Airbus Technical Notes

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1. Aircraft general

1.1. Dimensions

Table 1. Aircraft dimensions

Wingspan	34.1m
Length	33.84m
MTOW	75.5t

Max range	3000nm
Min pavement width for 180° turn	20.5m
Turn extremity	Wing tip

1.2. Unpressurised areas

The radome, air conditioning compartment, main gear bay, nose gear bay and tail cone are unpressurised

1.3. Misc

3 cargo compartments - forward, aft and bulk.

1.4. Lighting

The dome light is the only cockpit lighting with battery protection. The dim position is therefore recommended for takeoff.

The sliding potentiometers under the FCU control FCU lighting. The left controls integral lighting of labels, knobs and switches. The right controls the FCU display brightness.

If the strobe lights are set to AUTO, they will come on automatically at lift off. There are two sets of navigation lights, and the NAV light switch has a seperate position for each.

The AUTO position of the NO SMOKING sign puts the no smoking and exit signs on when the gear is extended and off when it is retracted. No smoking signs are always on on easyJet aircraft.

The "No Smoking", "Fasten Seat Belt", "Return to seat" and "Exit" lights automatically come on with excessive cabin altitude.

The EMER EXIT LT switch has OFF, ON and ARM positions. In the ARM position (the normal setting), the escape path lighting, EXIT signs and overhead emergency lighting come on automatically when normal electric supply is lost.

Taxi lights, takeoff lights and runway turnoff lights extinguish automatically when the landing gear is retracted.

Extension of the landing lights gives a LDG LT memo on the E/WD.

2. Auto flight

2.1. Overview

Main processing is carried out by two identical Flight Management Guidance Computers (FMGC) which normally work in tandem. Together they are known as the flight management guidance system (FMGS). The pilots provide inputs to the FMGS using two Multipurpose Control and Display Units (MCDUs) on the center pedestal and a flight control unit (FCU) on the glare shield.

The flight management part of the FMGS controls navigation, flight planning, performance optimization, predictions and display management. The flight guidance part provides flight director, autopilot and auto-thrust commands. The flight augmentation part provides flight envelope computation, maneuvring speed computation, windshear detection, α-floor protection and various yaw functions.

The FMGCs normally receive information from "on-side" sensors, and communicate between themselves to validate data. The FCU feeds both FMGCs.

The master FMGC is determined by autopilot and/or flight director engagement. FMGC1 is master if AP 1 is on, both autopilots are on or both flight directors are on. The autothrust is driven by the master FMGC. The flight directors are always driven from their on side FMGC.

If the cross talk between the two FMGCs is lost, the FMGCs can operate independently. This mode of operation is indicated by an amber IND light at the top of each MCDU. In independent mode, the same information must be entered into both MCDUs to receive the same guidance.

In the event of loss of an FMGC, the remaining FMGC continues to operate normally. If the lost FMGC was master, the A/P and A/THR will disengage. The AP of the healthy FMGC can be engaged, and subsequently the A/THR can be engaged. This situation, known as single mode, is indicated by an amber FM1 light at the top of the MCDU on the failed side. The MCDU will now be copy of the MCDU driven by the healthy FMGC. The FMA will annunciate e.g. 2FD2 to indicate that both flight directors are being driven from one FMGC. The healthy FMGC also tunes the offside navaids. To restore the ND on the failed side, the range and mode must be set identically to that set on the healthy side.

If an FMGC has a software problem, the FMGS will temporarily revert to single mode while the affected FMGC auto resets. This may result in autopilot and autothrottle disconnect and reversion to selected modes. MAP NOT AVAIL is shown on the ND of the affected side and the status page with a "PLEASE WAIT" message appears on both MCDUs. Use of the MCDUs should be avoided during the reset as it will increase the reset time. Reset usually takes a few seconds.

The FCU display is driven by two redundant FCU controllers. A single failure will have very little effect. A double FCU failure will lead to the loss of both autopilots, both flight directors and the autothrust. The autothrust will revert to thrust locked until the thrust levers are manually moved. All targets are lost on the PFD. The EFIS control panels are lost, leading to a reversion to STD, rose NAV 80nm on the NDs and a reversion needle selection of VOR1 and ADF2. Weather radar image is also lost.

A locked MCDU may be recovered by turning it off, then back on after five seconds. This failure is not automatically detected. An amber FAIL on the MCDU requires the same procedure.

2.2. FCU

{TODO: Add picture of FCU}

The FCU has two channels, each able to drive the entire FCU.

In general, turning a knob will select a guidance target and pulling it will then engage a mode to guide the aircraft to that target. Pushing a knob, on the other hand, engages a mode managed by the FMGS. When pushed, dashes and a white dot appear in the associated window.

Change over between speed and mach occurs automatically at approximately FL300, although this can be overridden with the SPD MACH button.

The HDG-VS/TRK-FPA button toggles the lateral mode between heading and track and toggles the vertical mode between vertical speed and flight path angle. It also toggles the display of the flight path vector (FPV) (or "bird") and Flight Path Director (FPD) on the PFDs. FMA lateral mode annunciation are HDG and TRACK respectively. The FCU displays HDG and V/S legends when in attitude mode and TRK and FPA legends when in flight path mode.

The altitude window contains the next applicable clearance altitude selected by the crew with the target altitude knob and is never dashed. Pushing the knob engages a managed mode which guides the aircraft to the target altitude while adhering to altitude constraints set in the FMGS. Pulling the knob gives a selected mode that disregards these FMGS altitude constraints.

The VS/FPA knob differs from the other three in that there is no associated managed mode. Pushing this knob commands an immediate level off. Negative indications on the FPA/VS display on the FCU indicate descent.

The "EXPED" button temporarily sets speed to best climb or best descent speed in order to expedite towards the target altitude.

The AP buttons engage one or both autopilots. The A/THR button engages or arms the autothrust. Disengagement of autopilot or autothrottle may be acheived by pressing a lit button, but this is not a recommended procedure.

2.3. FMA

The Flight Mode Annunciator (FMA) is displayed at the top of the PFD. It is split into 5 columns:

- Thrust
- Vertical
- Lateral
- Approach capability and DA/MDA
- FMGS engagement status

In certain modes the vertical and lateral columns combine to display "common modes" where the lateral and vertical modes are closely linked.

Each column has three lines. In the first three columns, the first line shows engaged mode, the second line shows armed modes and the third line shows reminders or messages.

When a mode changes, the mode is boxed on the FMA. A star next to a mode indicates a capture phase.

2.4. Flight director/ Autopilot

The flight directors come on automatically when the aircraft is first powered.

The AP can be used from just after lift off until the end of the landing roll-out. In most cases only one autopilot may be engaged at a time. The exception if on a coupled ILS approach, where the second autopilot may be engaged after arming approach.

Autopilots are disconnected by pushing the red pushbutton on either sidestick. Disconnection triggers a single aural alert and a temporary master warning with AP OFF message on the E/WD. A second push on the button cancels these warnings. Autopilots may also be disconnected by significant movement of the sidestick or rudder pedals, or by pushing a lit AP button on the FCU. This is treated as an involuntary disconnection and leads to a repeating aural warning and permanent master warning and message.

When flying manually with reference to the FD, the symbols for each PFD are driven by their on-side FGMC.

When taking off or landing on an ILS equipped runway, the flight director bars are replaced by a vertical green yaw bar to assist centerline tracking in LVOs.

When the bird is displayed, FD indications change to give FPA commands. The objective becomes to centre and align the bird with the green triangles at the wing tips. If TRK/VPA is selected when the basic modes are in force (HDG/VS), these modes automatically change to TRK and FPA.

2.5. Autothrust

Autothrust modes are automatically linked to AP/FD vertical modes. Autothrust speed mode, where the autothrust adjusts thrust to maintain a speed, is linked to trajectory type AP/FD vertical modes. Autothrust fixed mode is linked to AP/FD vertical modes where the speed is controlled by adjusting the aircraft attitude.

There are four detents on the throttle quadrant:

IDLE	
CL	Gives max climb thrust
FLEX/ MCT	Gives FLEX thrust for takeoff or max continuous thrust
TOGA	Give max takeoff or go around thrust.

The thrust levers do not move when autothrust adjustments are made. Instead, the thrust lever position controls the maximum thrust available to the autothrust system. It therefore does not operate when the thrust levers are at IDLE or in the reverse range.

The autothrust automatically arms when TOGA or FLEX/MCT is set for takeoff. At this point the thrust is still under manual control, indicated my a MAN indication in the FMA thrust segment. The autothrottle engages when the thrust levers are set to CL. Engagement is indicated by THR CLB appearing in green in the FMA thrust segment and A/THR appearing in the FMA engagement segment. In normal ops, the thrust levers are left at CL until retarded in the flare. Increased thrust may, however, be manually selected at any time by advancing the thrust levers beyond the CL detent. If an engine failure occurs, the autothrottle range is automatically extended to include the range between CL and MCT.

If autothrust disconnection is desired in flight, retard the thrust levers until the thrust lever position symbol roughly matches the present N1, then push the disconnect button on the side of the thrust lever. Autothrust may be completely inhibited for the remainder of the flight by holding one of these buttons down for more than 15 seconds.

2.6. Flight management

Each FMGC independantly calculates the aircraft position based on data from the ADIRS, the radio navigation aids and the GPS receivers. In normal ops, each FMGC uses the average position of the three IRSs. This is called Mix IRS. If an IRS fails, each FMGC uses a single IRS, either on-side or IRS3 as available. Each IRS also calculates a GPIRS position based on its own position and the average position indicated by the two GPS receivers. The FMGC uses only one of the three GPIRS positions which is automatically selected according to merit. The GPIRS data is subjected to integrity criteria, and if it fails, the GPS mode is rejected and the system falls back on radio position updating based on on-side auto-tuned radio navigation aids (DME,VOR and ILS). If this occurs, an amber GPS PRIMARY LOST message appears in the ND and the MCDU scratchpad.

The FMGC continually calculates a vector, known as BIAS, which represents the offset of the GPIRS or radio position (as available) from Mix IRS. The last known value of this vector is used to calculate the aircraft position if GPS and radio data become unavailable.

The FMGC also calculates an estimated position error (EPE) for RNP navigation purposes. EPE and FMGS database derived RNP are displayed on the MDCU. An ACCUR value is also provided. This is usually HIGH, but indicates LOW if EPE>RNP. If ACCUR is LOW, a RNPA NAV ACCUR DOWNGRAD warning is shown on the ND. If this occurs, or if GPS PRIMARY is lost, FM position should be manually cross checked with raw data. If the position is within 3nm, the FM position may continue to be used, but hourly raw data checks should be made.

The FMGS allows both a primary and a secondary flight plan to be entered. The secondary flight plan can be quickly activated when required.

When flying in NAV mode the aircraft is guided on a leg defined by a from and to waypoint. The to waypoint is shown in white on the MCDU and in the top right corner of the ND.

The flight plan is entered using the INIT page on the MCDU. It may be entered using a company route, a departure detination pair and manual entry of route or by sending a request for an active F-PLN initialization.

2.7. Rules for use of autoflight systems

Rules regarding FM navigation and flight planning

1. Crosscheck FM navigation accuracy periodically if GPS is not primary and whenever GPS PRIMARY LOST or NAV ACCUR DOWNGRADE messages occur. This is done by comparing the FMS bearing and distance to a beacon against raw data.

2. Ensure proper waypoint sequencing by monitoring the TO waypoint. If in heading mode with a large cross track error, waypoints will not be sequenced and will therefore require clearing manually.

3. Keep a flight plan discontinuity only when desired.

4. Anticipate your actions on the MCDU.

Rules regarding predictions

1. Predictions are based on the assumption that the F-PLN route is flown in managed modes. If the aircraft is off flight plan, a realistic trajectory for recapture is assumed.

2. Vertical deviation is shown on the altimeter as a round symbol (yoyo) in descent and against a scale as a brick in approach. In the latter case, 1 dot indicates 100ft deviation.

Rules regarding guidance

1. Engagement of the managed vertical modes (CLB and DES) is not possible in non managed lateral modes (HDG or TRK). If the lateral mode is changed to a non managed mode, the vertical mode will revert to a non managed mode (OP CLIMB in climb, V/S or FPA in descent).

2. NAV mode may be armed when HDG or TRK mode is used for F-PLN interception if the track crosses the active leg before the TO waypoint.

Rules regarding the displays

1. If GPS is not primary and the FM accuracy check is failed, raw data must be displayed on the ND.

2. Monitor FMS in managed modes. When NAV mode is used, monitor status on the FMA and adherence to required trajectory on ND. When CLB or DES modes are used, monitor altitude targets, speed targets and VDEV indications on PFD and pseudo waypoints on ND.

2.8. Guidance principals

A star after a mode on the FMA indicates a transitive capture mode, e.g. LOC* is displayed during the localiser capture maneuvre.

CLB is always associated to ALT mode. ALT will appear in the armed line in magenta if climb restrictions are associated with waypoints in the flight plan, otherwise it will appear in blue.

In DES mode, if the aircraft becomes high, the FMS prediction for regaining the profile assumes that half speed brakes will be extended.

When the aircraft reaches the cruise altitude set in the MCDU, ALT CRZ is displayed in the FMA. If the aircraft levels off prior to reaching this level, ALT is displayed.

RWY lateral mode provides lateral guidance from the start of the takeoff roll up to 30ft if a suitable LOC signal is available.

SRS (speed reference system) vertical mode provides vertical guidance up to acceleration altitude. As long as slats are extended and V_2 is available to the FMS, SRS engages automatically when power is applied for takeoff. It commands a speed of V_2+10 during normal operations. If an engine fails, V_2 is commanded. SRS also maintains a minimum rate of climb without regard to speed control to provide windshear protection. At acceleration altitude SRS is automatically replaced by CLB mode, which accelerates the aircraft to initial climb speed.

NAV mode engages automatically at 30ft provided a RWY and SID have been inserted in the flight plan.

Thrust reduction is indicated by a flashing LVR CLB message in the message area of the FMA thrust segment. Thrust levers must be manually moved to the CLB detent, wherupon the autothrottle will engage.

The localiser may be intercepted in NAV mode providing that accuracy is HIGH (i.e. epe>rnp) or GPS is primary.

In order to arm approach, the ILS and RA must be serviceable, both ILS receivers must be tuned to the same frequency and have the same course and the aircraft must be above 400ft. G/S* will generally not engage unless LOC* or LOC modes are active.

If the ILS ground transmitter becomes unserviceable during an approach, the deviation bars are removed, and the FD bars flash. The AP does, however, remain engaged in G/S and LOC modes.

If the aircraft suffers a dual ILS receiver failure, the deviation bars are replaced by failure flags, the guidance reverts to basic modes and the autopilot trips out.

LAND mode engages below 400ft when LOC and G/S modes are engaged. When LAND mode is engaged, inputs on the FCU are disregarded. It can only be disengaged by a go-around.

FLARE mode engages at 40ft. The FD bars are replaced by the yaw bar and the AP/FD commands a suitable pitch angle for the flare. If A/THR is active, an automatic RETARD call is made at 10ft.

Below 200ft, a red AUTOLAND warning will be triggered if:

- both autopilots trip off
- there is a loss of or excessive deviations in LOC (inhibited below 15ft)
- there is a loss of or excessive deviations in G/S (inhibited below 100ft)
- there is a disagreement in RA indications

The FMGS allows non precision approaches to be flown in managed mode as long as the approach is available in the nav database and the required aids and courses are manually set in the MCDU RADIO NAV page. Unless GPS PRIMARY is displayed, accuracy must be checked against raw data. Also, selected modes must be used if accuracy is LOW. The managed mode approach is armed with the APPR pb. If the lateral mode at this time is NAV, APP NAV will immediately engage. Otherwise it will arm, and will engage following the standard rules of NAV engagement. The vertical mode will arm FINAL and the FINAL APPR combined mode will engage when the preplanned decent path is intercepted. A V/DEV scale to the right of the attitude indicator then shows deviations from this path. The FINAL APPR mode disengages at MDA-50ft or 400ft AGL if MDA was not entered.

