

ToLiss Aeronautical Simulation Solutions

ToLiss Airbus A319 V1.5 – Aircraft manual

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1 Introduction

Thank you for purchasing the ToLiss Airbus A319 and for trusting us to provide you with one of the most realistic FBW simulation addons with complete custom systems for X-Plane.

This product has been developed since 2008. Its Fly-by-wire and Autopilot system are based on the FBW technology provided by QPAC. The Flight Management System has been completely reworked to provide a complete and accurate representation of the system in the real aircraft.

The hydro-mechanical and electrical systems of the aircraft model are also based on the latest QPAC technology with numerous significant improvements. The simulation supports accurate system behaviour in the presence of failures. For example, following the failure of an electrical bus, associated equipment, i.e. cockpit displays, exterior lights, certain computers, etc. fed by that bus will not be available anymore.

To improve the user experience, this model features situation saving and loading. Flights can be stopped at any point in time and continued from the exact same conditions another day. The model also provides situation autosaving; should something unforeseen happen during the flight, the autosave allows resuming the flight to try again.

About the manual: The ToLiss Airbus A319 comes with three manuals:

- A “simulation manual”: Describes installation, and setup of the model as well as usage of the “Interactive Simulation Control System”.
- A “tutorial flight”, which provides a step-by-step description of a complete flight from cold & dark to aircraft shut-down after landing. This is the best manual to learn flying the aircraft.
- An “aircraft manual” (this manual): which is primarily intended as a reference after the tutorial has been completed. It provides a reference for standard operating procedures, as well as a more in-depth look into the different systems of the aircraft.

The aircraft manual has three sections: The aircraft and systems briefing, which describes each of the systems on board as well as a short description how the systems interact with each other. The limitations section lists the weight and speed limits of the aircraft as well as implemented system limitations. The third section lists the standard operating procedures.

Note:

This manual is not yet completed; for missing sections please consult the tutorial, or internet resources. We are working hard to finish this in the course of the addon project.

2 Aircraft and Systems Briefing

This add-on simulates the Airbus A319, which is a 120-145 seat single-aisle aircraft for short and medium range missions. The add-on supplies two different engine variants for the aircraft:

- CFM56-5B6 engines – Airbus A319-112
- IAE V2524-A5 engines – Airbus A319-132

Weights

The simulated aircraft is subject to the following weight limits:

Maximum ramp weight (MRW):	70400kgs
Maximum take-off weight (MTOW):	70000kgs
Maximum landing weight (MLW):	62500kgs
Maximum zero fuel weight (MZFW):	58500kgs
Minimum flight weight (MFW):	35400kgs

Note that the minimum weight simulated in X-Plane is 40820kgs: the MFW quoted above is for empty cabins; with galleys, seats, lavatories etc. the weight goes up significantly from the MFW. The minimum weight simulated in X-plane corresponds to the Operating Empty Weight.

Dimensions

The principle dimensions of the aircraft are shown in the following figures:



Figure 1 – Aircraft dimensions in side view

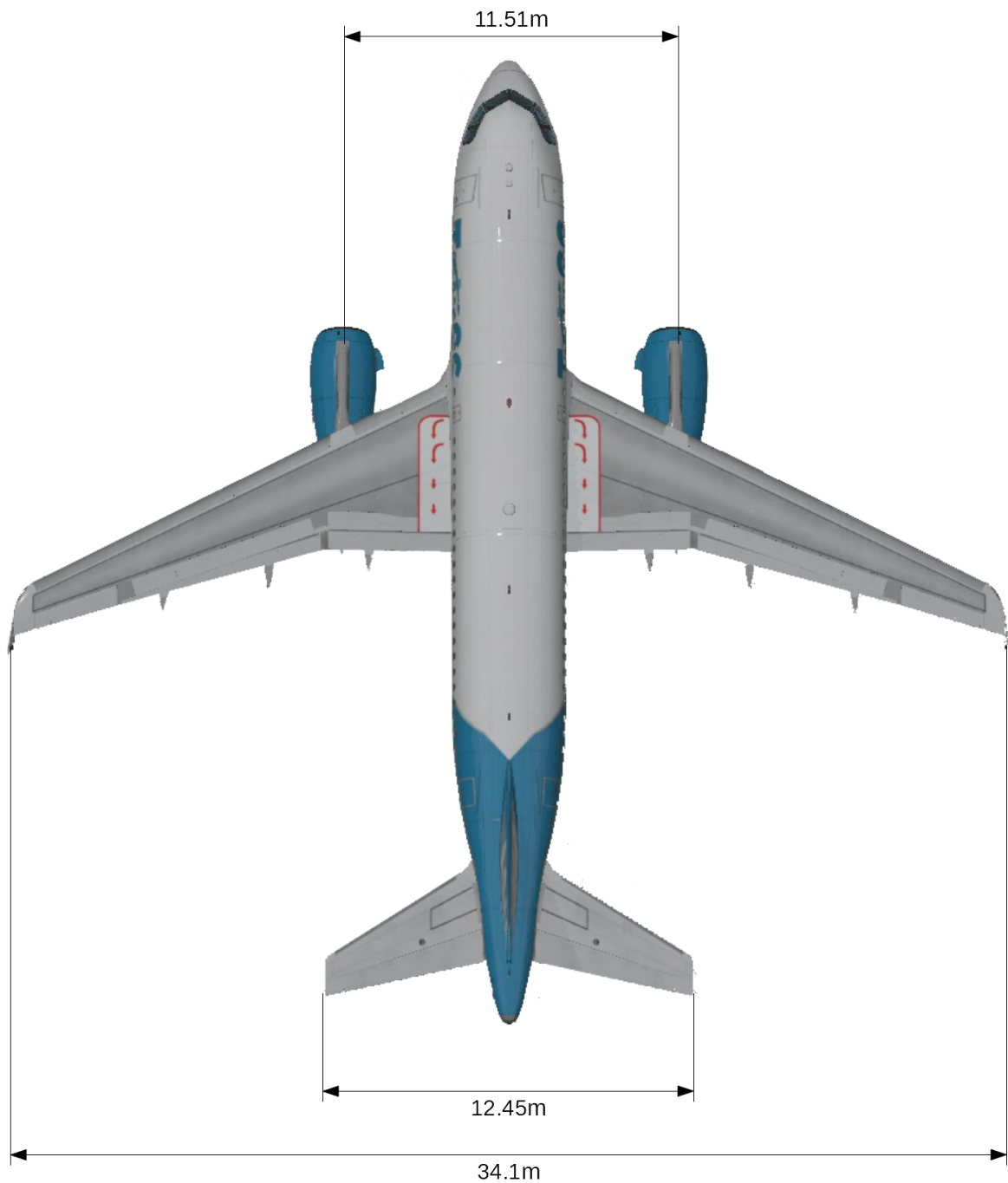


Figure 2 – Aircraft dimensions in top-down view

Payload

The aircraft as modelled can carry:

- 145 passengers, weighing on average 100kgs (220lbs) each – this weight includes check-in and cabin luggage

- 6786kgs of cargo, distributed between forward cargo hold (maximum 2268kgs) and aft cargo hold (maximum 4518kgs)

Fuel capacity

The aircraft has a total of 5 tanks, which are located in the wing box. The tanks have the following capacities:

Table 1 – Fuel tank capacities

Designation	Location	Capacity
Center Tank	Center wing box below fuselage	6476kgs (14281lbs)
Left wing tank	Left wing inboard	5435kgs (11982kgs)
Left outer wing tank	Left wing outboard	691kgs (1520lbs)
Right wing tank	Right wing inboard	5435kgs (11982kgs)
Right outer wing tank	Right wing outboard	691kgs (1520lbs)

Range

The range of the ToLiss 319 with typical payload is 3750NM. The exact range depends on payload, and weather.

2.1 Aircraft systems overview

A large number of different systems are installed on board of the aircraft to fulfil all functions required for a safe and comfortable execution of a flight. The systems are grouped either by function or by ATA chapters.

The real-life aircraft manuals (FCOM, FCTM, AMM, etc) use the ATA chapter classification as it is the industry standard. To learn the systems, it is more convenient to group them by function rather than ATA chapters. Therefore, this manual uses grouping by function with reference to the associated ATA chapters.

The functional blocks described in this manual are:

- **Power plant systems:** all systems required to supply the aircraft with the power required for the flight:
 - the engines (ATA chapters 70-80),
 - the APU (ATA chapter 49),
 - the fuel system (ATA28) which supplies the engines and the APU.

For the sake of this manual, we included the fire protection system (ATA26) in this group; this system provides fire protection not only for engines or APU, but also for the cargo compartment.
- **Electrical system:** The electrical system (ATA24) is presented on its own. It provides electrical AC power generated either by the engine generators, the APU generator or the ground power to the aircraft. It also converts parts of the electrical power to DC and provides batteries for DC power.

- **Pneumatic systems:** systems providing and distributing air or oxygen throughout the aircraft:
 - the pneumatics (or bleed) system (ATA chapter 36) takes compressed air from the engines or the APU and provides it to the environmental control system and anti-ice system.
 - the environmental control system (ATA chapter 21) is also called the air conditioning and pressurization system. It takes compressed, hot air from the bleed system and provides it temperature and pressure controlled to the cabin. Cabin pressure is regulated via an outflow valve that controls the amount of air escaping from the aircraft.
 - the ice protection system (ATA chapter 30) uses hot air from the bleed system to heat the wing leading edge and the inlet lip of the engine nacelles to prevent ice build-up on these surfaces. Electrical heaters heat the cockpit wind shield and air data sensors to protect these from ice build-up.
 - the oxygen system (ATA chapter 35) provides oxygen to crew and passengers in case of loss of cabin pressure. The flight crew has oxygen masks supplied by oxygen from pressurized gas cylinders. Passenger oxygen is typically provided by chemical oxygen generators and lasts about 15 minutes.
- **Hydromechanical systems:** systems that move parts of the airplane:
 - the flight control system (ATA chapter 27) moves the control surfaces on the wings and stabilizers in response to pilot or autopilot inputs. The Fly-by-wire flight control computers are also part of this system.
 - the landing gear system (ATA chapter 32) provides landing gear extension and retraction, as well as braking and steering.
 - the hydraulic system (ATA chapter 29) provides the mechanical power required by the flight control system and the landing gear system.
- **Autopilot and Flight Management system:** systems that provide lateral and vertical guidance for the aircraft trajectory:
 - The Flight management system (ATA chapter 22) computes the flight path and vertical profile; it also contains the interface for the pilot to program the flight plan
 - The auto flight system (ATA chapter 22) can replace the pilot inputs in order to fly the aircraft along the path computed by the flight management system or to follow trajectory commands from the pilot.
- **Avionics:** in principle, all computers and instruments installed on an aircraft are classified as avionics. In this scope, avionics is limited to aircraft state sensors (speed, altitude, attitude etc.), communication and indication devices.
 - Indication/recording systems (ATA chapter 31): this includes the cockpit displays, the clock, and the flight data recorder.
 - Communication system (ATA chapter 23): this includes the communication radios and the cockpit voice recorder.
 - Navigation system (ATA chapter 34): This includes all sensors measuring the aircraft state (air data, inertial data, radio altitude, GPS, etc.), standby

instrumentation, radio navigation, transponder, ground proximity warning system (GPWS), Traffic Collision Alert System (TCAS), and weather radar.

For reference, the following table lists the ATA chapters, as used in the real-life manuals:

Table 2 – ATA chapter overview

ATA	System title	ATA	System title
20	Aircraft General	31	Indicating/Recording systems
21	Air Conditioning	32	Landing Gear
22	Auto flight	33	Lights
23	Communications	34	Navigation
24	Electrical	35	Oxygen
25	Equipment	36	Pneumatic
26	Fire Protection	39	Water/Waste
27	Flight Controls	45	Maintenance
28	Fuel	49	APU
29	Hydraulic	52	Doors
30	Ice and Rain Protection	70	Power Plant

2.2 Power plant and power generation

2.2.1 Fuel system (ATA28)

System main purposes

- Store fuel
- Provide fuel quantity indication to flight crew
- Provide fuel to the engines and the APU

Fuel storage

Fuel is stored in 5 tanks, which are all located in the wing box:

Center tank

It is Located in center wing box under the aircraft cabin. It has a capacity of 6476 kgs. Fuel is only stored in this tank, if all other tanks are full. Fuel in this tank is used first, with some exceptions detailed in the "Provide Fuel" section.

L (R) Inner Wing Tank

These are the main tanks with a capacity of 5435 kgs each. They are located in the inboard portion of the left and right wing boxes. When fuel is not consumed from the center tank, it is fed to the engines from the inner wing tank on the respective side. Engine feed from the inner wing tanks is possible via gravity, i.e. without the help of a fuel pump

L (R) Outer Wing Tank

The fuel tanks are located outboard on the wings, just inboard of the ailerons. Each outer wing tank has a capacity of 691 kgs. The fuel in these tanks is used last. The purpose of maintaining fuel in the outboard portion of the wing as long as possible is a reduction of the in-flight wing bending moment. The return fuel from the engines is deposited in the outer tanks. If an outer tank is overfull it spills into the inner wing tank via a dedicated spill pipe.

Refuel sequence

The refuel sequence is adapted to the usage of fuel from the tanks:

1. Fuel is pumped in the outer wing tanks until the outer wing tanks is full
2. Fuel is then pumped into the inner wing tanks until the inner wing tanks are full
3. The center tank is fuelled last.

Fuel quantity indication to flight crew

Fuel quantity indication is provided by one dual-channel Fuel Quantity Indication Computer (FQIC) which reads dedicated sensors in each fuel tank. The total amount of fuel on board and the current fuel flow is shown on the Engine Warning Display:

The FUEL page of the system display shows the amount of fuel in each tank, the total fuel on board and the current fuel flow. Note that the fuel flow information is provided by the engine controllers (FADEC), not by the FQIC.

