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Presented by

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Airbus

AUTO FLIGHT SYSTEM
Part 1

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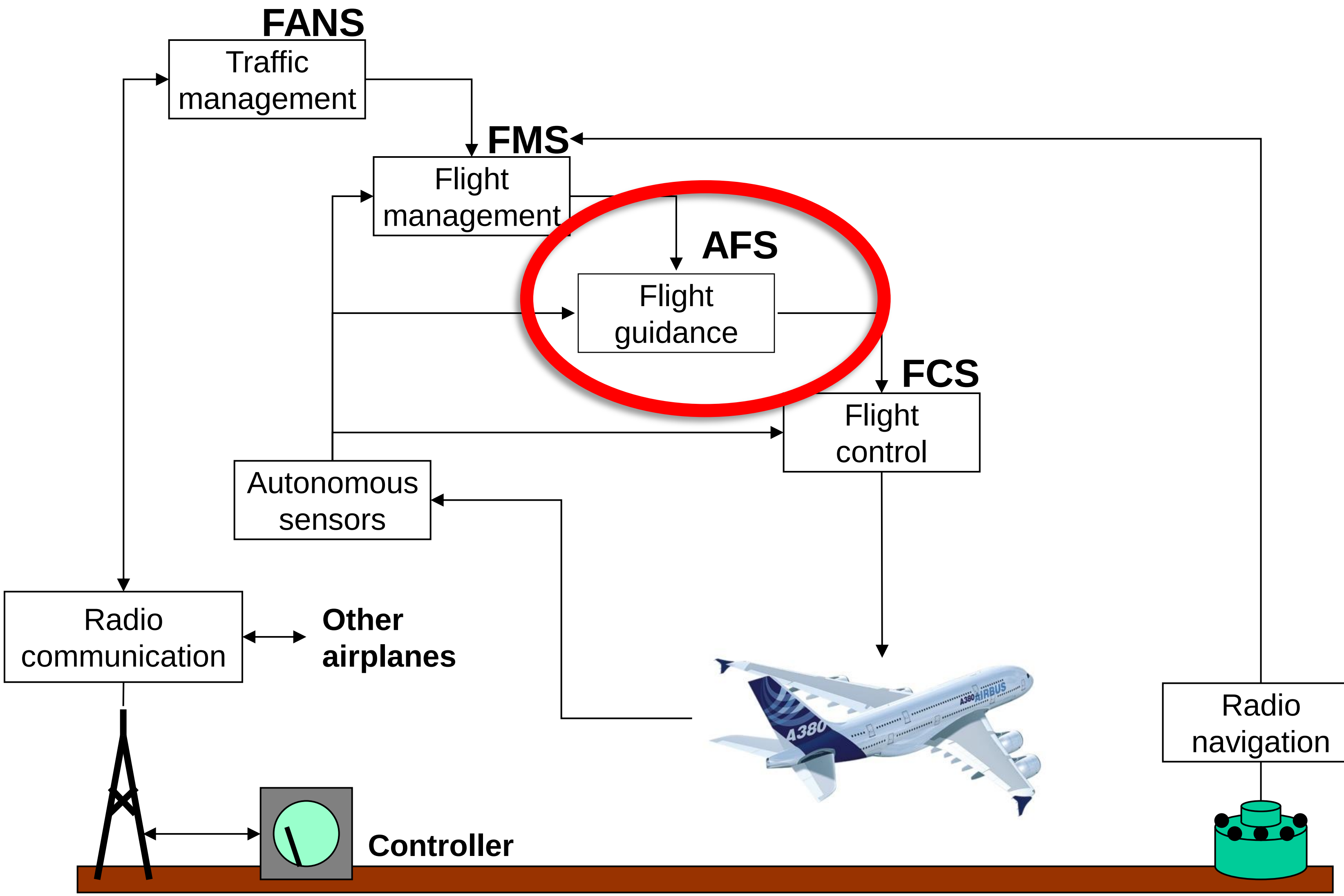
General
Place of the AFS



The INNER LOOP (control)

- control of the aircraft around its center of gravity (same domain than FC)
- computation of surface order deflection
- limitation in range and speed of the orders coming from outer loop

The OUTER LOOP (guidance)

- control of the aircraft center of gravity along a trajectory (part of flight plan)
- computation of outer loop orders
- limitation in range and speed of the targets (FCU, FMS)

The Navigation LOOP (navigation)

- control the sequence of trajectories (flight plan)
- computation of targets to follow

Composed of

- Automatic Pilot (AP)
    - Aircraft trajectory controlled by Flight Guidance System
- Flight Director (FD)
    - Provide guidance orders to crew
    - Displayed head-down and/or head-up
    - Aircraft trajectory controlled by crew following FD
- Automatic Throttle or Thrust (ATHR)
    - Engine power controlled by Flight Guidance System

Used by the crew thanks to

- Engagement & disengagement capacity
- Target selection capacity
- Status feedback on various displays

General

AFS objectives

PERFORMANCE

- Follow the targets
- Aircraft stability
- Robustness against disturbance
- Performance in autoland

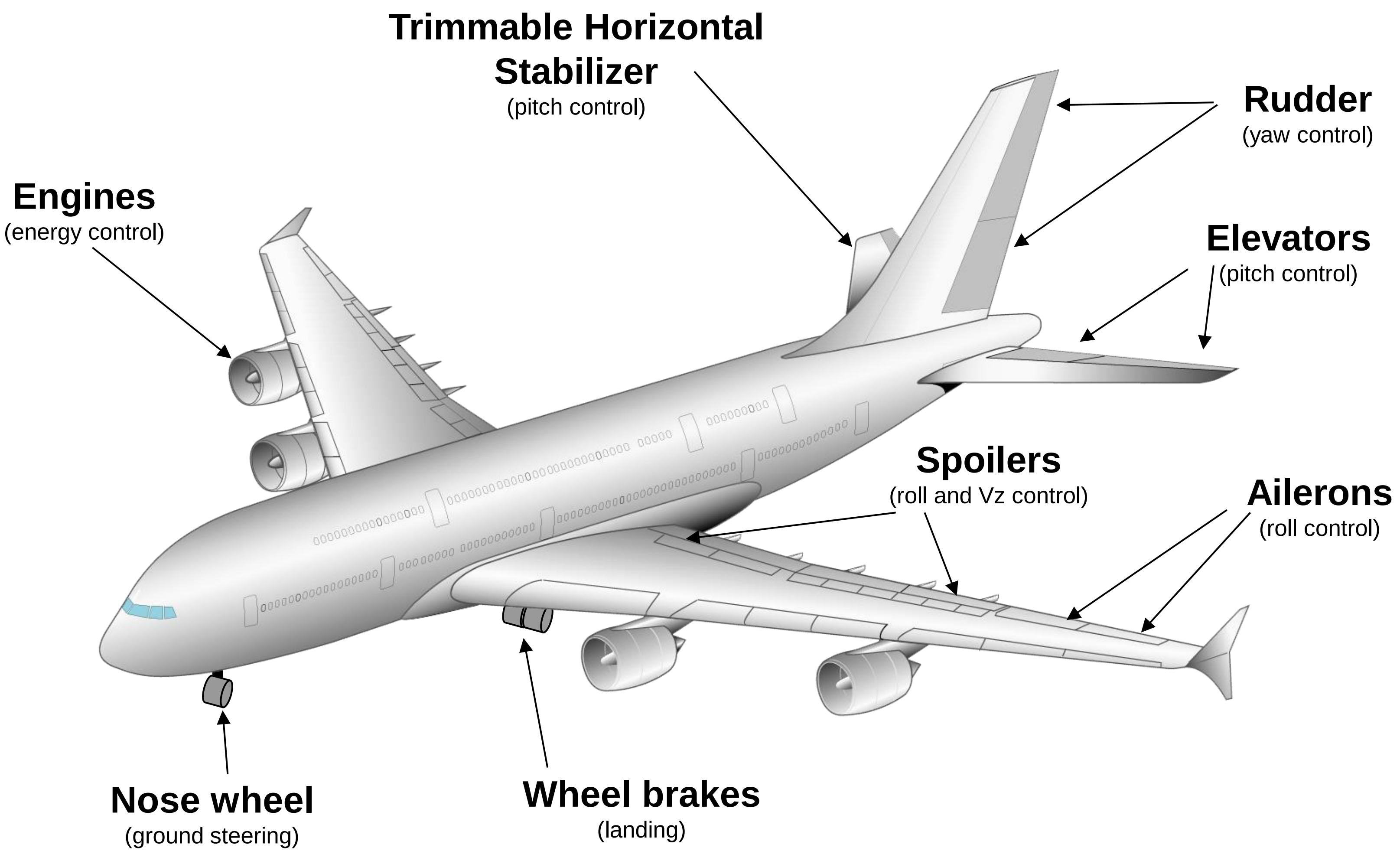
COMFORT

- Handling qualities
- Behavior in turbulence
- Confidence of the crew towards AP behavior

SECURITY

- Behavior in case of disturbance
- Behavior in case of failures
- Availability of functions
- Optimize the fatigue of the actuators

General
AFS surfaces



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Architecture
General principles

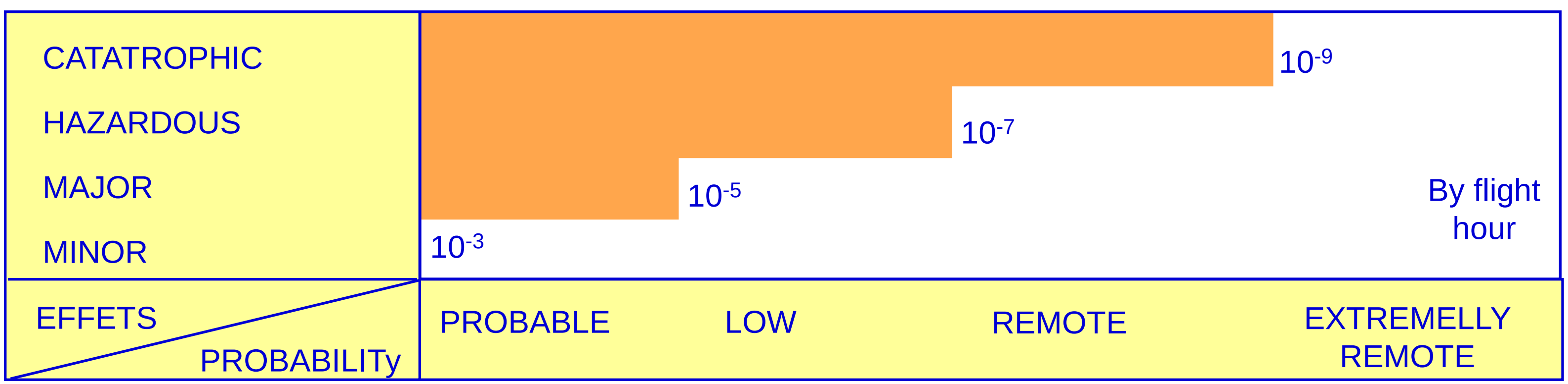
- Fail soft: to limit effect of a failure
  - Limits — Caravelle (cruise)

- Fail passive: to passivate the first failure
  - Duplex — Boeing (2 AP)
  - External monitoring — Caravelle (autoland)
  - Comparison (duplicated computation)
    - Consolidated points — Concorde
    - Voters — Airbus (1 AP)

- Fail operational: to continue after the first failure
  - Triplex — Boeing (3 AP)
  - Double monitored
    - Two active — Airbus A300
    - Active/Stand-by — Concorde and Airbus (other than A300)

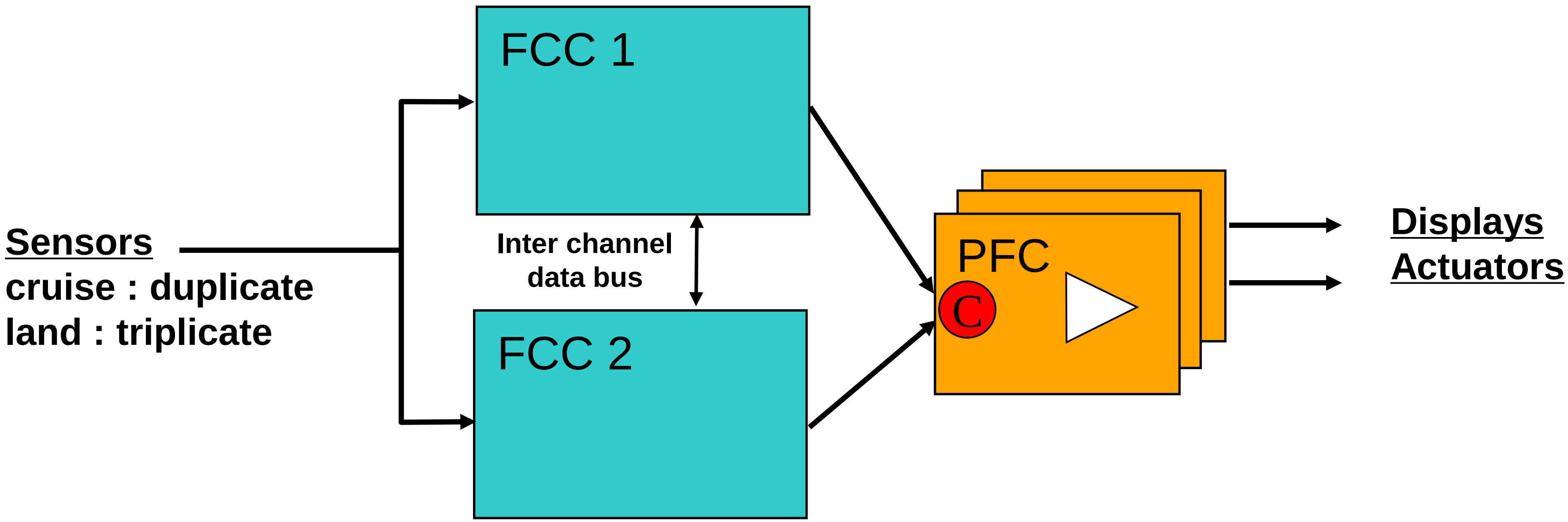
Architecture
General principles

- **MINOR**
  - low safety margins reduction
  - low crew workload increase (flight plan change)
  - passengers discomfort without injury
- **MAJOR**
  - significant reduction of safety margins
  - reduction of crew ability to fulfill its task
  - some injuries
- **HAZARDOUS**
  - large safety margins reduction
  - crew workload increase so as the crew is not able to fulfill all tasks
  - serious injuries or death of a limited number of passengers
- **CATASTROPHIC**
  - loss of the aircraft
  - death of passengers



