
- The FWS also computes the MEMO information (presented on the E/WD) and performs an automatic radio height call-out function.

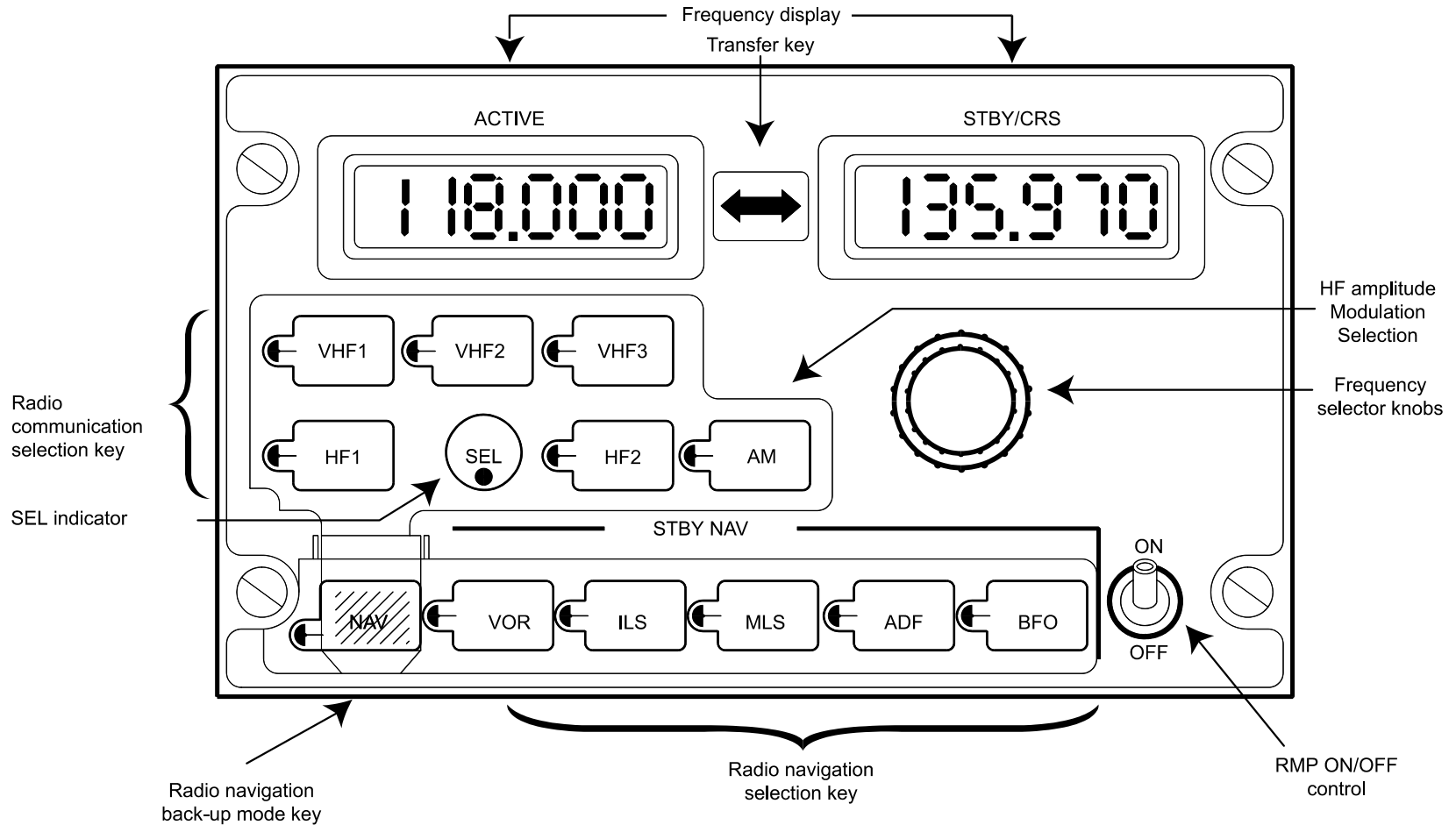


13. Radio management and communication



A330 radio management and communication

Radio Management Panel (RMP)