The amount of fuel used by the engines, as provided by the FADECs is shown on the engine page of the system display.

Fuel distribution

Two fuel pumps are installed in each of the inner wing tanks and the center tank to feed the aircraft engines and to allow fuel transfer left/right. The fuel pumps of the left inner wing tank and the left center tank pump feed the left main fuel line. The fuel pumps of the right inner wing tank and the right center tank pump feeds the right main fuel line. The two main fuel lines are interconnected via a cross-feed valve.

The left engine is fed by fuel from the left main fuel line. If the center fuel pump for the left fuel line is running, it produces higher pressure than the wing tank pumps and fuel is consumed from the center tank only. When the center fuel pump is stopped, the left engine feeds from the left inner wing tank. This feed is possible by gravity even if the fuel pumps are off. In this case, the flight crew has to avoid low g-values in order to prevent fuel starvation for the left engine.

Note: gravity feed from the center tank is not possible.

Not all of the fuel pumped to the engine is actually consumed by the engine; the excess fuel is used to cool the oil of the engine integrated drive generator (IDG) and returned into the outer wing fuel tank. If the outer wing tank is full, the excess fuel flows through the spill pipe into the inner wing tank

Note: due to this arrangement, it is important not to operate the center tank pumps when the outer and the inner wing tank are fuel. In this case, the return fuel from the engine has nowhere to go and spills overboard.

The outer tank cannot feed the engines directly. If the inner tank content drops below 750kgs, transfer valves open and the outer tank fuel flows (by gravity) into the inner fuel tank. The fuel is then consumed by the engines from the inner tank. Once open, the transfer valves cannot be reclosed in flight.

Center tank pump logic

While the wing tank pumps are always running in a normal flight, the center tanks are switched off and on automatically. The center tank pumps switch off automatically, if the center tank is empty. They are also off, if the inner wing tank level is close to full in order to avoid fuel spilling. (see fuel return path described above.)

APU feed

The APU feeds fuel from the left main fuel line. There is a dedicated APU fuel pump in case the main fuel pumps are not running. The APU fuel pump can run off power from battery 1 via the Static Inverter Bus. The APU fuel pump runs automatically when the APU main switch is ON.

System operation

The controls for the fuel system are located in the FUEL part of the overhead panel. In normal operation, all switches are in a position such that the integrated switch lights are OFF. On aircraft shut-down the six fuel pump switches are placed in the OFF position. On aircraft start-up from cold and dark, the fuel pumps are switched on. Switching the pumps off on the ground is done to ensure that the pumps are off when the aircraft is being refuelled.

Note: in normal operation there is no need to interact with the FUEL panel throughout the flight.

Manual control of the center tank pumps

The center tank pumps operate normally in automatic mode. To force the pumps into the manual mode, press the MODE SEL button on the FUEL overhead panel. The "MAN" label appears in the button and the center fuel pumps run whenever the center fuel pump switches are in the ON position. To stop the center tank pumps in manual mode, set the center pump switches to OFF.

Caution: Do not operate the center fuel pumps, if the inner and outer wing tanks are completely full.

Note: when the center tank pumps are in AUTO mode, the pumps are prevented from running, when the associated pump switch is set to OFF. If the center pump logic commands the pumps to run, but the pumps are switched off, the pumps show amber OFF on the system display fuel page.

If the center pump logic commands the pump to off, the pump is shown green OFF on the system display fuel page.

Fuel cross-feed and balancing

To perform cross-feed, i.e. feeding the left engine from the right wing tanks and vice versa, the cross-feed valve must be opened by setting the X-feed valve button in the overhead panel to ON. To perform fuel balancing, i.e. moving fuel from the wing tank on one side to the wing tank on the other side, switch off the wing tank fuel pumps on the receiving side. For example, if you want to pump fuel from the right wing tank into the left wing tank, switch off the left wing tank pumps and open the cross-feed valve. When fuel balancing is finished, close the cross-feed valve and restart the fuel pumps on the receiving side.

2.2.2 Engines (ATA70-80)

System main purposes

- Provide a controllable level of thrust to the aircraft for control of the vertical trajectory
- Provide electrical power to the aircraft
- Provide pressurized air to the aircraft
- Provide hydraulic pressure to the aircraft

Engine description

All engines of the aircraft are two-shaft, high-bypass ratio turbofan engines with 12-15 axial compressor stages (including the fan), an axial, annular combustor and 5-7 turbine stages.

Surrounding air enters the engine through the inlet and is compressed in a first stage by the engine fan. The majority of the compressed air is then expanded and accelerated in the bypass duct providing the majority of the thrust for the aircraft.

A small portion of the air is passed into the core of the engine where it is first compressed up to 30 times its original pressure. It then enters the combustion chamber where the temperature of the air is increased to values of up to 2000 degree Celsius by combusting the fuel fed to the engine. This hot compressed air then passes into the turbine. In the turbine the thermal energy of the air is converted into mechanical power (the rotation of the engine shafts) to drive the compressors and the fan. Not all the energy in the air from the combustion is needed to drive the compressors and the rest of the energy is used to further expand and accelerate the air before it leaves the engine. This adds additional thrust.

Each engine features an accessory gearbox which is driven by the high-pressure (N2) shaft. The gearbox powers an electrical generator, hydraulic pumps, the engine integrated fuel pump, a separate permanent magnet generator to supply the FADEC independent of aircraft electrical supply and other devices. The starter motor for the engine can drive the N2 shaft via the accessory gear box during the engine start process.

Thrust control

The rotational speed of the engine and consequently the thrust generated is controlled by one dual-channel "Full authority Digital Engine Control" (FADEC) which controls the amount of fuel injected into the combustion chamber. The FADEC ensures that the amount of fuel injected is within the limits for the current operating conditions, i.e. the FADEC prevents injection of too much fuel, leading to compressor surge, or too little fuel, leading to engine flame-out. The FADEC also controls the ignition state and the starter motor of the engine providing a fully automatic engine start. Actuation of the thrust reverser doors and the associated engine speed control is also performed by the FADEC.

Thrust reversers

The engines of the aircraft can provide thrust reversal in order to help with the deceleration of the aircraft after landing. Thrust reversion is achieved by opening doors on the side of the engine cowling and moving deflectors into the by-pass air stream. This deflects the air of the by-pass duct which now exits the engine in a sideways-forward direction rather than backwards. Due to the forward component of the airflow, the bypass air now provides a braking force.

Note: the air passing through the engine core is not deflected and continues being expelled towards the back.

Electrical power generation

Each engine is fitted with one 115V, 400Hz, 90kVA generator that is driven at a constant speed by the accessory gearbox. The minimum N2 value to drive the generator at the required speed is 55% of N2. The generators can power up to two main aircraft AC busses, from where the power is distributed to other buses by the electrical system.

Pressurized air generation

The aircraft pneumatic system can be supplied by the engines using bleed air from one of the compressor stages. A small fraction of the compressed air is extracted from the compressor and directed towards the precooler located in the engine pylon. The precooler reduces the temperature of the air to levels acceptable for the aircraft pneumatic system. From the precooler, the compressed air is fed into the left or the right main line of the pneumatic system.

Depending on the current engine speed, aircraft altitude, and other parameters the bleed air is either taken at the end of the compressor just before the combustion chamber, or it is taken from the middle of the compressor, if pressure at that stage is sufficient.

Hydraulic pressure generation

Each engine is fitted with one engine driven hydraulic pump (EDP) that supplies 3000psi of pressure to the associated hydraulic circuit. Full hydraulic pressure is available from as low as 10% N2, as long as there is little to no hydraulic flow. To provide 3000psi at the full rated flow of the pump, N2 values of 60% or higher are required.

System operation

The thrust command to the FADEC is generated either by the pilot via the thrust levers or by the auto-thrust system, if auto-thrust is active. See section 2.6.1 for more details.

To command thrust reversal, the pilot needs to move the thrust levers to the idle position, then lift the thrust reverser locks and move the thrust levers further aft. Thrust reverser activation is only possible with weight on at least two of the three landing gear struts.

Note: this logic is implemented in the ToLiss such that reverse activation is only possible if:

- Thrust levers are in idle
- The aircraft is on the ground, and at least one main gear strut is compressed.

Engine start is fully automatic. Engine start requires bleed air at the engine location to allow operation of the engine starter motor. To start the engine, place the engine mode switch into the START/IGN position while the engine master switch is OFF. Then set the engine master switch to ON. The automatic start process takes about 60 seconds.

There is also an option to perform a manual start if the automatic start should fail. This is not yet implemented.

The main engine parameters are permanently shown on the Engine/Warning Display EWD. These parameters are the engine speeds for each shaft, N1 and N2, exhaust gas temperature (EGT) and fuel flow (FF). On some engines, the Engine Pressure Ratio (EPR) is used instead of N1 as indicator for the current engine thrust. In this case EPR is shown as main parameter also.

Secondary engine parameters are shown on the Engine page of the System Display and a subset is shown on the Cruise page. These parameters include fuel used, oil parameters, and engine vibration parameters.

2.2.3 APU (ATA49)

System main purposes

- Provide electrical power and pressurized air to aircraft independent of external sources or aircraft engines

APU description

The APU is a self-contained small gas turbine with radial compressor and turbine. It is installed in the tail of the aircraft. APU fuel pump and starter motor for the APU can be powered by aircraft batteries allowing APU start on batteries alone. The APU operation is fully automatic with a dedicated Electronic Control Box (ECB) managing ignition, start motoring and fuel injection during APU start, run, and shut-down.

The APU shaft is connected to the APU generator which provides 115VAC, 400Hz power with 90kVA maximum power.

The APU shaft is also connected to a load compressor providing compressed air that at low altitudes can be used for air conditioning operation, engine start, and, with limitations, for wing anti-ice.

System operation

The APU is controlled via two buttons on the forward section of the overhead panel: the APU master switch and the APU start switch. Note that before starting the APU, a test of the APU fire detection system is required. This is described in Section 2.2.4.

To start the APU, press the APU Master switch. The ON label appears in the switch, and the system display automatically displays the APU page, unless a system page has been manually selected. The APU air inlet flap will open, and the APU fuel pump starts operating, if necessary. Subsequently, press the APU start button. The ON label will also appear in this switch and the APU begins the automatic start procedure which can be observed on the system display APU page.

Note: APU flap opening takes up to 20 seconds; APU start will only begin once the flap is fully open.

Once the start process is complete, the ON label in the APU switch will extinguish and shortly after the AVAIL label will appear in the button. APU availability is also shown by the EWD memos APU AVAIL, or APU BLEED, if APU bleed is selected.

Note: there is no need to switch the APU generator on or off; this is fully automatic.

2.2.4 Fire protection (ATA26)

System main purposes

- Detect fires in fire risk zones
- Provide means to control fire in zones that are not accessible in flight

Fire detection

Fire detection is provided for the engines and the APU. The detection system features two separate fire detection loops. These loops consist of conductors that change electrical properties in the presence of high temperatures. The loops are routed in the engine and APU along those zones, where a fire is most likely to occur. Detection of a fire by a single fire loop is sufficient to trigger a fire alarm.

If a fire is detected in the engines or the APU, a continuous alarm is sounded in the cockpit, a fire warning posted on the EWD and the associated fire push button in the overhead panel lights up.

Fire detection for the cargo compartment and the lavatories is provided via smoke detectors. If one of the smoke detectors detects smoke, a warning is posted on the EWD.

Fire extinguishing

Fire extinguishing is provided via Halon fire extinguishing agents and by isolating flammable fluids from the affected fire zone.

If an engine or APU fire is detected, in a first step the fuel and electricity supply is cut off. For engines, this is performed both via the Engine master switch which closes the LP fuel valve in the engine and via the engine fire switch which shuts off the fuel in the engine pylon. The engine fire switch also isolates the electrical supply, hydraulic fluid and bleed connection from the engine. Once

all flammable fluids have been isolated and the electrical supply has been cut, the two Halon fire extinguishing agents can be released one at a time into the fire to extinguish the existing flames.

For the APU, there is only one extinguishing agent that is released into the APU after the APU fire button has been pressed.

In case of a cargo fire, there is a Halon fire extinguishing agent that can be released into the cargo compartment.

Note: Cargo fires and the associated fire extinguishing are not modelled in the current version of the aircraft.

System operation

If an engine fire alarm is activated, the first step is to shut off the master switch of the affected engine. If the fuel line to the LP valve is not damaged, this provides the best elimination of flammable liquids from the fire. 5 seconds after switching off the engine master switch, the fire push button for the affected engine is pressed to shut off the fuel supply in a second valve in the engine pylon. This serves isolating the fuel supply in case of mechanical damage to the fuel pipe or the LP valve inside the engine.

Wait until the engine has spooled down and then release fire extinguishing agent 1 by pressing the AGENT 1 button. If the fire is still present half a minute after releasing the first agent, release agent 2 by pressing the AGENT 2 button.

If the APU fire alarm is activated, press the APU fire switch. This disconnects fuel and electrical supply from the APU and shuts off the APU bleed. Once APU has started spool down, release the fire extinguishing agent by pressing the AGENT button.

Fire system tests can must be conducted before each flight by pressing the TEST button on the overhead panel in vicinity of the fire push button. This tests the fire detection loops and the signal chain for the alarm. When pressing the button, the lights in the fire push button and the agent buttons have to light up. The associated fire warning is posted on the EWD and the master warning sounds.