2.9. Protections

Engine failure compensation

If an engine fails with the AP on, the FMGC provides automatic yaw compensation. This is acheived using the yaw damper during take-off and go-around and the automatic rudder trim in all modes.

SRS pitch mode automatically adjusts the target speed if an engine fails during take-off or go-around.

Low speed protection

The A/THR will not fly speeds below V_{ls}, even if selected by the pilot.

When between 100ft and 2000ft and in configuration 2,3 or FULL, a drop in speed that is significantly below V_{ls}, taking into account deceleration rate and flight path angle, will trigger a repetetive "SPEED, SPEED, SPEED aural warning.

If angle of attack increases above a given threshold known as the alpha floor and the aircraft is above 100ft, the A/THR engages in A FLOOR mode and commands TOGA thrust. This occurs even if the A/THR is turned off. Alpha floor protection is usually available from lift off until 100ft RA on approach, but may be lost in cases of multiple failures and when an engine-out occurs above CONF 1. When A FLOOR mode exits, TOGA LK mode engages which locks the thrust at TOGA without regard to thrust lever position. To regain control of the thrust, the auto-throttle must be disengaged.

Windshear

Reactive windshear warnings are available from lift off to 1300ft at take off and from 1300ft down to 50ft on landing, provided at least CONF 1 is selected. It triggers an aural "WINDSHEAR, WINDSHEAR, WINDSHEAR" alert and a red WINDSHEAR message is displayed on the attitude indicator.

When SRS mode is engaged a minimum rate of climb is commanded regardless of speed. If the angle of attack gets too great, the autopilot disengages, but pilot assistance is still provided by the fly by wire maximum angle of attack protection.

In approach, the GS mini function adjusts speed with wind variation, ensuring that ground speed does not drop below a minimum value.

Mode reversions

When an altitude that is lower than the current altitude is selected during climb or an altitude higher than the current altitude is selected during descent, the vertical mode reverts to VS at the current rate of climb or descent.

If the lateral mode is changed from a managed to an unmanaged mode when the vertical mode is CLB, it will revert to OP CLB. The aircraft attitude will not change, but altitude constraints will be lost. Similarly a change to unmanaged lateral mode in descent leads to DES changing to VS with the current rate of descent. Again, aircraft attitude is unchanged.

With FDs engaged and AP disengaged, if failure to follow flight director commands with the A/THR in THR IDLE mode results in speed dropping to V_{ls}-2kt (V_{ls}-17kt with speedbrakes extended), the flight director bars are removed. This causes the A/THR mode to revert to SPEED and the target speed to be recaptured. Similarly, if the aircraft speed reaches V_{max}+4kt with the A/THR in THR CLB mode, the A/THR will revert to SPEED to recapture the target speed.

3. Air conditioning

3.1. Cockpit and cabin

Figure 1. Air conditioning controls

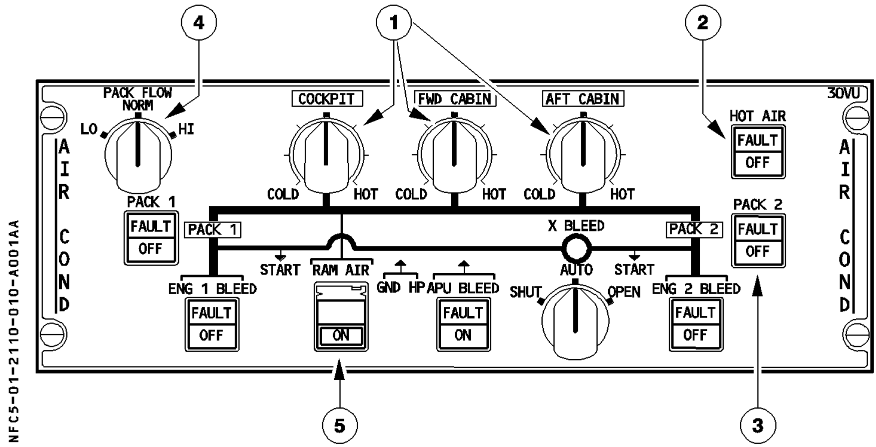
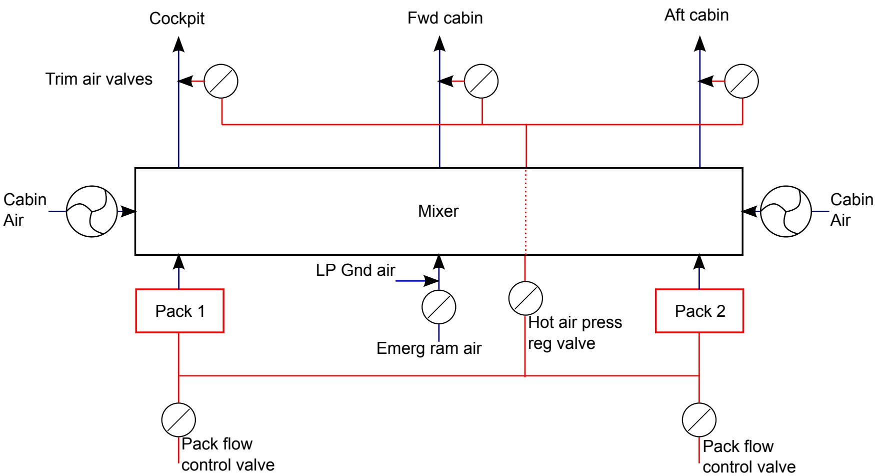


Figure 2. Simplified air conditioning schematic



The air conditioning system is controlled by two dual lane air conditioning system controllers. They provide inputs to the pack flow control valves, the packs, the hot air pressure regulating valve (controller 1), the cockpit trim air valve (controller 1) and the cabin trim air valve (controller 2). There is no effect from a single lane failure, as the backup lane takes over all duties.

The pack flow control valves regulate flow of warm pre-conditioned air (originating from the pneumatic system) to the packs. They are pneumatically operated, electrically controlled and spring loaded to the closed position. They automatically close when a pack overheats, during starting or when either the fire or ditching push buttons are pressed. They can also be manually closed by pushing the related PACK button (Figure 1, "Air conditioning controls" (3)). The amber light in this button indicates valve position disagreement or pack overheat (monitored at compressor outlet and pack outlet).

The PACK FLOW selector (Figure 1, "Air conditioning controls" (4)) allows the selection of flow rate from 80% to 120%. If only one pack is in use or the APU is supplying bleed air, the system will deliver high flow regardless of this selection.

Each pack consists of an air cycle machine and a ram air duct for the heat exchangers. The air cycle machine turbine also drives a cooling fan that draws cool air over the heat exchangers. Temperature in the pack is regulated by bypassing air around the air cycle machine via a turbine by-pass valve and by modulating the ram air intake flaps. These flaps are closed during take-off (take-off power set, main gear struts compressed) and landing (main gear struts compressed, speed above 70kt until speed less than 70kt for 20 seconds) to avoid FOD ingestion. In the event of failure of the air cycle machine the pack may still be operated with reduced flow using the heat exchanger only.

The cooled air from the packs is then fed into a mixer unit where it is mixed with recirculated air from the cabin. The mixer then supplies air to three independent zones, the cockpit, the forward cabin and the aft cabin.

Temperature requirements of between 18°C and 30°C are set on the air conditioning panel (Figure 1, “Air conditioning controls” (1)), and cabin zones may be trimmed ±2.5°C by controls on the forward attendants panel. The output temperature for each zone is a function of actual temperature (measured by sensors in the cockpit and in the lavatory extraction circuit and galley ventilation systems) and demanded temperature. Controller 1 regulates cockpit temperature and controller 2 regulates cabin temperature. The packs are controlled to provide air at the lowest temperature required, then the temperature of the other zones is trimmed by mixing in hot air that has bypassed the packs via the hot air pressure regulating valve and trim air valves. If temperature requirements cannot be met the system will attempt to increase flow. If LO flow is selected, the system will override to NORM flow. The system can also increase flow by increasing bleed pressure by requesting increases in engine minimum idle or APU flow output as required.

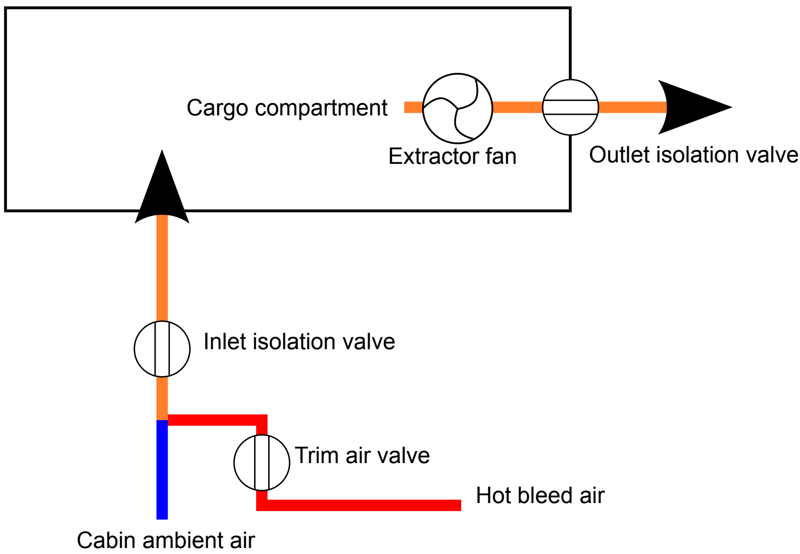
The hot air pressure regulating valve is pneumatically operated, electrically controlled and spring loaded to the closed position. It closes automatically in the case of a duct overheat (which also closes the trim valves), if either the cockpit trim valve fails or *both* cabin trim valves fail, or if both lanes of a system controller fail. It can be closed manually with the HOT AIR button (Figure 1, “Air conditioning controls” (2)). If the hot air pressure regulating valve fails open, there is no effect as the trim valves take over its duties. If it fails closed, optimized regulation is lost and the packs are used for all regulation (pack 2 controls to the mean of FWD and AFT temperatures). The amber FAULT light in the HOT AIR button indicates duct temperatures in excess of 88°C. It will extinguish once temperature drops below 70°C and OFF is selected.

Control of zone temperature is provided by a Zone Control Computer. This computer controls the trim valves and provides data to the pack controllers. It is dual channel. Failure of a single channel gives a ALTN MODE indication on the ECAM COND page. If a dual channel failure occurs, there is no trimming and zone temperature is purely a function of pack outlet temperature. A dual channel failure produces a PACK REG legend on the ECAM COND page, with amber crosses shown for the trim system and zone temperatures.

The mixer may also be supplied with ram air. This is controlled with the RAM AIR push button (Figure 1, “Air conditioning controls” (5)) and is used in the case of double pack failure or smoke removal. A check valve located in the ram air duct opens only when cabin differential is less than 1 psi, thus preventing backflow if the cabin is pressurised. The RAM AIR push button also opens the outflow valve to approx. 50% if the outflow valve is under automatic control and differential pressure is less than 1 psi. Since operation of the ram air valve leads to aircraft depressurisation, it should not normaly be operated above FL100/MORA. Opening of the ram air duct is inhibited if the DITCHING button has been pressed. When parked, low pressure conditioned air may be fed into the ram air duct to allow ground conditioning. The packs must be turned off when LP ground air is used.

3.2. Cargo compartments

Figure 3. Simplified schematic of cargo bay air conditioning



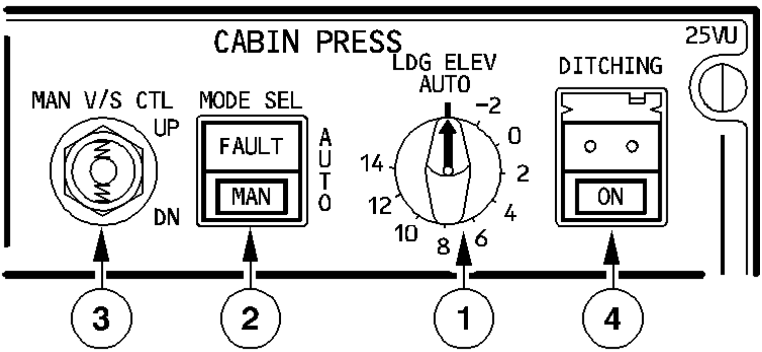
Cargo compartment air conditioning is fully automatic. Ambient cabin air enters the compartment via an inlet isolation valve. An extractor fan or differential pressure is used to exhaust the air overboard via an outlet isolation valve. Operation of the two valves and the extractor fan is controlled automatically by a cargo ventilation controller.

Cargo compartment heating is provided by hot bleed air that enters via a trim air valve. This valve is controlled by a cargo heating controller. The bleed air source for trimming the forward hold is the same duct that is used for trimming the cockpit and cabin and thus uses the same hot air valve. The rear compartment has its own independent hot air valve.

The cargo heat panel is on the right hand side of the overhead panel. Two rotary selectors set temperature in the compartments, with the normal 12 o'clock position being approx. 16°C.

4. Pressurisation

Figure 4. Pressurisation controls



Pressurisation control is provided by an outflow valve and two safety valves, one to prevent over-pressurisation (>8.6 psi), the other to prevent under-pressurisation (>1 psi below ambient).

Two identical cabin pressure controllers, one acting as master, the other as a reserve, provide automated control of pressurisation. Each controller has an associated motor with which to modulate the outflow valve. A third motor provides for manual control. The pressure controllers exchange roles 70 seconds after each landing.

The LDG ELEV selector (Figure 4, “Pressurisation controls” (1)) can be set to AUTO or to an altitude. In AUTO the controller uses the landing elevation from the FMGC. If using a manually selected landing elevation, the CAB ALT on the ECAM PRESS page should be used rather than the coarse scale.

The landing QNH is usually sourced from the FMGC. If this is not available, the captain's baro reference from the ADIRS is used.

The automatic pressurisation control operates in 6 modes:

Ground(GN)	Before takeoff and 55 seconds after landing, the outflow valve is fully opened. At touchdown any residual cabin pressure is released at a cabin vertical speed of 500 fpm.

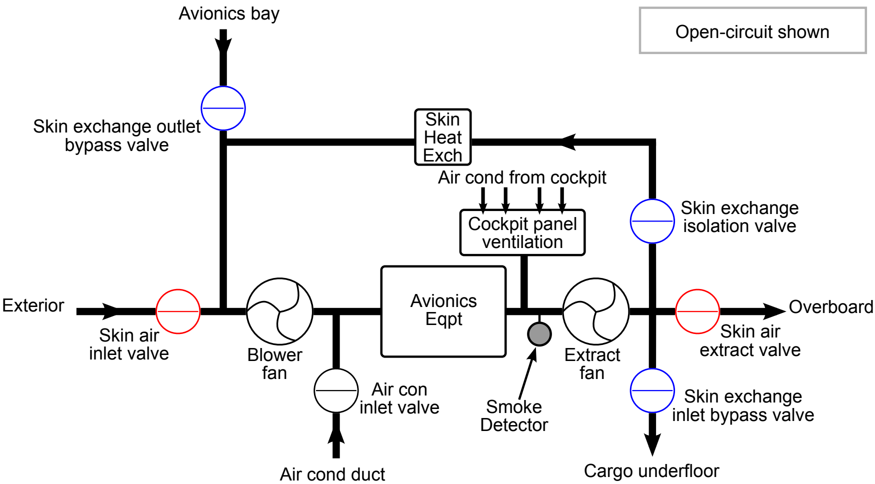
Takeoff(TO)	The aircraft is pre-pressurised to 0.1 psi diff at a rate of 400 fpm.
Climb(CL)	Cabin altitude if a function of actual rate of climb.
Cruise(CR)	The higher of cabin altitude at level-off or landing field elevation is maintained.
Descent(DE)	Cabin rate of descent maintained so that cabin pressure equals landing field pressure, with a maximum R.O.D. of 750fpm.
Abort(AB)	Cabin pressure set to take-off altitude + 0.1 psi.