A330 radio management and communication

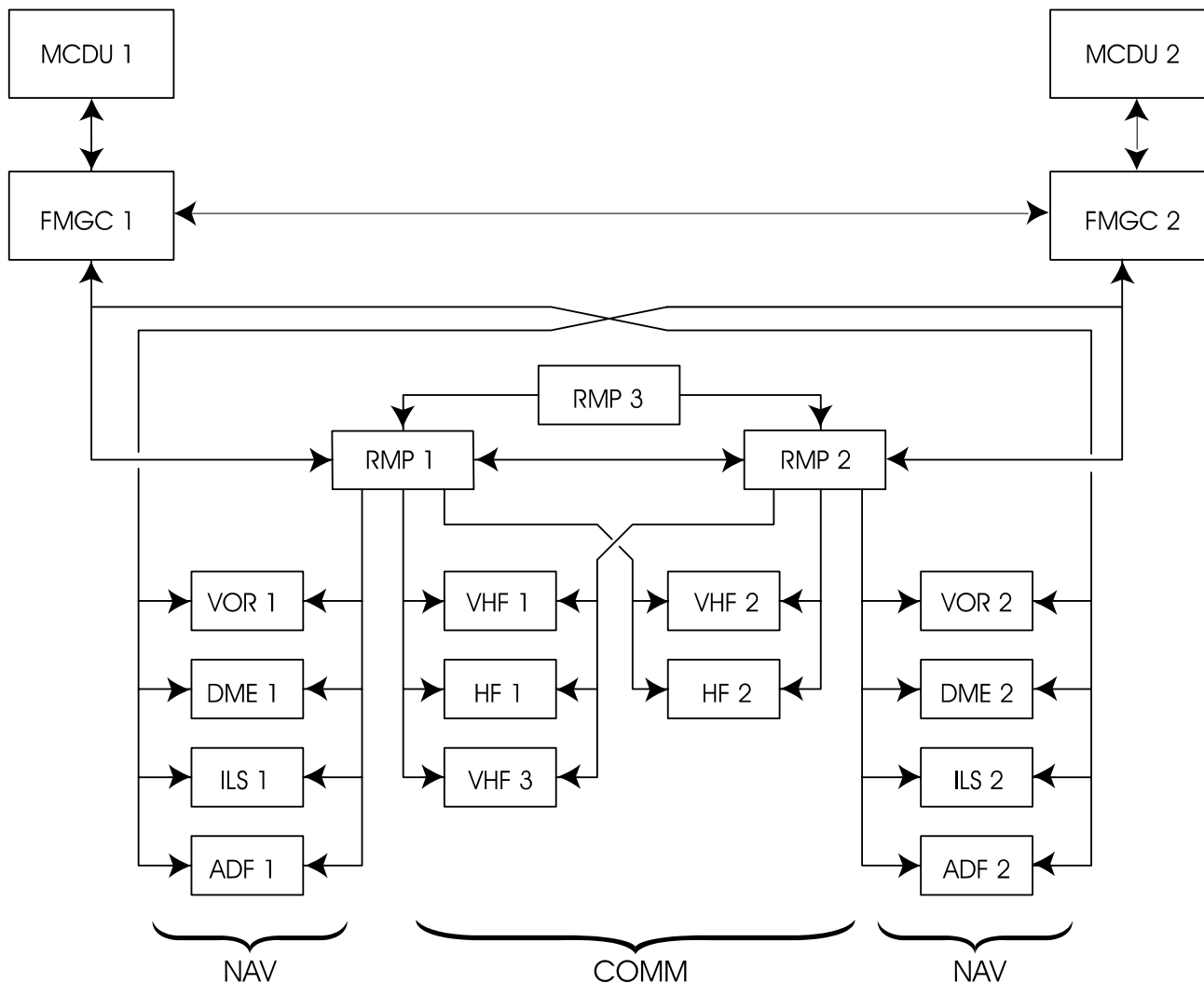
Concept

- Radio Management Panel (**RMP**) system provides :
 - crew control of all radio communication systems.
 - back-up to the two FMGCs for controlling all radio navigation systems.
- Basic installation includes :
 - two RMPs on pedestal
 - a third RMP on overhead panel (not available for NAV back up).
- The **ATC** transponder is tuned by a separate conventional control panel.