Architectures

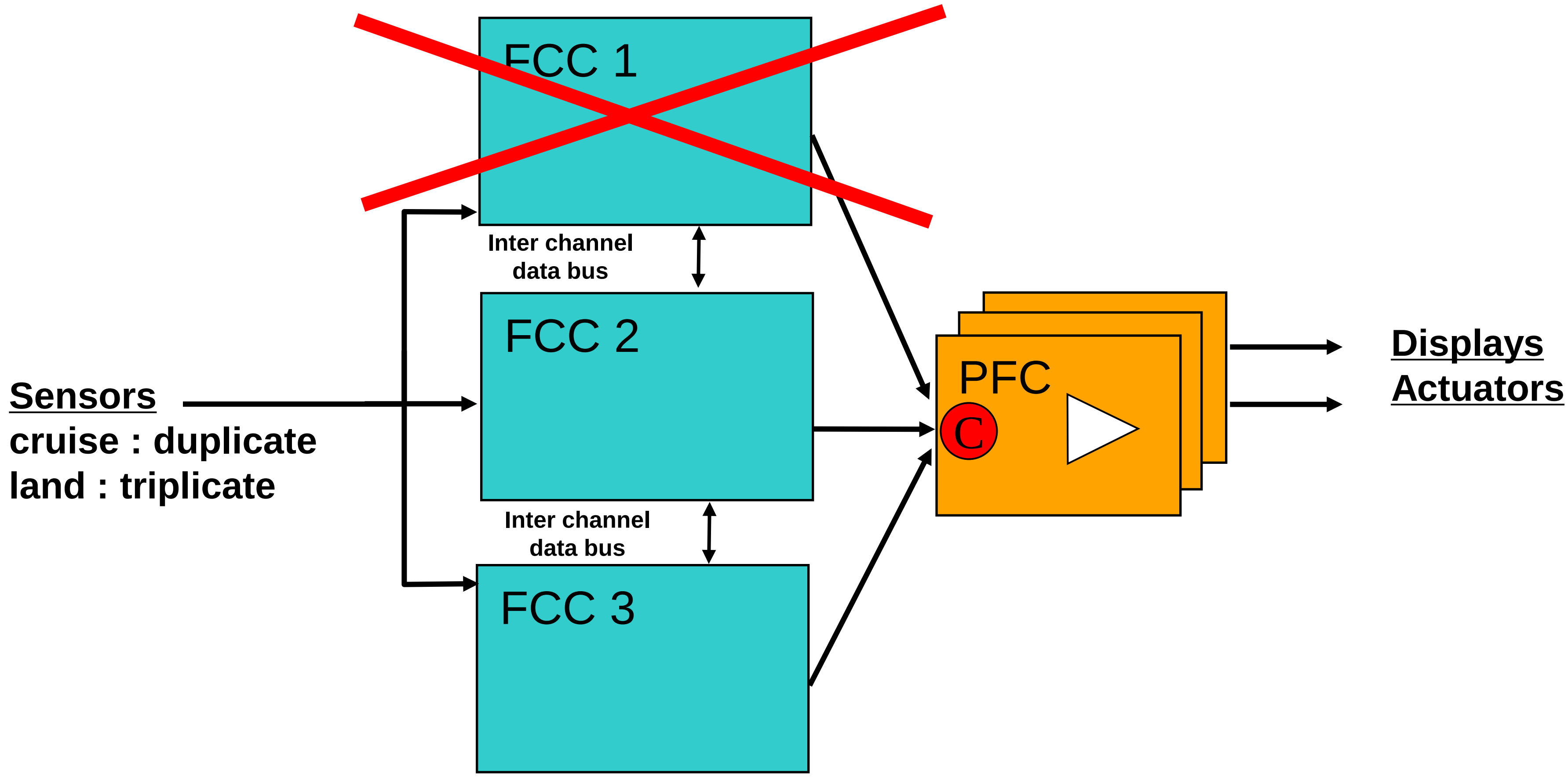
Boeing answer to "Fail passive" (777)



FCC : Flight **C**ontrol **C**omputer (Separated FMS)
PFC : Primary **F**light **C**omputer

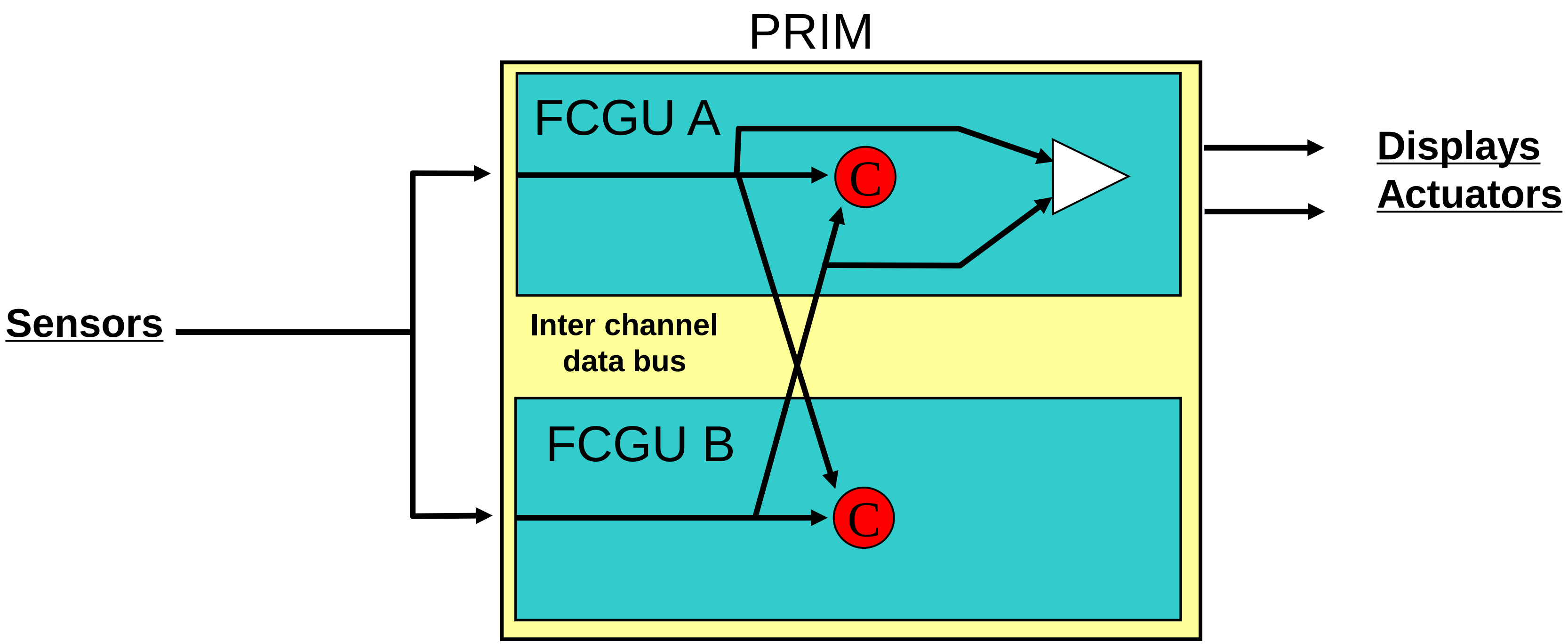
AIRBUS

Architectures
Boeing answer to “Fail operational” (777)



Architectures

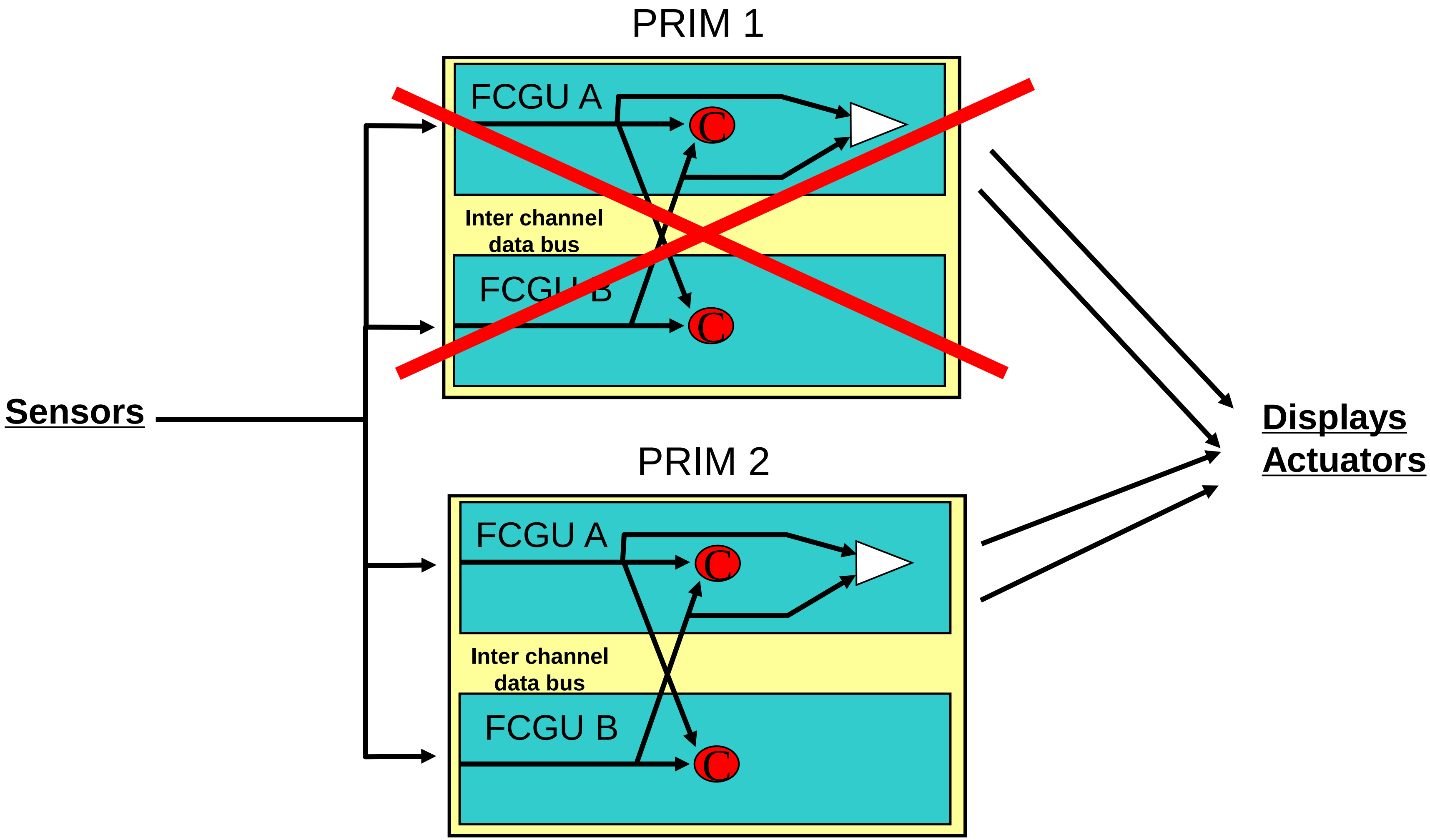
Airbus answer to “Fail passive” (A380)



FCGU : Flight **C**ontrol and **G**uidance **U**nit (Separated FMS)
PRIM : PRIMary flight comtrol computer

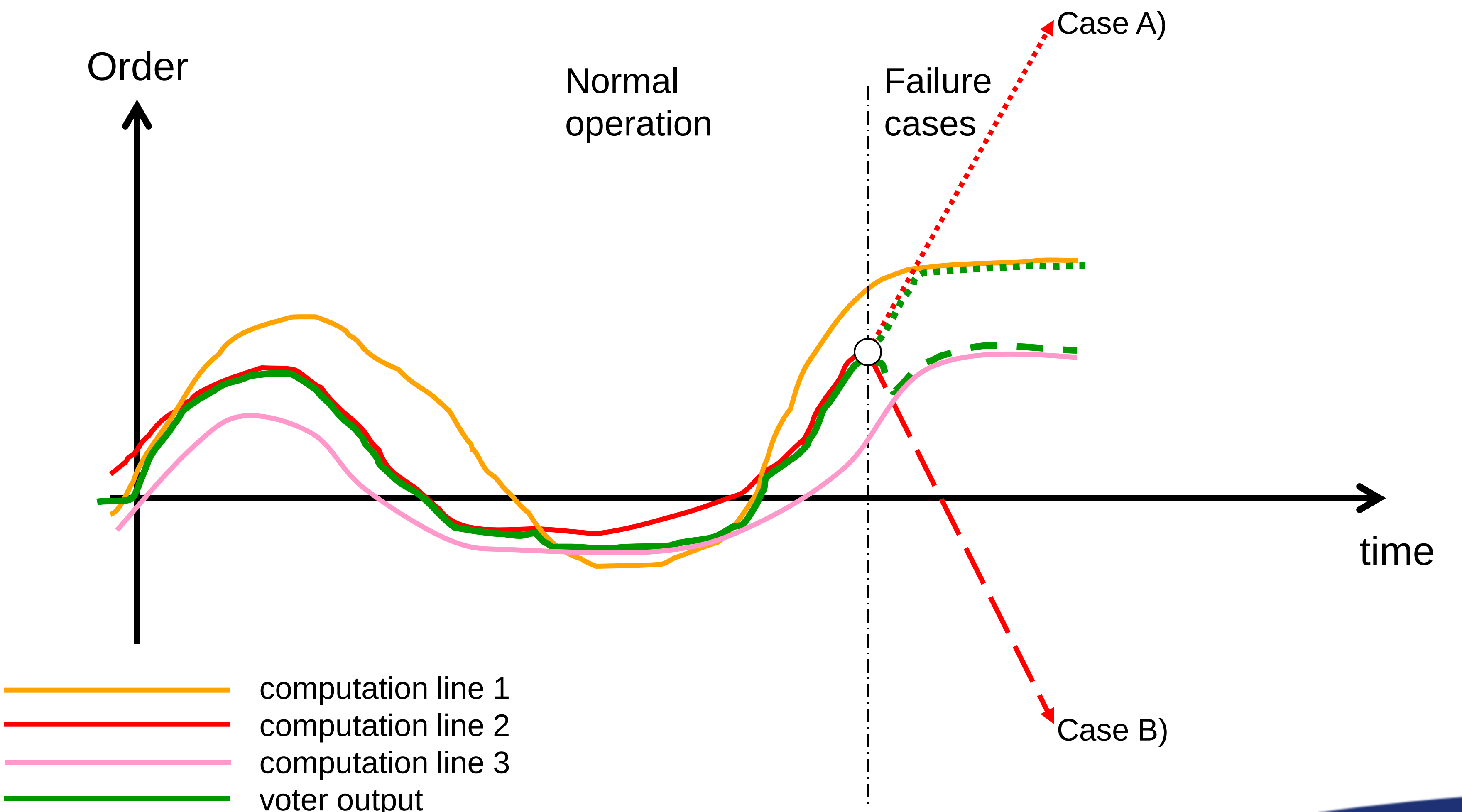
Architectures

Airbus answer to “Fail operational” (A380)



Architecture

Airbus principles – voter (3 entries)