2.3 Electrical system

2.3.1 Electrical power generation and distribution (ATA24)

System main purposes

- Generate 115VAC 400Hz and 28VDC power
- Distribute the electrical power to the consumers

AC power generation

The electrical system has 5 possible sources for 115VAC, 400Hz electrical power, which are used in the priority order listed:

- 1) 1 electrical generator per Engine. Power rating: 90kVA
- 2) 1 electrical generator in the APU. Power rating: 90kVA
- 3) 1 power connection for ground power.

- 4) 1 emergency generator as backup source. It runs on hydraulic pressure from the blue hydraulic system.

In normal configuration, the generator in engine 1 supplies AC1 bus and the generator in engine 2 supplies the AC2 bus. If one engine generator is not available, the remaining engine generator can supply both AC busses via the Bus Tie. If APU or external power are available, they can supply either of the two AC busses via the bus tie as long as the associated engine generator is not available.

Besides the busses AC1 and AC2, there is a third essential AC bus, called AC ESS. This bus is normally supplied by AC1 but can be switched to be supplied by AC2 bus via a switch in the overhead panel. If both AC1 and AC2 busses are lost, the AC ESS bus can be supplied directly by the emergency generator.

For the emergency case of the aircraft flying on batteries only, the AC ESS bus can also be supplied via a static inverter directly from battery 1.

DC power generation

The electrical system features two batteries as sources for 28VDC supply. These are used, if no other source of power is available. With an AC source available, the DC power is generated by three Transformer rectifier units (TRU) that are fed by one of the AC busses each. In the absence of failures, only TRU1 connected to the AC1 bus and TRU2 connected to the AC2 bus are active. If one of these TRUs fails, the third TRU connected to the AC ESS bus takes over.

TRU1 feeds the DC1 bus, TRU2 feeds the DC2 bus, and TRU ESS, if active, feeds the DC ESS bus. Without failure, the DC ESS bus and the DC Bat bus are supplied by the DC 1 bus. In case of failure of a TRU, the DC ESS bus transitions to supply from the TRU ESS and DC1, DC2 and DC BAT are supplied by the remaining TRU.

Power distribution

As discussed in the previous paragraph, the AC power distribution is performed by three busses:

- AC1 bus
- AC2 bus
- AC ESS bus (with possibility to shed some AC loads)

The systems are distributed across the three busses such that loss of one bus would not result in total loss of one system. For example, the main tank fuel tanks are distributed over AC1 and AC2 busses. If AC1 bus is lost, half of the fuel pumps are lost, but there is still one pump left per tank; no tank is left without fuel pump.

The AC ESS bus powers a minimum set of systems required for continued safe flight and landing. A portion of the systems powered by AC ESS are on the so-called SHED bus, which can be disabled if required. For example, the captain PFD and the EWD are powered by the AC ESS bus as these are absolutely required devices to land the aircraft after a major combination of faults. The captain ND on the other hand is on the AC ESS SHED bus. If there is a total loss of electrical power generation, the ESS SHED bus is disabled while the aircraft is flying on batteries only – Captain ND is lost. Once the RAT extended and the emergency power generator is providing power to the AC ESS bus, the shed-part of the bus is powered again and the captain ND is recovered.

- DC power distribution is performed by a total of 6 busses:

- DC1 bus
- DC2 bus
- DC ESS bus (with possibility to shed some DC loads)
- DC BAT bus
- HOT1 bus
- HOT2 bus

As discussed in the section power generation, the DC1, DC2, DC ESS and DC BAT busses are normally powered by the TRUs unless battery power is the only power source available. The HOT busses represent a direct connection to the battery via a circuit breaker. These supplies are always available as long as the battery has charge. The batteries are automatically recharged from the DC BAT bus, if the DC BAT bus is powered by a TRU.

If the DC ESS bus is powered by a battery source, some of the loads on the bus are disabled, i.e. shed.

System operation

The operation of the electrical system, including reconfigurations in presence of some failures is fully automatic. In normal operation the only interaction with the electrical system is the enabling or disabling of external power and switch the batteries ON/OFF during aircraft start-up/shut-down. All other switches should be left in the AUTO position, i.e. no white labels visible.

In the case of loss of AC1 bus, it is necessary to manually configure the AC ESS bus to feed from AC2. In order to do so, press the ALTN FEED button in the overhead panel. The white label ALTN will light up.

All other switches do not need to be operated inflight, unless a checklist on the EWD asks to do so.

2.3.2 Lights (ATA33)

System main purposes

- Provide external illumination for aircraft visibility (collision avoidance), illumination of taxiway/runway and wing inspection.
- Provide internal illumination in cockpit and cabin
- Provide emergency illumination for evacuation

External lights

The external lights serve three purposes:

- Make the aircraft better visible for other aircraft to avoid collisions. The following external lights fulfil this function:
 - Navigation lights
 - Strobe lights
 - Logo light
 - Beacon light

- Illumination of taxiway and runway for pilot control. The following external lights fulfil this function:
 - Nose wheel light
 - Runway turnoff light
 - Landing lights
- Illuminate the wings for inspection for ice build-up. The following external lights fulfil this function:
 - Wing lights

The navigation lights are located on the right wing tip (colour green), the left wing tip (colour red) and the rear end of the aircraft fuselage in white. There are two sets of navigation lights directly next to each other in each of these locations. One set is supplied by AC BUS 1, the other supplied by AC BUS 2.

In the vicinity of the navigation lights are also the strobe lights, i.e. on each wing tip and at the rear end of the fuselage. The strobe lights are always supplied by the AC2 bus. They can be operated in an AUTOMATIC mode or manually switched ON or OFF. In automatic mode, the strobes are off on the ground and come on automatically as soon as the main landing gear leaves the ground.

The logo light illuminates the tail of the aircraft. The logo light on the left side is powered by AC1, the logo light on the right side is powered by AC2. The logo lights are on automatically when the navigation lights are on and the aircraft is on the ground or the flaps/slats are extended.

The beacon light is the equivalent of the anti-collision light in general aviation. It consists of two red flashing lights one on top of the fuselage, one at the bottom of the fuselage.

The nosewheel lights consist of two lights attached to the nosewheel strut. One light serves as illumination during taxi and a second, much stronger light serves for runway illumination during take-off. These lights are powered by AC1 BUS and AC2 BUS.

The runway turnoff lights are also attached to the nosewheel but illuminate the path to the left and the right of the aircraft to allow runway and taxiway turnoffs at night. These lights are also powered by AC1 and AC2.

The landing lights are located under the wings close to the fuselage. They are retractable in flight. They serve to illuminate the runway during take-off and landing. The left landing light is powered by AC1, the right landing light is powered by AC2.

The wing lights are located on the side of the fuselage and illuminate the wing leading edge. This is used for inflight inspection of the wings if ice build-up is suspected. In contrast to the other external lights, for the wing lights the right light is powered by AC1 and the left light is powered by AC2.

Internal lights

The internal lights are used to illuminate the cockpit and the cabin.

The cockpit can be lighted via numerous different light sources:

- Dome light
- Flood lights for main panel and pedestal
- Panel integrated lighting
- Annunciator lights

The dome light is the most important light source in the cockpit. It is supplied by the DC ESS bus and is together with the left panel flood light the only light source available in an electrical emergency. It can be operated at two different brightness levels.

The flood lights illuminate the main panel (between the screens) and the pedestal. The brightness of these lights can be adjusted via rheostats. The flood lights are powered either by the DC1, or the DC ESS bus.

The integrated lights illuminate the background of the main panel, the overhead panel and the pedestal to allow reading the text on these panels at night. Integrated light brightness can also be adjusted via rheostats. The integrated lights are supplied by the AC 1 bus.

The annunciator lights are the lights integrated into the push buttons in the overhead and main panel as well as the pedestal. The brightness of these lights can be set to DIM or BRT and they can also be tested. When testing the lights all the lights are on simultaneously. This allows checking for broken bulbs. The annunciator lights are powered by numerous AC busses, including the AC STAT INV bus which allows having the lights working with electrical power only from BAT 1.

The cabin lighting in the ToLiss is fully automatic. Cabin lights are on during dusk, night and dawn and are automatically dimmed during take-off and landing. Cabin lights are powered by the AC1 bus.

Emergency lights and signs

The cabin is equipped with emergency lights for evacuation after total loss of power. The most important part of the emergency lights are the exit signs. The exit signs are powered by their own internal batteries. These batteries are charged from the DC ESS Shed bus, if power is available. The exit lights light up when the associated switch is in the ARM position and the landing gear is down, or electrical power is lost. The lights can also be forced on, by setting the EXIT SIGNs switch to ON.

The Fasten seat belts sign can be switched on and off from the dedicated switch in the cockpit.

The No Smoking signs are on, whenever the NO SMOKING switch is not in the OFF position. When the NO SMOKING switch is set to the ON position, this forces the emergency exit lights to ON.

System operation

The lights are operated via the switches located in the forward portion of the overhead panel with the external lights being to the left and the internal lights being to the right of the APU switches.

Main panel and pedestal flood lights and main panel integrated light are controlled via knobs located on the pedestal.

2.4 Pneumatic systems

2.4.1 Bleed air (pneumatic) system (ATA36)

System main purposes

- Produce pneumatic air with controlled temperature and controlled pressure
- Distribute the pneumatic air to the consumers: Air conditioning, engine start, and anti-ice systems
- Perform leak detection to protect the surrounding structure from overheating

Bleed generation

Engine Bleed

Bleed air can be generated by two sources: the aircraft main engines or the APU. On ground, it is also possible to feed bleed air into the aircraft via the external bleed connector

Engine bleed generation is the main bleed air supply in flight. The bleed air is tapped from the engine high pressure compressor before the air enters the combustion chamber. Due to the compression ratios achieved in the engine, the air has heated up significantly compared to the ambient air temperature. The exact tapping location depends on the current operating regime of the engine and the ambient air pressure.

At low engine speeds and low ambient pressures, the air is tapped after the last compressor stage just before the combustion chamber. If the engine is running fast enough that the pressure half way down the compressor is sufficient to supply the bleed consumer systems, bleed air can be tapped at an intermediate stage of the compressor.

The tapping point is managed via the engine-internal HP bleed valve and a check valve at the intermediate tapping point. If the HP bleed valve is closed, the air comes from the intermediate tapping point. If the HP bleed valve is open, the higher pressure of the HP bleed forces the check valve to close and the HP tapping point supplied bleed.

After being tapped from the engine, the bleed air passes through a Pressure regulation valve (PRV) to control the bleed delivery pressure and a precooler. The precooler takes air from the outer engine airflow to cool the bleed air to the desired target temperature of about 200degC. Downstream of the precooler the bleed air is supplied to the bleed distribution ducts. The PRV regulates the bleed pressure to the target value of about 44psi.

APU Bleed

The APU can also supply bleed air provided by a dedicated compressor stage, the APU load compressor. This compressor is driven by the APU exhaust gas via a dedicated turbine. The compression ratio of the APU load compressor is such that pressure or temperature regulation are not required.

The APU bleed is fed into the bleed air distribution system via the APU bleed valve and a separate check valve. The check valve prevents reverse flow through the APU of the higher-pressure engine bleed air.

Bleed Air Ground Connection

A HP air connection on the underside of the aircraft allows supplying the system by external means when the aircraft is on the ground. This can, e.g., be used to start the engines when the APU is not available.

Bleed distribution

The bleed air is distributed to the consumers via a left side duct and a right side duct. The HP ground connector, engine 1, and the APU provide their bleed air into the left side duct. Engine 2 provides bleed air to the right side duct. The left and right side can be interconnected via the cross-bleed valve.

The left bleed duct supplies air conditioning pack 1, left side wing anti ice, and the left engine starter motor. Analogously, the right bleed duct supplies air conditioning pack 2, the right side wing anti ice and the right engine starter motor. Note that engine anti-ice is not supplied by the bleed system, but directly by the engine.

The cross-bleed valve can be controlled from the cockpit via the cross-bleed switch which has 3 positions: Open, Auto, and Shut. In positions Open and Shut, the cross-bleed valve will follow the switch command as requested. In Auto position, the Cross-bleed valve will be open if the APU is providing bleed air, otherwise it will be closed.

Leak detection

Bleed gas is very hot and can be damaging to surrounding structure in case of bleed leakage from the duct. Bleed leaks must therefore be detected and bleed supply to the leaking duct shut off. This task is performed by two bleed management computers (BMC).

In order to detect possible bleed leaks, bleed detection loops are routed along the bleed ducts. These detection loops contain an inner electrical conductor and an outer electrical conductor, separated by an isolating material. If hot bleed air hits the bleed leak detection loop, the isolating material between the two conductors becomes electrically conductive, short circuiting the inner and outer conductor at the location of the leak. This short circuit is detected by the BMC. The BMC then automatically closes the engine and APU bleed valves of the affected zone. Note that the bleed ground supply cannot be closed by the BMC. If the cross-bleed valve is set to Open, it also cannot be closed by the BMC.

System operation

In normal operation, the only Bleed related switch that needs to be manipulated is the APU bleed pushbutton in the overhead panel. While on ground, after APU start, the APU bleed switch is put to ON in order to supply the bleed system with pressurized air. This pressurized air is used to start the engines. Once engine start is complete, the APU Bleed air button is switched off again.

All other buttons on the bleed panel (ENG x Bleed and Cross-Bleed Switch) are only used after failure cases. In this case follow the ECAM instructions to set the switches in the required position.