A330 radio management and communication

RMP architecture





A330 radio management and communication

Concept architecture

Communications tuning

Any communication receiver can be tuned from either of the three RMPs. Either RMP can take over from the other in the event of failure.

Navigation tuning

Three different operating modes exist :

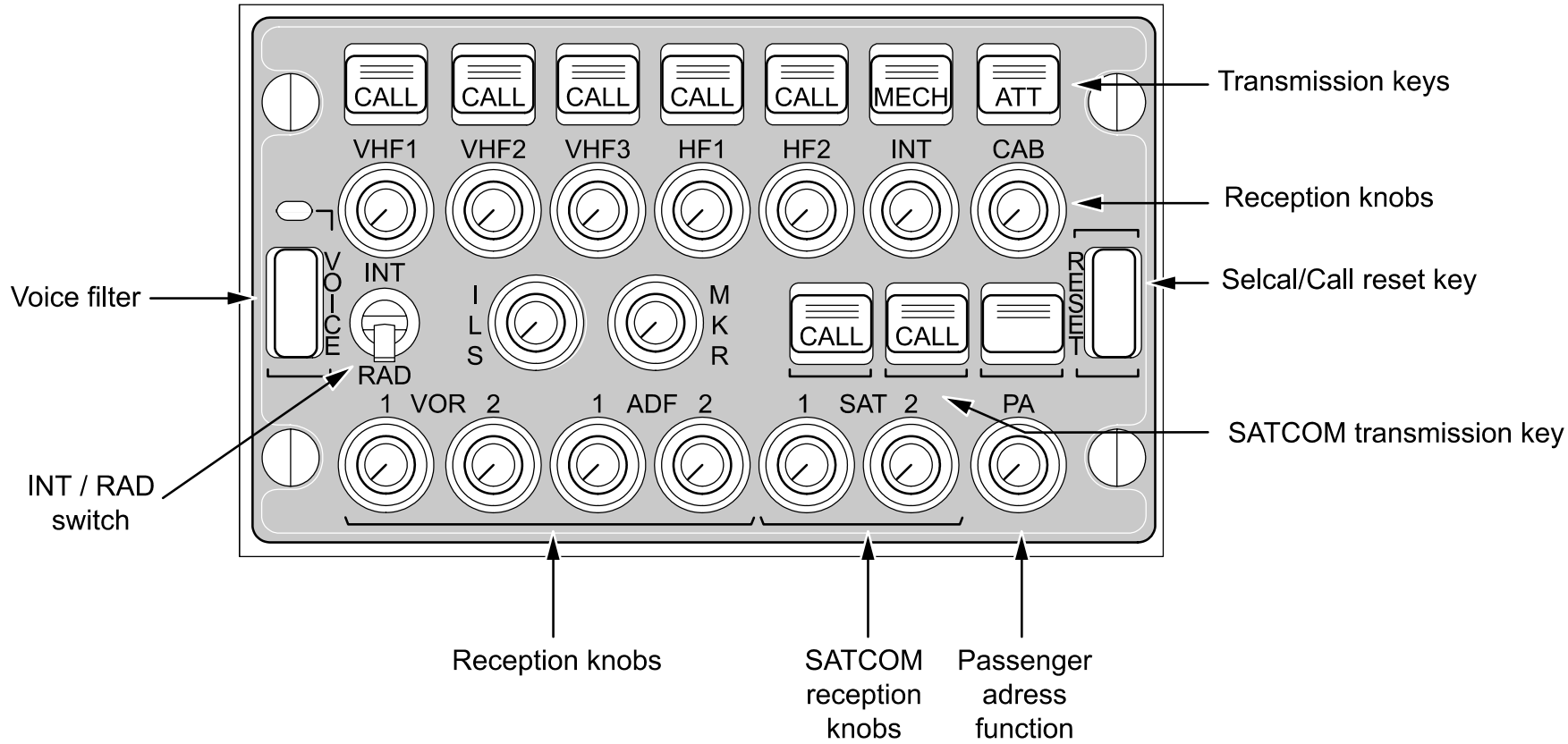
- Automatic tuning : VOR/DME, ILS and ADF are automatically controlled by the FMGC.
- Manual tuning : for selection of a specific frequency through the FMGC MCDU which overrides the automatic function of the FMGC.
- Back-up tuning : when both FMGCs are inoperative, any NAV receiver may be tuned by the crew from RMP 1 or 2.