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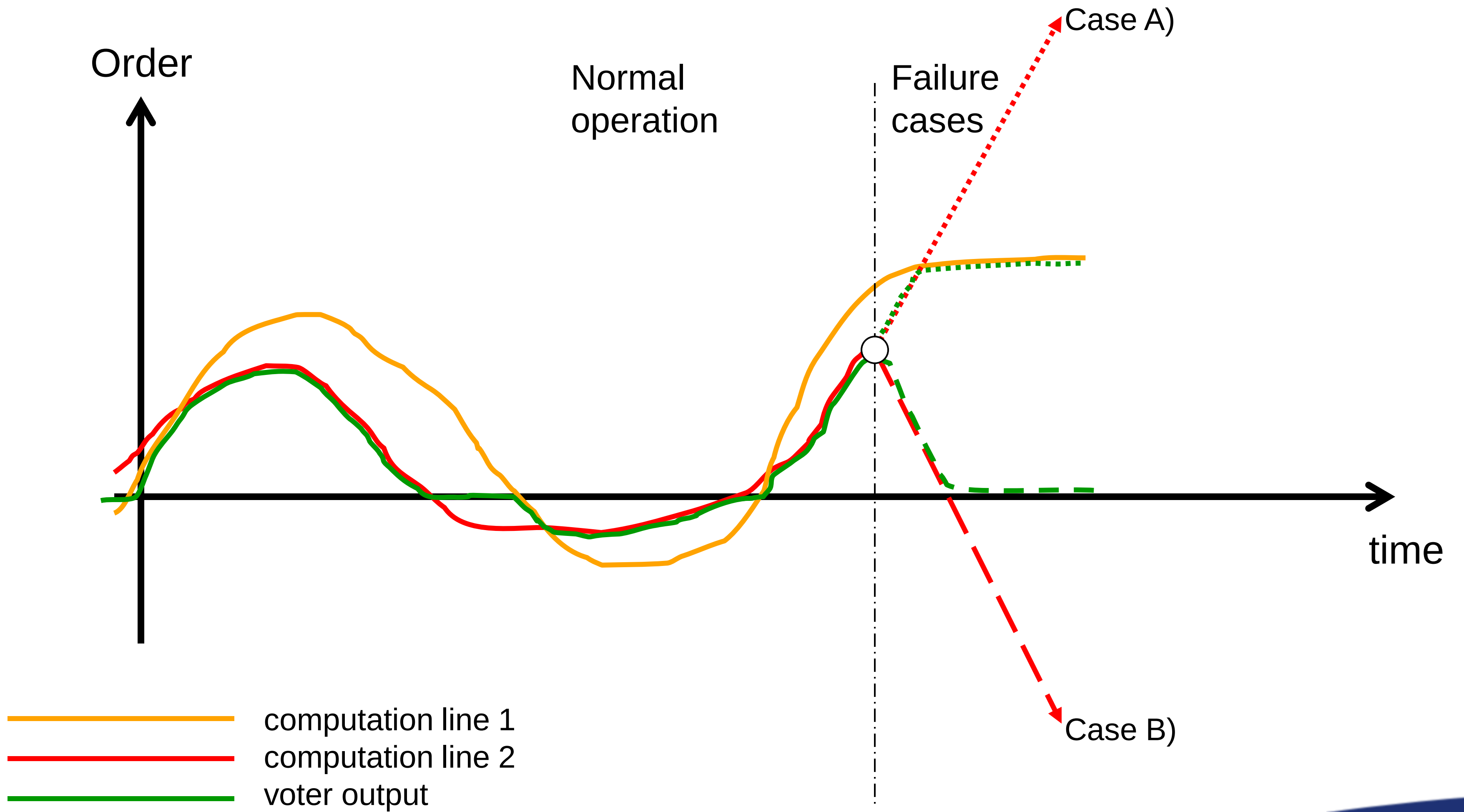
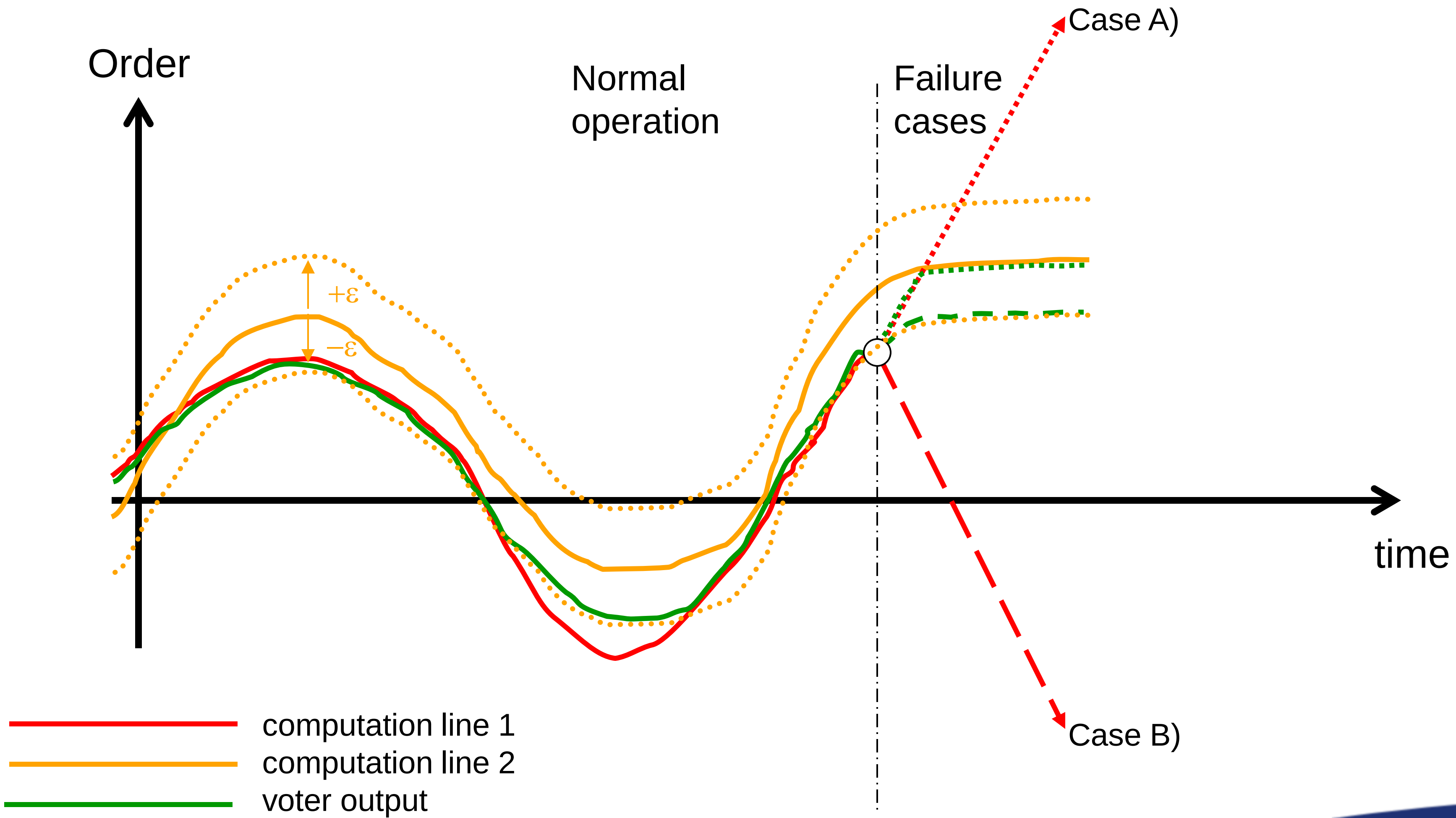
Architecture

Airbus principles – voter (2 entries)



Architecture

Airbus principles – passivator (2 entries)



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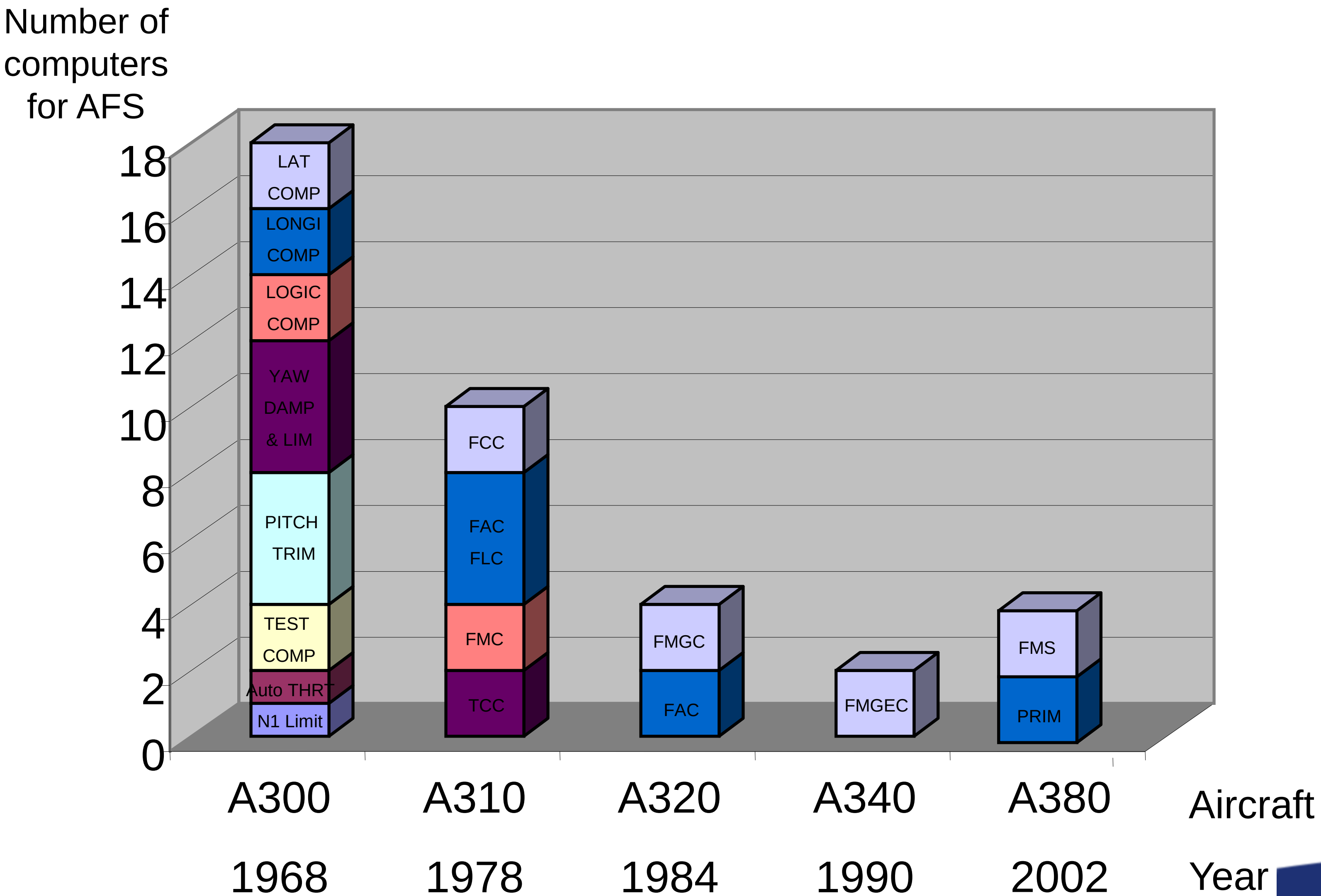
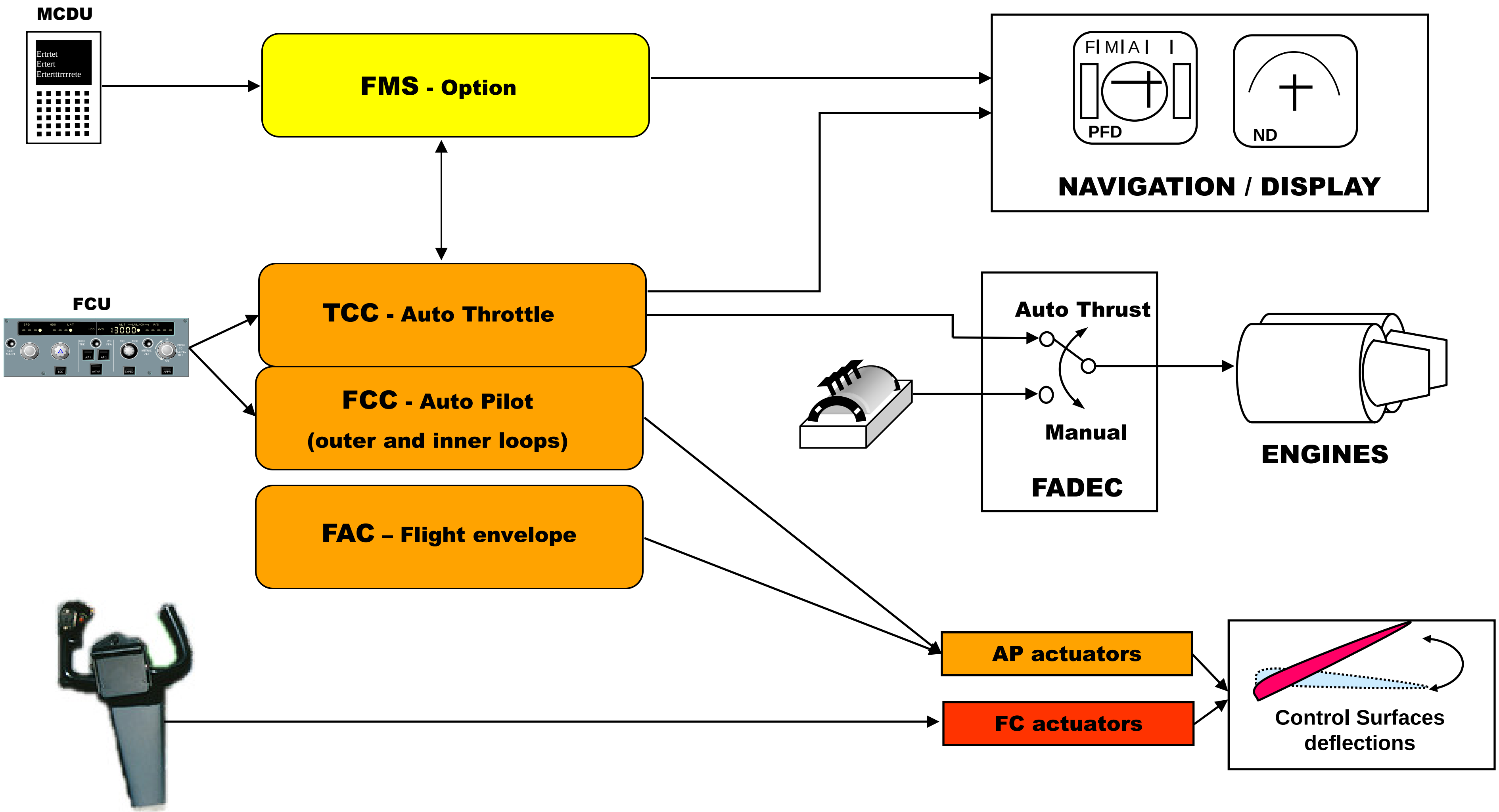
Airbus AFS Architecture evolution