2.4.2 Environmental control system / Air conditioning (ATA21)

System main purposes

- Generate temperature-controlled air from bleed air (ATA 21-60) to use as fresh air supply to the cabin air distribution subsystem.
- Control cabin temperature (ATA21-63)
- Distribute fresh air in the cabin (ATA21-20)
- Control the cabin pressure (ATA21-30) in order to provide a sufficiently high cabin pressure for the occupants without overstressing the aircraft structure
- Provide ventilation of the avionics equipment to prevent equipment overheat (ATA21-26)

Generation of temperature-controlled air (Air conditioning packs)

The aircraft has two air conditioning packs which use bleed air from the pneumatic system to generate cold air used for the cabin air supply. Pack 1 takes bleed air from the left side bleed duct, pack 2 takes bleed air from the right side bleed duct.

In the packs, the air is guided through 2 heat exchangers and an air cycle machine in order to reduce the temperature to the desired value. The bleed flows first into the primary heat exchanger where it is cooled down using surrounding air passing through the aircraft belly fairing. This cooled air is then passed through a compressor in which temperature and pressure increase again. Subsequently it goes again into a heat exchanger cooling the air with the help of the airflow through the belly fairing. Subsequently, the air flows through a turbine in which it is expanded to slightly above cabin pressure. In this process the air cools down. This turbine drives the compressor of the air cycle machine and it also drives a fan to drive ambient air through the heat exchangers. The fan is only required for operation on ground; otherwise the wind around the aircraft is sufficient to drive ambient air through the heat exchangers.

The pack outlet temperature is controlled via the turbine bypass valve. This valve passes air from after the first heat exchanger directly to the pack outlet, reducing the overall cooling effect of the pack. Also, the ram air inlet can be modulated to change the flow of ambient air through the heat exchangers, reducing the cooling effect of the heat exchangers.

The pack controller drives the turbines bypass valve and the ram air inlet in order to achieve the cabin air inlet temperature requested by the cabin temperature zone controllers.

Cabin temperature control

There are three zones in the aircraft cabin for which the target temperatures can be selected individually: the cockpit, the forward cabin and the aft cabin. Temperature control is performed by the zone controllers. The zone controllers mix some unconditioned bleed air, called trim air, to the pack outlet air in order to achieve the desired target temperature for the air entering the cabin.

The lowest demanded zone entry temperature is sent to the pack controllers and the packs adjust the outlet temperature accordingly. The inlet temperature for the other two zones is adjusted via the trim air valves by adding the desired amount of hot air.

Cabin air distribution

The core component of the cabin air distribution is the mixer unit. The mixer unit receives the fresh air from both air conditioning pack as well as air from the 2 cabin air recirculation fans. The cabin air recirculation fans pull in air from the cargo compartment; this air has previously been in the aircraft cabin but moved into the cargo compartment through the gaps between the cabin floor and the outer aircraft skin. The purpose of the recirculation is to provide better air circulation in the cabin without having to take all the air required for that from the cabin.

When on the ground, a low pressure ground connection can also be used to provide fresh air to the mixer unit; this allows cooling or heating the cabin in extreme temperatures without having to start the aircraft bleed air system.

From the mixer unit, the air is guided to the three zones: cockpit, forward cabin and aft cabin. Before being released into the cabin through a large array of cabin air outlets, the air is mixed with the trim air in order to achieve the desired cabin inlet temperature.

Cabin pressure control

The cabin pressure is adjusted to its target value by controlling the amount of air leaking from the cabin. There is a small amount of natural leakage of the aircraft fuselage that cannot be prevented; however, most air is vented overboard through the outflow valve located in the rear right of the aircraft fuselage.

The cabin pressure controller regulates the open area of the outflow valve in order to achieve the desired cabin pressure target. Cabin pressure remains constant if the amount of air provided by the packs equals the amount of air flowing through the outflow valve and the amount of air leaking from the fuselage through other openings.

The cabin pressure control aims at adjusting the cabin pressure to 0.1psi above the aerodrome pressure for both take-off and landing. In cruise the cabin pressure is reduced as a function of cruise altitude. The lowest normal cabin pressure equals to the air pressure at 8000ft altitude. When landing at airports that are higher than 8000ft (e.g. La Paz in Bolivia), the cabin pressure actually reduces when the aircraft initiates the descent for landing.

In the rear pressure bulkhead, i.e. the rear limit of the pressurized fuselage are two safety valves. These open when the pressure difference between the cabin and the ambient air exceeds certain thresholds: if the pressure in the cabin is more than 8.6psi above the ambient pressure the valves open; they also open if the cabin pressure is less than the ambient pressure by more than 1psi.

Avionics equipment ventilation

The avionics equipment ventilation provides the necessary amount of cooling air to the avionics computers in the cockpit and the avionics bay. This function is available as long as the aircraft is powered in order to prevent overheating of any of the computers installed in the aircraft.

The system operation is fully automatic. The Avionics equipment ventilation computer (AEVC) drives the blower fan, the extract fan, the skin air inlet valve, the skin air extract valve and a number of internal valves. The system can operate in closed circuit configuration, intermediate configuration, or open configuration, depending on the air/ground status of the aircraft and the ambient temperature.

The closed configuration is used most times in flight, and on ground, if the ambient temperature is below about 12 degC. In this case the skin valves are closed and the air for equipment cooling is

extracted by the blower fan from the avionics compartment. The air is expelled by the extract fan into the cargo compartment underfloor area and some air is returned to the blower fan via a skin heat exchanger to cool the air.

The intermediate configuration is used in flight only, if the ambient temperature is too hot for the closed-circuit configuration. The intermediate configuration is almost identical with the closed configuration with the exception that part of the air from the extract fan is expelled overboard via the partially open skin air extract valve.

The open configuration is used on ground, if the ambient temperature is greater than 12degC. In this case, the blower fan pulls in air from the outside via the skin air inlet valve and provides it to the avionics equipment. The extract fan expels the air outside through the skin air extract valve.

Following failures of the blower of the extract fan, the air can be taken from the air conditioning duct to fulfil the avionics cooling function. In case of avionics smoke, both fans are switched off and air is taken from the air conditioning duct, passed through the avionics bay and expelled overboard through a partially open skin air extract valve.

System operation

Most of the air conditions system operates fully automatically. The pilot can change the system configuration via the Air Conditioning panel, the pressurization panel, and the Ventilation panel in the overhead panel.

In normal operation, the pilot only needs to set the pack flow and the desired zone temperatures. Low pack flow can be selected if there are less than 115 passengers on board, otherwise the pack flow needs to be set to NORM. At very hot airports, it may be necessary to set the pack flow to High in order to achieve the desired cabin temperature.

For take-offs where the maximum engine thrust is required, the packs can be switched off for take-off via the PACK1 and PACK2 push buttons in the Air conditioning panel.

All other switches are only required after system failures. In that case, follow the ECAM actions.

2.4.3 Ice protection system (ATA30)

System main purposes

- Protection of the wings against ice accretion
- Protection of the engine inlets against ice accretion
- Protection of the air data probes and wind shield against ice accretion
- Detection of environmental icing conditions

Wing ice protection

The wings are protected against ice accretion as ice on the wings leads to a significant increase in aircraft weight and drag as well as a decrease of aircraft lift. To prevent ice accretion, the wing ice protection system uses hot bleed air which it blows against the inside of the wing leading edge. This raises the wing leading edge temperature to levels at which ice cannot form. (or already existing ice is melted) The left wing ice protection system uses bleed air from the left bleed air duct, the right wing ice protection system uses bleed air from the right bleed air duct.

The outer 3 slats of the wing are heated by the wing ice protection system. The wing valve is just outboard of the engine pylon and controls the amount of bleed air fed to the wing slats.

When operated on the ground, the system operates for a maximum of 30s.

Engine ice protection

The engine inlet lip can be heated in order to prevent ice accretion on the engine inlet. This is necessary as ice accretion on the engine inlet can disturb the airflow through the engine to a level that prevents thrust generation in the engine and the engine may shut down uncommandedly.

The hot air used to heat the inlet lip is tapped directly from the engine compressor and therefore independent of the bleed air system.

The engine anti-ice valve controls the flow of hot air to the engine inlet and is controlled by a switch in the overhead panel.

Air data probes and wind shield ice protection

The air data probes (pitot tubes, angle of attack sensors, static ports and total air temperature probes) are subject to icing as they protrude from the aircraft. If the sensors ice up, the data indicated by the probes will be erroneous which can lead to a dangerous flight condition.

The windshield can also ice up obstructing pilot vision.

All air data probes and the windshield are protected against icing by electrical heating circuits. The heating of these items works automatically as soon as the aircraft is in flight, or on ground if at least one engine is running (for the air data probes) or both engines are running (for the wind shield)

To prevent overheating, the heating level of the pitot tubes, TAT probes and wind shields is low when the aircraft is on ground and high when the aircraft is in flight.

In the overhead panel is a switch labelled "Probe/Window heat". The only effect that this switch has is that it enables probe heating if the aircraft is on ground with both engines shut down. It has no effect in flight.

Ice detection system

On the side of the aircraft are two sensors installed such that in icing conditions, ice will accrete first on these probes. If ice accumulates on the probes, this is detected and annunciated via ECAM messages. The probes are heated in regular intervals to shed any ice that accumulated on them in order to sense if the aircraft is still in icing conditions.

System operation

The Anti Ice panel in the overhead panel contains the wing anti-ice switch and the engine anti-ice switches. When flying through suspected icing conditions, switch on the engine and wing anti-ice systems. Keep in mind though that on ground, the wing anti-ice system will operate for 30s only to prevent leading edge overheating.

If the ECAM displays a caution about ice detected or severe ice detected switch on the anti-ice system as requested by the ECAM actions. When the ECAM displays a memo "Ice Not Detect", the anti-ice system can be switched off again.

Note that there is no need to switch on the “Probe/Window heat” button as this button only has effect when the aircraft is on ground.

2.4.4 Oxygen system (ATA35)

System main purposes

- Provide gaseous oxygen to the flight crew in case of low cabin pressure
- Provide gaseous oxygen to the passengers in case of low cabin pressure

Flight crew oxygen

In the side consoles besides the pilot and co-pilot seats, there are two oxygen masks that the flight crew puts on if the cabin pressure exceeds 10000ft. These masks are supplied by an oxygen tank located under the cockpit. The masks mix the oxygen from the bottle with the surrounding air in order to provide the optimal oxygen level to the flight crew.

A switch in the overhead panel allows isolating the oxygen bottle in case of leaks.

Passenger oxygen

Above each row of passenger seats is a chemical oxygen generator attached to four masks. If the cabin pressure exceeds 14000ft, these masks automatically drop into the cabin. When the passengers pull on the mask, a pin is removed from the gas generator and the oxygen starts to flow.

A switch in the overhead panel allows manual deployment of the oxygen masks.

System operation

The oxygen masks are located in the side console next to the pilot seat. To don the oxygen mask, click on the console. A second click in the same location removes the mask.



An ECAM warning will be issued when it is necessary to don the oxygen mask.

The passenger oxygen masks can be released manually via a guarded switch in the overhead panel:



2.5 Hydro-mechanical systems

2.5.1 Flight control system (ATA27)

System main purposes

- Control aircraft motion, i.e. attitude, speed and direction of travel (ATA27-00)
- Increase lift to allow slower take-off and landing speeds (ATA27-50)

Primary flight controls (ATA27-00)

The primary flight control system controls the aircraft motion, meaning aircraft attitude, speed and direction of travel. The motion is control via the flight control surfaces:

- Two ailerons, one on the outboard portion of each wing: Used to control the aircraft roll angle
- Two elevators, one on each side of the horizontal stabilizer: Used to control the aircraft pitch angle
- One rudder on the vertical stabilizer: Used to control the aircraft sideslip angle
- 10 spoiler surfaces, 5 on each wing: Used for roll assist, for drag increase, and – after landing – for lift reduction
- The horizontal stabilizer trim: Used to reduce the elevator deflection to 0 for steady-state flight conditions

Note that technically speaking, the spoilers (ATA27-60) and the horizontal stabilizer trim (ATA27-40) are part of the secondary flight controls. However, in the scope of this manual, secondary flight controls refers to the high lift surfaces flaps (ATA27-50) and slats (ATA27-80) only.

All flight control surfaces are hydraulically actuated. Aileron, elevator and horizontal stabilizer trim can be actuated by two hydraulic circuits each which typically operate in an active/standby configuration. That means only one actuator is active at any given time and the second actuator only steps in when required. The rudder is actuated by three hydraulic actuators which are all three active simultaneously. The spoilers only have one actuator per panel with the hydraulic supplies being evenly distributed between the spoiler panels.

The ailerons, spoilers and the elevators are commanded electrically via commands from the ELAC (Elevator and Aileron Computer) and the SEC (Spoiler and Elevator Computer). Normally, the elevators receive order from the ELAC only, but following ELAC failures, this surface can revert to order from the SEC. Note that ailerons are not available anymore following a dual ELAC failure and spoilers would not be available if all three SEC are lost.

The rudder is commanded mechanically by the rudder pedals. The deflections from an electrically moved rudder trim actuator and from the yaw damper are mechanically added to the rudder pedal input. The yaw damper and the rudder trim actuator are commanded by the 2 FAC (Flight Augmentation Computers.)

The flight control system can operate in three different modes: Normal law, alternate law, and direct law. In absence of failures, it operates in normal law. Reversion to alternate law takes place if too many sensor data are lost to sustain normal mode or if flight control computers or 2 hydraulic circuits are lost. As landing in alternate law is difficult, the aircraft will revert from alternate to

direct law upon landing gear extension. A direct reversion to direct law would only take place in case of loss of all inertial data, as these are required to compute the alternate control laws.

Normal Law

Normal law is active unless a failure prevents its operation. In normal law, the pilot uses the sidestick to command an aircraft motion rather than a surface deflection:

- The pitch law is a C^* law. This means that the sidestick commands a blend of pitch rate and load factor. With the sidestick at neutral, the system attempts to maintain the load factor to 1g and the pitch rate to 0. The pitch law also contains turn compensation up to 30degrees of roll. That means that the aircraft automatically maintains the pitch attitude and flight path angle during turns without requiring sidestick input.