If a single pressure controller fails, the other automatically takes over. If both pressure controllers fail, an amber FAULT light appears on the MODE SEL push button (Figure 4, “Pressurisation controls” (2)). Pressing this button puts the pressurisation in manual mode, and the spring loaded MAN V/S CTL toggle switch (Figure 4, “Pressurisation controls” (3)) must be used to control the pressurisation. When in MAN mode, the CAB V/S display on the ECAM CRUISE page changes to a gauge format to assist with manual control. Changing to manual mode for 10 seconds and then back to auto mode will cause the pressure controllers to swap roles.

The outflow valve is below the ditching water line. Pressing the ditching button (Figure 4, “Pressurisation controls” (4)) closes the outflow valve unless it is under manual control. Note that use of the ditching button and low pressure ground air will cause a build up of differential pressure.

5. Avionics ventilation

Figure 5. Simplified avionics cooling schematic



Ventilation of the avionics is primarily provided by two fans, one acting as a blower, the other as an extractor. Control is provided by the Avionics Equipment Ventilation Computer (AEVC). The system's normal modes are:

Close-circuit
: Used when skin temperature is low. The skin exchange outlet bypass, inlet bypass and isolation valves (shown in blue in Figure 5, "Simplified avionics cooling schematic") are open and all other valves are closed. This leads to air being drawn from the avionics bay and exhausted into the underfloor of the cargo bay, with a return loop via the skin heat exchanger.

Intermediate
: Used in flight when skin temperature is high. This is similar to close-circuit except the skin air extract valve is partially opened to allow some air to exhaust overboard.

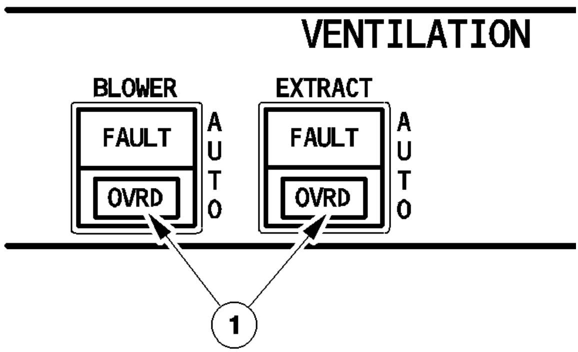
Open-circuit
: Used for ground operations (oleo compressed, thrust below TO) with a high skin temperature. In this mode only the skin air inlet and extract valves (shown in red in Figure 5, "Simpli-

fied avionics cooling schematic") are open, meaning air from outside the aircraft is moved across the avionics equipment and then exhausted externally.

The skin temperature thresholds are different for flight and ground cases and incorporate a dead band to prevent rapid mode switching. The bands are 9°C to 12°C on the ground and 32°C to 35°C in flight.

Cooling of the cockpit panels is provided by drawing air conditioned air from the cockpit over the panels in all modes.

Figure 6. Avionics ventilation controls



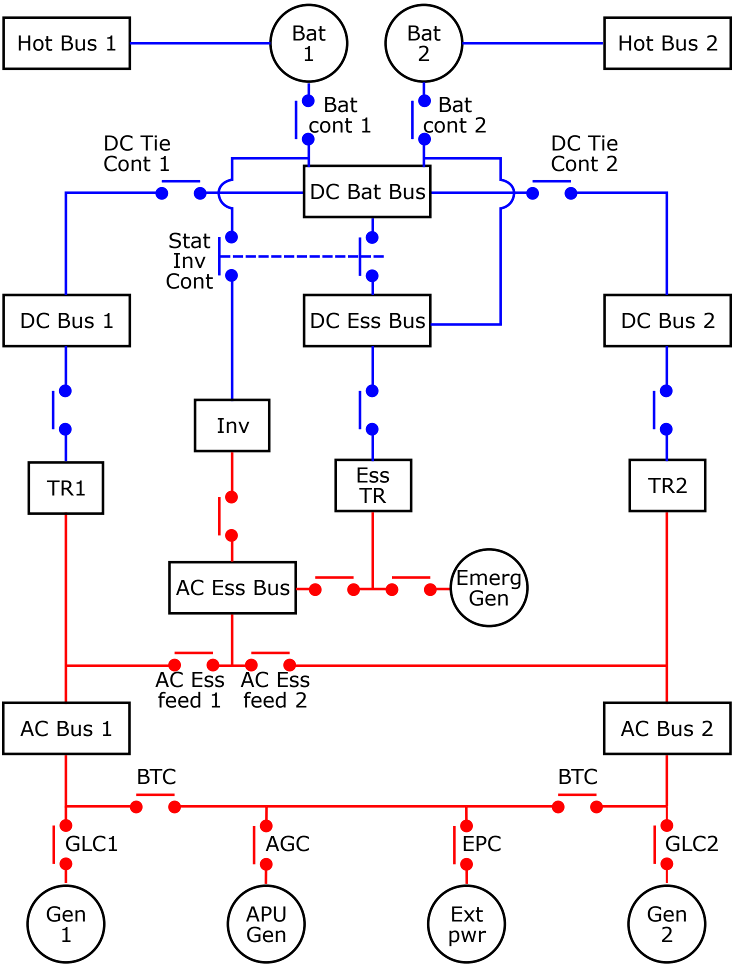
If a fault occurs with one of the fans, a FAULT light will illuminate on the associated button (Figure 6, "Avionics ventilation controls" (1)). The BLOWER FAULT light is also used to indicate a duct overheat. Selecting OVRD puts the system in closed-circuit configuration and opens the air conditioning inlet valve so that air conditioned air assists with the cooling. If the BLOWER button is in OVRD, the blower fan is stopped. If the EXTRACT button is in OVRD, the extract fan is controlled directly from the pushbutton and both fans continue to run. {TODO: There appears to be a conflict between the text and the diagram with regards to the action of the skin exchange inlet bypass valve when EXTRACT is in OVRD. The diagram essentially indicates air con as sole intake and no exhaust!}

A smoke detector is situated immediately upstream of the extract fan. If smoke is detected both FAULT lights come on. Selecting OVRD on both buttons puts the system in smoke removal mode. This is similar to open-circuit except the intake air is provided by the air-conditioning rather than from outside the aircraft and the blower fan is stopped.

{TODO: Controller failure - manual is very unclear what happens here.}

6. Electrics

Figure 7. Simplified schematic of electrical system



The electrical system consists of a three phase 115/200V 400Hz AC system and a 28V DC system.

Primary AC supply is from two 90 KVA engine driven integrated drive generators (IDGs). Each IDG has an associated generator control unit (GCU) which provides frequency, voltage and generator line contactor (GLC) control. A third 90 KVA generator is driven by the APU. This generator, along with ground power, is controlled by the Ground and Auxiliary Power Control Unit (GAPCU). Each of the three main generators is capable of supplying the power requirements of the entire system. The generators cannot be connected in parallel, and are automatically brought on line according to priority rules. The IDGs are highest priority, followed by EXT PWR when connected, followed by the APU generator.

A 5KVA hydraulically powered (blue system) constant speed emergency AC generator and associated GCU provide power in the event of failure of normal sources. In addition a 1KVA static inverter supplies emergency power to part of the AC essential bus if the batteries are the only remaining power source.

Primary DC power is provided by two 200A transformer rectifier units with automatic protection circuits that disconnect the TR in the event of overheat or minimum current. A third identical TR, the "essential" TR provides power for the DC Essential bus in the event of loss of all normal AC generators (the Ess Tr is capable of drawing power from the emergency AC generator) or in the event of loss of one or both of the main TRs.

Two 23Ah batteries are also provided for emergency DC power. Each has an associated battery charger limiter (BCL) to monitor charging and control its battery contactor. The minimum required offline battery voltage is 25.5V. If the battery voltage is below minimum, they can be recharged by connecting the batteries to the battery bus and applying external power for approximately 20 minutes. In the event of failure of all other power sources, the batteries can provide emergency power for approximately 30 minutes.

Two types of CB are fitted. Monitored CBs are green and trigger ECAM warning messages when out for more than one minute. Non-monitored CBs are black and do not cause ECAM warnings. The Wing Tip Brakes (WTB) CBs have red caps to prevent them being reset.

In normal flight, the AC Busses are supplied via a their associated generator and the AC Ess Bus is supplied from AC Bus 1 (i.e. AC Ess feed 2 is open). TR1 supplies DC Bus 1, the battery bus and the DC essential bus, and TR2 supplies DC Bus 2 (i.e. DC Tie Cont 2 is open). When battery charging is required the BCL closes the required battery contactor to connect the battery to the DC Bat Bus.

If a single engine driven generator is lost, the system will automatically replace it with the APU generator if available, or else it will shed part of the galley load and route power from the other engine driven generator. If all main generators are lost, AC Bus 1 and AC Bus 2 are lost. If aircraft speed is sufficiently high (> 100kt) a ram air turbine (RAT) automatically deploys. This powers the blue hydraulic system which, in turn, powers the emergency AC generator. Once this generator is online (approx 8 seconds for RAT deployment and generator coupling), it powers the AC Ess bus, the Ess TR and hence the DC Ess bus. If the RAT stalls or the aircraft speed is below 100kt, the AC Shed ESS and DC shed ESS buses are shed and the remains of the essential system are powered via the batteries and static inverter. Once on the ground, the DC bus is automatically connected to the batteries below 100kt and the AC Ess Bus is shed below 50kt.

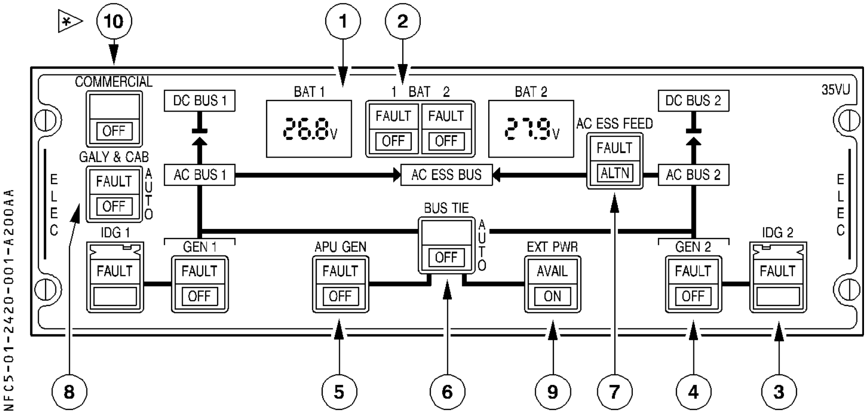
A "smoke configuration" is provided that sheds 75% of electrical equipment, the remaining 25% being controlled by easily accessible CBs on the overhead panel (with the exception of equipment attached to the hot busses). It is essentially the same as for the loss of all main generators, except the fuel pumps are connected upstream of the Gen 1 line connector.

If AC bus 1 fails, power for the AC Ess bus must be re-routed from AC bus 2. Automatic re-routing is available on some aircraft. Manual re-routing is achieved by pressing the AC Ess feed pushbutton. TR1 is lost causing the Ess TR to supply the DC Ess bus and, after a 5 second delay, DC bus 2 to provide power to DC bus 1.

If both main TRs are lost, DC Bus 1, DC Bus 2 and the DC Bat bus are lost. The DC Ess bus is powered by the Ess TR.

With the engines shut down on the ground, either the APU or external power may be used to supply the entire system. In addition, external power can supply the AC and DC GND/FLT buses directly without supplying the entire system using the MAINT BUS switch in the forward entrance area.

Figure 8. Electrical controls on overhead panel



When an IDG must be disengaged, the IDG button should be pressed and held until the Gen FAULT light comes on, but should not be held for more than 3 seconds.

In the event of a generator having out of limit load but continuing to power its AC bus, the amber FAULT light in the GEN button will not illuminate.

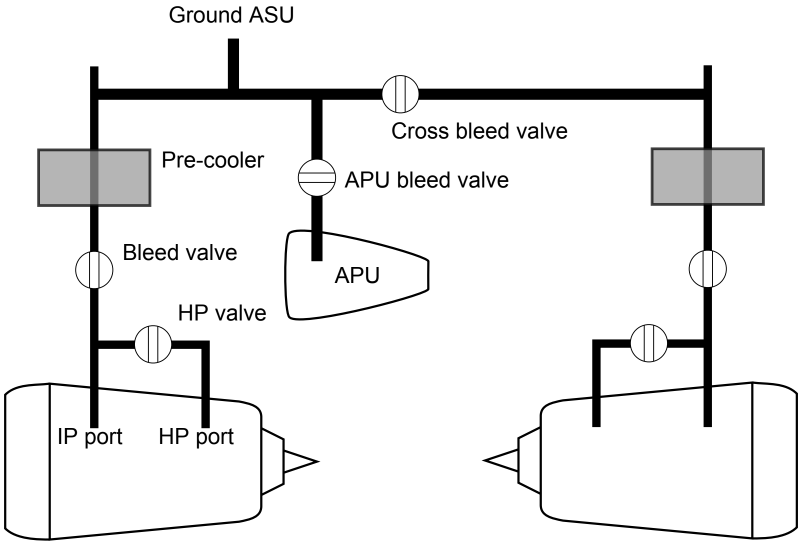
Pressing the BUS TIE button (OFF position) manually opens the bus tie contactors (BTCs). In this case, only IDG 1 can supply AC 1 and only IDG 2 can supply AC 2. This may be used to isolate a short circuit that has affected both halves.

7. Pneumatics

The pneumatic system provides high pressure air for:

- Air conditioning
- Wing anti icing
- Water pressurisation
- Hydraulic resevoir pressurisation
- Engine starting

Figure 9. Simplified schematic of pneumatic system



The sources of air are:

- The engines
- The APU
- High pressure gound air

Two Bleed Monitoring Computers, one per engine, control and monitor the pneumatic system. They are partially redundant, so in the event of a failed BMC, the other BMC can take over most of its functions.

Sensors in the vicinity of the hot air ducts detect leakage. If leakage is detected, the BMCs are signalled and they automatically shut down the affected area.

Engine bleed air is tapped at two compressor ports known as the Intermediate Pressure (IP) port and the High Pressure (HP) port. The HP port only provides air when the IP pressure is insufficient. The system automatically controls the delivery of air from the HP port using an HP valve.

The pre-cooler uses cold air from the engine to cool the bleed air.

The APU bleed air has priority over the engine bleed air. The engine bleeds valves will therefore remain closed whenever the APU bleen is ON.

The GND indication on the ECAM bleed page is always displayed on the ground, even if no ground HP unit is connected. Its purpose is solely as an indication as to where ground HP air would enter the system. The presence of ground HP air can be determined by examining the bleed pressures relative to attached sources. APU bleed air should not be connected when HP ground air is in use.

A single engine bleed can supply both packs. It can only supply one pack, however, when supplying the wing anti ice system.