Airbus AFS Architecture evolution



Airbus AFS Architecture evolution

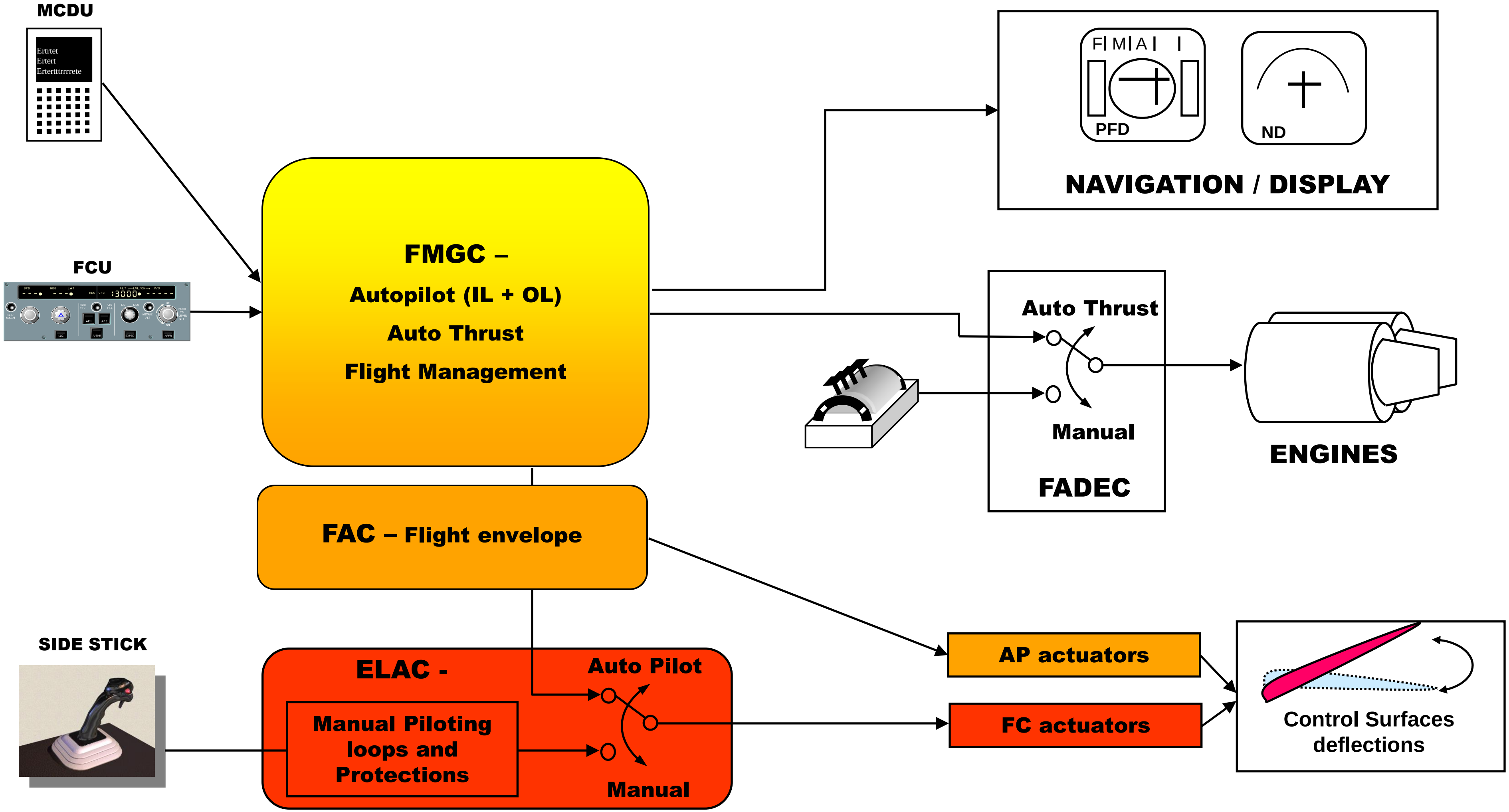
Integration AP/FC - Architecture A310



AIRBUS

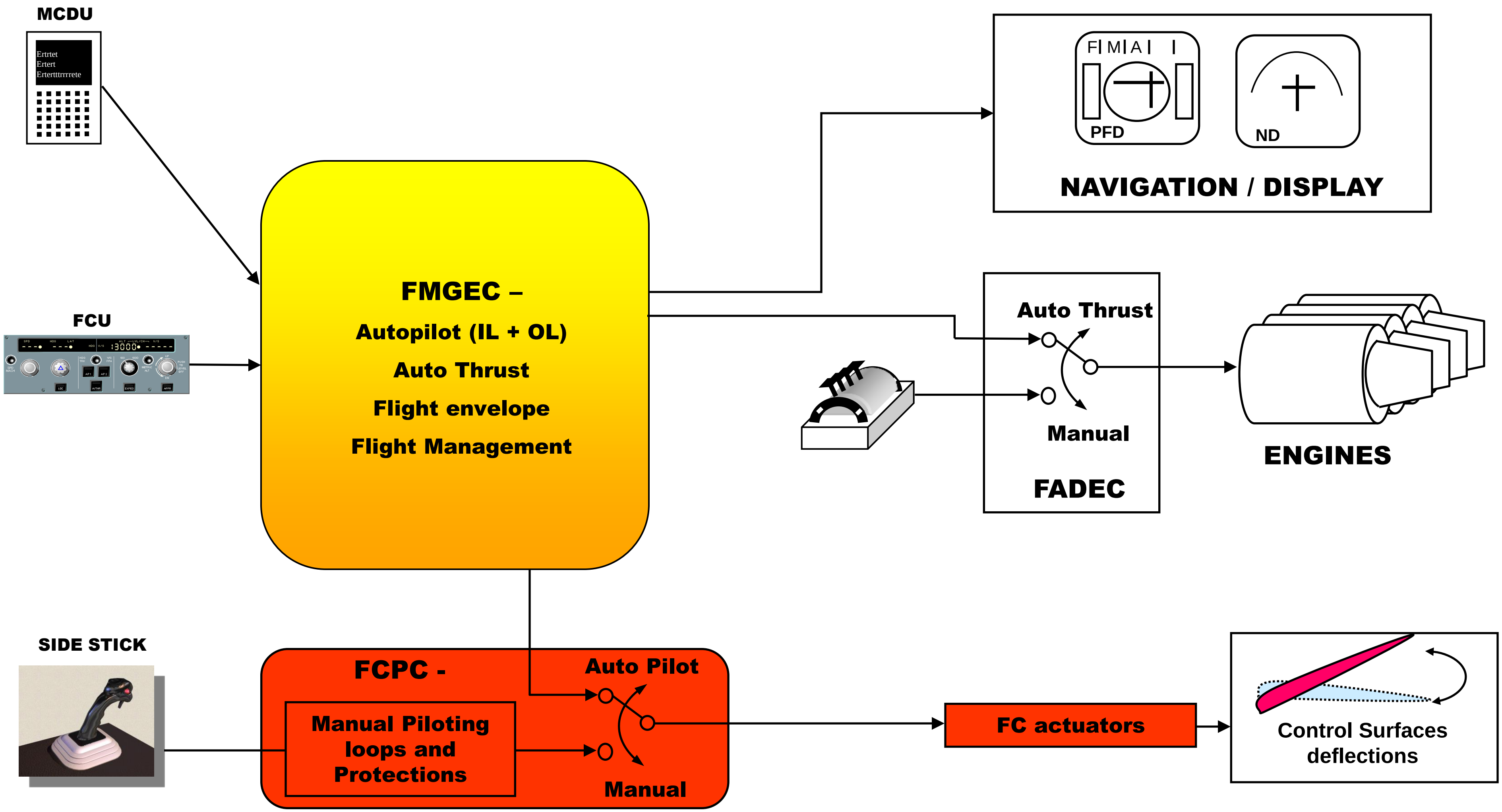
Airbus AFS Architecture evolution

Integration AP/FC - Architecture A320



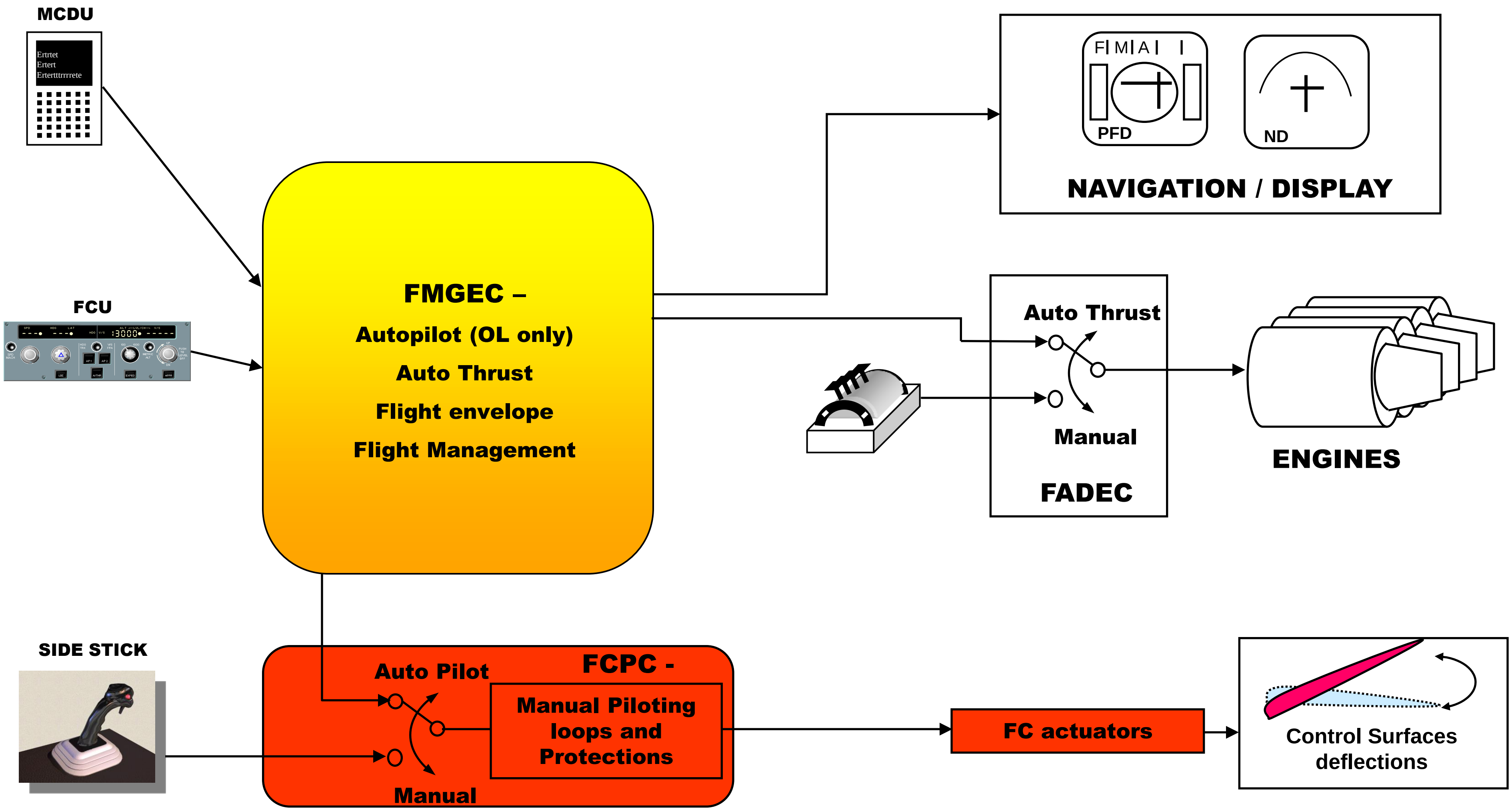
Airbus AFS Architecture evolution

Integration AP/FC - Architecture A330-A340



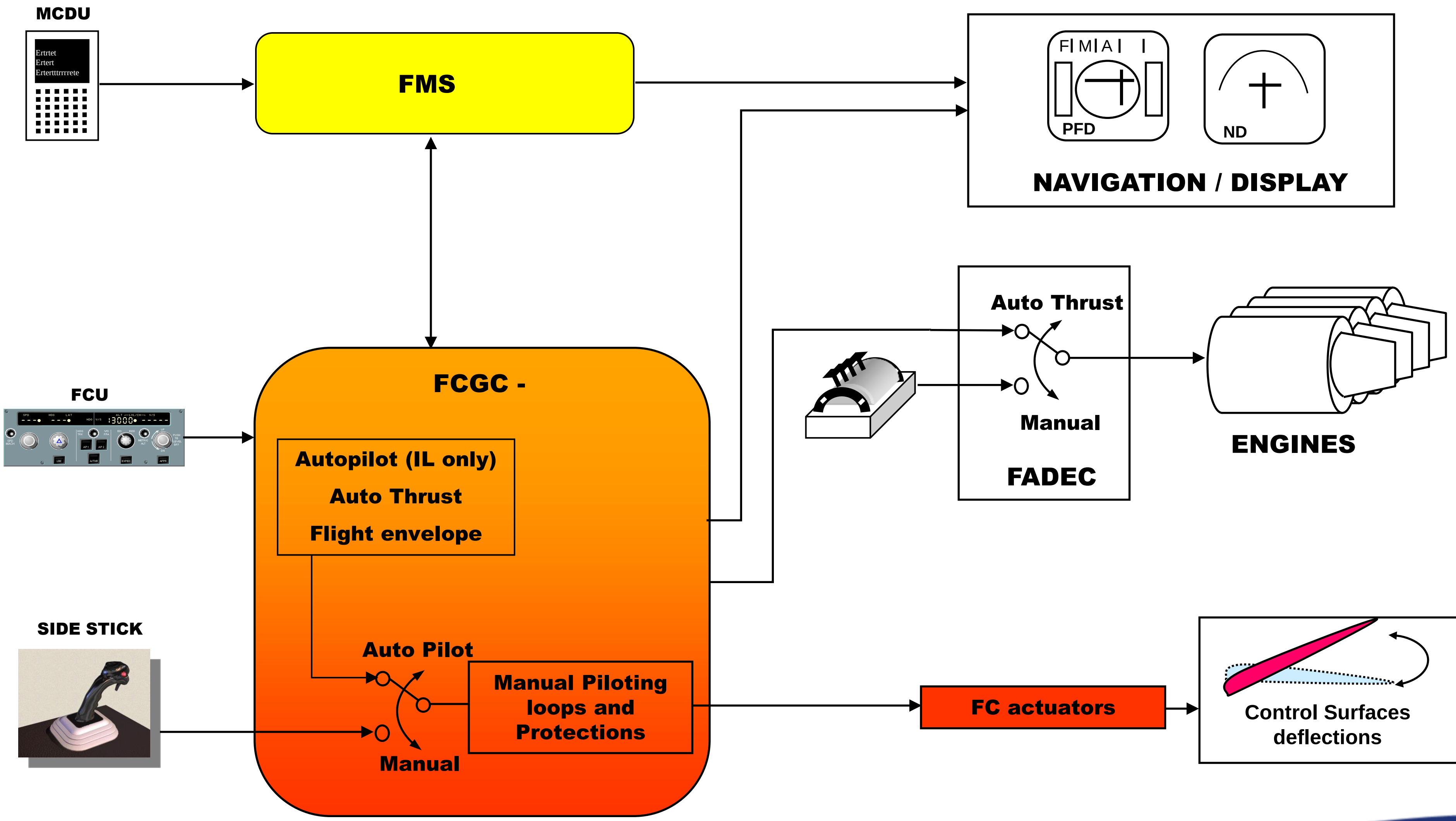
Airbus AFS Architecture evolution

Integration AP/FC - Architecture A340-600



Airbus AFS Architecture evolution

Integration AP/FC - Architecture A380-A350



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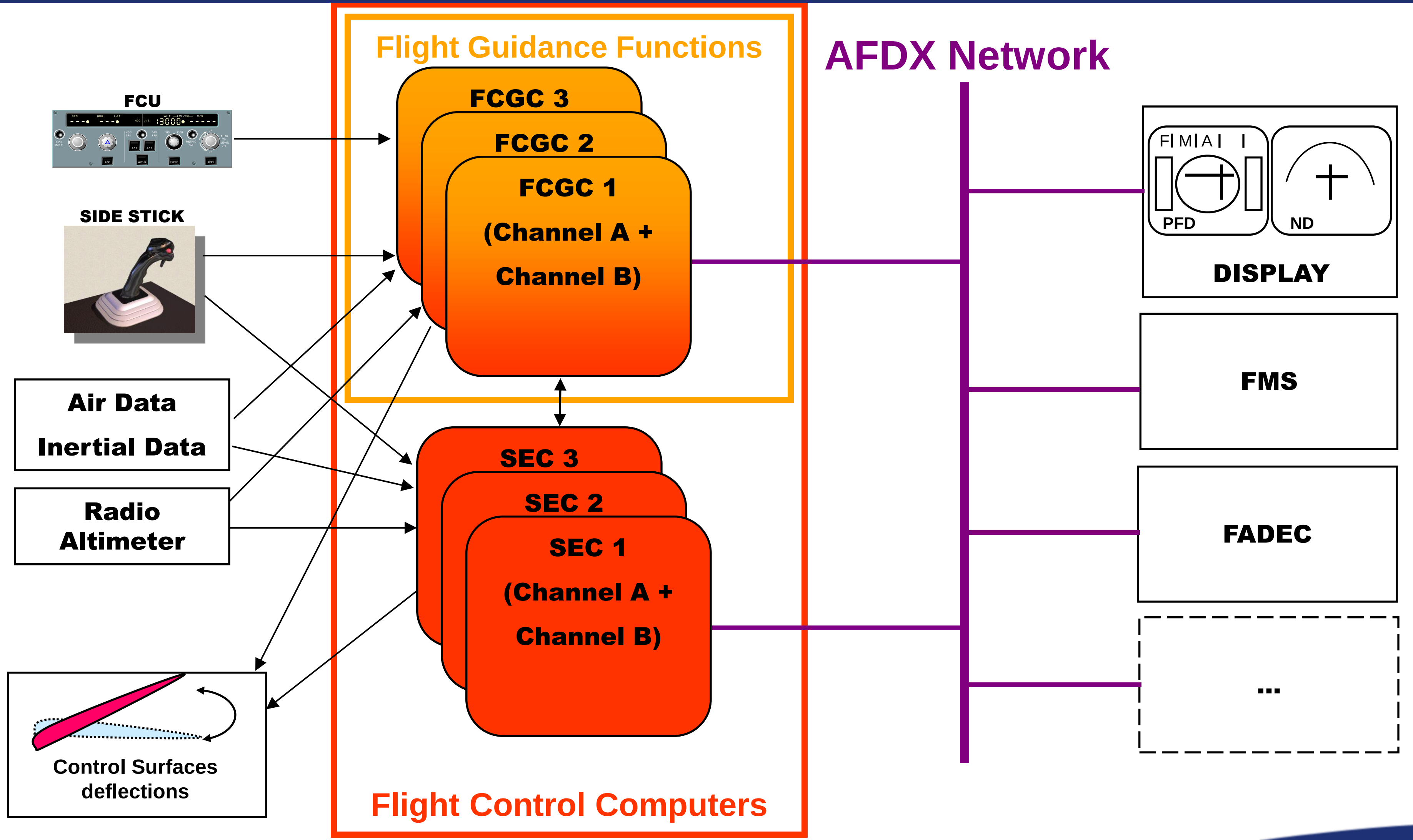
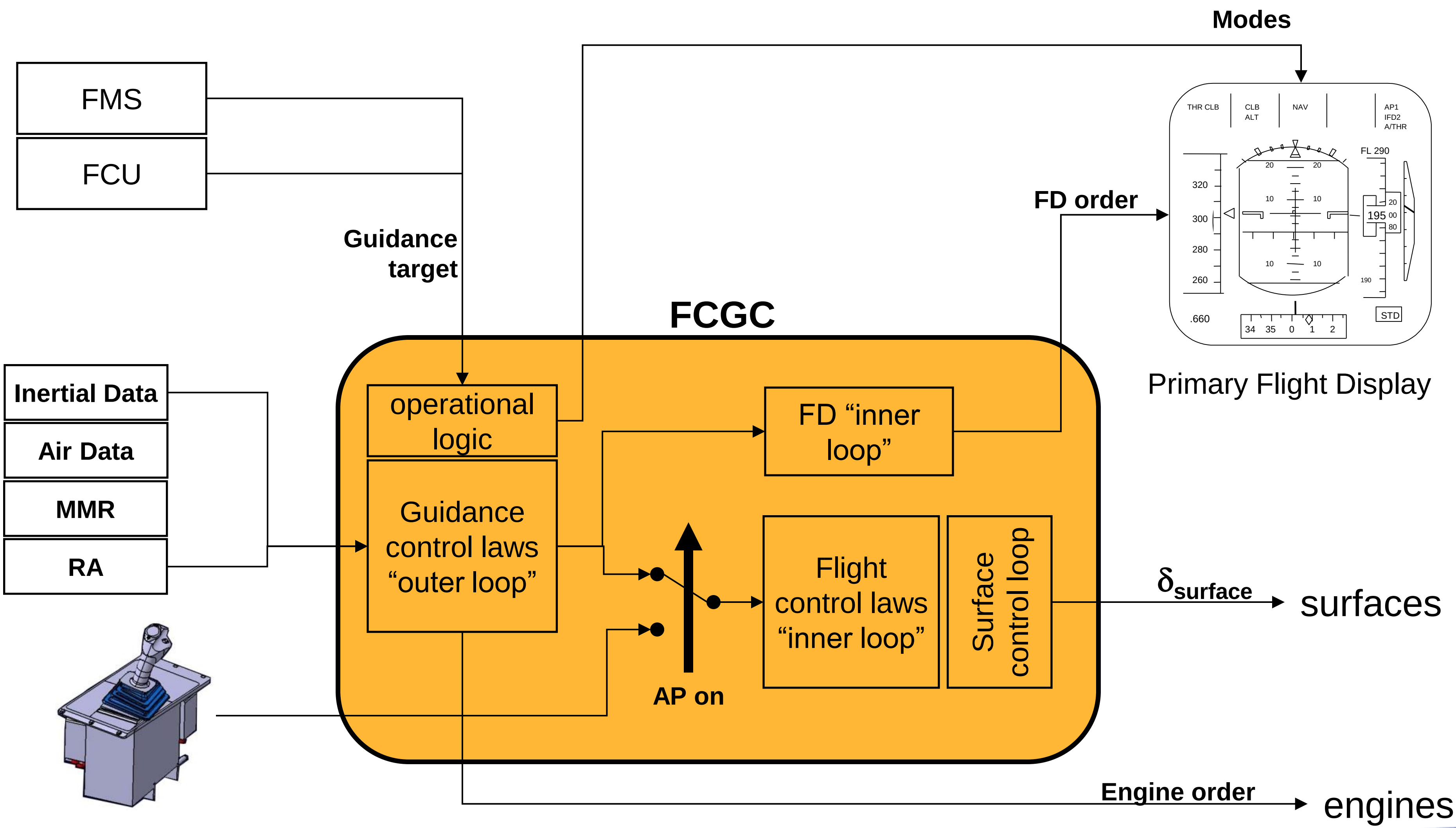
Airbus AFS Architecture

Detail of FCGC (A380 – A350)

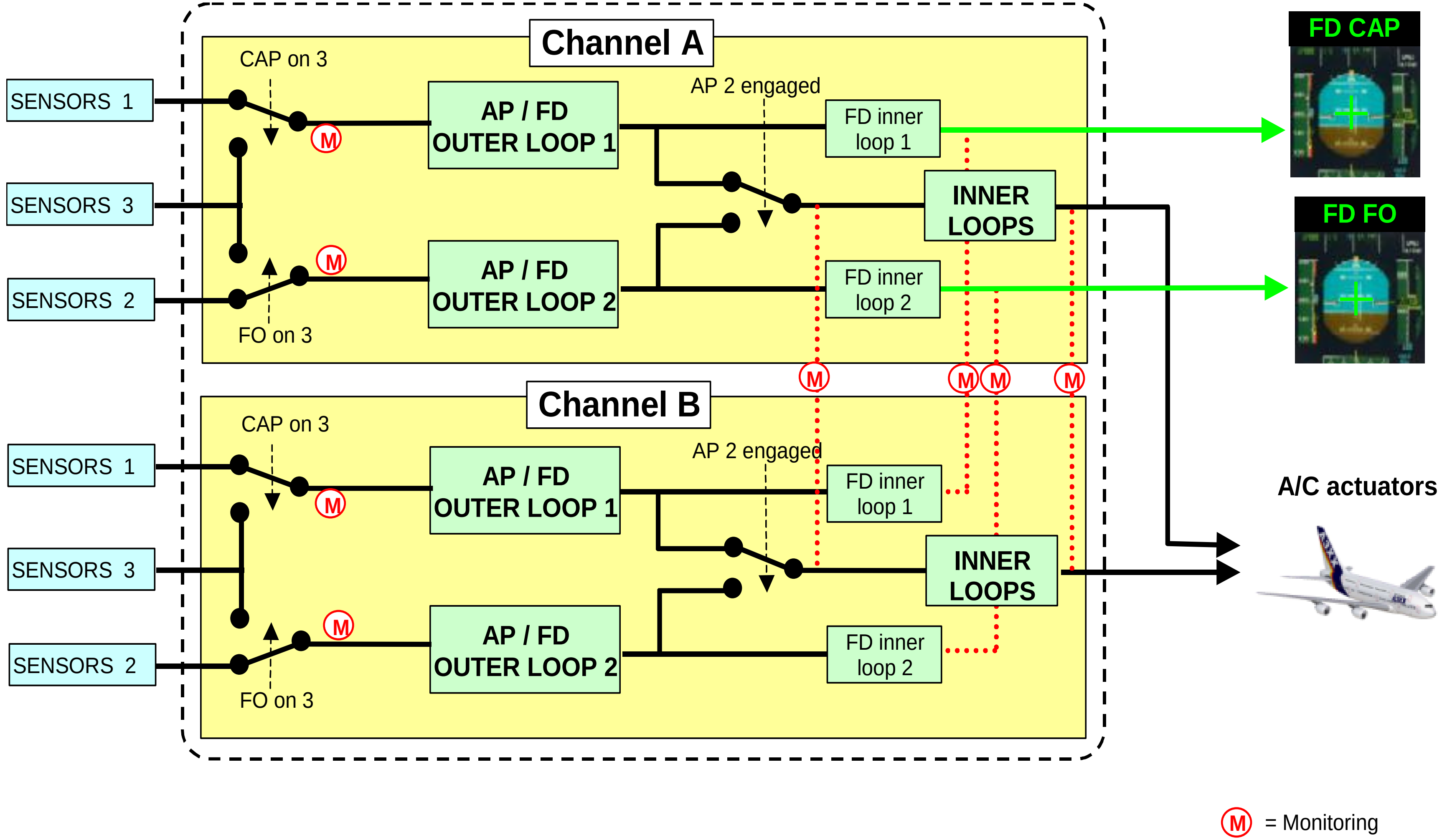


Airbus AFS Architecture

Detail of FCGC (A380 – A350)



Airbus AFS Architecture
Detail of FCGC (A380 – A350)



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AFS components
Airbus Human Machine Interface

- Three main interfaces