Note: The C^* parameter is the following blend between load factor and pitch rate:

$$C^* = \Delta N_z + \frac{V_{co}}{g} q$$

With V_{co} being the blendover speed in m/s. Below this speed, the pitch control is dominated by the pitch rate, above the speed its dominated by the load factor.

- The roll law is a roll rate command law: A full sidestick deflection requests a roll rate of 15deg/s. With neutral sidestick the aircraft maintains the current roll angle.
- The yaw law consists of yaw damper and turn compensation: the rudder is commanded to maintain a zero sideslip angle and to alleviate the Dutch roll motion.

If while in normal mode the aircraft approaches the limits of flight envelope, protection functions will replace the control functions listed above:

- Roll angle protection: If the aircraft roll is above 30degrees, it will return to 30 degrees automatically once the stick is returned to neutral. With the stick fully deflected the maximum achievable roll angle is 67degrees.
- Pitch angle protection: This function limits the maximum aircraft pitch to +30 degrees and the minimum aircraft pitch to -15 degrees.
- High speed protection: If the aircraft exceeds the maximum operating speeds VMO/MMO, this function activates and pulls up the aircraft nose to reduce speed. It also limits the maximum permissible bank angle to 45 degrees and returns the aircraft to level wings if the sidestick is at the neutral position in roll. The function is designed to ensure that the maximum dive speed demonstrated in flight test (VD/MD) are not exceeded at any point in time.
- Stall protection: This function activates, if the angle of attack comes dangerously close to the maximum angle of attack. When active, the pitch control law is replaced by an angle of attack command law with the sidestick fully aft commanding the maximum permissible angle of attack. Like the high speed protection, the angle of attack protection limits the bank angle to 45 degrees or less. To deactivate this mode, the sidestick needs to be pushed forward of the neutral position.
- Load factor protection: The C^* command is scaled such that the maximum load factor that can be achieved by full sidestick deflections cannot exceed the structural limits.

When landing, the aircraft transitions to the flare law replacing the pitch control law by a pitch angle request law.

On ground, the sidestick commands directly the control surface deflections.

Alternate Law

The flight control system changes to alternate law, when the resources required for normal law are not available anymore. The control around each of the three axes changes as follows:

- The pitch law remains a C* law however with changed gains. Nevertheless, pitch behaviour in normal and alternate law is very close, as long as there are no protections active. Load factor protection is still available.
- The roll control law becomes a direct law. The aileron deflection is proportional to the sidestick roll command.
- The yaw command is limited to the yaw damping function. If both FAC are failed, Y+G hydraulics are failed or the yaw damper itself is failed, the yaw command is limited to the mechanical command from the rudder pedals.

If while in alternate law, the aircraft approaches the limits of the envelope, the following protections are available:

- Load factor protection: This protection is available in all flavors of the alternate law. It prevents overstressing the aircraft structure
- Low and high speed stability: These functions are available as long as the system still receives one valid source of air data. These functions modify the stick neutral C* target in order to stabilize speed. When the aircraft speed drops below stall warning speed, the neutral stick C* target is reduced to lower the nose and stabilize the speed. Analogously, if the speed exceeds the maximum permissible speed, the stick neutral C* target is increased in order to raise the aircraft nose and stabilize the speed.

The alternate law does not have a specific flare law. Therefore, the system transitions to the direct law when the landing gear is extended and the autopilot is off. If no landing gear information is available, the system transitions to direct law when flaps are selected to position 2. Autoland in alternate law is not permitted.

Direct Law

The flight control system changes to direct law, if all inertial data are lost, or when the aircraft is in alternate law and the landing gear is extended. (For details see the previous section.) In direct law, the side stick commands directly the elevator and aileron deflections while the pedals command directly the rudder. If the aircraft is in direct mode with inertial data available, the yaw damping function is still available.

Direct law does not provide any protection functions.

Reconfiguration between laws

The following failures will bring the aircraft from normal law to alternate law when in flight:

- Any dual hydraulic failure
- Loss of two or more air data sources. (Be it loss of ADR or miscompare between all available ADRs)
- Loss of two inertial data sources
- Dual ELAC fail or dual FAC fail
- Loss of both ailerons
- Loss of all spoilers, including triple SEC fault
- Loss of one elevator

- Combinations of loss of 1 ELAC and 1 hydraulic system such that one elevator reverts to SEC control

The following failures will bring the aircraft directly from normal law to direct law:

- Validity loss for all three inertial sources. (Loss of source or miscompare of all available inertial data.)

When the conditions for normal law are met again, i.e. the failure leading to loss of normal law has been resolved, an ELAC or a FAC reset can return the aircraft to normal law when in flight.

System operation

The operation of the flight control system is more or less transparent to the pilot. The pilot uses the sidestick and pedals to control aircraft like on any other airplane. Possible control law reversions are annunciated via ECAM. In normal operation, it is not required to push any of the flight control computer switches in the overhead panel.

If the aircraft has reverted to alternate or direct law and the conditions for normal law have been restored, a FAC reset or ELAC reset via the overhead panel switches is required to restore normal law.

The speed brake lever located in the pedestal is used to extend the speed brakes in flight which allows higher rates of descent than with speed brake retracted. The speed brake lever is also used to arm the ground spoiler function. Pulling the speed brake lever up, while it is in the retracted position arms the ground spoiler function. The arming is indicated by the white band visible around the speed brake lever. The function will deploy the ground spoilers when:

- The aircraft is on the ground
- Air speed is higher than 72knots
- Both thrust levers are at idle or close to idle

High lift system – description and operation

The high lift system is used to increase the available lift for take-off and landing. During landing, it can also be used to increase drag which facilitates the speed management on approach.

The system consists of 5 leading edge slats per wing and 2 trailing edge flaps per wing. The leading-edge slats, when extended, increase the stall Angle of Attack and therefore the available lift. The trailing edge flaps, when extended, increase the lift produced at a given angle of attack, but they slightly reduce the stall angle of attack. Overall, flaps still lead to an increase of the maximum available lift.

The high lift system provides 6 predefined positions for slat and flaps:

High lift position	Slat position [deg]	Flap position [deg]
0	0	0
1	18	0
1+F	18	10
2	22	15
3	22	20
FULL	27	35/40 (depending on engine type)

On the ground, position 1 is not available, a selection of the flap lever to position 1 will always lead to selection of position 1+F which is most frequently used for take-off.

In air, setting the flap lever to position 1 will give configuration 1, if the flap lever was in position 0 before. If the flap lever was in position 2 or higher and airspeed is less than 210kts, setting the flap lever to position 1 will lead to a selection of configuration 1+F. If configuration 1+F is selected and the aircraft accelerates beyond 210kts, the configuration will change from 1+F to 1 automatically.

The slat system and the flap system are driven by two hydraulic motors each. The slat system motors are supplied by the green and blue hydraulic systems. The flap system motors are supplied by the green and yellow hydraulic systems. The motors are combined such that the motor speeds add up. If one of the hydraulic systems driving a motor is lost, the surfaces can still move but will do so at half speed.

2.5.2 Hydraulic system (ATA29)

System main purposes

- Provide power the flight control system
- Provide power to the landing gear
- Provide power to the thrust reversers
- Provide power to the emergency generator (if required)

System architecture

The hydraulic system has three individual hydraulic circuits which are isolated from each other. If one circuit loses hydraulic liquid, the remaining circuits remain unaffected. The circuits are labelled “green”, “blue”, and “yellow”

Each of the circuits has two or three pumps that can provide hydraulic pressure to it. The different pressure sources are listed in the following table:

Hydraulic pressure sources for each circuit		
Green	Yellow	Blue
Left engine Pump	Right engine pump	Electrical pump
Power transfer Unit	Power Transfer Unit	Ram Air Turbine
	Yellow electrical pump	

The engine driven pumps for the green and yellow systems are connected to the N2 shaft of the respective engine and produce pressure as soon as N2 is greater than 10%. However, at N2 values below idle, the hydraulic flow available from the pumps is insufficient to supply all systems operating. The pumps can only solidly pressurize the systems, if the engine is running at idle or higher.

The blue electrical pump is powered by the AC bus 1. It runs automatically, if the aircraft is in air or if at least one engine is running. There is also a switch in the Maintenance portion of the overhead panel that allows operating the blue pump on the ground with both engines OFF.

The power transfer unit can power either the green or the yellow system. In order to power one system, it is driven the other system. The PTU is typically used following engine failures to keep both the green and yellow system pressurized. The PTU run automatically if the pressure difference between green and yellow system exceeds 500psi and the aircraft is in air. On ground, the PTU can also run, if the pressure difference exceeds 500psi and both engine master switches are in the same position or the parking brake is not set and the aircraft is not being towed.

The yellow electric pump is most frequently used on ground to operate the cargo doors when the aircraft is shut down. Operation of the pump under these conditions does not require pilot interaction.

So-called leak measurement valves allow shutting off the hydraulic supply to consumers far away from the central fuselage, i.e. all primary flight control surfaces and the flap/slat wing tip brakes. These valves can be closed via the switches in the Maintenance part of the Overhead Panel. In normal operation, these switches are always left in the ON (no light in switch) position.

System operation

The operation of the hydraulic system is fully automatic and does not require any pilot action unless system failures occur. In case of system failures follow the ECAM actions to reconfigure the hydraulic system as required.

2.5.3 Landing gear system (ATA32)

System main purposes

- Provide a means for the aircraft to operate on ground
- Provide a means to retract the landing gear to reduce drag
- Provide aircraft steering on ground
- Provide braking action after landing and during taxi

Landing Gear general description

The landing gear of the Airbus A320 family of aircraft consists of two main landing gears, one under each wing, and one nose landing gear. The main landing gears and the nose landing gear can be retracted in flight to minimize aircraft drag.

The two main landing gears are equipped with brakes to slow down the aircraft after landing and during taxi.

The nose landing gear can be rotated to steer the aircraft on ground.

Extension and retraction – description and operation

The landing gear can be retracted in flight in order to reduce aircraft drag. Landing gear extension and retraction is selected by the pilot via the landing gear lever located in the cockpit main panel to the right of the lower ECAM screen. In case of failure of the normal extension/retraction function, a hand-crank in the aircraft pedestal can be used to extend the landing gear using its own weight.

Extension and retraction of the gear requires opening the gear well doors, then moving the struts to the desired position and closing the doors again. Door actuators and gear strut actuators are supplied by the green hydraulic system. Proximity switches on the gear doors detect the door position and enable movement of the gear strut once the doors are detected fully open.

If the green hydraulic system is failed, normal gear retraction/extension is not possible. In this case, the pilot can flip up a hand crank at the rear of the cockpit pedestal and turn the crank three times, this opens all the gear uplock bolts and puts the hydraulic valves into bypass mode. The gear can then extend under its own weight, pushing open the doors as required. In this case, the gear doors remain open even when the gear is fully extended.

Nose wheel steering – description and operation

The nose wheel can be rotated using power from the yellow hydraulic system. The maximum steering angle is 75 degrees and steering is only available if:

- The nose landing gear is on the ground (if not, the wheel centers automatically)
- Yellow pressure is available
- The A/SKID & N/W STRG switch in the main panel is set to on.

Nose wheel steering is controlled via the pedals and via the nose wheel tiller.

The pedals can command the nose wheel up to 6 degrees left right. Beyond 40 kts ground speed this authority is slowly reduced until it is 0 at 130knots ground speed.

The nosewheel tiller can order up to 75degrees nose wheel deflection. This angle reduces starting at 20kts ground speed, reaching 0 degrees of deflection at 80 knots ground speed.

Note that in the ToLiss Airbus A319, if you did not assign a tiller axis, the pedals have full tiller authority up to 20knots. This reduces to a value of 3 degrees of steering from 20 knots to 80 knots. Beyond 80 knots is slowly reduces to 0 when reaching 130 knots. This feature has been implemented to allow taxiing the aircraft for users that do not have a nose wheel tiller.

The A/SKID & N/W STRG switch is located in the main panel to the right of the upper ECAM screen. It is normally in the ON position throughout the entire flight. Certain failures may require to set it to OFF. If this is the case, an ECAM action item will ask the pilot to set it to OFF. Only set it to OFF, if requested to do so by the ECAM system.

Braking system – description and operation

The aircraft has two wheel braking systems: The normal system, powered by the green hydraulic system and the alternate system, powered by the yellow hydraulic system. A brake pressure indicator in the central main panel shows the brake pressure applied by the alternate braking system. There is no indication for the normal brake system pressures as the anti-skid system ensures that the brake pressure does not go so high that the brakes could lock.

The brakes can be applied manually through the brake pedals or automatically via the auto-brake system.

The autobrake system can be activated by selecting the desired level of braking action on the A/BRK panel located on the main panel to the right of the upper ECAM screen. It is only available with the normal braking system. That means, the green hydraulic system must be pressurized and the A/SKID & N/W STRG switch must be in position on. Three levels of braking can be selected:

- LO: Target deceleration rate of 1.7m/s^2 . At this deceleration rate, the slowdown from 130kts to stand still takes about 40 seconds, using 1360m of runway from the moment the autobrake system triggers, which is 4 seconds after ground spoiler deployment.
- MED: Target deceleration rate of 3.0m/s^2 . At this deceleration rate, the slowdown from 130kts to stand still takes about 23 seconds, using 800m of runway from the moment the autobrake system triggers, which is 2 seconds after ground spoiler deployment.
- MAX: This mode is normally selected for take-off and allows the most rapid deceleration possible during a rejected take-off. The system activates immediately when the ground spoilers deploy.