8. Communications

Three radio management panels (RMP), two on the center pedestal and one on the overhead panel, and three audio control panels (ACP), each located next to an RMP, control radio communications. The RMPs also provide a backup for radio nav aid tuning.

Each RMP can tune any communication radio. Usually, however, RMP1 is dedicated to VHF1, RMP2 to VHF2 and RMP3 to VHF3 or HF. A white SEL light illuminates when a radio that is not dedicated to an RMP is selected. Note that the standby frequency is specific to the RMP, not the radio currently being tuned.

The ACPs incorporate SELCAL and interphone call alerts. When any of these calls occurs, a buzzer sounds and the relevant transmit button flashes amber. The RESET button is used to silence these alerts. The VOICE key supresses a nav aid's ident so that voice transmissions can be heard more clearly.

A CALLS panel situated in the left lower corner of the overhead panel.The MECH button illuminates a light on the external power panel and sounds an external horn. Pressing either the FWD or AFT buttons causes a high/low chime in the cabin and a "CAPTAIN CALL" message to appear at the selected cabin station. The ALL button does the same, except the message appears at all cabin stations. Activation of the emergency call system, either initiated by the flight crew by pressing the EMER button or initiated by the cabin crew, causes the CALL light in the EMER button to flash amber and the ON light to flash white. If the call is to the cabin, three high/low chimes sound in the cabin. If it is from the cabin, three long buzzers sound on the flight deck.

The CVR, when activated, records the last two hours of communications and aural warnings from the cockpit. It is controlled from the RCDR panel. In AUTO mode, it runs for five minutes after power is applied to the aircraft, then automatically shuts down. It then restarts after first engine start and continues running until five minutes after the last engine has been shut down. Pushing the GND CTL pushbutton manually powers the CVR on the ground. The CVR ERASE and CVR TEST buttons are inhibited unless GND CTL is ON, the aircraft is on the ground and the parking brake is set. Pushing the CVR ERASE button for two seconds erases the CVR recording. Pushing the CVR TEST button sounds a tone through the loudspeakers if the CVR is serviceable.

The system monitors the communication radios and will produce an ECAM warning if there is continuous transmission.

A switch on the overhead panel allows for deselection of a failed ACP and its replacement by ACP3.

9. APU

The APU may be started with DC from the batteries or with AC. The APU panel is located at the bottom centre of the overhead panel. External APU controls are located on the external power panel in the nose gear bay.

To start the APU, first press the master switch button, then the start button. The start sequence begins when the APU inlet flap is fully open.

To shut down the APU, turn off the master switch. If the APU bleed has been used, the shutdown sequence incorporates a delay of between 60 and 120 seconds before shutting down. As long as the AVAIL light is still displayed, the shut down sequence can be cancelled by turning the master switch back on. If APU bleed has not been used, the shutdown is immediate.

The APU control is completely automatic. Auto-shutdown is available whenever the APU is running. Automatic deployment of the APU extinguisher is also available on the ground. APU emergency shutdown is initiated by pressing the APU fire button or by pressing the APU SHUT OFF button on the external panel. An APU fire in flight will show the APU FIRE procedure on the ECAM, followed by the APU EMER SHUT procedure. On the ground, a fire will cause the APU AUTO SHUT DOWN procedure to be shown after the APU fire procedure.

The LOW OIL LEVEL on the ECAM indicates that the APU can only be used for a further 10 hours before maintenance is required. The amber FUEL LOW PR indication occurs during start if fuel pressure is low. It is only an advisory.

9.1. Limitations

Table 2. APU limitations

APU bleed air with 2 packs	15,000ft
APU bleed air with 1 pack	22,500ft
Battery restart limit	25,000ft
Operation and restart ceiling	39,000ft
APU elec power	39,000ft

10. Cabin

The Cabin Intercommunication Data System (CIDS) consists of two directors, one active and one hot standby. The CIDS communicates with cabin, passengers and crew via Decoder Encoder Units (DEUs) and is programmed and tested via a Programming and Test Panel (PTP).

The Forward Attendant Panel (FAP) is located at the purser station and consists of:

- An optional air conditioning panel
- A lighting panel
- An audio panel
- A water and miscellaneous panel

The PTP is located behind a hinged access door to the left of the FAP. It is equipped with a Cabin Assignment Module (CAM) containing airline specific data. It is the PTP communicates system status to the crew.

The Aft Attendant Panel (AAP) is located at the rear left crew station. It allows control of a subset of cabin systems.

An Attendant Indication Panel (AIP) is located near each main cabin crew station. It displays communication and system related messages.

Area Call Panels (ACP) are located in the ceiling at either end of the cabin. Their indications are:

Pink steady or pink flashing	Crew communication
Blue steady	Passenger call
Amber steady	Lavatory call
Amber flashing	Lavatory smoke detection

The controls on the main doors consist of an opening handle with an associated mechanical door status indicator located towards the top of the door and a slide arming lever with associated status indicator just above the lever. An emergency opening cylinder and assocated pressure gauge are situated in the door support and a white gust lock button is located on top of the door support. Each door has an observation window, and two indicators are fitted at the bottom of this window. The first is a cabin pressure indicator which flashes red if the cabin is still pressurised when the engines are shut down and the slide is disarmed. A white indicator illuminates as the opening handle is first moved if the slide is armed.

The overwing exits have a single opening handle with a protective cover. If the cover is removed, a white "SLIDE ARMED" light will illuminate.

The slides deploy automatically if the doors are opened when the slide is armed. A red manual inflation handle is provided on the right side of the girt bar for the main doors and in the exit frame for the overwings. The main door slides are single lane, and the overwing slides are dual lane. All slides are fitted with integral lighting and emergency lights are fitted to the aircraft below the overwing exits to illuminate the route to the slide. Red handles are fitted to the sides of the slide near the bottom to allow the slide to be used as a rag slide in case of pressure loss. The main door slides have a white handle under the girt bar cover that allows the slide to be quickly detached from the aircraft. It will remain attached to the aircraft by a tether, and a knife is provided to cut this tether. In case of ditching, it is possible to transport a slide from an inoperative door and deploy it from an operative door once that door's slide has been detached.

Emergency oxygen generators are fitted above each row of passenger seats, above each cabin crew station and in the lavatories. The generators start automatically when any of the masks attached to it are pulled down.

An emergency evacuation system is fitted, with contols on the FAP, AAP and cockpit. An EVAC panel is situated on the left of the overhead panel. The CAPT & PURS/ CAPT switch determines which stations can initiate an evacuation alert.

11. Navigation

11.1. Air Data and Inertial Reference System (ADIRS)

There are three identical Air Data Intertial Reference Units (ADIRU). In general ADIRU 1 and ADIRU 2 supply on-side systems and ADIRU 3 is a hot spare. Each ADIRU combines an Air Data Reference (ADR) computer and a laser gyro based Inertial Reference (IR) system. The two sub-units are completely independent. The ADR part gathers data from aircraft probes and sensors, and provides the following data to other systems:

- Airspeed and Mach number
- Temperature
- Barometric altitude
- Angle of attack
- Overspeed warnings

The IR part provides the following data:

- Attitude

- Heading
- Aircraft position
- Track
- Acceleration
- Ground speed
- Flight Path Vector

The ADIRS control panel is located at the top left of the overhead panel. ADR controls are at the bottom of the panel and IR controls are at the top, with the rotary selectors affecting both sub-systems. The ON BAT light indicates that the IRs are being powered by the aircraft batteries. This light will illuminate for a short time during the self-test at the start of the alignment sequence. The ALIGN lights are illuminated steady during the alignment sequence, and should extinguish after approximately ten minutes when the sequence is complete. The lights will flash white under the following conditions:

- IRU alignment fault
- No present position entered on the INIT page of the MCDU after 10 minutes from the start of alignment sequence.
- The entered position differs from the shutdown position differs by more than 1°.

A display, keypad and selectors are provided for viewing IR information directly on the ADIRS panel. The TEST position tests the lights on the keypad and provides a test pattern on the display. If HDG is selected on the display during alignment, a time to navigation (TTN) readout is shown.

IR realignment is usually uneccessary on turn arounds. If an IR has a residual ground speed >5kt (shown on one of the NDs for IR1 and 2 and on the ADIRS panel for IR3) a quick align should be carried out. This is acheived by selecting the OFF position on the IRS selectors then reselecting NAV within 5 seconds.

The ADIRS have a comparator feature and will alert the crew to differences in the attitudes displayed on the PFDs. The faulty data can be determined by cross checking with the standby attitude indicator and the third ADIRU can then be selected as required.

11.2. Radio navigation

FMGCs auto-tune VORs, ILSs and DMEs for position updating. The ADFs are only auto tuned under specific circumstances. Manual tuning of the aids is via the RAD NAV MCDU page. When aids are manually tuned, FMGC auto tuning continues in the background. If an ILS approach is selected the PFDs show the on-side ILS and the NDs show the off-side ILS.

If both FMGCs fail, radio aids may be tuned using the nav mode of RMP1 and RMP2. The RMPs tune their on-side VORs, DMEs and ADFs. The ILS frequency tuned on either RMP is sent to both ILSs. When a NAV key is pressed on an RMP, the RADIO NAV page blanks, showing only the titles. DME information will ot be displayed on the PFD for an ILS/DME tuned on an RMP.

Standby display of radio data is provided on the DDRMI. This combines a traditional RMI presentation with raw DME data for any selected VORs. The compass card displays the bearing supplied by ADIRU 1.

11.3. Standby instruments

A standby ASI, altimeter and attitude indicator are provided to the right of the captain's ND and a pull down standby compass is fitted on top of the windshield centre post. The standby attitude indicator is the only standby instrument requiring electrical power. It will operate for approximately five minutes after a total electrical failure.

11.4. EGPWS

The EPGWS normal inputs are:

- RA1
- ADIRS1
- ILS1
- FMGC1

- LGCIU1

The basic GPWS has no forward looking capability - it mainly monitors RA1 for potentially hazerdous values or trends. The warnings and alerts provided are:

Condition	**Alert**	**Warning**
High descent rate at low level	"Sink rate"	"Whoop whoop pull up"
Rising ground	"Terrain, Terrain"	"Whoop whoop pull up"
Rate of descent during initial climb or go around	"Don't sink"	None
Gear and/or flaps retracted close to ground	"Too low terrain", then "Too low gear" or if gear is down "Too low, flaps"	None
Significantly below ILS glideslope	"Glideslope"	"Glideslope" (louder)

The "Glideslope" alert and warning are accompanied by an amber G/S light on the GPWS warning light. All other alerts and warnings give a red GPWS warning.

Some basic GPWS warnings may be supressed using the GPWS panel on the left side of the overhead panel. The most common supression is GPWS FLAP 3, used for flap 3 landings. FLAP MODE OFF is used for landings below flap 3. G/S MODE inhibits glideslope warnings. The system can be completely deactivated by pressing the SYS button.

The EGPWS system provides a look ahead capability by comparing caution and warning terrain envelopes generated from a terrain database to FMGS position data and baro data from the Captain's altimeter. Both en-route terrain and runway clearance floor envelopes are provided. The extended functions are inhibited when navigation performance is LOW.

The terrain is displayed on the ND when the TERR ON ND putton on the center panel is pressed. Areas not included in the database are color coded magenta. Dotted red areas are more than 2000ft above the aircraft, dotted orange areas more than 1000ft above the aircraft and amber areas are between 1000ft above and 500ft below (250ft below with gear down) the aircraft.

The EGPWS derived en-route *caution* generates a "Terrain Ahead" aural alert combined with an GPWS red light, a TERR AHEAD amber message and conflicting terrain displayed solid yellow on the ND. The en-route *warning* generates "Terrain ahead, pull up" and the message and terrain are displayed in red in the ND. The clearance floor alert generates a "Too low terrain" aural alert. The terrain display is automatically shown in all cases {TODO: check true for CF case}.

The enhanced functions may be inhibited with the TERR button on the GPWS panel. A failure in the extended functions will cause an amber FAULT light on the SYS button, but this will not affect basic GPWS functions.

EPGWS warnings are overridden by stall or windshear warnings.

The system can be tested by pushing the GPWS/GP warning light.

11.5. Radio altimeter

There are no cockpit controls for the radio altimeters. They self test when AC power is first applied to the aircraft, then enter a standby mode. They become active at lift off and operate continuously until touchdown.

Rad alt data is displayed whenever below 2500ft radio height. This consists of color coded digits at the bottom of the attitude indicator, a red ground bar on the altimeter scale and a white ground bar on the attitude indicator. The ground bar merges with the horizon at touch down. Radio heights are also announced by a synthetic voice during approach.

If a single radio altimeter fails, data from the remaining one will be displayed on both screens.

12. Fire protection

12.1. Engine and APU

Each engine has an identical fire detection system, comprising two parallel detection loops monitored by a fire detection unit (FDU). Normally, both loops must indicate a fire to produce a warning. The loops are monitored and automatically disabled if they malfunction. Loss of a single loop produces a level 1 ECAM warning. Loss of both loops, or loss of an FDU, leads to a level 2 ECAM warning indicating loss of fire detection capability on that engine. If both loops break within 5 seconds, a fire warning is triggered. Each engine has a guarded fire button on the overhead fire panel. This lights up to provide fire indications. When pushed, the fire button pops out as a physical indication of activation. Pushing the fire button arms the squibs and closes the following on the affected engine:

- Pneumatic bleed valves
- Pack valves
- Fuel valves
- Hydraulic valves

The APU has an identical fire detection to the engine. When pushed, the APU button ... {TODO}

Each engine has two fire bottles and the apu has a single fire bottle. These are discharged by pressing one of the AGENT buttons situated near their respective fire buttons. The APU fire extinguisher may also be discharged automatically in the case of an APU fire on the ground. Secondary engine fire indications are provided by fire lights on the pedestal ENG panel, and a secondary external APU fire indication, together with a guarded APU SHUT OFF button, is provided on the EXTERNAL POWER panel. Once a fire is extinguished, the light in the fire button will extinguish.

Test buttons for each system are situated near their respective fire button.

12.2. Cargo

There are two detector loops for the cargo compartments. Each loop has two detectors in the aft cargo compartment and one in the forward. A Smoke Detection Control Unit (SDCU) receives indications from these detectors and forwards them to the FWC which displays warnings on the CARGO SMOKE panel. If smoke is detected, the inlet and exhaust valves for the affected cargo bay are automatically closed. A single fire bottle is provided for both compartments. The aft compartment has two nozzles, and the forward compartment only one. When a DISCH button is pushed on the CARGO SMOKE panel, the bottle is completely emptied into the selected compartment. Smoke warnings will not extinguish once a fire is extinguished as the smoke will remain isolated in the cargo compartment and the smoke detectors are sensitive to the extinguishing agent.

12.3. Other

A smoke detector is provided for the avionics in the air extraction duct. Its operation is detailed in Section 5, “Avionics ventilation”.

Each lavatory has a smoke detector. These are conected to another SDCU which transmits data to the flight warning computer (FWC) and cabin intercommunication data system (CIDS). Each lavatory waste bin has an automatic fire extinguishing system.

13. Ice & rain protection

13.1. Wing anti-ice

The three outboard slats of each wing are anti-iced using hot bleed air from the pneumatic system. APU bleed air must not be used for wing anti-icing. Each wing has a single electrically (DC ESS SHED) operated valve that controls flow of air to the slats. Both valves are controlled by a single WING button on the anti-ice panel. The valves fail closed in the event electrical power is lost.

Selecting wing anti-ice causes the FADECS to decrease N1 limit and increase idle N1.