  - Flight Control Unit (FCU)
    - AP, FD and ATHR engagement capability
    - Mode engagement and associated target selection
  - Flight Management System (FMS)
    - Flight plan creation and modification
    - DIR TO capability
  - Primary Flight Display (PFD)
    - For AP, FD and ATHR engagement status
    - Current modes in control “engaged modes”
    - Current target

- Additional quick disconnection means
  - On the side stick for AP
  - On the throttles for ATHR

AFS components

Airbus Human Machine Interface

Flight Control Unit (FCU)

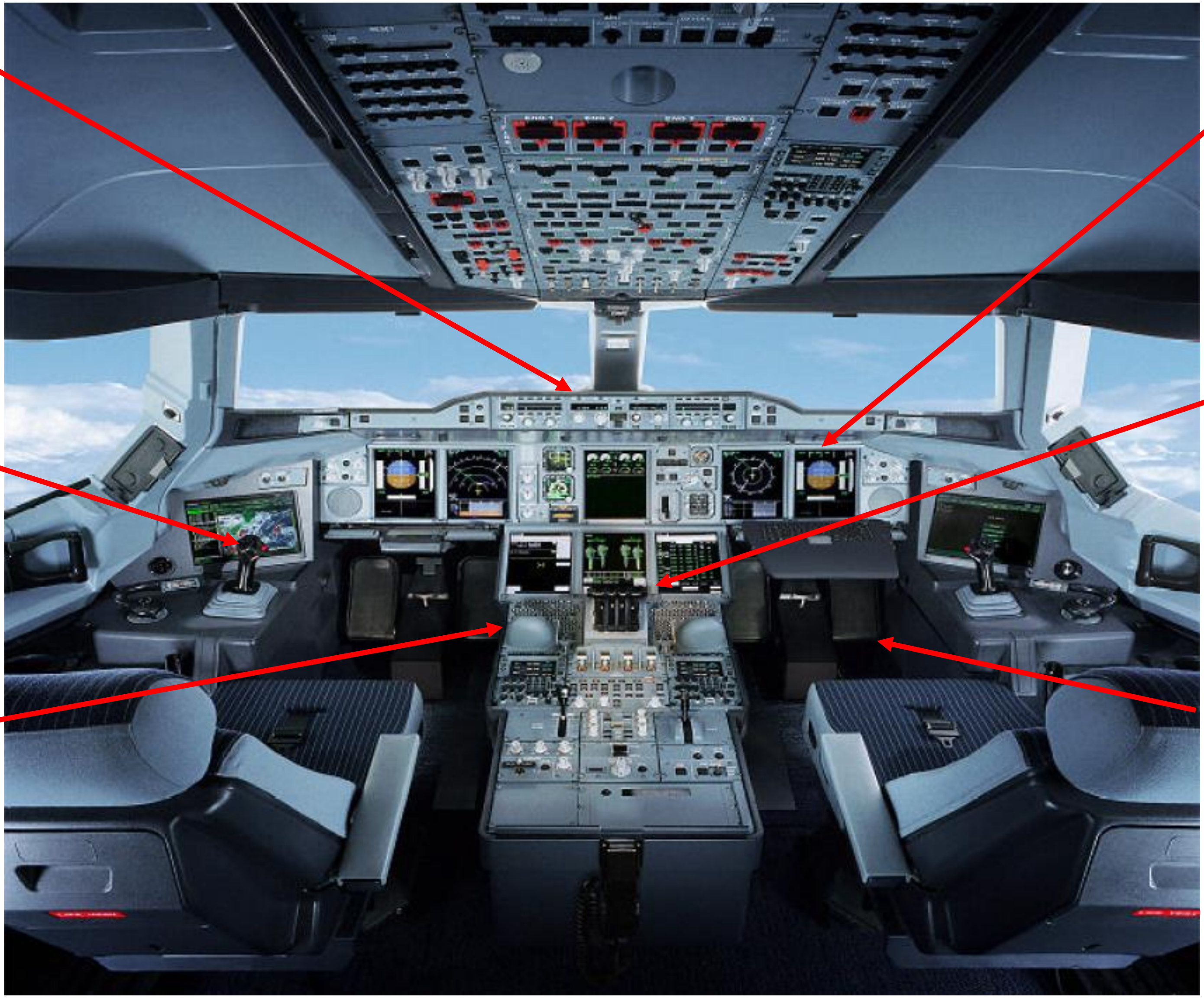
(Display of targets and modes control)

side sticks and ID P/B

(quick AP disconnection)

KCCU and MFD

(control of the AP in managed mode)



Primary Flight Display (FPD)

(Display of modes and targets)

THR levers and ID P/B

(modes engagement, ATHR limitation, quick ATHR disconnection)

Pedals

(AP disconnection on ground)

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AFS components

Airbus Human Machine Interface

AIRBUS

AFS components

Airbus Human Machine Interface – FCU (A330/A340)