Note that all three levels of auto braking require ground spoiler deployment to activate. If you did not arm the ground spoilers prior to take-off or landing, or if the thrust levers are not at idle, the autobrake system will not operate.

Manual braking is performed via brake pedal deflections or via the x-plane brake commands. If normal braking is available, the anti-skid system will prevent locking of the wheels.

The system also features a park brake lever which can be used to set the brakes to a fixed pressure when the aircraft is stationary. The park brake also serves as a last means of braking, if all other brake systems have failed. The park brake and the alternate braking system can operate off a brake accumulator which allows at least 7 full brake applications even if yellow and green hydraulic system pressures are low.

Note that in the ToLiss Airbus A319, the X-Plane brake commands can toggle the parking brake if the aircraft is stationary and the engines are OFF or at idle. This feature allows easier use of the park brake without having to assign a separate button to it.

2.6 Autopilot and flight management (ATA22)

2.6.1 Autoflight system

The operation of the auto-flight system is described in detail in the tutorial flight.

2.6.2 Flight management system

The operation of the flight management system is described in detail in the tutorial flight.

2.7 Avionics

2.7.1 Indicating and recording system (ATA31)

System main purposes

- Pilot awareness of the current aircraft motion, planned path, and actual trajectory (EFIS)
- Pilot awareness of the aircraft system status (ECAM)

High level system description and operation

The core of the indicating and recording system are 6 display units: 2 in front of the pilot, 2 in front of the co-pilot and two in the center of the main panel. Display brightness setting for each of these units is described in the simulation manual and the tutorial flight.

Under normal conditions the display units in front of pilot and co-pilot are part of the Electronic Flight instrument system (EFIS) and display a Primary Flight Display (PFD) and a Navigation Display (ND) for each pilot. The center screens are displaying the data related to the Electronic Centralized Aircraft Monitoring (ECAM) and display aircraft system information.

The PFD and the ND location can be swapped using the PFD/ND XFR button located outboard of the 2 display units in front of the (co)pilot. If the PFD fails or is turned off, the PFD image is automatically transferred to the ND on the same side. The PFD/ND XFR button can then be used to cycle this display between PFD or ND information.

The two display units in the center of the main panel show the ECAM data. Under normal conditions, the upper ECAM screen shows the Engine Warning Display (E/WD) which displays all engine parameters, the flap/slat positions and all ECAM messaging, i.e. warnings, cautions, actions and memos. The lower ECAM screens shows the synoptic pages for the different aircraft systems, called system display (SD). The displayed page is automatically chosen depending on flight phase and possible failures. This selection can be overridden by push buttons on the ECAM Control Panel (ECP) located in the pedestal forward of the thrust levers.

If one ECAM screen fails, the remaining ECAM screen will revert to showing the E/WD only. In this case, the E/WD image can be replaced by the SD when the pilot pushes an SD page button on the ECAM Control Panel. It is also possible to move the SD to one of the Navigation displays using the ECAM/ND XFR switch located just below the lower ECAM DU. If both ECAM displays are failed or OFF, the ECAM/ND XFR switch moves the E/WD to the selected navigation display. In this case, a SD page can be shown on that ND by pressing the respective SD page button on the ECP.

2.7.2 Navigational equipment (ATA34)

The operation of the navigational equipment is described in detail in the tutorial flight.

2.7.3 Communication system (ATA23)

The operation of the communication system is described in detail in the tutorial flight.

3 Limitations

The following general limitation apply for the operation of this aircraft:

Speed limitations

The following speeds must not be exceeded during normal operation:

Table 3 – Aircraft maximum speeds

Flap/Slat position	Maximum Speed
0	350kts CAS (VMO) / Mach 0.82 (MMO)
1	230 (VFE)
1+F	215 (VFE)
2	200 (VFE)
3	185 (VFE)
FULL	177 (VFE)

With the landing gear not retracted, the following additional speed limit applies

- Landing gear extended (VLE): 280kts CAS / Mach 0.67
- Maximum speed for gear retraction (VLO): 220kts CAS
- Maximum speed for gear extension (VLO): 250kts CAS

The landing gear must not be extended above altitudes of 25000ft.

The **minimum speeds** are computed in flight and indicated on the Primary Flight Display (PFD). The stall speed for a load factor of 1G (VS1G) is indicated by solid red tape. The lowest speed at which autopilot functionality is available, called “Lowest Selectable Speed” (VLS) is indicated by an amber rectangle.

VLS is typically 1.23 times VS1G, except after take-off when it is 1.13 times VS1G. With flap/slats retracted, VLS is 1.28 times VS1G to ensure sufficient margin between VLS and activation of the angle of attack protection.

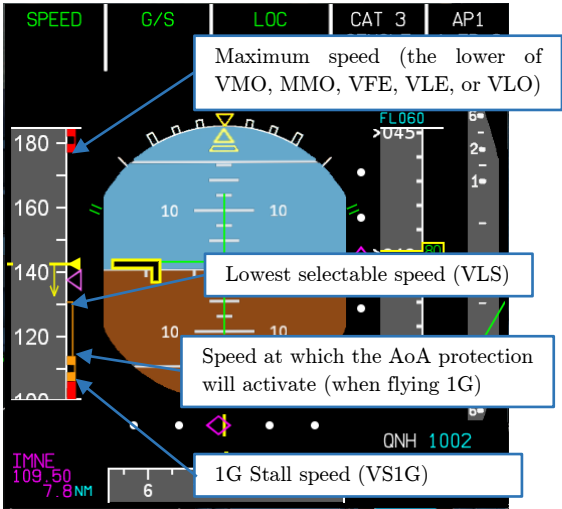


Figure 3 – Indication of characteristic speeds on PFD

Weight and CG limitations

The weight and center of gravity limitations for the ToLiss Airbus A319 are shown in the following figure:

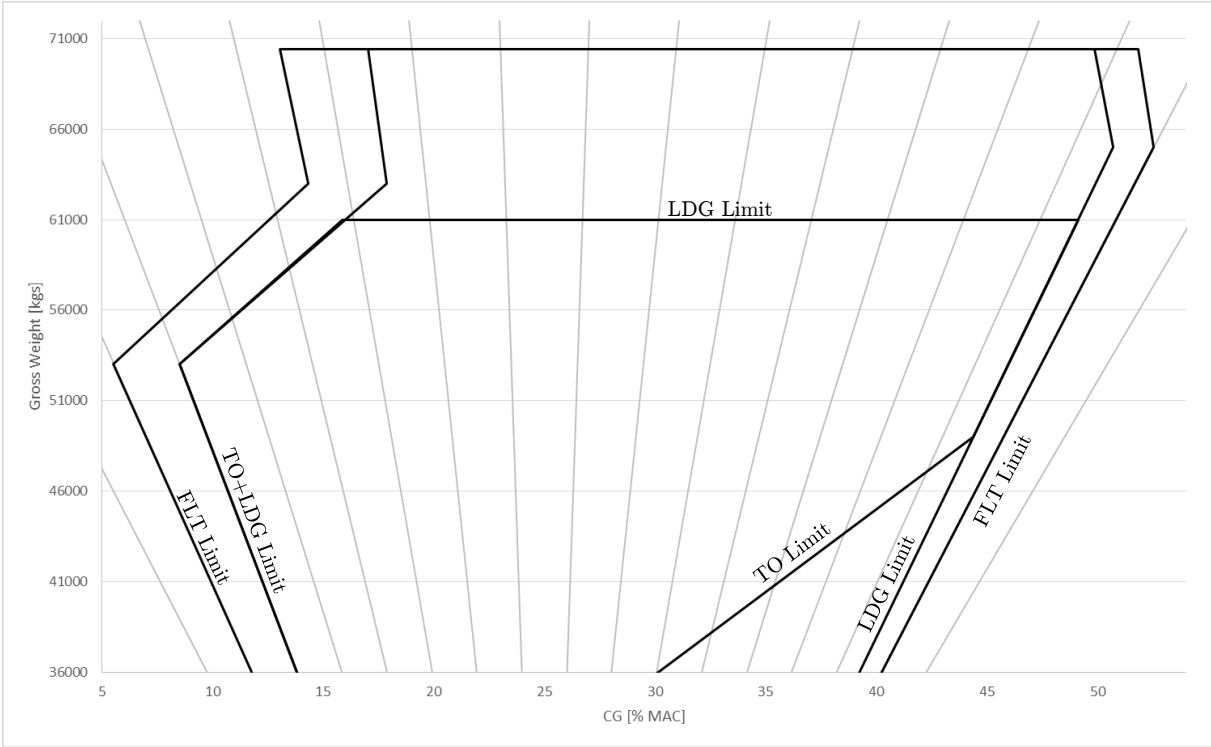


Figure 4 – Aircraft weight/CG envelope

Altitude limitations

The maximum altitude independent of weight is 39500ft. The maximum permissible altitude for different weights is shown in the following figures, depending on the engine type:

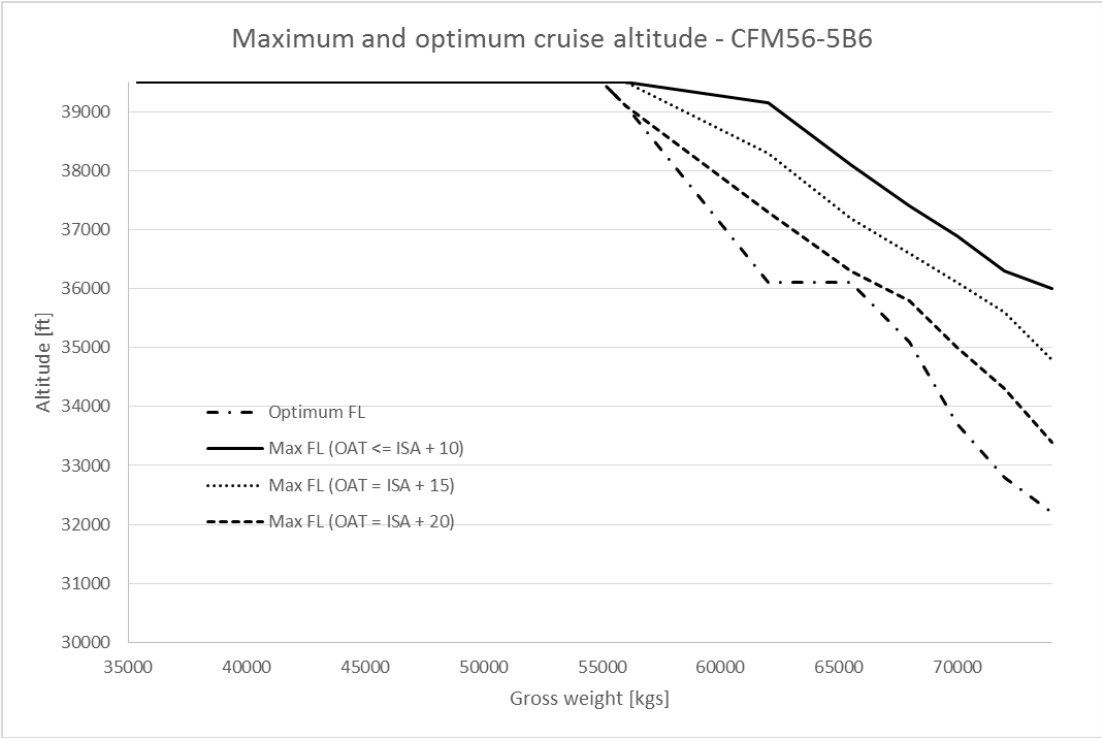


Figure 5 – Optimum and maximum altitude with the CFM engine

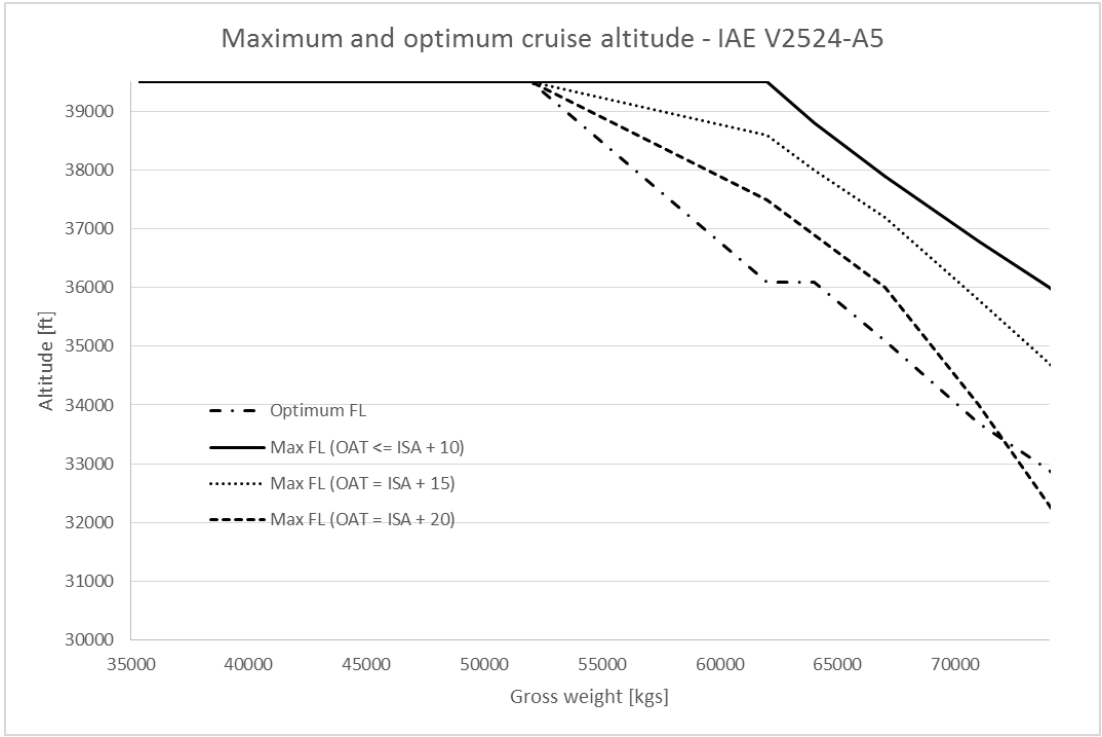


Figure 6 – Optimum and maximum altitude with the IAE engine

Airport operation limitations

Maximum pressure altitude for take-off and landing:	14500ft
Maximum temperature for take-off and landing:	ISA + 40 degC
Minimum temperature for take-off and landing:	- 45 deg C (at Sea level) - 56 deg C (at 14500ft)
Maximum runway slope:	+/- 2%
Nominal runway width:	45m (150ft)
Maximum crosswind take-off:	29kts (gusting 38 knots)
Maximum crosswind landing:	33kts (gusting 38 knots)
Maximum tailwind:	10kts
Maximum tire speed:	195kts

Note ISA + 40degC is the temperature of the International standard atmosphere (ISA) at the given altitude + 40 deg Celsius. For example, at sea level the ISA temperature is 15 degC. Take-offs are allowed for outside air temperatures (OAT) of 55degC or less.