If a hot air leak is detected, the wing anti-ice valve on the affected side automatically closes.

If the WING button is pushed on the ground, a 30 second self test of the wing anti-ice system is initiated. If left on, the valves will open automatically once airborne.

13.2. Engine anti-ice

The engine air intakes are anti iced using an independent air bleed from the HP compressor. For each engine, hot air is routed via an electrically controlled (DC1 and DC2), pneumatically operated engine anti-ice valve to the intake. These are controlled by the ENG1 and ENG2 buttons on the anti-ice panel. The valves close if no air is available, but fail open if electrical power is lost.

The fan blades are not anti-iced. If icing conditions last longer than 30 minutes or significant icing induced engine vibrations occur, the fan ice can be shed by running the engines up to 70% N2 for 30 seconds [FCOM 3.3.9.1000] (n.b. parking brake limitation of 75% N1 [FCOM 3.1.32.1000]). This run up should also be carried out just prior to takeoff if conditions require it. In freezing rain, freezing fog or heavy snow, ice shedding can be enhanced by momentary run ups to 70% at intervals of less than 10 minutes.

13.3. Window heat

The windshield and side windows are heated electrically. Each side has an independent Window Heat Computer (WHC) that automatically regulates the system and provides overheat protection and fault detection. The window heat operates whenever at least one engine is running. On the ground, the windshield heat operates in a low power mode, with an automatic changeover to normal power once airborne. The windows only have one heating level. If window heat is required before engine start it can be switched on manually with the PROBE/WINDOW HEAT button on the anti-ice panel.

13.4. Probe heat

The pitot heads, static ports, AOA probes and TAT probes are elecrically heated. The Captain's probes, F/O's probes and standby probes each have an independent Probe Heat Computer (PHC). These provide automatic regulation, overheat protection and fault detection. The probes are heated whenever at least one engine is running. On the ground, the pitot heating operates at low level and the TAT probes are not heated. Changeover to normal heating is automatic once airborne. If probe heat is required before engine start it can be switched on manually with the PROBE/WINDOW HEAT button on the anti-ice panel.

13.5. Other

Each front windshield has a two-speed electric wiper controlled by a rotary selector. The maximum speed for wiper use is 230kt [FCOM 3.1.20].

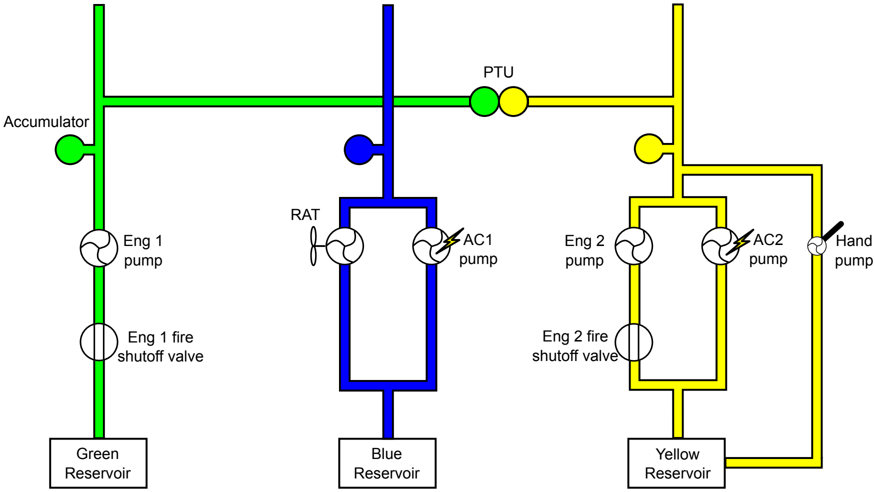
In moderate to heavy rain only [FCOM 3.4.30.4000], rain repellent can be applied to the windshield. Each windshield has an independent RAIN RPLNT button that applies a measured quantity when pressed. The rain repellent is stored in a nitrogen pressurised bottle in the rear cockpit. If the pressure gauge is in the yellow or the REFILL float is visible, the bottle needs replacing. A smell of orange peels in the cockpit may indicate a toxic leak of rain repellent fluid. A smell of pine needles may indicate a non-toxic leak [FCOM 3.2.26.6000].

An external lighted visual ice detector is installed between the two windshields.

The water drain masts are electrically heated. This heat is reduced when on the ground.

14. Hydraulics

Figure 10. Simplified schematic of hydraulic system



There are three continuously operating hydraulic systems, designated green, yellow and blue.

Each hydraulic system has its own reservoir. The reservoirs are pressurized by bleed air to prevent cavitation. The normal source is engine 1, but if pressure becomes low bleed air is taken from the cross-bleed duct. The reservoirs are monitored for low fluid level, low air pressure and overheat.

The green and yellow systems are normally pressurized by engine driven hydraulic pumps. These pumps have a upstream shutoff valve that cuts off the flow of hydraulic fluid when the associated engine fire button is pushed. The yellow hydraulic system may also be pressurized by an electric pump. This pump may be powered by either AC2 or external power. It operates automatically to partially pressurize the yellow system when the cargo doors are moved. It may be selected on manually using a switch on the hydraulics panel, in which case it fully pressurizes the yellow system. Operation is signified on the ECAM HYD page by the hollow white triangle next to the word ELEC becoming solid green. A hand pump is provided to partially pressurize the yellow system and enable the cargo doors to be opened in the absence of electrical power.

The blue system is normally pressurized by an electric pump powered by AC1. This pump operates whenever AC power is available unless the aircraft is on the ground with both engines shut down. In this case it may be operated using the BLUE PUMP OVRD pushbutton on the maintenance panel.

In an emergency situation, the blue system may also be pressurized by a Ram Air Turbine (RAT). The RAT deploys automatically if both AC BUS 1 and AC BUS 2 are lost. It may also be deployed manually using the RAT MAN ON button on the hydraulics panel. The RAT cannot be restowed in flight. Deployment of the RAT is indicated on the ECAM HYD page by the hollow white triangle next to the word RAT turning solid green.

The engine driven pumps and the electric pumps supply 3000psi. The RAT supplies 2500psi. The pumps are all monitored for low output pressure. The electric pumps are also monitored for overheat.

A Power Transfer Unit (PTU) allows cross pressurization between yellow and green systems without transfer of fluid. It activates automatically when differential pressure between the two systems is greater than 500psi. The PTU is inhibited during the first engine start and self tests during the second engine start sequence. The PTU is also inhibited during, and for 40 seconds after, automatic operation of the yellow electric pump. Operation of the PTU is indicated by a HYD PTU memo appearing on the E/WD.

An accumulator is provided for each system to help maintain constant pressure during transient demands. Each system also has a priority valve to cut off heavy users (flaps, slats, gear, emergency generator) if system pressure gets too low to operate the flight controls.

Each system has a leak measurement valve upstream of the primary flight controls. These can be closed by operation of switches on the maintenance panel. The effect of closing these valves is to shut off hydraulic supply to the primary flight controls.

The flight controls all receive hydraulic power from at least two sources. This is detailed in {TODO: add flight controls xref here once its done}. The other hydraulic systems are powered as follows:

Table 3. Hydraulic power source of systems (excluding flight controls)

Green	Yellow	Blue
• Landing gear • Normal brakes • Eng 1 reverser • Yaw damper 1	• Nose wheel steering • Alternate and parking brakes • Eng 2 Reverser • Yaw damper 2 • Cargo doors	• Emergency generator

15. Landing gear

The main gear are dual wheel and retract inboard. The nose gear is also dual wheel, and retracts forward.

The main gear are equipped with:

- Carbon brakes
- An anti-skid system
- An automatic braking system
- A brake fan
- A Tyre Pressure Indicating System

The nose gear is equipped with a nose wheel steering system.

The gear and gear doors are controlled by two Landing Gear Control and Interface Units (LGCIUs). Gear sequencing is electrical and actuation is hydraulic (green system). A complete gear cycle is controlled by a single LGCIU, with an automatic toggle to the other LGCIU at the end of each retraction. There is also an automatic switchover if a failure is detected. A seperate safety valve is also incorporated. This shuts off hydraulic pressure to the actuators when the aircraft exceeds 260kt, and restores pressure only when the gear lever is selected down with the aircraft below 260kt.

Emergency extension of the gear is possible. This is acheived through a cut off valve that isolates the landing gear from the hydraulics and by manually removing gear and door uplocks. The gear extends via a combination of gravity, aerodynamic forces and locking springs. The gear doors will remain open after extension. Emergency extension is controlled by a crank located at the rear of the center pedestal. Reset is possible in flight.

The LGCIUs also gather and processes data from proximity detectors on:

- Gear locks
- Shock absorber struts
- Gear doors
- Cargo doors
- Flaps (flap disconnect only)

Gear lock position and gear door position are presented on the ECAM WHEEL page and on the LDG GEAR indicator. On the ECAM page, each gear is represented by two triangles, one per LGCIU. When down and locked, the triangles are green. When unlocked, the triangles are red. When fully retracted, the triangles are not shown. A green indication on either triangle is sufficient to determine that the gear is down and locked. The lights on the LDG GEAR indicator are controlled by LGCIU 1 only, and have their standard meanings.

The LGCIUs uses the shock absorber position to supply air/ground data to various client systems.

The gear, gear door and shock absorber proximity detectors are monitored for electrical failure. If a proximity detector suffers an electrical failure, flight condition is assumed for the detector (i.e. shock absorber extended, landing gear uplocked), and the unaffected LGCIU takes over landing gear operation. Mechanical failure of proximity detectors is not monitored. In the event of electrical failure of an LGCIU some client systems may receive incorrect air/ground data.

A subset of the cargo door proximity detectors are monitored for electrical failure. When these fail, a non locked condition is assumed.

Data from the flap disconnect proximity switches is forwarded to the SFCCs. SFCCs are not monitored by the LGCIUs.

The nosewheel steering is controlled electrically by a dual channel Brake and Steering Control Unit (BSCU) and actuated hydraulically (yellow system). The BSCU receives steering requests from the steering handwheels, the rudder pedals and the autopilot. The steering handwheels have authority for 75° of nose wheel deflection up to 20kt, reducing linearly to 0 at 80kt. If inputs are made on both handwheels, the request generated is the sum of the deflections requested. The rudder pedals have authority for 6° of deflection up to 40kt, reducing linearly to 0 at 130kt. The steering servo valve is electrically inhibited when the aircraft is on the ground and when neither engine is running. It may also be inhibited with the ASKID NWSTRG switch or with the towing contol lever. When the steering is deactivated with the towing control lever "NW STRG DISC" is displayed on the memo display and the nosewheel can be moved through 95°.

A switch is provided on the steering handwheel to electrically disconnect the rudder pedals from the BSCU in order that rudder control checks may be carried out.

The nosewheel is centered after takeoff by an internal cam mechanism.

Two braking systems are provided. The normal system utilises green system hydraulics, and the alternate system uses the yellow system. The alternate system also has a backup hydraulic accumulator designed to supply at least seven full brake applications or provide parking brake pressure for a minimum of 12 hours.

Braking requests may be initiated by rudder pedal deflection, by the autobrake system or automatically during gear retraction. When the normal system is active, these requests are processed by the BSCU. When the alternate system is active, they are processed by the Alternate Braking Control Unit (ABCU). The alternate system is activated automatically when green system pressure is insufficient or manually using the ASKID NW STRG switch.

The BSCU also provides:

- Antiskid (available with both systems via seperate servo valves)
- Residual pressure checking
- Brake temperature monitoring
- Wheel speed monitoring

The master BSCU channel automatically toggles at each DOWN selection of the landing gear lever, or when a fault is detected.

The anti-skid system determines wheel slip ratio by comparing aircraft speed from the ADIRUs with tyre speed from tachometers on the wheel. When tyre speed reduces to 0.87 of aircraft speed, a servo valve is actuated to release the brakes. If all ADIRUs have failed, the maximum main gear speed may be used to approximate aircraft speed. The anti-skid will be unavailable with complete BSCU failure or when yellow and green hydraulic sytems are both lost. It may also be turned off with the ASKID & NW STRG switch. If the anti-skid system is not available, brake pressure is automatically limited to 1000psi.

The autobrake system allows braking to be applied on a deceleration schedule. It is only available with the normal braking system. It is armed by selecting the LO, MED or MAX autobrake pushbutton switches (MAX is for RTO and can only be selected on the ground). Activation is linked to ground spoiler extension. The autobrake system will therefore not activate on an RTO where speed remains less than 72kt since the ground spoilers will not automatically deploy below this speed. LO mode applies the brakes 4 seconds after ground spoilers deploy and decelerates the aircraft at $1.7m/s^2$. MED mode applies the brakes 2 seconds after ground spoilers deploy and delerates the aircraft at $3m/s^2$. MAX mode applies maximum brake pressure as soon as the ground spoilers deploy. The green DECEL light on the AUTOBRK selector indicates that at least 80% of the required deceleration rate has been acheived. The system is deactivated when the ground spoilers retract, or when it is disarmed. Disarming occurs automatically when the landing gear is fully retracted. The system may also be disarmed by manually braking or by deselecting the armed autobrake pushbutton.

The parking brake applies full pressure from either the yellow hydraulic system or accumulator via the parking brake control valve. If no pressure is available from these sources, the normal braking system is enabled and the brake pedals may be used.

THE BSCU also sends brake temperature data to the ECAM WHEEL page. If any brake is >100°C, a green arc appears on the ECAM page. If the temperature exceeds 300°C, an amber arc appears, indicating that takeoff must be delayed to let the brakes cool. If the brake fans are on, the brake temperature sensors are not accurate. Takeoff must be delayed if brake temperatures are over 150°C with the brake fans on. After landing, if the brake temperatures on one gear differ by more than 150°C or the difference in the mean temperature of each gear exceeds 200°C, maintenance action is required.

Brake wear indicators are provided on the brakes. They must be checked with the parking brake on. If any of the brake wear indicator is showing, the brake unit is serviceable.

During gear retraction, the main gear is automatically braked. The nose gear is braked by a brake band.

Various messages may be displayed on the ECAM WHEEL page. The UPLOCK message on the ECAM WHEEL page indicates that the landing gear is down and locked with an uplock engaged. The L/G CTL message on the ECAM wheels page indicates a discrepancy between demanded landing gear position and actual position.

16. Flight controls

16.1. Overview

The primary flight controls consist of:

- Ailerons
- Elevators
- Trimmable Horizontal Stabilizer (THS)
- Rudder
- Ground spoilers/ Speed brakes

The ten spoilers (five each side) have several functions, each using different surfaces:

Speed brakes	Use the 3 central surfaces to increase drag.
Roll control	Use the four outer spoilers to assist in rolling the aircraft.
Ground spoilers	Deploy all spoilers to dump lift to get weight on the wheels.

Seven flight control computers take input from the sidestick, analyse it to ensure it is a safe command, then use it to manage the control surface servos. There are:

- Two Elevator and Aileron Computers (ELAC)
- Three Spoiler and Elevator Computers (SEC)
- Two Flight Augmentation Computer (FAC)

Two Flight Control Data Concentrator computers (FCDC) process data from the ELACs and SECs for use by the EIS. The FACs send their data directly. The FCDCs are redundant. Failure of both FCDCs will lead to flight control data not being available to the EIS.

Two FLT CTL panels, one on either side of the overhead panel, are used to control the flight control computers.

Each pair of flight control computers is redundant. The SEC3 is only used for spoiler control, and does not participate in flight control system reconfiguration.