Mode engagement & target selection capability

Speed / Mach

Heading / Track

Altitude

Vertical Speed / Flight Path Angle

LOC only approach arming

Approach arming

Specific engagement & arming

Current altitude acquisition & hold

Automatism engagement

AP engagement

ATHR engagement

AFS components

Airbus Human Machine Interface – FCU (A380)

Only 1 FD P/B

No more « push to level off »

Increase dissimilarity

AFS components

Boeing Human Machine Interface – MCP

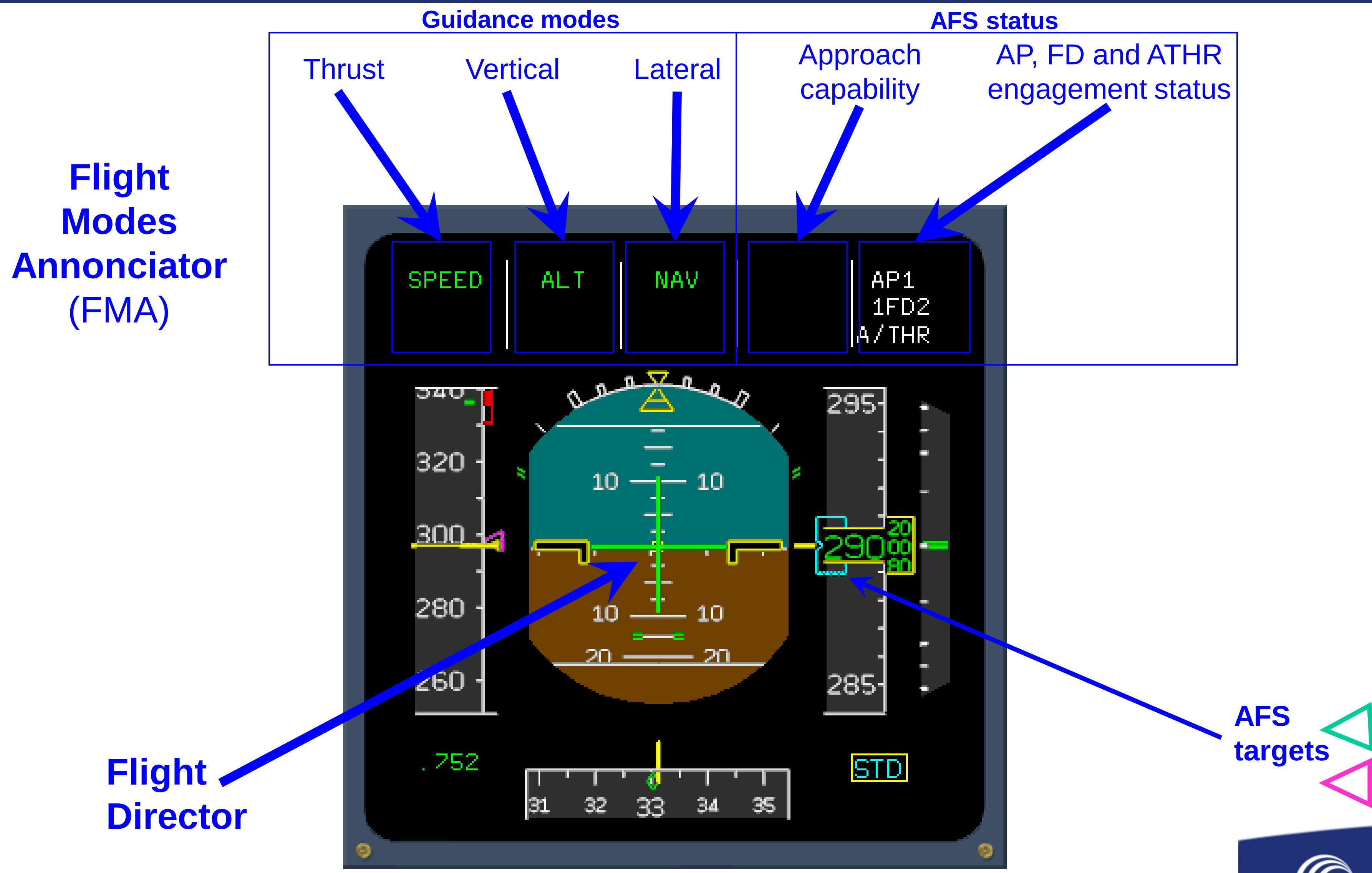
MCP 777 (Mode Control Panel)

MCP 787 (Mode Control Panel)

AIRBUS

AFS components

Airbus Human Machine Interface - PFD



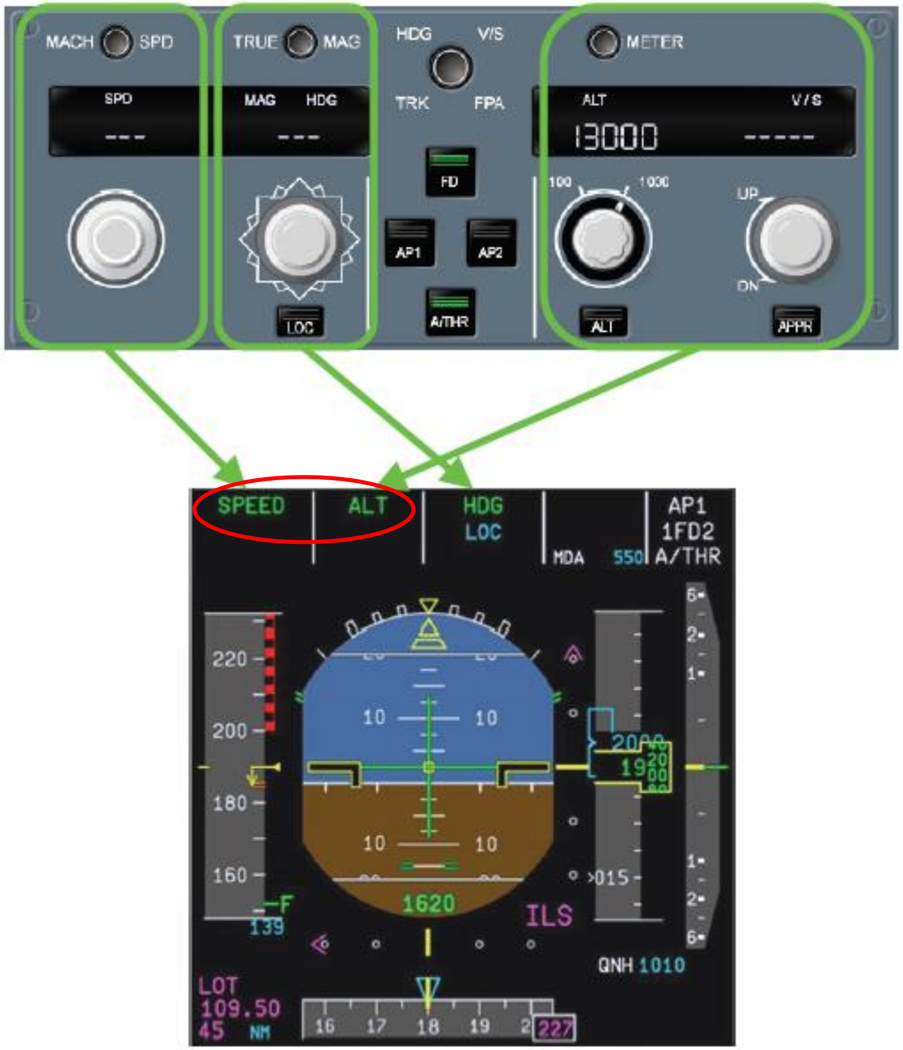
SPD
LNAV
VNAV PTH
.842
36000
A/P
.838
310H
MAG
STD
1018 HPA
GS455 TAS485
285°/ 33
TRK 310 MAG
PPD24
0443.2z
26.6NM
KARDY
IBEKA
0453Z
JAB
0447Z
PPD25
0444Z
ARPT
WXR
TFC
VOR L
JAB
DME63.3
VOR R
JAB
DME63.3

AFS components

Coherence MCP – PFD (Boeing)

AFS components

Coherence MCP – PFD (Airbus)



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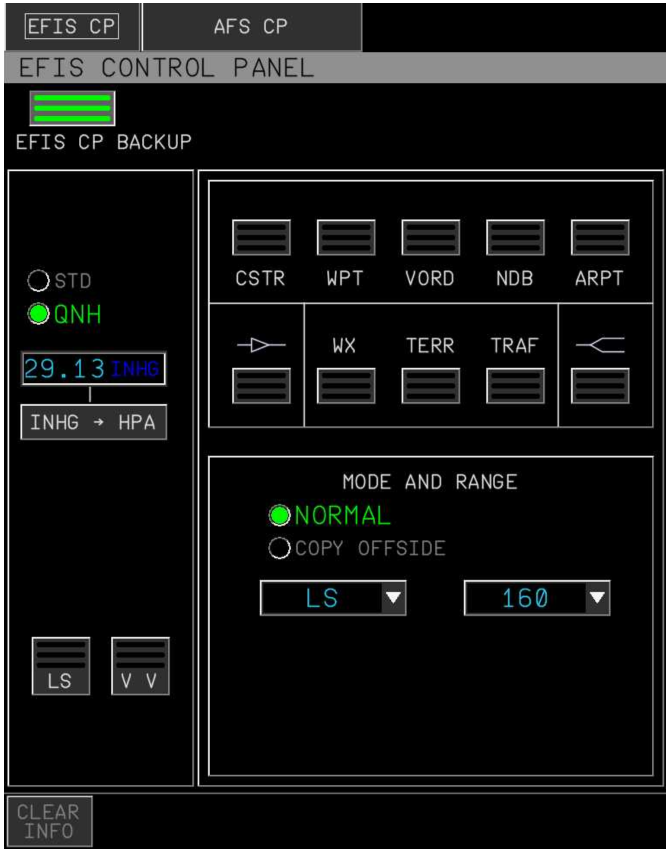
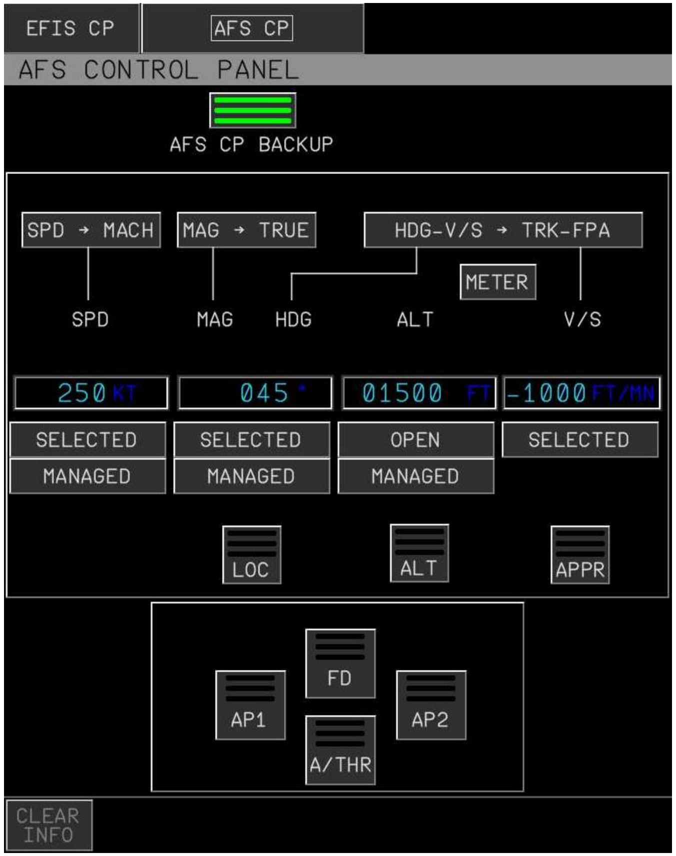
AFS components
FCU Back-up (A380)

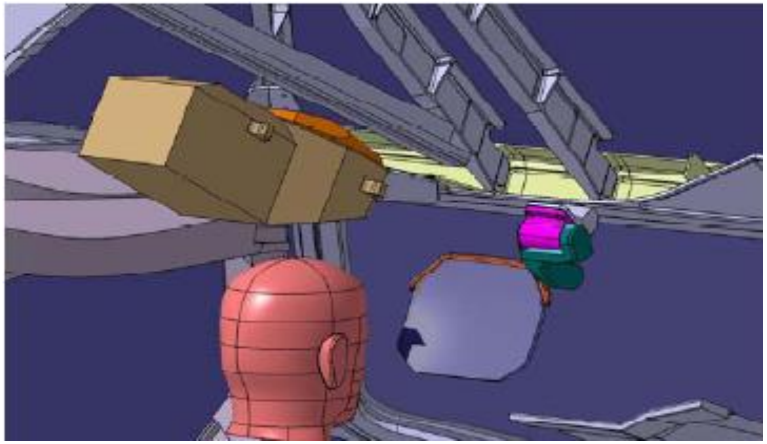
- Main benefit :
  - Increase FCU availability -> FGE availability

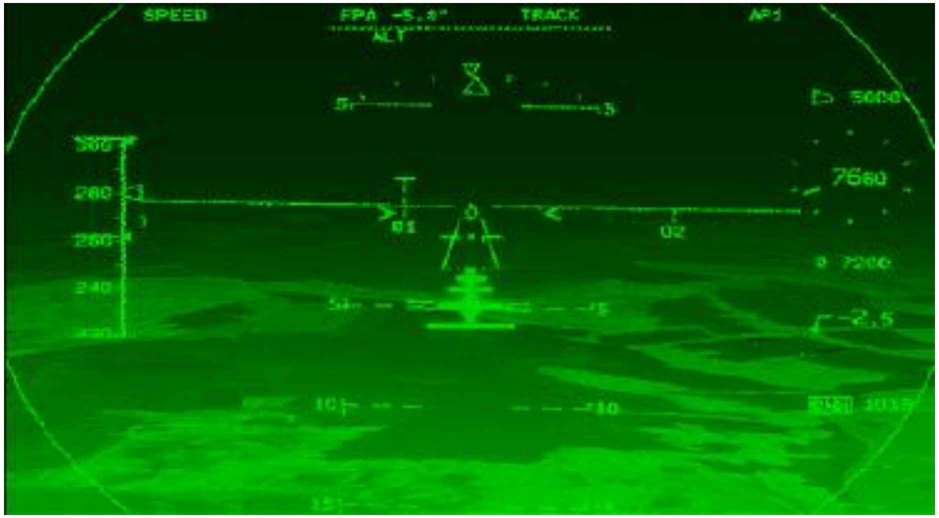




AFS components
HUD (A380)