When one FMGC is inoperative, the remaining one controls all receivers.



A330 radio management and communication

COMM - Audio Control Panel (ACP)





A330 radio management and communication

COMM - Audio system

The audio integrating system provides the management of all audio signals produced by feeding the radio communications, radio navigation and interphone systems :

- Basic installation includes :
 - three Audio Control Panels (**ACP**) - two on pedestal, one on overhead panel.
 - one Audio Management Unit (**AMU**) in avionics bay.
 - one **SELCAL** code selector in avionics bay.
- Provision exists for supplementary ACPs.
- All selections and volume adjustments are carried out by the crew through ACPs.
- All ACPs are fitted for maximum capacity (three VHF, two HF, public address, calls, two VOR, two ADF, ILS and provision for MLS).
- Each ACP and associated AMU electronic card are fully independent and microprocessor controlled.
- Optional : The Satellite Communication (SATCOM) system allows the exchange of information between the ground station and the aircraft (technical information, voice transmission) via satellites.



A330 Central Maintenance System

Left intentionally blank



A330 Central Maintenance System (CMS)

General

Line maintenance of the electronic systems is based on the use of a Central Maintenance System (CMS).

The purpose of the CMS is to give maintenance technicians a central maintenance aid to intervene at system or subsystem level from multipurpose CDUs located in the cockpit :

- to read the maintenance information.
- to initiate various tests.

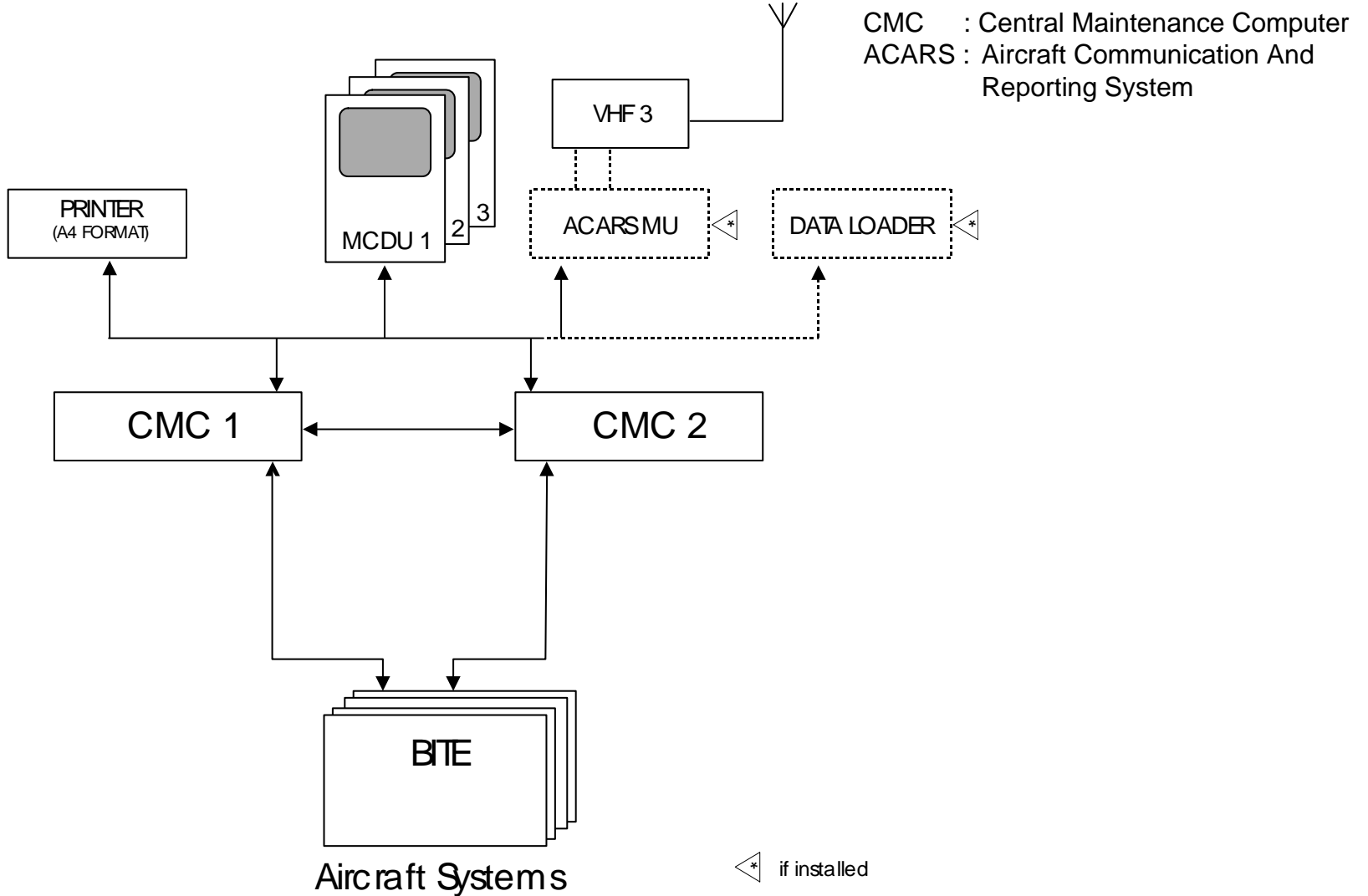
Two levels of maintenance should be possible using the CFDS :