The ailerons, elevators and pitch trim are powered by two independent actuators, each powered by a seperate hydraulic source. The rudder is powered by three independent actuators. Each actuator is controlled by a different computer. At any one time, one actuator will be in active mode, and the other will be in damping mode. In the event of a flight control computer failure, the actuators controlled by that computer will automatically be switched to damping mode, and those controlled by the other computer will become active.

If both ELACs fail, active control of the ailerons is lost and they revert to damping mode. SEC2 takes over control of the elevators and the stabilizer. Roll function is provided by the spoilers. If SEC2 also fails, it will be replaced by SEC1.

With an elevator fault, the remaining elevator remains operative, but its deflection limits are reduced to prevent excessive torsional loads on the tail. Normal flight is possible in this configuration. If the elevators are lost entirely, they are automatically set to the neutral position.

Providing suitable hydraulic power is available, mechanical control of the stabiliser and rudder is always available.

Each spoiler is fitted with a single actuator. If a hydraulic system fails, its associated spoiler will remain in its last position unless pushed down by aerodynamic forces. Spoiler control is shared by the three SECs. Failures are shown on the ECAM F/CTL page by an amber number above the failed spoiler. An amber triangle above the number indicates a failure in the extended position. If possible, the spoiler will be automatically retracted by its controlling SEC and then it and its symmetrical pair on the opposite wing will be inhibited.

Under certain conditions, speed brake extension is inhibited and spoilers are automatically retracted. This may lead to a SPD BRK DISAGREE ECAM caution.

Auto ground spoilers are armed by pulling the spoiler lever up to expose a white collar. A memo on the E/WS confirms arming.

Rudder trim is isolated in flight when the autopilot is engaged. Its position is shown by a blue line on the ECAM F/CTL page.

When the autopilot is engaged, speed brakes will not deploy past approximately half, even if the speed brake lever is moved to full.

The "SPEED BRK" memo on the E/WD will flash amber if speed brakes are extended and any engine is above idle.

Auto ground spoilers deploy automatically when both main gear are compressed and thrust levers are at idle or behind. If only one main gear is compressed, the spoilers only partially deploy. They will automatically retract if power is applied for a go-around.

Lift augmentation devices consist of:

- Five slats on each leading edge
- Two flaps on each trailing edge

The lift augmentation devices are hydraulically actuated. They are electrically controlled by two Slat Flap Control Computers (SFCC). Each SFCC has two channels, one for the slats and one for the flaps. The SFCCs are redundant, but a system associated with a failed channel will move at half speed.

When flaps are selected, both ailerons are dropped by about 5°. This is indicated on the ECAM F/CTL page by the aileron position indicator pointing to a boxed position on the scale rather than there normal double dashed position.

The flaps have an auto retract function. In configuration 1+F, the flaps will automatically retract when airspeed reaches 210kt. There is no corresponding automatic slat retraction, so this is known as configuration 1.

When deploying flaps when airborne, selecting 1 on the flap lever only moves the slats - i.e. configuration 1 is acheived rather than 1+F.

Flap and slat faults are indicated in amber on the flap/ slat display on the E/WD. Locked flaps or slats may be caused by the Wing Tip Brakes (WTB) locking the affected surface movement if assymmetry, overspeed, symmetrical runaway or uncommanded movement are detected. WTBs cannot be released in flight. The slats and flaps have independant WTBs, so locked flaps will not cause locked slats, and vice versa. An ALIGNMENT FAULT indicates flap attachment failure.

A-LOCK pulsing blue on the E/WD indicates that the slats have been locked due to high angle of attack and/or low speed.

The rudder deflection is limited depending on speed by the rudder travel limiter. The current rudder travel limit is shown on the F/CTL ECAM page by white ticks below the rudder scale.

16.2. Side sticks

The side sticks are spring loaded to neutral and do not provide feedback. They are not interconnected. If both side sticks are operated at the same time, their inputs are added algebraically. If this happens, a "DUAL INPUT" aural warning is activated and green lights show on the SIDE STICK PRIORITY warning lights. Dual inputs are not recommended.

When the autopilots are engaged, the side sticks are locked in neutral. If the lock is overcome, the autopilot is disconnected.

The button on the side stick is dual function. If an autopilot is engaged, pushing the button will disconnect the autopilot and pushing it a second time will silence the associated warning. If no autopilot is engaged, pressing and holding the button prioritises the side stick. This results in a "PRIORITY LEFT/RIGHT" message and a red arrow indication on the opposite side stick priority warning light. Moving the low priority sidestick now just results in a green light in the side stick priority light on the prioritised side. If both priority buttons are pushed, the last pressed will give priority. The opposite sidestick can be permanently deactivated by pressing and holding the button for 40 seconds. In this case, a momentary push on either button will reactivate the deactivated side stick.

On the ground, a combined side stick deflection indicator is shown as a white cross on the attitude indicator. This only indicates side stick positions, not control surface positions. Control surface positions are shown on the ECAM F/CTL page, which is automatically called if either the sidesticks or the rudder pedals are moved on the ground. The side sticks become operable on the ground as soon as hydraulic power becomes available (i.e. after first engine start).

16.3. Normal Law & protections

Normal law operates in three modes:

Ground mode	Conventional controls when the aircraft is on the ground and electrically and hydraulically powered.
Flight mode	Operates in the air after a gradual transition from ground mode, commencing at lift off.
Flare mode	Introduces conventional feel to the landing phase. This is acheived by memorizing the aircraft attitude at 50ft, then progressively reducing this attitude, meaning the pilots must perform a gentle flare.

In flight mode, control surface deflection is not directly proportional to side stick deflection. Instead, side stick input is a rate of roll demand in roll and a load factor demand in pitch. Control surface movement will occur with no input on the side stick. An attitude is set with the sidestick and the sidestick is then allowed to return to its neutral position. As pitch and roll rate demands are now zero, the flight control computer holds the attitude until further inputs are made with the sidestick. Yaw control is conventional, but turn co-ordination and dutch roll protection are provided, meaning rudder inputs are not generally required.

Normal law provides the following protections:

Load factor limitation	Structural load is limited to: • +2.5g to -1g in clean configuration • +2g to 0g in flaps extended configuration
Pitch attitude protection	Pitch is restricted to a maximum of between 20° and 30° nose up (depending on configuration and speed) and a maximum of 15° nose down. The current limits are indicated by green dashes on the attitude indicator.
High angle of attack protection	Prevents the aircraft stalling and ensures optimum performance during extreme maneuvres. It takes priority over all other protections. $V_{\alpha\text{-prot}}$ is displayed as the top of an amber barber pole on the speed scale. This is the lowest speed that the aircraft is allowed to reach with the stick neutral. The pilot can override $V_{\alpha\text{-prot}}$ using the side stick and reduce to $V_{\alpha\text{-max}}$, which is represented by the top of the solid red bar on the speed scale. In the protection range, normal law demand is modified to be an angle of attack demand rather than a load factor demand. If the sidestick is released at $V_{\alpha\text{-max}}$ the speed will increase to $V_{\alpha\text{-prot}}$.
High speed protection	Prevents exceedance of V_{MO}/M_{MO}. This is shown on the speed scale as the bottom of the red barber pole. Green dashes indicate the speed at which protection activates. Momentary exceedance of V_{MO}/M_{MO} is allowed for maneuvring, but the speed will

	then return to protection speed. With stick released, the speed returns to V_{MO}/M_{MO}. When high speed protection is active, roll stability is augmented so that the aircraft will roll wings level if the sidestick is released.
Bank angle protection	Bank angle is limited to 67°, shown by green dashes on the bank angle scale on the PFD. The FD bars will disappear if bank angle exceeds 45°. If the side stick is released and the bank angle is >33°, the bank angle will return to 33°. Autotrim is inhibited above 33°. If the angle of attack or the high speed protection is active, bank angle is limited to 45°.

16.4. Reconfiguration laws

Overview

Whilst a single failure will not result in degradation of normal law, it is possible that multiple failures may.

Alternate law

Degradation to alternate law is annunciated on the E/WD as F/CTL ALTN LAW (PROT LOST). The effects are:

Ground mode	As in normal law,
Flight mode	Pitch as in normal law. Conventional roll control, i.e surface deflection proportional to side stick deflection. In yaw, turn coordination is lost and damping has limited authority.
Landing mode	Direct law when landing gear is selected down.

Load factor limitation is provided similarly to normal law. Pitch attitude protection is lost, indicated by the green pitch limit dashes on the attitude indicator being replaced by amber crosses. Bank angle protection is lost. Again, this is indicated by the green dashes on the bank angle scale being replaced by amber crosses.

The high angle of attack protection is replaced by low speed stability. Stall warning speed, V_{SW} indicated by a red baber pole on the speed indicator replaces the V_{α} indications. As speed approaches V_{SW} a progressive nose down pitch input is introduced. This can be overridden with side stick inputs. A "STALL,STALL" aural warning sounds at V_{SW}, and the aircraft will stall if the warning is ignored. Alpha floor protection is also inoperative in alternate law.

High speed stability replaces high speed protection. A nose up input is added when speed is above V_{MO}/M_{MO}. This can be overridden with sidestick inputs. As in normal law, an aural over speed warning is triggerred when V_{MO}/M_{MO} is exceeded.

According to the failures, it is possible that the stabilities will also be lost. In this case only load factor limitation and the stall and overspeed warnings remain.

Direct law

Direct law is indicated by the ECAM message FCTL DIRECT LAW (PROT LOST). In direct law, there is a direct relationship between side stick and control surface positions. There are no protections available, although stall and over speed warnings are still available. Auto-trim is not available. A "USE MAN PITCH TRIM" message appears on the FMA. Auto turn coordination and dutch roll damping are also lost.

Mechanical backup mode

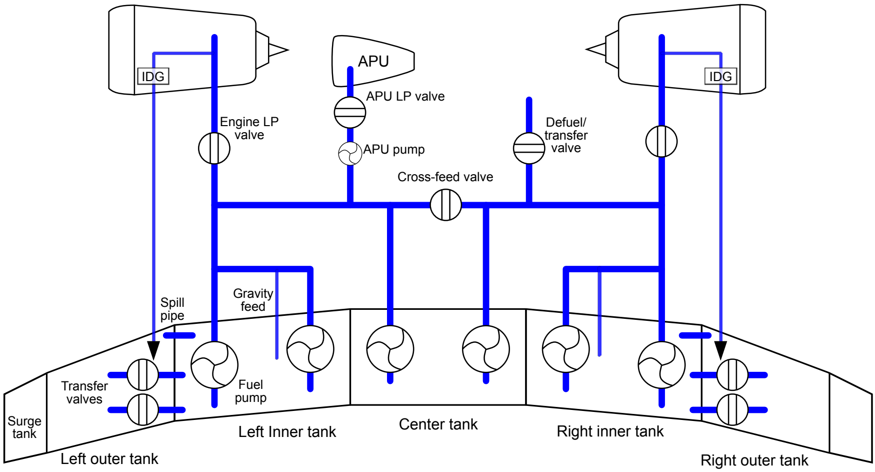
Pitch is controlled solely through the use of manual pitch trim. "MAN PITCH TRIM ONLY" appears on the FMA. Lateral control is solely through the use of the rudder pedals. In most cases, action can be taken to recover to either alternate law or direct law.

Abnormal attitude laws

In the event the aircraft attitude leaving the protected envelope, the flight controls revert to alternate law without the stability enhancements. Once the aircraft is recovered, it stays in alternate law. It will not, however, revert to direct law when the gear is deployed.

17. Fuel

Figure 11. Simplified schematic of the fuel system



Each wing incorporates an inner tank, an outer tank and a vent surge tank. A center tank is incorporated into the fuselage.

The outer tanks are used for wing bending and flutter relief. There are two electrical transfer valves connecting each outer tank to its associated inner tank. These are controlled by level sensors in the inner tanks. Each inner tank has two sensors, and each of these sensors controls a symmetrical pair of transfer valves. When any sensor detects the fuel level in an inner tank falling below approximately 750kg, it opens its symmetrical pair of transfer valves (i.e. one for each wing), allowing all outer tank fuel to transfer simultaneously to the inner tanks. This event is indicated by the E/WD memo "OUTER TK FUEL XFRD" and green triangles appearing in the outer tanks on the ECAM FUEL page. The transfer valves, once open, remain open until the next refueling operation.

The outer tanks are also connected to the inner tanks by a spill pipe. This allows fuel returned to the outer tanks by the fuel recirculation system (see below) to flow to the inner tanks if the outer tanks are already full. It is also used during refueling, since fuel destined for the inner tanks is routed via the outer tanks.

The vent surge tanks protect against thermal expansion of fuel. Fuel may expand by at least 2% (equivalent to Δ20°C) without spilling. There are no cockpit indications for these tanks.

The inner, outer and vent tanks each have overpressure protectors. The center tank has an overpressure protector connected to the left inner tank.

There are six electrical fuel pumps, two in the center tank and two in each inner tank. Under normal conditions the fuel system is split, with one center tank pump and the two same side wing tank pumps supplying each engine. A double motor cross feed valve, controlled by the X FEED button, allows the fuel system to be unified. A green OPEN light in this button indicates that the valve is in the fully open position.

The inner tanks incorporate suction valves that allow for gravity feeding of fuel in the event of loss of both pumps. The service ceiling of the aircraft may be affected if the fuel has not had time and altitude to deaerate. Gravity feeding is not available from the center tank.

The wing tank pumps operate continuously unless switched off with their associated TK PUMPS button. The #1 pump in each tank is powered by AC1 and controlled by DC1, and the #2 pump is powered by AC2 and controlled by DC2. The #1 pump in each tank also has an alternate power feed directly from its associated IDG, and an alternate control feed from DC ESS. The pumps incorporate pressure relief sequence valves in order that fuel is delivered preferentially from the center tank if the associated center tank pump is producing normal output pressure. An amber FAULT on their associated button indicates low delivery pressure with the button in the "On" position.

The center tank pumps have automatic and manual modes, controlled by a single MODE SEL button. The FAULT light in this button indicates that fuel is being burnt out of sequence, inferred from >250kg in the center tank with <5000kg in one of the wing tanks. In general, when in automatic mode a pump is inhibited whenever slats are extended, whenever its associated wing tank is full (with a latch until 500kg has been burnt from the tank) or once 5 minutes have elapsed since the center tank reached low fuel level. The exception is that for two minutes after its associated engine has been started, the pump is only inhibited by the center tank low fuel condition. This allows the center tank fuel lines to be pressurized if center tank fuel is going to be used. In manual mode, all "auto stop" logic is inhibited and the crew must provide the logic directly using the CTR TK PUMP buttons. The FAULT light in each of these buttons indicates low delivery pressure with the associated pump operating. The #1 pump is powered by AC1 and controlled by DC1, and the #2 pump is powered by AC2 and controlled by DC2. Note that takeoff with the center tank pumps operating is prohibited.

On the ECAM FUEL page, if a fuel pump is shown as an amber boxed LO, the pump is on but it is not producing adequate pressure. An amber box with a cross line indicates that a pump has been switched off manually.

Fuel pressure for APU startup is normally provided by the left hand side of the fuel system. If pressure is unavailable due to loss of tank pumps or loss of normal AC supply, an APU fuel pump can be used. This is normally powered by the AC ESS SHED BUS, but has an alternate feed directly from the AC STAT INV BUS.

The design of the engine fuel system (see Section 19.4, “Engine fuel system”) and the requirement for IDG cooling leads to some fuel being returned to the tanks. This is routed to the outer tanks and from there to the inner tanks via the spill pipe or transfer valves depending on the configuration of the fuel system. Overfilling is prevented by controlling the center tank pumps. Overfilling (and hence venting) is possible with the center tank pumps in manual mode.