3.1 System specific limitations

3.1.1 Air conditioning and pressurization (ATA21)

Cabin pressure differential limits:	Minimum -1psi; maximum 8.6psi
Maximum normal cabin altitude:	8000ft
Cabin altitude warning limit:	9550ft (+/- 350ft)

3.1.2 Autopilot system (ATA22)

Autoland limitations

The following limitations apply for full automated landing, flare and roll-out:

Maximum headwind:	30kts
Maximum tailwind:	10kts
Maximum crosswind:	20kts
Maximum runway altitude:	2500ft
Range of glide slope angles:	2.5deg to 3.15deg
High lift configuration:	Flaps 3 or flaps FULL

Decision heights for autoland:

CAT II ILS:	100ft
CAT III ILS with 1 AP engaged:	50ft
CAT III ILS with 2 AP engaged:	minimum 20ft, unless no DH approved

3.1.3 Electrical system (ATA24)

Maximum continuous load per generator: 100% (90kVA)
Maximum continuous load per TRU: 200A

3.1.4 Flight Control system (ATA27)

Maximum altitude for flight with flaps/slats extended: 20000ft

3.1.5 Fuel system (ATA28)

Maximum imbalance between left and right tanks is as per following table:

Table 4 – Permissible fuel imbalances

Outer tanks balanced; inner tanks imbalanced	
Content of tank with most fuel [kgs]	Maximum imbalance [kgs]
Full (5350)	1500
4300	1600
2250	2250
Outer tank imbalanced	
530	530

Note: Imbalance of the outer tanks is only permitted, if on the side with less fuel in the outer tank there is more fuel in the inner tank (up to 3000kgs more)

Minimum fuel for take-off: 1500kgs

3.1.6 Hydraulic system (ATA29)

Nominal hydraulic system pressure is 3000psi (+/-200psi)

3.1.7 Landing Gear system (ATA32)

Maximum brake temperature for take-off: 300deg C
Maximum thrust with parking brake on: 75% N1 or 1.18 EPR

3.1.8 Auxiliary Power Unit (ATA49)

Maximum EGT during operation: 675degC
Maximum EGT during start: 1090degC
Maximum altitude for APU bleed: FL200

3.1.9 Power Plant (ATA70)

Maximum time with thrust above MCT level:

5 minutes

10 min in case of engine failure

4 Standard operating procedures

Note that these procedures are for reference and assume that the user knows the location of the individual switches. Please perform the tutorial flight ones for familiarization.

4.1 Cockpit preparation from cold and dark

- Check that engines master switches are off
- Check engine mode selector in position NORM
- Check landing gear lever in position DOWN
- Check battery voltages above 25.5 Volts
 - If batteries below 25.5Volts, charge cycle required:
 - Set BAT1 and BAT 2 switch to position ON
 - Switch on external power
 - After 20 minutes
 - Set BAT1 and BAT2 to OFF
 - Check voltage above 25.5V
 - Repeat as required
- Set BAT1 and BAT 2 to AUTO
- Set DOME light (Panel INT LT) to brightness appropriate to current
 - BRT during daytime
 - DIM during night-time
- Check Parking brake is ON
- Check brake pressure at 1000psi or above (Triple pressure indicator on main panel)

4.2 Application of AC power

AC power can be applied either via ground power or by starting the APU from battery, if ground power is not available.

4.2.1 External power

The green AVAIL light in the external power switch must be lit up for this

- Switch external power to ON

Continue section 4.2.3.

4.2.2 APU start from battery

If the green AVAIL light in the external power button is not available, start the APU:

- Check that APU fire pushbutton is IN and guarded
- Check that APU fire extinguishing agent lights are OFF
- Press the APU fire test button
 - APU fire pushbutton must light up red

- SQUIB and DISCH lights in the APU fire Agent button light up
- Master warning sound and APU FIRE warning appears on ECAM
- Set APU Master Switch to ON
- Set APU Start switch to ON

4.2.3 Continued cockpit preparation

Note: Start the checklist here, if the start-up option is set to EXT POWER ON

Cockpit lights

- Set cockpit lights as required
 - Overhead panel integrated lights
 - Dome light
 - Annunciator lights (BRT at daytime, DIM at night)
 - Main panel flood light
 - Pedestal flood light
 - Main panel integrated lights
- Set brightness for the 6 display units as required
- Set brightness for the MCDU as required

Flight controls

- Check flap position shown on EWD matches flap lever position.
(If not, adapt flap lever position to position shown on EWD to prevent flap motion upon hydraulic pressurization.)
- Check speed brake lever retracted (white band not visible)

Overhead panel configuration

- Check Probe/Window heat is set to Auto (no lights visible in overhead panel switch)
- If APU running: Switch on APU bleed
- Check that all white lights on AIR COND panel are off
- Ensure Cross-bleed in position AUTO
- Set temperature control as desired
- Check in ELEC panel that only the GEN 1 (2) FAULT lights are on, plus EXT PWR ON light as applicable
- Check in the VENTILATION panel that all lights are off

4.2.4 Flight preparation

Navigation equipment

- Switch on the three ADIRUs:
 - Set ADIRU 1 switch to mode NAV.
 - Check that the ON BAT light lights up and wait until ON BAT extinguishes

- Set ADIRU 3 switch to mode NAV.
- Check that the ON BAT light lights up and wait until ON BAT extinguishes
- Set ADIRU 2 switch to mode NAV.
- Check that the ON BAT light lights up and wait until ON BAT extinguishes

Lighting

- Set Exterior lights as required:
 - STROBE to AUTO
 - NAV & LOGO to system 1 or system 2 (as desired)
- Set cabin illuminated signs as required:
 - SEAT BELT to ON
 - NO SMOKING to AUTO
 - EMER EXIT LT to ARM

Environmental Control System (ATA21):

- Set LAND ELEV switch to AUTO
- Select PACK FLOW:
 - Less than 115 passengers: Select LO
 - Otherwise: Select NORM
 - If at hot and humid airport: Select HI

Fuel panel (ATA28):

- Switch on all fuel pumps (no white lights in overhead fuel panel)

Engine fire protection test

- Check that ENG 1 and ENG 2 FIRE pushbuttons are IN and GUARDED
- Check that AGENT 1 and AGENT 2 lights are off
- Press ENG 1 FIRE TEST pushbutton:
 - ENG 1 FIRE pushbutton must light up red
 - SQUIB and DISCH lights in the Agent 1 and Agent 2 buttons light up
 - Master warning sound and ENG 1 FIRE warning appears on ECAM
- Press ENG 2 FIRE TEST pushbutton:
 - ENG 2 FIRE pushbutton must light up red
 - SQUIB and DISCH lights in the Agent 1 and Agent 2 buttons light up
 - Master warning sound and ENG 2 FIRE warning appears on ECAM

If APU is not yet running:

- Check that APU fire pushbutton is IN and guarded
- Check that APU fire extinguishing agent lights are OFF
- Press the APU fire test button
 - APU fire pushbutton must light up red
 - SQUIB and DISCH lights in the APU fire Agent button light up
 - Master warning sound and APU FIRE warning appears on ECAM

Communications (ATA23):

- Switch on each Radio Management panel (2 on pedestal, 1 in overhead panel)
 - Check that the green NAV light is OFF
- Tune appropriate frequency.
 - Use VHF1 for ATC (in emergency electrical configuration only VHF1 is available)
 - Use VHF2 for ATIS

4.3 FMGS initialization

Note: Start the checklist here, if the start-up option is set to APU + ADIRU ON

MCDU Aircraft status page

- Check engine type and aircraft type
- Check database validity

MCDU INIT page

- Press INIT key to access MCDU init page
- Fill TO/FROM city pair as per intended flight or use LOAD function in first line to load the active flight plan
- Enter ALTN (alternate) airport, or use LOAD function in second line to load the alternate flight plan.
Note: Only flight plans departing from the selected destination airport can be loaded as alternate flight plans.
- Enter flight number
- Enter Cost Index
- Enter intended initial CRUISE FL
- Check and modify LATitude and LONGitude to match current aircraft position
- Press ALIGN IRS (unless start-up option was set to APU + ADIRU ON)

F-PLN A page

- Press F-PLN key to access MCDU Flight Plan page
- Select departure route for the departure airport:
 - Click Left LSK next to departure airport to access “Lateral revision”
 - Click LSK next to “Departure”
 - Select desired Runway, SID and Transition
 - Select insert
- Enter airways towards destination as appropriate:
 - Click Left LSK next to last SID waypoint to access “Lateral revision”
 - Click LSK next to Airways
 - Enter airways designator and final waypoint as desired

Note: Up to 5 airways can be entered at one time

- Enter individual waypoints as required:
 - Enter waypoint name in scratchpad
 - Click left LSK next to waypoint, BEFORE which the waypoint shall be inserted
- Select arrival at destination airport:
 - Click Left LSK next to arrival airport to access “Lateral revision”
 - Click LSK next to “Arrival”
 - Select desired Approach, Via, STAR and Transition
 - Select insert
- Verify no discontinuities, except after MANUAL legs or Holdings
- Fill Alternate flight plan following the steps for the active flight plan.
- Verify Climb Speed limit:
 - Click right LSK next to a waypoint before the Top of Climb to access “Vertical Revision”
 - Verify CLB SPD LIMIT value and altitude. Update as necessary
- Verify Descent Speed limit:
 - Click right LSK next to a waypoint after the Top of Descent to access “Vertical Revision”
 - Verify DES SPD LIMIT value and altitude. Update as necessary
- Enter step altitude (if applicable):
 - Verify that waypoint with intended step is after T/C and at least 50NM before T/D.
 - Click right LSK next to waypoint for which step altitude is intended to access “Vertical Revision”
 - Select STEP ALTS
 - Enter step
- Enter speed or altitude constraints from ATC (if applicable):
 - Click right LSK next to waypoint with constraint to access “Vertical Revision”
 - Enter speed and altitude constraints as applicable
- Enter Climb and cruise wind
 - Click right LSK next to a waypoint before the Top of Climb
 - Select “WIND DATA” to access “Climb wind” page
 - Enter winds manually or use “Wind Request” feature to automatically retrieve wind data
 - Select “Next PHASE”
 - Enter the wind manually for the first cruise waypoint
 - Use up-down arrows to scroll to other waypoints and enter wind data as required.

Note: Wind data are automatically promoted from first cruise waypoint to all other cruise waypoint.

- Check flight plan on ND:
 - Set ND to plan mode
 - Return to FPLAN A page using FPLN button
 - Scroll through flight plan using the arrow keys and verify flight path on ND

RAD-NAV page

- Check Radio Navigation auto-tuning:
 - Select RAD NAV page
 - Verify autotuned ILS, VOR and ADF frequencies match flight plan

INIT B page

- Press INIT key to access MCDU init page
- Press SLEW KEY left or right to access INIT B page
- Insert Zero Fuel CG (ZFWCG) and Zero Fuel Weight (ZFW). (Data can be found on ISCS aircraft configuration tab.)
Note: Weight is entered in tons
- Insert Block Fuel in tons.

PERF page

- Press PERF key to access MCDU PERF Take-off page
- Set take-off speeds V1, VR, V2.
You can use the take-off performance calculator on the ISCS page “Aircraft configuration” to get these data.
- Insert Flex take-off temperature (if applicable)
You can use the take-off performance calculator on the ISCS page “Aircraft configuration” to get the flex temperature.
- Set or check Thrust reduction (THR RED) and Acceleration (ACC) altitudes
- Set or check Engine out acceleration (EO ACC) altitude
- Insert Flap position and THS position reminder.
You can use the take-off performance calculator on the ISCS page “Aircraft configuration” to get the THS position.

4.4 Startup preparation

- Set Glareshield integrated light and flood light as required
- Set baro reference to current value
You can get the current baro reference (altimeter setting) via ATIS or by making the indicated altitude match the departure airport elevation
Note: Don't forget to do this for pilot and co-pilot side!