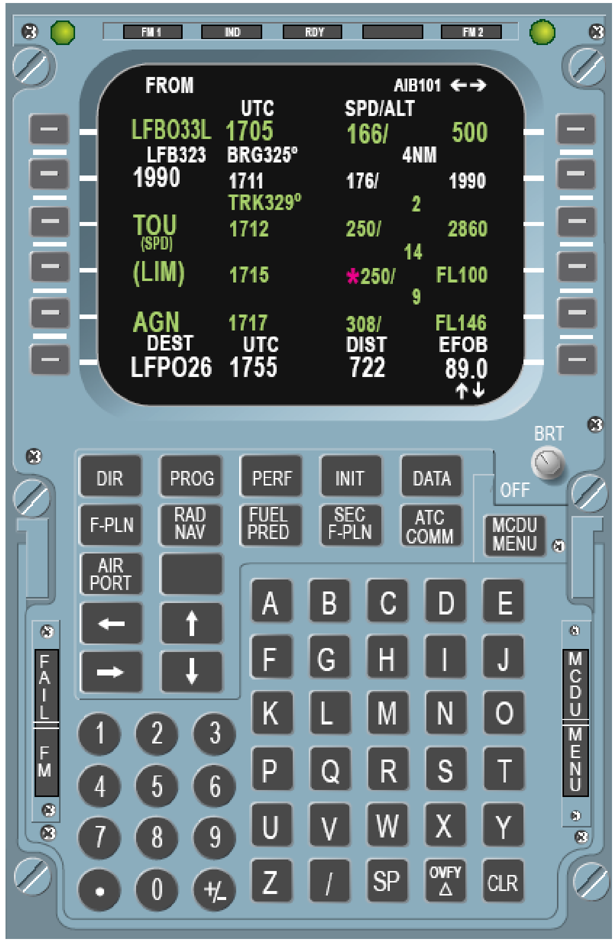
- Main benefit :
  - Ease for head up - head down transitions
  - Reduction of minimas for take-off (RVR)
  - Reduction of minima in approach
  - Possibility to perform CAT 2 operation on CAT 1 runways

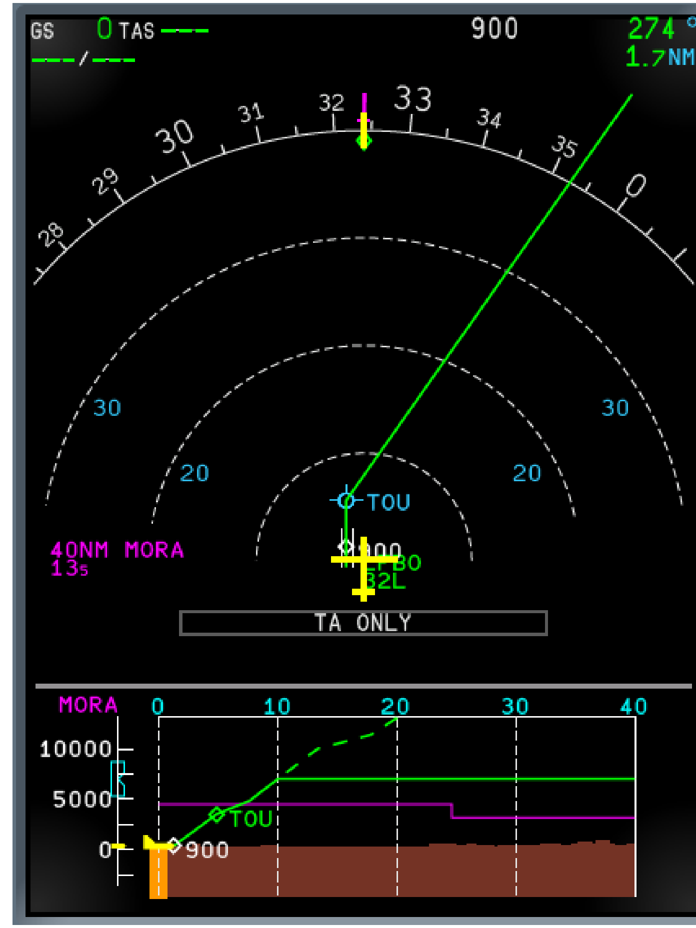




AFS components
HUD (A380)

Specific key
to request
managed
mode





AFS components

AP description

The **Auto pilot (AP)** acts on the surfaces and on the nose wheel in order to :

- maintain targets selected by the pilot (heading, track, vertical speed, altitude, …),
- follow a flight plan generated by the FMS (climb, cruise, descent and approach),
- perform an automatic landing (including roll out on ground),
- perform a Go Around.

The AP can't be engaged on ground for take-off roll

(engagement only possible 5 sec. after aircraft lift off).

The AP can or can not be coupled with the **Autothrust (ATHR).**

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AP engagement

- Engagement possible 5 sec after the aircraft lift off by action on one of the AP push-button of the FCU.
- Only one AP can be engaged at once, except in ILS approach/autoland and go around.
- When both AP are engaged, AP 2 is in stand-by.
- When the AP is engaged, the side-sticks and pedals are locked.

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AP disengagement

Volontary pilot disconnection:

- action on Instinctive Disconnect button on side-stick
- action on AP FCU push-button
- action on the side-sticks
- action on pedals (only on ground on A340)

Entry into protection:

- VMO, MMO
- angle of attack
- excess roll ($|\Phi| > 45°$)
- excess pitch ($\Theta > 25°$ or $<-13°$)

Failures:

- loss of surface
- loss of sensors
- loss of FCU
- …

Transition between Manual piloting and Automatic control

Manual ➔ AP

Neutral side stick: the AP order is immediately taken into account.
Deflected side-stick: the AP engages but is not active as long as the side-stick is deflected. The pilot has 4,5 sec to release the side-stick before AP disengagement.
In both cases, when the AP becomes active, the AP order is first synchronized on the manual order in order to avoid surface jerk.
Deflected pedals: the AP order is immediately taken into account.
(A340) except if the side-stick is deflected. The pilot has 4,5 sec to release the pedals before AP disengagement.

AP ➔ Manual

At AP disengagement, synchronization of the manual order on the AP order.

AFS components

FD description

The **Flight Director (FD)** provides guidance information, displayed on the PFD, in order to allow, in manual control:

- maintain targets selected by the pilot (heading, track, vertical speed, altitude, …),
- follow a flight plan generated by the FMS (climb, cruise, descent and approach),
- perform an automatic landing (including roll out on ground),
- perform a Go Around.

The FD can be engaged on ground for take-off roll.

The FD can or can not be coupled with the **Autothrust (ATHR).**

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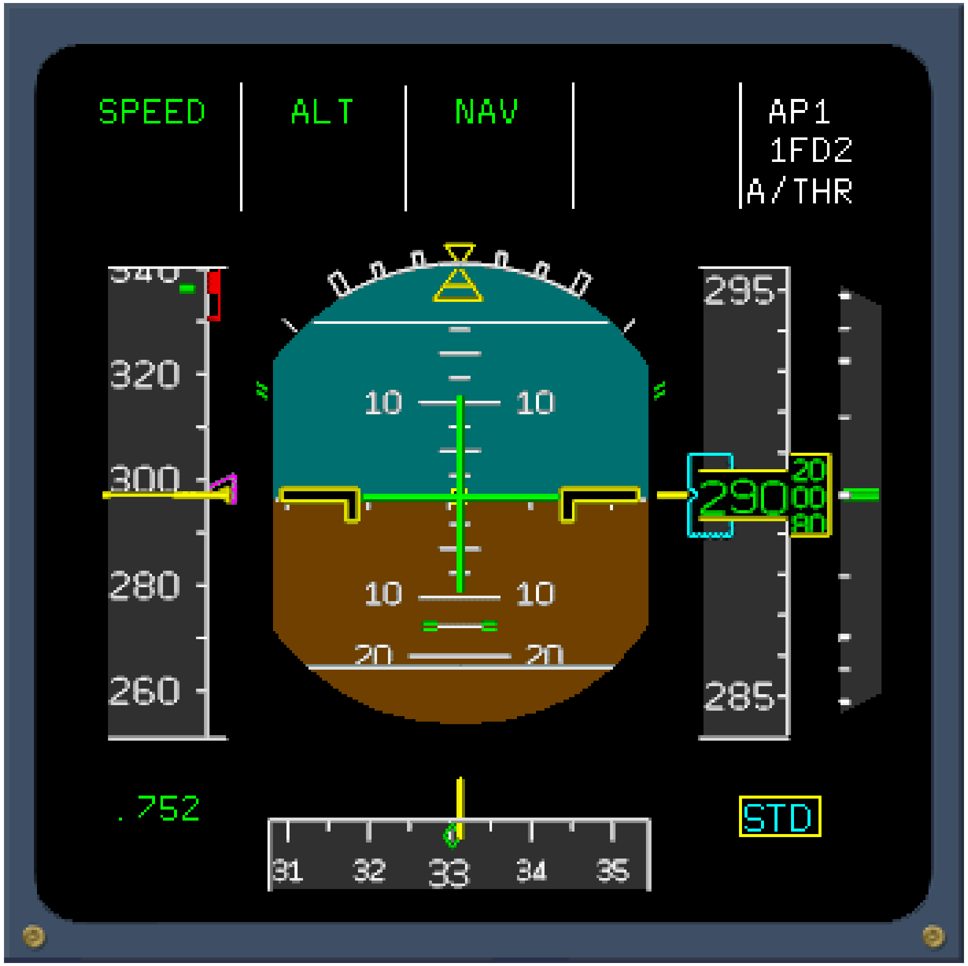
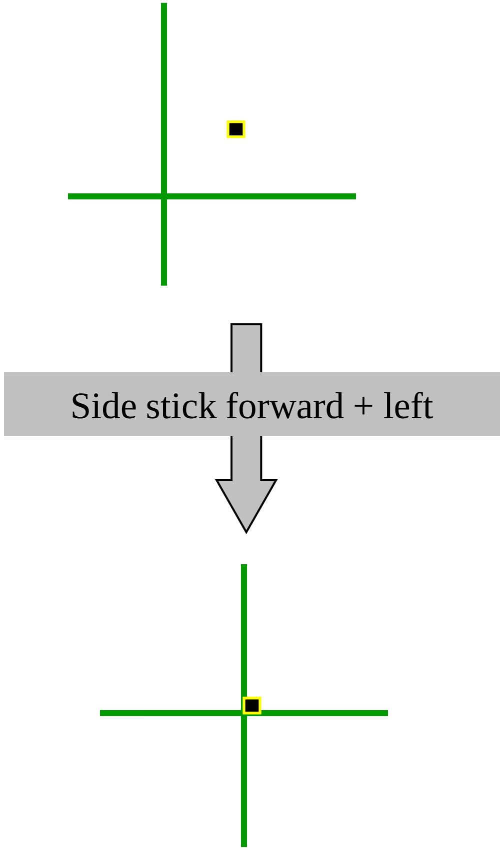
AFS components

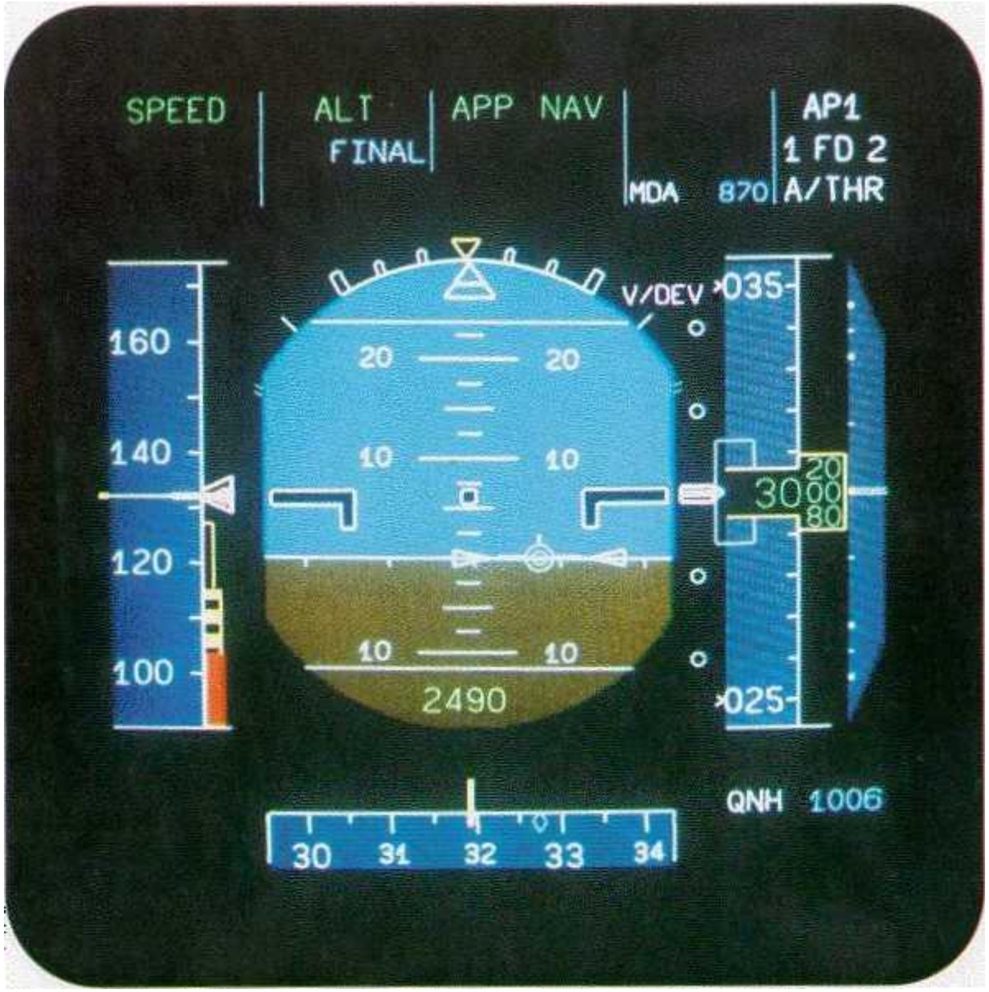
FD representation 1 (cross bars)

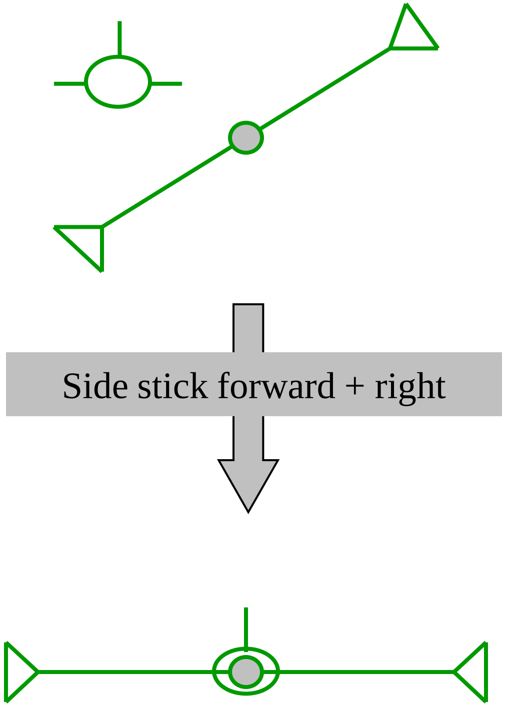




AFS components

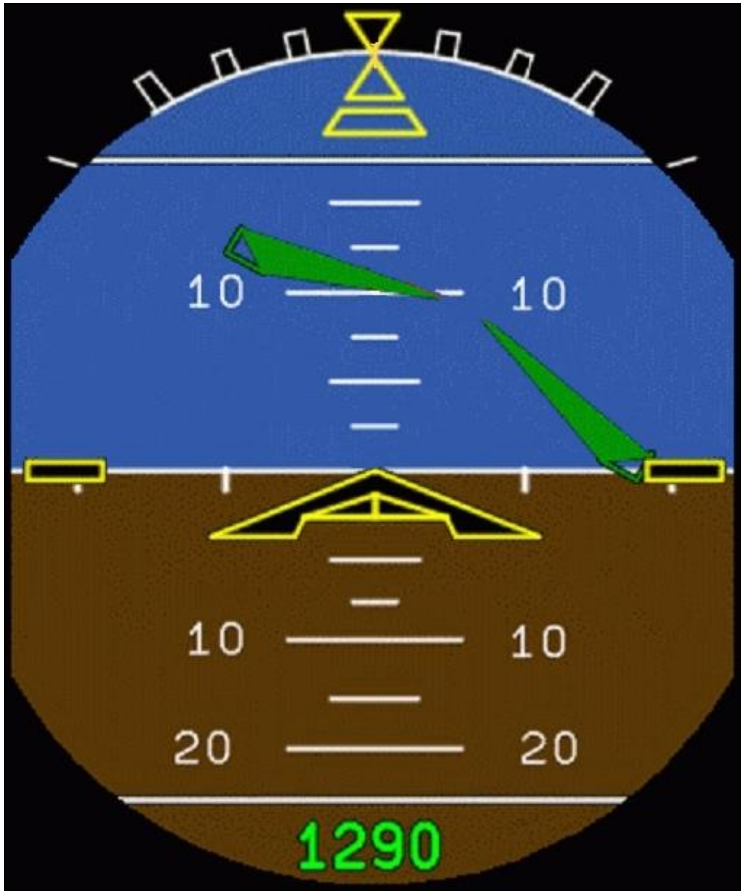
FD representation 2 (FPD)