The refuel coupling is situated under the wing outboard of the #2 engine, near the leading edge. The refuel panel is situated on the fuselage below the right wing. Fueling is usually automatic, controlled by setting the required quantity with the preselector rocker switch and selecting the MODE SELECT switch to REFUEL. Manual control is available by selecting the REFUEL VALVES switches to OPEN and SHUT as required. Fueling with battery power is available by momentarily selecting the BATT POWER switch to ON. Gravity fueling is also possible. The REFUELG memo on the E/WD only indicates that the refuel panel door is open.

A de-fuel/ transfer valve connects the right hand side of the fuel system to the refueling/ de-fueling gallery. It is opened by selecting the MODE SELECT switch to DEFUEL. An amber light illuminates next to the switch to indicate that the valve is open.

A Fuel Quantity Indication (FQI) system provides fuel mass, quantity and temperature data to the ECAM and controls automatic refueling. This system comprises an FQI computer, a set of capacitance probes to measure fuel level and temperature, a densitometer and a Capacitance Index Compensator (CIC) (used in case of densitometer failure).

Degradation of a fuel quantity sensor is indicated by two amber dashes across the last two digits of the FOB value. On the ECAM FUEL page, the affected tank also shows the dashes on its quantity value.

Fuel temperature exceeding a limitation results in a master caution and the fuel temperature of the affected tank being shown in amber on the ECAM FUEL page.

A shroud drain mast is situated under the fuselage. This drains any fuel that leaks from the system.

Each tank has a magnetic fuel level indicator to allow fuel to be measured manually. These should normally be flush with the aircraft surface. Each tank also has a water drain valve. These should be checked for leaks.

18. Oxygen

Both crew and passenger oxygen systems are pretty much identical to the Boeing. They are contolled by the OXYGEN panel located on the overhead panel. The system is monitored on the ECAM DOOR page.

Passenger oxygen automatically deploys when cabin altitude>14,000ft. It can also be manually released by the gaurded button on the OXYGEN panel. The PASSENGER SYS ON light illuminates when masks are deployed. There are approximately 13 minutes of passenger oxygen available.

The OXY legend on this page is amber until the crew oxygen supply is turned on. A half amber box is displayed underneath the unregulated oxygen pressure on this page when it is below 1500psi. This indicates that the MIN FLT CREW OXY CHART should be checked before flight.

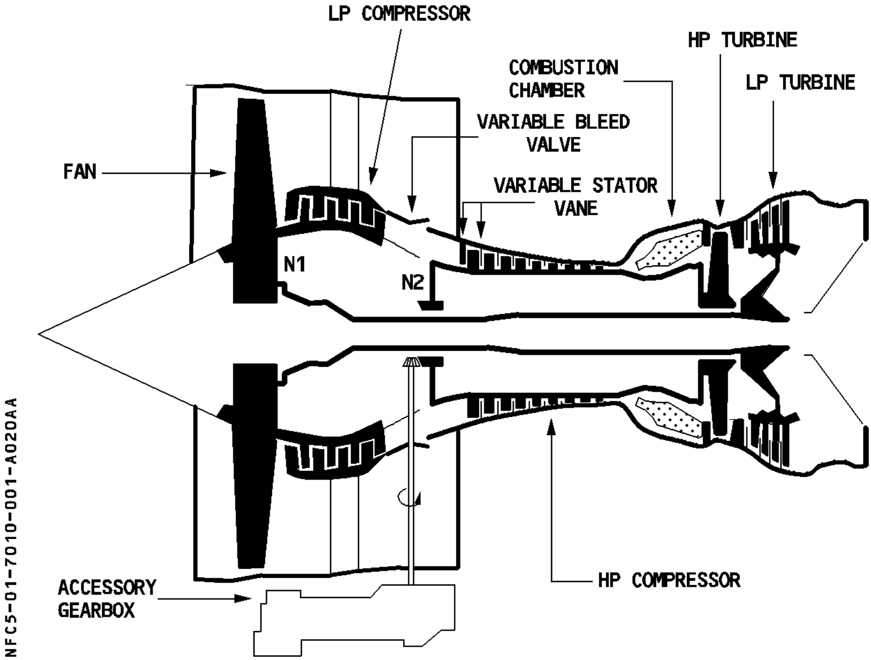
If the amber REGUL LO PR is displayed, the oxygen pressure at the regulator is low, and maintenance should be called.

The mask microphone is automatically energised when oxygen is flowing, either when being worn or when the test and emergency buttons are pushed together.{TODO: This is only inferred - check it is true}

19. Power plant

19.1. General description

Figure 12. Simplified schematic of CFM56-5B



The engines are designated CFM56-5B. Each engine has two rotors. The low speed N1 rotor consists of a front fan, a four stage compressor and a four stage turbine. The high speed N2 rotor consists of a nine stage compressor and a single stage turbine. The N2 rotor also drives an accessory gearbox located at the bottom of the fan case. The combustion chamber has 20 fuel nozzles and two igniters.

19.2. FADECS

Each engine is controlled by a two channel Full Authority Digital Engine Control System (FADEC), also known as the Engine Control Unit (ECU). One channel is active, the other is a standby with automatic failover. The active channel toggles after each flight {TODO: this is an assumption - check it}.

The FADECS are self powered by an internal magnetic alternator when N2>58%. Channel A may also be powered by DC ESS. Channel B may also be powered by BAT BUS for engine 1 and DC BUS 2 for engine 2. Pushing the FIRE button for an engine disconnects the FADECs from their external power sources. After power is first applied to the aircraft the FADECs power up for 5 minutes to allow self testing {TODO: again an assumption - to check}, then power down until IGN/START is selected on the ENG MODE switch. They continue to be powered for 5 minutes after their respective engine master switch is turned off.

Data for the FADECs is directly sourced from the ADIRS, engine sensors and thrust levers. All other required data is amalgamated and supplied by an Engine Interface Unit (EIU).

The primary function of the FADECs is responding to thrust demands from the thrust levers or autothrust system whilst respecting thrust rating, idle settings and N1 and N2 limitations. This is acheived by controlling flow of fuel both to the engine and back through the recirculation system to the tanks. Engine performance is further optimised through control of variable bleed valves, variable stator vanes and turbine and rotor clearances.

During a start sequence, the FADEC also controls the start valve, HP fuel valve and ignition. For automatic starts N1, N2, fuel flow and EGT are actively monitored, and automated abort and recycle is provided. Passive monitoring of these parameters is provided for manual starts.

When reverse thrust is selected, the FADECs control the blocker doors.

19.3. Thrust control system

The thrust levers can only be moved manually. There are 2 detents and 3 stops on the thrust quadrant. These are the TOGA stop, MCT/FLX detent, CL detent, Idle stop and Max reverse stop. In addition there is a notional (i.e. non-phyiscal) reverse idle detent acheived by pulling up the reverse levers and selecting a position slightly behind the idle stop.

In normal operation, autothrust is available when the thrust levers are in the range between the idle stop and CLB detent. When an engine out condition is detected, autothrust is available between the idle stop and MCT/FLX detent. When the autothrust is not engaged, either because it is not armed or because the thrust lever is set outside the autothrust range, the Thrust Lever Angle (TLA) maps directly to an N1 demand. Each of the detents/stops maps to its given limit, and there is a straight line TLA to N1 relationship between these positions.

The N1 for the MCT/FLX detent will be MCT except when on the ground with a FLEX temperature set, in which case it will be the computed FLEX N1. Once airborne the detent reverts to MCT when the thrust levers are either moved to the TOGA stop or moved to or through the CL detent.

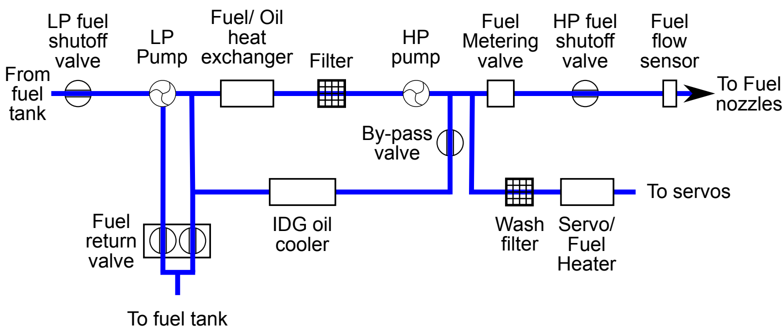
The N1 for the idle detent is normally "modulated idle", a value regulated according to bleed system demand. When in flight with the flap lever not at zero position, the idle detent is "approach idle". This is an idle setting designed to allow rapid acceleration to TOGA thrust and it is regulated according to aircraft altitude without regard to bleed configuration. The N1 for the notional reverse idle detent is "reverse idle", a value slightly higher than forward idle thrust.

When the autothrust is engaged, the N1 it can command is limited to between the N1 for the TLA set and the N1 at the idle detent.

A special case is alpha floor protection. If a very high angle of attack is detected, TOGA thrust is set regardless of TLA. See {TODO: cross reference once done}.

19.4. Engine fuel system

Figure 13. Simplified schematic of engine fuel system



The engine fuel system is pressurised by two engine driven pumps {TODO: engine driven is inferred from the diagram in 1.70.40.1000- check its true}, a low pressure (LP) pump and a high pressure (HP) pump. These provide a supply of high pressure fuel to the inlet of a Fuel Metering Valve (FMV). The FADEC controls this valve to provide the fuel flow required to satisfy the N1 demand and keep all other engine parameters within their defined limits. A bypass valve located immediately before the FMV modulates to maintain a constant pressure drop across the FMV in order to maintain a linear relationship between FMV position and fuel flow acheived. This bypass valve is also used by an independent overspeed governor that limits N2 to 107.2% in the event of FADEC malfunction.

The FMV, along with other actuators under the control of the FADEC (variable stator veins, variable bleed valves etc) are operated hydro-mechanically using high pressure fuel tapped from the fuel lines after the HP pump.

Two shut off valves are incorporated into the fuel line, a low pressure shut off valve located before the LP pump, and a high pressure shut off valve located after the FMV. Both these valves are closed when the engine master switch is selected off, but only the low pressure shut off valve is closed by the fire button.

Fuel is also used to provide IDG cooling. The FADEC modulates the bypass valve and fuel return valve to control flow of fuel through the IDG oil cooler to acheive the required cooling.

19.5. Engine oil system

The supply side of the engine oil system consists of an oil supply pump that draws oil from the oil tank and passes it through an oil filter to the bearings and gearbox. The oil filter incorporates a by-pass valve in case of clogging. Oil pressure and temperature are monitored downstream of the filter.

The scavenge side consists of four scavenge pumps {TODO: inferred from diagram 1.70.50}, through a scavenge filter then back to the oil tank via the servo fuel heater and fuel/oil heat exchanger. The scavenge filter incorporates a bypass valve in case of clogging.

19.6. Engine bleed air system

Bleed air is tapped at the 5th and 9th stages of the HP compressor and from the fan. It is used to supply the pneumatic system (see Section 7, “Pneumatics”) and to provide cooling air to the active clearance control systems. The active control clearance systems are a function of the FADEC which uses fuel pressure to modulate bleed air control valves in order to control the temperature, and hence size, of the turbine casings and the HP compressor casing. The LP Turbine Clearance Control (LPTCC) system uses fan air to cool the LP turbine case. The Rotor Active Clearance Control (RACC) system uses 5th stage bleed air to cool the HP compressor case. The HP Turbine Clearance Control (HPTCC) system uses both 5th and 9th stage bleed air to cool the HP turbine case.

19.7. Reverse thrust system

Reverse thrust is acheived using four pivoting blocker doors per engine which are used to deflect the airstream from the fan forward. Each blocker door has a hydraulic actuator, a latch and a position switch. The FADEC moves the doors using a Hydraulic Control Unit (HCU) consisting of a pressurizing solenoid valve and a directional solenoid valve. An independent hydraulic shut off valve controlled by the spoiler elevator computers (SECs) controls inlet pressure to the HCU.

Actuation required input from a number of systems. Firstly the SECs must receive a signal from the thrust levers to open the shut off valve and allow pressure to the HCU. Secondally, the EIU must receive a signal from the thrust levers to enable the directional solenoid valve, which will otherwise be inhibited. Finally, at least one channel of the FADEC must receive the correct signals from the thrust levers, N2 sensor and LGCIU (via the EIU). If it detects the TLA is in the reverse segment, N2>50% and both main gear compressed, the FADEC signals the HCU to open the blocker doors.

When on the ground with the engine running and N1<70%, an auto restow function is available. This stows any door that is detected unstowed with reverse thrust not selected.

Idle protection is available in all flight phases when reverse thrust is not selected. This selects idle thrust if pressure is detected in the HCU and any door is detected unstowed or with an indefinite position. It also selects idle thrust regardless of HCU pressure if all four blocker doors are detected unstowed.

19.8. Ignition and start

The FADEC start module receives input from the engine master switches, the engine mode selector, the manual start buttons and the LGCIU, all via the EIU. It controls the start valve, the igniters and the HP fuel valve. The engine master switch also independenly inhibits the opening of the HP fuel valve when selected off.

Each engine has two identical independent igniter systems. Normally, each FADEC channel controls a single igniter system, but in failure cases both igniter systems can be controlled by a single FADEC channel.

For automatic starts on the ground, a single igniter is used. It is energised at 16% N2 and de-energised at 50% N2. The FADEC toggles between the four channel/igniter system permutations after each start.

For manual starts and in flight starts, both igniters are energised when the master switch is turned on. De-energisation at 50% remains automatic.

Automatic continuous ignition is provided if a flame out is detected. It is also provided if the EIU fails whilst the engine is running.{TODO: There is a third case: Engine running and ignition delay during start - this doesn't seem to make much sense} Continuous ignition can also be selected manually using the engine mode selector.

Engine spin up is provided by an air turbine starter that is powered by the pneumatic system. Supply of air to the turbine is controlled by a start valve which is controlled electrically by the FADEC. There is also a handle on the engine to allow the start valve to be operated manually if electrical control fails. In an automatic start sequence, if the starter is required (i.e. on the ground or insufficient windmilling speed), the FADEC opens the start valve at the start of the sequence and closes it at 50% N2. In a manual start sequence the FADEC still closes the start valve at 50% N2, but opening of the valve is acheived by pressing the manual start push-button. All manual start sequences are starter assisted.

For automatic starts, the FADEC opens the HP fuel valve at 22% N2 on the ground and 15% N2 in flight. For manual starts, the HP fuel valve opens when the engine master switch is turned on.

The FADEC also provides start monitoring. It will detect hot starts, hung starts, stalls and wet starts and provide an appropriate ECAM message. If these conditions are detected during an automatic start, the FADEC will automatically run an abort sequence including dry cranking and then attempt further starts. An automatic start can be aborted at any time by turning the engine master switch off. This closes both fuel valves and signals the FADEC to close the start valve and de-energise the ignition. Dry cranking, if required must then be done manually using the crank position of the engine mode selector and the manual start button. For manual starts, the FADEC has very limited authority to abort a start. The sole case is when on the ground and a start EGT exceedance occurs before 50% N2. In all other cases, it is the pilot's responsibility to interrupt the start sequence by either deselecting the manual start button or turning the engine master switch off as appropriate.

The completion of the start sequence is indicated by the grey background on the N2 indicator disappearing. The stable N2 value is approximately 58%. It is recommended that the engines are operated at or near idle for at least two minutes after start.

19.9. Engine indications

The warning lights below the engine master switches have two segments, a red FIRE segment and an amber FAULT segment. The FIRE segment aids the crew in selecting the correct master switch during an engine fire drill. The amber segment indicates an aborted automatic start or an HP fuel valve position disagreement.