- Check the flight director buttons are on (both sides)
- Select LS scales if required for take-off
- Set ND mode and range as required.
If after take-off direction changes of more than 70 degrees are planned, it is recommended to use mode ROSE NAV, otherwise use mode ARC.
- Set ND VOR/ADF selectors as required
- Flight control unit setup:
 - Check Speed Mach window is dashed. (Push SPD knob, if not)
 - Check Heading window is dashed (Push HDG knob, if not)
 - Dial first ATC cleared altitude into the altitude window
- Check loud speaker volume (pilot and co-pilot side)
- Reset timers on main panel Clock to zero (if applicable)
- Check that A/SKID and NW STRG switch is in ON position.
- Check on Switching panel that all switches in NORM position
- ATC transponder panel setup:
 - Dial in correct code
 - Set ALT RPTRG to ON
 - Select system 1
- Place MCDU in Take-off configuration:
 - Pilot flying side to display PERF TO page
 - Pilot non-flying side to display FPLN A page

4.4.1 APU start

This is only necessary, if the aircraft has been on External power up to now.

- Set APU Master Switch to ON
- Set APU Start switch to ON

Once APU AVAIL shows on EWD:

- Set external power to OFF
- Use ISCS to disconnect external power
- Switch on APU bleed

4.4.2 Push back preparation

- Switch on Beacon on EXT LT panel
- Check all doors closed
- Call push-back truck

Use appropriate procedure for plugin used for pushback

If pushback allows engine start, you can immediately continue to the next section.

4.5 Engine Start

- Set ENG MODE selector to position IGN/START
- ANNOUNCE “Starting Engine 2”
- Set ENG 2 MASTER switch to ON
- Monitor engine start:
 - N2 increases
 - Ignition (shown on lower ECAM ENG page) start around 16% N2
 - Fuel flow and EGT increase start around 22-25% N2
 - At 50% N2: Start valve is closed
 - Engine should stabilize around idle: about 60% N2 and about 20% N1
- ANNOUNCE “Starting Engine 1”
- Set ENG 1 MASTER switch to ON
- Monitor engine start as for engine 1

4.6 After Engine Start

- Set ENG MODE selector to position NORM
- Set APU BLEED to OFF
- ARM the Ground Spoilers by PULLING up the SPD BRK lever
- Set RUD TRIM to ZERO via the rudder trim reset button
- Set FLAPS LEVER to desired take-off position (1, 2, or 3 are valid take-off flap settings)
- Set PITCH TRIM to take-off setting. (Value computed by ISCS take-off calculator)
- Set ENG ANTI ICE as required.
- Set WING ANTI ICE as required
Note: Icing conditions if the Outside Air Temperature (OAT) temperature is less than 10 degrees Celsius with visible moisture in the air, or with contaminated runway (water, snow, etc.)
- Set APU MASTER switch to OFF
- Check that all slides are ARMED on ECAM DOOR/OXY page

4.7 Taxi

- Set NOSEWHEEL LIGHT to position TAXI
- Set PARKING BRAKE to OFF
- Start Elapsed Time counter on the main panel clock (lower timer)
- Advance THR LEVERS as required for taxi
Note: Idle thrust is normally sufficient to sustain taxi around 15kts
- Perform a BRAKE CHECK once the airplane started moving.
Aircraft must slow down on brake application. When the brake system is correctly supplied by the green hydraulic system, the brake pressure indicators (next to the gear lever) must

stay at 0 during braking action. These indicators show alternate braking system brake pressure only.

- Perform a flight control check:
 - Check full travel of ailerons, spoilers, elevators by moving the sidestick through its full range of motion and verifying the surface motion on the lower ECAM F/CTL page.
 - Give full rudder pedal inputs and verify full travel of the rudder.
Note that the PEDAL DISC command should be used in order to prevent the pedal orders leading to nosewheel deflections.
- Check the Flight Mode Annunciator (FMA) – modes NAV and CLB should be armed
- Check no red flags on PFD or ND
- Confirm Transponder code, set transponder to Mode XPNDR
- Set TERR ON ND as required
- Set AUTO BRK to MAX
- Call Purser to receive Cabin Report (CABIN READY)
- Press the TO CONFIG button to check TO configuration – no alarm must trigger
- Check that the TO MEMO on the EWD has no blue lines

4.8 Before Take-off

- Check brake temperature:
 - Maximum 150 degrees C with brake fans on. Maximum 300 degrees C if brake fans were not running during taxi
- Obtain take-off clearance
- Check approach path clear of traffic
- Advise cabin crew to be seated for take-off
- Set ENG MODE selector as required:
 - Set to position START/IGN, if the runway has standing water or heavy rain expected
- Set PACK1 and 2 as required:
 - Switching off Packs is only required on short runways with Full power take-offs (NO Flex)
- Set EXTERIOR LIGHTS
 - RWY TURN OFF to ON
 - LAND LIGHTS (L and R) to ON
 - NOSEWHEEL LIGHT to TO
 - STROBE to ON
- Set XPNDR to mode TA/RA
- If required, set WX RADAR system switch to system 1.

4.9 Take-off

- Taxi onto the runway and align with runway heading.
Note: Rolling take-off is permitted.
- Announce “TAKE-OFF”
- Start the Chrono displayed on the ND
- Perform the take-off:
 - Set engines to 50% N1 and wait until engines stabilized at this value
 - Release the brakes
 - Move thrust levers into the FLEX or TOGA detect
 - Push the stick halfway forward until the aircraft reaches 80kts.
 - Beyond 80knots gradually release the stick until it is neutral at 100knots.
 - Use rudder for directional control
 - Announce “V1” (when aircraft speed reached V1.)
 - Announce “Rotate” (when aircraft speed reached VR.)
 - Pull gently on the sidestick to rotate the aircraft at a rate of about 3deg/sec to a pitch attitude of 15 degrees. (This rotation should take 5 seconds)
- Follow the flight director bars
- Announce “POSITIVE RATE” when vertical speed is 500fpm or greater)
- Retract landing gear
- Disarm ground spoilers
- Switch off exterior lights:
 - NOSE WHEEL light
 - RWY TURN OFF light
- Engage AP as required
- At thrust reduction altitude (LVR CLB flashing on FMA):
 - Move thrust levers to CLB detent
 - Switch on packs (if selected off for take-off)
- At acceleration altitude check FMA:
 - CLB or OP CLB vertical mode
 - THR CLB for A/THR mode
- If take-off was with flaps 2 or flaps 3:
 - At F-speed, retract flaps 1 notch.
- At S-speed, retract flaps completely

4.10 After take-off

- If APU running:
 - Set APU Bleed as required
 - Consider shutting of APU if not required anymore

- Set ENG MODE selector as required:
 - NORM in no, light, or medium precipitation and no icing conditions
 - IGN/START in heavy precipitation or icing conditions
- Set ENG ANTI ICE as required:
 - On if TAT is less than 10 degrees with icing conditions expected
 - Off otherwise

4.11 Climb

- Standard MCDU configuration:
 - Pilot flying side: PERF CLB page
 - Pilot non-flying side: F-PLN page
- When passing through transition alt (QNH flashing on PFD):
 - Set Baro ref to Standard. (Pilot and co-pilot side)
- Set CRZ FL on FCU in accordance with ATC clearance
- At 10000ft:
 - Switch off and retract LAND lights
 - Set SEAT BELTS sign as required

4.12 Cruise

- Periodic system checks on SD:
 - ENG page: Oil pressure and temperature
 - BLEED page: Bleed parameters (no overheats)
 - ELEC page: generator loads, bus health
 - HYD page: Check for decrease in quantities
 - FUEL page: Check even fuel distribution
 - COND page: Duct and Zone temperatures. No large differences for passenger comfort
 - FLT CTL: No unusual surface positions
- Flight progress check:
 - Check fuel prediction every 30 minutes. Sudden decrease in remaining fuel may hint at fuel leak.
- If step alt selected and approaching step waypoint:
 - Dial target altitude in FCU and press ALT selector knob

4.13 Descent preparation

Descent preparation should be started about 50NM before the Top of Descent displayed on the ND.

- Check LDG ELEV set to AUTO
- Complete/Check arrivals page:
 - Click Left LSK next to arrival airport to access “Lateral revision”
 - Click LSK next to “Arrival”

- Confirm or update desired Approach, Via, STAR and Transition
- Select insert, if approach was changed
- Enter DEST data in PERF APPR page:
 - QNH
 - Temperature
 - Wind
 - Verify transition level
 - Enter DH, or MDA
 - Select CONF 3, if landing in CONF3 is expected.

Note: QNH, Temperature and Wind can be retrieved from the METAR string on the Aircraft Configuration tab of the ISCS
- Enter DESCENT winds:
 - Click right LSK next to a waypoint behind the Top of Descent to access Vertical Revision page.
 - Select “WIND DATA” to access “Descent wind” page
 - Enter winds manually or use “Wind Request” feature to automatically retrieve wind data. Wind request is available, if it shows an asterisk next to the label.
- Set GPWS flaps 3 switch on OHP as required:
 - If landing is expected with flaps 3, set the switch to ON
- Set Autobrake as required: Lo for long runways, Med for short runways. Do not use Max for landing.
- Set Ice protection as required:
 - ENG ANTI ICE should be on, if icing conditions expected during descent.

4.14 Descent

Initiate the descent at the earliest 20NM before the Top of Descent. Earlier descent will be interpreted as a cruise altitude step change.

- Initiate descent by selecting the initial approach altitude on the FCU (typically 3000ft above airport level, unless specific constraints provided in approach chart.)
- Push the ALT selector knob to engage DES mode.

Note: This changes the Autopilot phase from CRZ to DES phase.

- If descent initiated after T/D:
 - Extend speed brakes by half until merged onto descent profile
- Set MCDU to Descent configuration:
 - Pilot flying side: PROG DES page (to monitor vertical deviation from descent profile)
 - Pilot non-flying side: F-PLN page
- Set Terrain on ND as required
- When passing through transition level:
 - Set Baro ref to Arrival QNH for pilot and co-pilot side and standby instrument.
- At 10000ft:

- Switch on LAND lights
- Switch on SEAT BELTS sign
- Select CSTR option on the ND
- Select LS pushbutton as required.
- Check RAD NAV page for tuned ILS, VOR, ADF frequencies

4.15 Approach

- Ensure approach phase activates at Deceleration point
- Ensure SPD is in managed mode
- Use speed brakes as required to slow down
- Select flaps 1 as soon as airspeed drops below 230 knots

4.15.1 ILS approach

- Press APPR push button when ILS is tuned, and there is no risk of erroneous LOC intercept, i.e. after the last crossing of the runway centreline (if applicable)
- Engage both APs
- Check LOC capture
- Check GS capture. If above GS:
 - Select mode V/S
 - Set FCU altitude above aircraft altitude
 - Select V/S to capture the LOC
- Set Go-around altitude on FCU once GS is engaged

4.15.2 Non-ILS approach

- Press APPR button after the Initial approach fix, but before reaching the Final approach Fix
- Engage both APs
- Check engagement of FINAL mode when passing the Final Approach Fix
- Set Go-around altitude on FCU once FINAL is engaged

4.15.3 Common for all approach types

- At 2000ft AGL: Select Flaps 2
- Select Landing Gear Down
- Arm the ground spoilers by pulling the speed brake lever
- Confirm Auto Brake setting
- Select flaps 3 if speed below VFE Next
- Check ECAM WHEEL page: All gear indicators green
- Select flaps FULL (unless flaps 3 landing was selected)

- Check ATHR in SPEED mode
- Set exterior lights:
 - NOSE WHEEL to TAXI
 - RWY TURN OFF to ON
 - Confirm LAND Lights are ON
- Get Cabin report (press one of the purser call buttons)
- Check LDG Memo on EWD has no blue lines
- If no Autoland or non-ILS approach:
 - Disconnect AP at 400ft
 - Switch of the flight directors for non-ILS approach
 - Perform visual approach/landing
 - Initiate flare at 50ft to achieve smooth touch down
 - Use rudder for decrab and to maintain runway center line
- At 20 feet retard thrust levers to idle
- After touch-down move thrust levers to reverse idle, then move to max reverse.
- Check ground spoiler deployment
- When passing through 70kts: Reduce reverse thrust to reverse idle.
- If not using autobrake:
 - Use braking as required to slow-down for the desired taxi-way
- At the latest at 20kts disengage autobrake by applying brake pressure on the pedals.
- At taxi speed:
 - Set Engines for forward idle

4.16 After landing

- Retract landing lights
- Set STROBE lights to AUTO
- Disarm ground spoilers
- Set ENG MODE selector to NORM (if applicable)
- Set WX RADAR system selector to OFF (to avoid exposing the gate crew to excessive amounts of radiation)
- Set transponder mode to XPNDR
- Retract flaps
- Start the APU by pressing first the APU Master switch, then the APU Start switch
- Check Brake Temperature for discrepancies between the wheels
It is recommended to not start the brake fan until at least 5 minutes after landing to allow thermal equalization of the brakes.

4.17 Parking

- Check parking brake ACCU PRESS in green area

- Set PARKING BRK to ON
- Set ANTI-ICE to OFF
- Set APU BLEED to ON
- Switch off ENG1 and ENG2 master switches
- Set exterior lights:
 - Select OFF the RWY TURN OFF lights, WING lights, NOSE WHEEL lights
 - Select BEACON off once engines have spooled down
- Set SEAT BELTS to OFF
- Set ELAPSED TIME counter to STOP (lower part of main panel clock)
- Set all 6 fuel pumps to OFF
- Set Transponder to STBY
- DIM the 6 display units (PFD, ND, EWD, SD) and the MCDUs
- Switch brake fan to OFF (if not required)

4.18 Securing the aircraft

- Check PARKING BRAKE is ON
- Set ADIRUs (1, 3, 2) to OFF
- Switch off all exterior lights
- Switch APU BLEED OFF
- Set APU Master Switch to OFF
- Set EMER EXIT LT switch to OFF
- Set NO SMOKING switch to OFF
- Set Batteries 1 and 2 to OFF



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