- maintenance at an out-station (LRU change).
- maintenance in the hangar or at the main base (troubleshooting).



A330 Central Maintenance System

Architecture





A330 Central Maintenance System

Advantage of the CMS

A revised maintenance concept provides a :

- reduction of the duration of operations
- reduction of the maintenance crew training time
- simplification of technical documentation
- standardization of the equipment
- simplification of the computers which no longer display any BITE

Integration of the CMS

The CMS includes :

• Basic equipment

- the BITE (Built-In Test Equipment) for each electronic system.
- two fully redundant Central Maintenance Computers (CMCs).
- three MCDUs (Multipurpose Control Display Units)
- one printer.

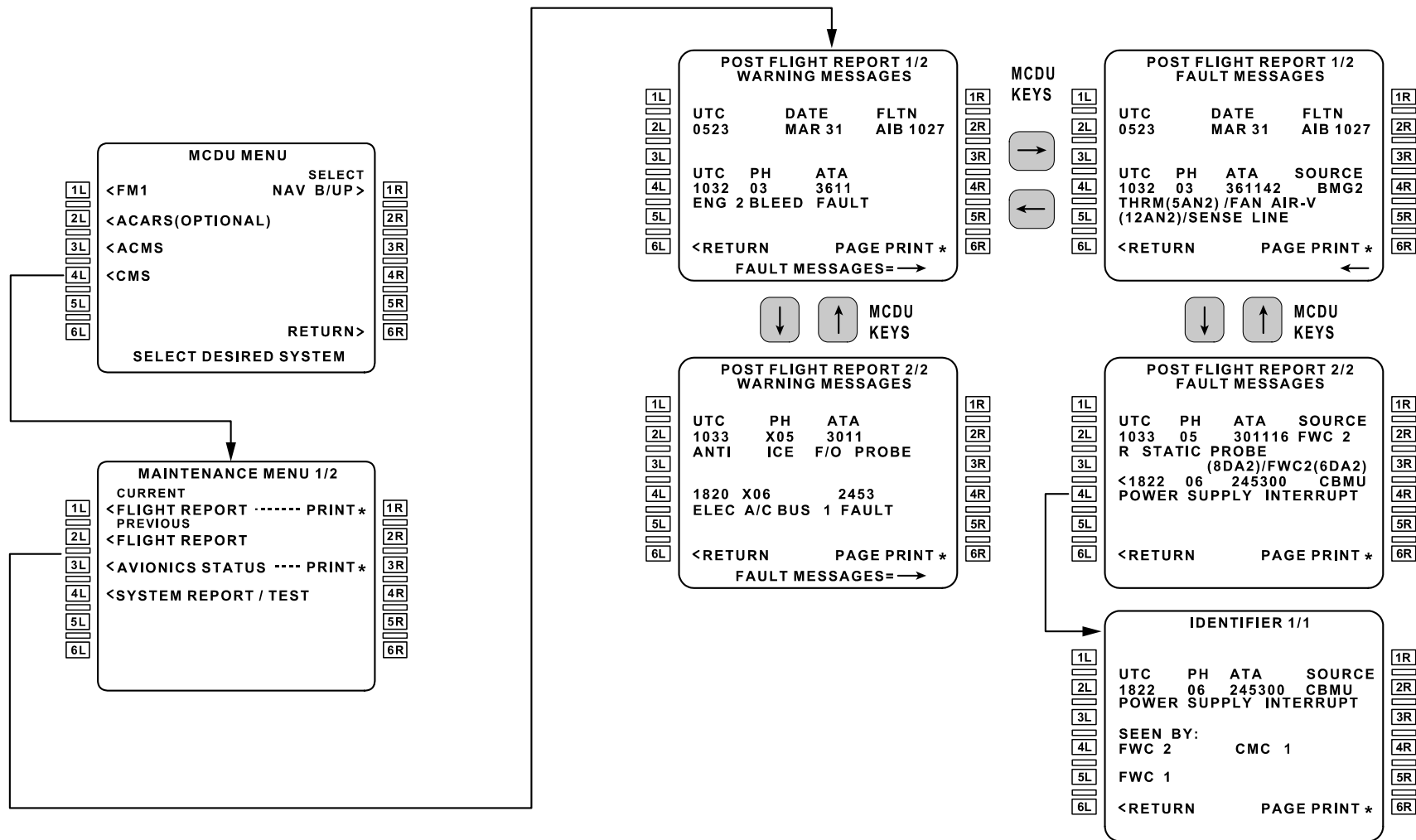
• Optional equipment

- ACARS (Aircraft Communication And Reporting System) which dialogue with the CMC for display of information or initiation of tests.
- Data Loader which allows to upload data bases and operational software or to download system reports from various onboard computers.