The N1 gauges display a caution range by an amber line representing TOGA N1 and a warning range by a red arc. The lower end of the red arc represents max N1 (104%). If N1 enters the caution range, the N1 needle and digital indication, which are normally steady green, pulse amber. If N1 enters the warning range, they pulse red, and a red tell tale is left at the maximum acheived N1. A blue circle above the index indicates the N1 corresponding to the current TLA. If the autothrust is active, trend indications are displayed as green triangles next to the needle. The longer of the two triangles represents the difference between the demanded and actual N1. The smaller of the two triangles shows the direction and rate of current N1 changes. If the last digit of the digital display is a dash, it indicates that N1 data is degraded due to failure of both N1 sensors.

The status of the reverses is also indicated on the N1 gauge. An amber REV indicates that at least one door is unstowed or unlocked. In flight this indication will initially flash for 9 seconds. The REV becomes green when all the reverser doors are fully deployed.

The current thrust limit mode and N1 rating limit are displayed to the right of the N1 gauges. If a FLX takeoff is selected, the FLX temperature will also appear here.

The EGT, like the N1 gauge, has a caution range indicated by an amber line and a warning range indicated by a red arc. The bottom of the red arc is at max permissable EGT (950°C). If EGT exceeds this value, the needle and digital display pulse red, and a red tell tale is left behind at maximum acheived EGT. The amber line is the start limit (725°C) during the start sequence. Otherwise, except when operating at high power, it is 915°C. If actual EGT is above the amber line value, the needle and digital display pulse amber.

N2 is represented as a digital value only. This is normally green, but turns red with a red cross next to it if N2 exceeds 105%. If both N2 sensors fail the last digit is replaced by an amber dash. The numbers have a grey background during the start sequence. The removal of this grey background indicates completion of the sequence.

Fuel flow is also indicated as a digital value only.

An amber CHECK indication below the N1, N2, EGT or fuel flow values indicates a discrepancy between the values on the FADEC-DMC bus and those displayed. {TODO - how does this occur?}.

Fuel used, oil quantity, oil pressure, oil temperature, N1 vibration, N2 vibration and nacelle temperature are displayed on the ECAM Engine page. During the start sequence the nacelle temperature is replaced by indications of start valve position, available bleed pressure and ignitor status.

The fuel used indication is reset when the master switch for the engine is selected on. If fuel flow data is lost for more than one minute, the last two digits are dashed. An amber CLOG indication below the figures indicates clogging of the fuel filter.

The oil quantity gauge will pulse when oil quantity falls below 3 qt, with a dead band up to 5 qt.

The oil pressure gauge will pulse when oil pressure exceeds 90 psi, with a dead band down to 85 psi, or when the oil pressure is below 16 psi, with a dead band up to 20 psi. The indication turns red when pressure falls below 13 psi. An amber CLOG below the gauge indicates clogging of the main scavenge filter. {TODO - is there monitoring of the filter on the supply side of the oil system?}

The oil temperature numbers will pulse when temperature exceeds 140°C, with a dead band down to 135°C. They turns amber (with accompanying ECAM message) when temperature reaches 155°C or if temperature is >140°C for more than 15 minutes.

The vibration numbers pulse when above 6 units for N1 and above 4.3 units for N2, although these thresholds may be reduced to the maximum vibration experienced during the last flight by an MCDU procedure.

The nacelle temperature gauge pulses when temperature exceeds 240°C (indicated by a white dash).

During the start sequence, IGN in white and the letters A,B or AB indicate energisation of the indicated ignitor. Start valve position is indicated in the standard way. The bleed pressure reading is the bleed pressure upstream of the precooler. If it drops below 21 psi with N2 >= 10%, or if there is an overpressure, it will turn amber.

19.10. Engine handling

Takeoff thrust is normally applied in two stages. The thrust is first set to approximately 50%, and the engines are allowed to stabilise. Either FLX or TOGA is then set. This is modified to three stages in strong crosswinds.

At thrust reduction altitude, thrust is set to CL, and the autothrust becomes active.

If heavy rain or turbulence is expected after take off or during initial approach, the ignitors can be switched on by selecting the END MODE selector to IGN START. The E/WD memo area will display IGNITION. Continuous ignition is automatically selected when engine anti-ice is turned on. {TODO: This is from CBT and I'm not sure that it is correct}

REV IDLE should be selected on landing when speed reaches 70kt.

A three minute cooling period is recommended following the use of maximum reverse thrust.

20. EIS

20.1. EFIS

Overview

Data from the ADIRS and FMGC is fed directly into three display management computers (DMCs). Normally DMC1 supplies the Captain's EFIS and the ECAM DUs and DMC2 supplies the FO's EFIS, with DMC3 being used as a selectable backup. DMC2 will automatically take over the ECAM DUs if required.

PFD

Do not fly with only one flight director selected on.

Rad alt displayed below 2500ft

On the PFD, items colour coded magenta indicate that the FMGS is managing the item and blue items indicate that an item has been manually selected on the FCU.

Airspeed index is yellow line and triangle. A speed trend arrow, also yellow, gives the speed in 10 seconds time.

During take-off, V_1 is shown in blue and V_2 is shown in magenta. They are shown as numbers when they are above the displayed scale, and appear on the scale as a blue "1" and a magenta triangle respectively. Immediately after take-off, the flight director commands V_2+10 kt, so the aircraft speed will be greater than the magenta triangle. Minimum flap retraction speed (F speed) is shown as a green F. Flap limit speed is shown by a barber's pole. As flaps are retracted to flap 1, minimum slat retraction speed (S speed) is indicated by a green S.

Once flaps are retracted the barber's pole indicates V_{mo} of 350kt when below approximately 25,000ft and M_{mo} of M0.82 when above. A MACH indicator appears once M0.5 is achieved.

When clean, a green circle indicates "green dot speed. This is the best lift:drag.

During FMGS managed decent, the magenta managed speed indicator splits to indicate that a range of speeds may be used to maintain correct path.

When below 15,000ft ?in a descent?, two amber bars indicate "V_{fe} next", the maximum speed for deployment of the next stage of flap.

Protection speeds are displayed as a solid red bar and two amber hollow boxes (see {TODO: get reference}).

On the altimeter scale, the red ribbon indicates a ground reference derived from the rad alt. In the final stages of approach, this is augmented with an FMGS database landing elevation indicated by a blue line across the altimeter. When outside the displayed scale, the target altitude is shown either above or below the altimeter as applicable. It will show in feet when QNH is selected and as a flight level (e.g. "FL330" when STD is selected). When within the displayed scale, it is shown on the altimeter with a target box to the left. It will be magenta if the restriction originates from the FMGS and blue if selected on the FCU. The baro setting is shown in blue below the altimeter. Standard pressure setting is indicated by "STD" when the baro reference selector is pulled.

The vertical speed is displayed in amber when high.

On the compass display, a green diamond indicates track and a yellow line indicates heading. Selected heading appears as a blue triangle or a figure on the appropriate side if outside the displayed scale.

When an ILS is selected, the frequency and ident appear in magenta in the bottom left corner, along with DME range if available. The front course appears on the compass display in magenta, either as a figure when outside the compass scale or as a dagger when within. Localiser and glideslope deviation is shown by a hollow magenta diamond on deviation bars.

ND

Ground speed, air speed and wind data are displayed in the top left of the ND in all modes. Magnetic heading is a fixed yellow line. Selected heading or track is displayed as a blue triangle when within displayed scale or blue digits when not. Actual track is shown by a green track diamond.

Rose ILS mode shows standard magenta course bar incorporating localiser deviation and white glideslope deviation scale with a magenta diamond indicator. Frequency course and ident are shown in the top right corner.

Rose VOR mode gives a blue course deviation bar. Course must be set in the MCDU RAD NAV page. VOR data is shown in the top right of the ND.

Bearing pointers are selected on the EFIS control panel and are shown in white for VOR and green for ADF. #1 pointers are single lined and #2 pointers are double lined. Ident and range information are shown in the bottom corners of the ND. A small white M next to this information indicates manual selection of the aid.

Rose NAV mode dispalys a map oriented to the aircraft. The range selector sets the diameter of the map. Planned track is shown in green and waypoints are shown in blue. Id, range and ETA for the next waypoint are shown in the top right corner.

Arc mode is the normal mode, displaying the forward 90° of the map shown by rose NAV mode. The range selector now sets the distance from the aircraft to the edge of the map.

Additional data points for airports, NDBs, VORs and Waypoints can be shown in map modes by selecting pushbuttons on the EFIS control panel. These data points show in magenta.

20.2. ECAM

Overview

Data from certain aircraft system sensors is routed directly to the ECAM channel in the three DMCs. The majority of the data, however, is routed to the two System Data Acquisition Concentrators (SDACs), for processing. The SDACs then provide system page data to the DMCs. Normally, DMC1 supplies the E/WD, DMC2 supplies the SD and DMC3 is available as a backup. Two Flight Warning Computers (FWCs) receive data directly from aircraft sensors to generate red warnings and receive data from the SDACs to generate amber warnings. The FWCs control the attention getters and aural alerts and send data to the DMCs for display of alert messages.

Failure of a single FWC generates a Level 1 caution, since there is a redundant system available. This will, however, downgrade the aicraft to Cat III single. It will also lead to only one half of the Master Caution and Master Warning lights illuminating. The loss of both FWCs will remove all automatic monitoring of the aircraft systems. The ECAM system pages and overhead panels must be monitored for local failure indications.

The EMER CANC button can be used to supress the caution associated with an intermittant nuisance warning. Pressing and holding the RCL key for 3 seconds will unsupress the caution.

Information on the ECAM displays is colour coded:

Green	A normal condition
Amber	Abnormal indication requiring crew awareness but *not* immediate action.
Red	Serious parameter exceedance or warnings that requires immediate crew action.

The ECAM system divides the flight into various stages. If a warning occuring in the take-off or landing phase can be delayed, it is inhibited until a less critical stage of flight is reached.

ECAM warnings are presented in various ways depending on severity:

ECAM advisory	If a parameter approaches its limit, the relevant SD page is brought up and the parameter pulses, but remains green to indicate that no exceedance has yet taken place.
Level 1	A loss of redundancy or a loss of a system that does not affect the safety of the flight has occured. An amber message is displayed on the E/WD. As the fault only requires crew awareness, the handling of the fault can be delayed if required. Pressing the CLR key on the ECAM control panel will move the message to the status page, which will be brought up. The status page is then reviewed and subsequently removed by pressing either a CLR key or the STS key.
Level 2	A failure that hasn't any direct consequence on flight safety. This is similar to a level 1 alert, except the crew is alerted by illumination of the master caution light and an aural warning. Pressing the master caution light extinguishes it.

Level 3 — A failure that requires immediate crew action. The red master warning illuminates and a continuous chime sounds. Pressing the master warning light extinguishes it, stops the chimes and resets the alerting system. In this case, the messages shown on the E/WD are in red.

ECAM displays the failure message on the E/WD in order of priority, so that high priority failures are dealt with before low priority failures. It is possible that a high priority failure will be placed above a failure that you are currently running the actions for.

A white MAINTENANCE message on the ECAM status page does not mean that the aircraft is unserviceable, only that a particular procedure is required at the next programmed servicing.

A boxed failure indication is a primary failure that has associated secondary failures. The secondary failures are indicated in the right hand column by starred items.

E/WD

The upper area of the E/WD display is used for main engine parameters, fuel on board (FOB) and slat/flap positions. The lower part of the E/WD display is normally used to show memos. If a failure occurs, the memos are replaced by warning/ caution messages and a series of blue action items. Boxed failures indicate a primary failure that will affect other systems. Starred failures on the right of the memo area are secondary failures.

Approximately two minutes after engine start, a takeoff memo appears. The items on this memo put the aircraft into a suitable configuration for takeoff.

During the takeoff phase, a magenta T.O. INHIBIT message appears. This indicates that some warnings and cautions are now inhibited. T.O. INHIBIT is in effect from application of T.O. thrust up to 1500ft AAL or 2 minutes after lift off.

On passing 1500ft in the descent, a landing memo is displayed.

At approximately 800ft, a LDG INHIBIT message appears. This indicates that the vast majority of warnings and cautions have been inhibited for the landing phase.

SD

There is a permanent area at the bottom of the SD. This always displays TAT, SAT, time and gross weight.

The SD page automatically provides pilots with information on a "need to know basis".

An aircraft STATUS page may be displayed to check the state of the aircraft. The content of this page varies depending on what failures are present, but may contain limitations, approach procedures, information and inoperative systems. If the status page is not clear, a white boxed STS legend appears at the bottom of the E/WD display, and, if there are any messages affecting approach and landing, the status page will automatically be displayed when the slats are extended. If the status page has a green overflow arrow at the bottom, pressing a CLR key will display the next page.

Controls

The pilot interface for the ECAM display is the ECAM Control Panel on the pedestal. The middle two lines of buttons manually bring up their associated ECAM page. When manually selected, the button lights up, and pushing it again will remove the page and allow the automatic sequencing of pages.

The RCL button, when pressed for at least three seconds, recalls any warnings or cautions that have been cleared since the last power up. If there is nothing to recall, a NORMAL message will be displayed on the E/WD.

The T.O. CONFIG key is used to carry out a takeoff configuration check prior to takeoff. This simulates setting of takeoff power, and generates a warning if the aircraft is not in a proper takeoff configuration.

20.3. Reconfiguration

In general, the PFD has priority over the ND and the E/WD has priority over the SD.

Normally, DMC1 supplies the Captain's PFD and ND, and the E/WD. DMC2 supplies the FO's PFD and ND, and the SD. DMC3 is a backup.

If a DMC fails, all information is removed from the displays it controls and replaced by a white diagonal line to indicate a working display with a failed source. ECAM will detect the failure and provide a sequence of alerts. Due to the priority rules, the E/WD display will move to the lower DU if it was DMC1 that failed. The EIS DMC switch is used to replace the failed DMC with DMC3.

In the event display failures, there will be no white diagonal. The displays have priority rules so that the remaining displays are utilised most effectively. The PFDs have priority over the NDs unless a PFD/ND switch on the misc panels is pushed. The E/WD has priority over the SD. The ECAM screens can be given priority over an ND with the ECAM/ND XFER switch.

A single screen ECAM mode is available. This displays the E/WD, but can be made to display an SD page for a maximum of 30 seconds by pushing and holding the relevant page button on the ECP. If an advisory condition occurs, the page is not automatically displayed. Instead the page button lights up and a boxed ADV message is shown on the E/WD. If an ECAM warning or caution is triggered, again there is no automatic page display. The normal aural and visual indications are given. The underlined word in the warning indicates which SD page needs to be viewed. The page should be checked both before and after running the ECAM actions, and the status page will have to be called manually. The status page can be displayed for a maximum of three minutes. On the approach, the STS message pulses to indicate that the crew should manually call and review the status page.

21. LVO

The approach may be broken down into phases, with the response to a failure determined by the phase. The phases are:

Above 1000ft	A reversion to a lower category of approach can be made as long as the required minimas are available, all ECAM actions are completed by 1000ft and the reversion is briefed.
Between Alert Height and 1000ft	Go around for any master caution, master warning, mode reversion or instrument flag. A new approach to higher minimas may be attempted once rebriefed.

Below 200ft	Go around in the event of an AUTOLAND light.
By 350ft	LAND should be displayed at 400ft RA. If it is not displayed at 350ft, go around. In addition, ILS course should be checked by 350ft. If it is incorrect, a reversion to Cat II minimas followed by autopilot disconnect by 80ft and a manual landing is permissable.