A330 Central Maintenance System

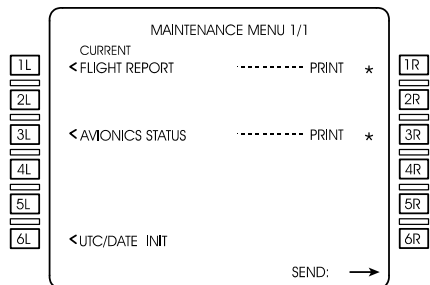
Example of use





A330 Central Maintenance System

Example of use (cont'd)



MAINTENANCE CURRENT FLIGHT REPORT				LEG-00
AIRCRAFT IDENTIFICATION / F-GGEA DATE / MAR31		ENGINE ON/ENGINE OFF / 1015/1720		PRINTING DATE : APR02 TYC : 1406
FLIGHT NUMBER: AF 427		FROM/TO : LFBO/LFBT		
DESCRIPTION		FAULTS		
ATA 36-11 MESSAGE DISPLAYED ENG 2 BLEED FAULT	UTC : 1032 FLIGHT PHASE : TAKEOFF ROLL	ATA 36-11-42 SOURCE : BMC3 MESSAGE : THRM (5HA3)/FAN AIR-V (12HA3)/SENSE LINE	INERMITTENT	CLASS 1 IDENTIFIERS : CP1C CPC2
ATA 30-11 MESSAGE DISPLAYED ANTI-ICE F/O PROBE	UTC : 1033 FLIGHT PHASE : CLIMB	ATA 36-11-16 SOURCE : PHC2 MESSAGE : R STATIC PROBE (8DA2)/ PHC2 (6DA2)	HARD	CLASS 1 IDENTIFIERS : ADIRU1 ADIRU2 ADIRU3
ATA 24-53 MESSAGE DISPLAYED ELEC AC 1.1 BUS FAULT	UTC : 1822 FLIGHT PHASE : CRUISE	ATA 24-53-00 SOURCE : SDAC MESSAGES : POWER SUPPLY INTERRUPT	HARD	CLASS 1 IDENTIFIERS : CBMU

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