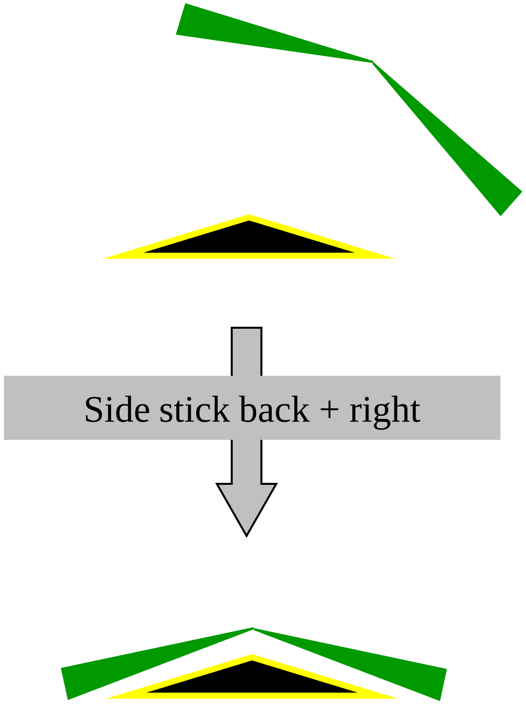




AFS components

FD representation 3 (V bars)





AFS components

ATHR description

The **Auto Thrust (ATHR)** acts on the engines (FADEC) in order to:

- maintain a thrust,
- track a speed or a Mach.

The ATHR can be engaged on ground for take-off.

The ATHR works always with the same sensors side than the AP.

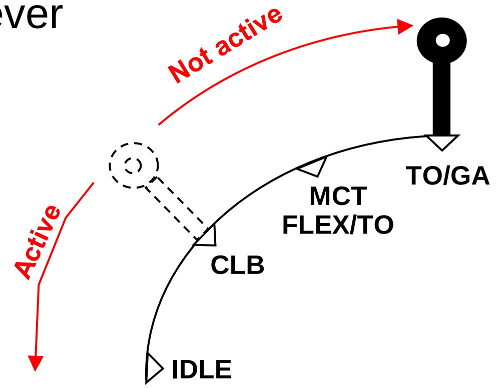
The ATHR can be “killed” for the whole flight by a long action (15 sec) on Instinctive Disconnect push-button on thrust levers.

ATHR engagement

- Manual engagement by action on the ATHR push-button of the FCU.
- Automatic engagement on ground or in Go around when the thrust levers are set on TOGA (max thrust).
- Automatic engagement in case of Alpha Floor.
- The ATHR order is max limited by the position of the levers.

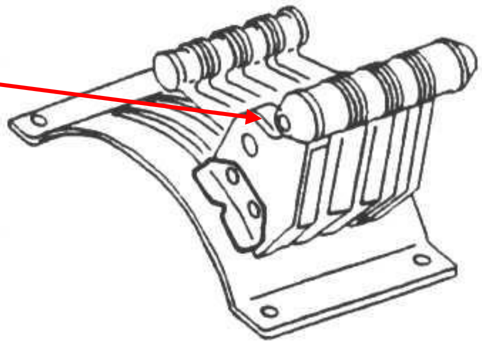
Once engaged, the ATHR is active (ie it really commands the engines) only if the levers are set between Idle and CLB detent.

When the ATHR is engaged and active, the operational lever position is on CLB detent (or MCT in case of engine out).



ATHR disengagement

- Action on Instinctive Disconnect button on thrust levers,
- Action on ATHR FCU push-button,
- Reduce all levers on Idle,
- Failure cases (sensors, engines, …).



At ATHR disengagement by ID button, the engine thrust goes immediately to the thrust corresponding to the levers position.

Else, the thrust is frozen to current value until the pilot moves the thrust levers.

AFS components

Modes, Operational logic and Control laws

Once an automatism is engaged (AP or FD or ATHR), the Flight Guidance System controls the aircraft (or provides information).

The crew can chose:

- To impose the guidance reference
  - ✓ use of FCU selectors to set SPEED/MACH, HDG/TRACK, ALT, V/S/FPA
  - ✓ short term action
  - ✓ Airbus "**selected modes**"
  - ✓ Pull action on selector to engage the modes

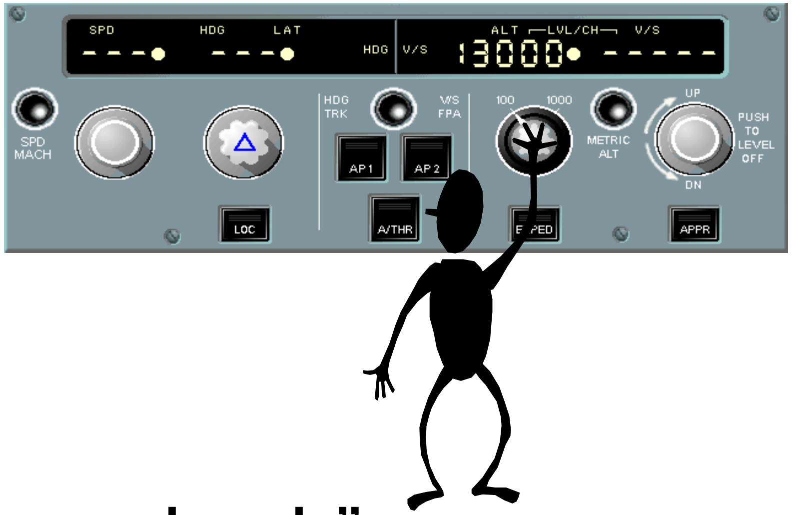
- To give the hand to the FMS which will give the guidance reference (lateral and longitudinal flight plan, speed or Mach),
  - ✓ flight plan input & modification in the FMS
  - ✓ long term action
  - ✓ Airbus "**managed modes**"
  - ✓ Push action on selector to engage the modes

Each mode:

- provides control for the aircraft in a specific manner by activating a corresponding control law.
- has specific conditions of engagement (operational logic)

AFS components
Modes, Operational logic and Control laws

Pull: “the pilot takes over” => “selected mode”



Push: “the pilot let the system” => “managed mode”

Lateral axis modes

Name	Runway	heading	track	navigation		
Display	**RWY TRK**	**HDG**	**TRK**	**NAV**	**APP NAV**	**FINAL APP**
Control law	TRK	HDG	TRK	HDG **or** TRK **or** HPATH		
Type	selected	selected	selected	managed	managed	managed

Name	Go Around	localizer capture	localizer track	landing		Roll out
Display	**GA TRK**	**(F-) LOC***	**(F-) LOC**	**LAND**	**FLARE**	**ROLL OUT**
Control law	TRK	LOC			LOC and ALIGN	roll out
Type	selected	LS approach and landing				

Lateral control law brief description

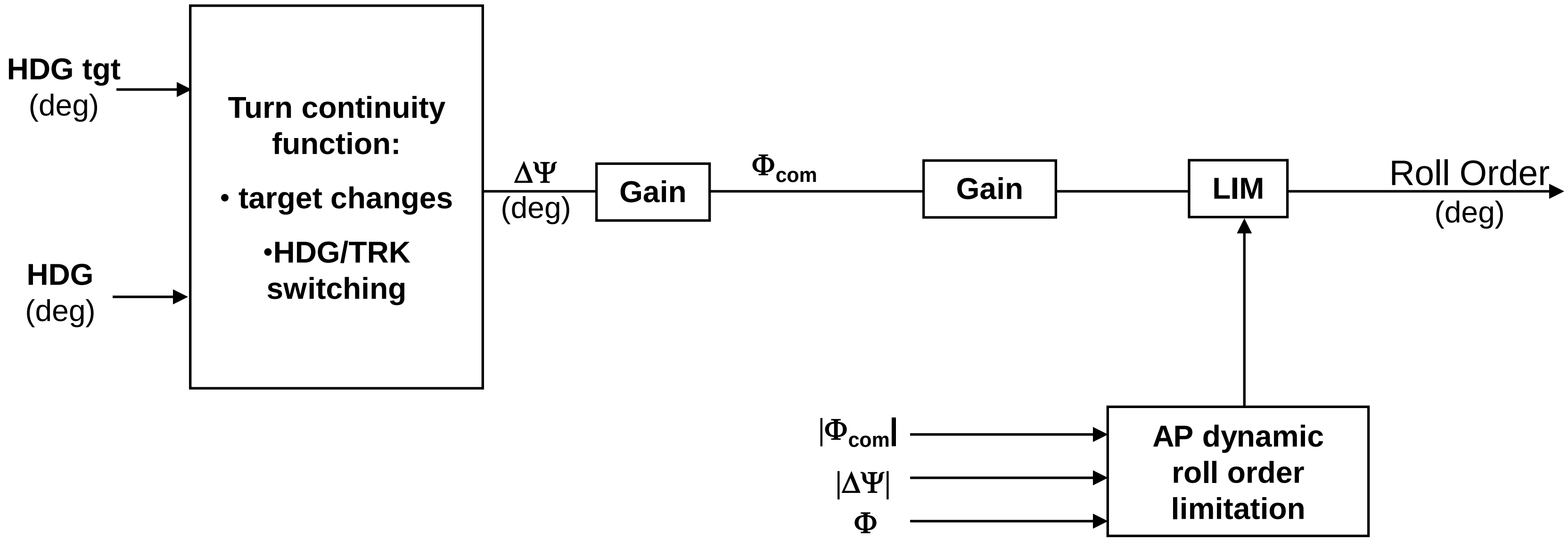
HDG	acquisition and hold of a heading (true or magnetic) value
TRK	acquisition and hold of a track (true or magnetic) value
Bank	acquisition and hold of a bank angle value
HPATH	acquisition and hold of a lateral profile
LOC	acquisition and hold of a localizer beam
ALIGN	aircraft alignment with runway axis (crosswind conditions)
roll out	acquisition and hold of runway axis following automatic landing

AFS components
Heading Control Law

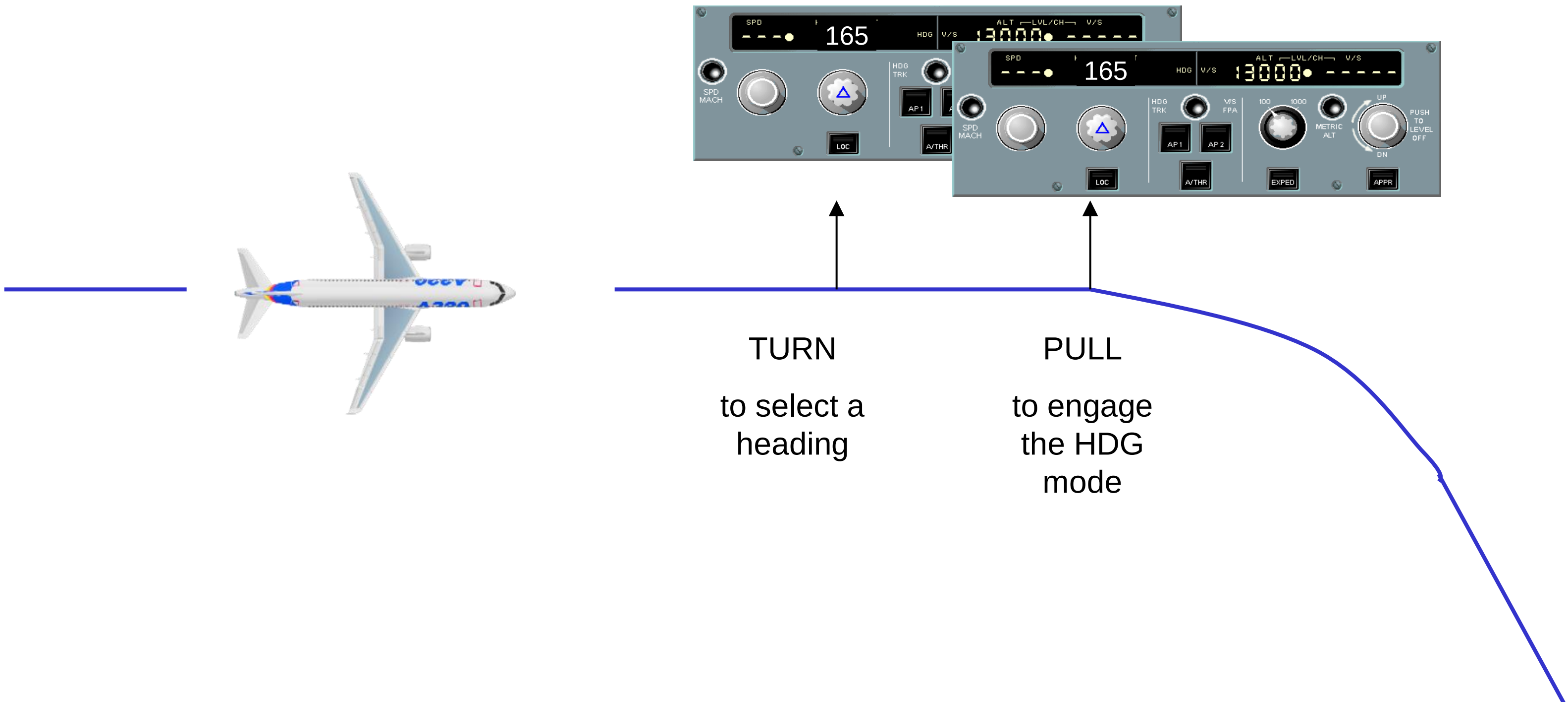
- **Objectives**

  The aim of the HDG control law is to capture and then hold the heading target.

- **Principles**



Capture and hold of a heading



AFS components

Modes, Operational logic and Control laws

Vertical axis modes

Name	open descent	open climb	vertical speed	flight path angle
Display	**OP DES**	**OP CLB**	**V/S**	**FPA**
Control law	SPD/MACH	SPD/MACH	V/S	FPA
Type	selected	selected	selected	selected

Name	altitude acquisition	altitude hold	descent		climb
Display	**ALT***	**ALT**	**DES**	**FINAL DES**	**CLB**
Control law	ALT star	ALT	VPATH **or** SPD/MACH **or** V/S		SPD/MACH
Type	selected or managed	selected or managed	managed	managed	managed

Name	glide capture	glide track	landing		speed reference system
Display	**(F-) G/S***	**(F-) G/S**	**LAND**	**FLARE**	**SRS**
Control law	Glide			flare → nose down	SRS
Type	LS approach				selected

Longitudinal control law brief description

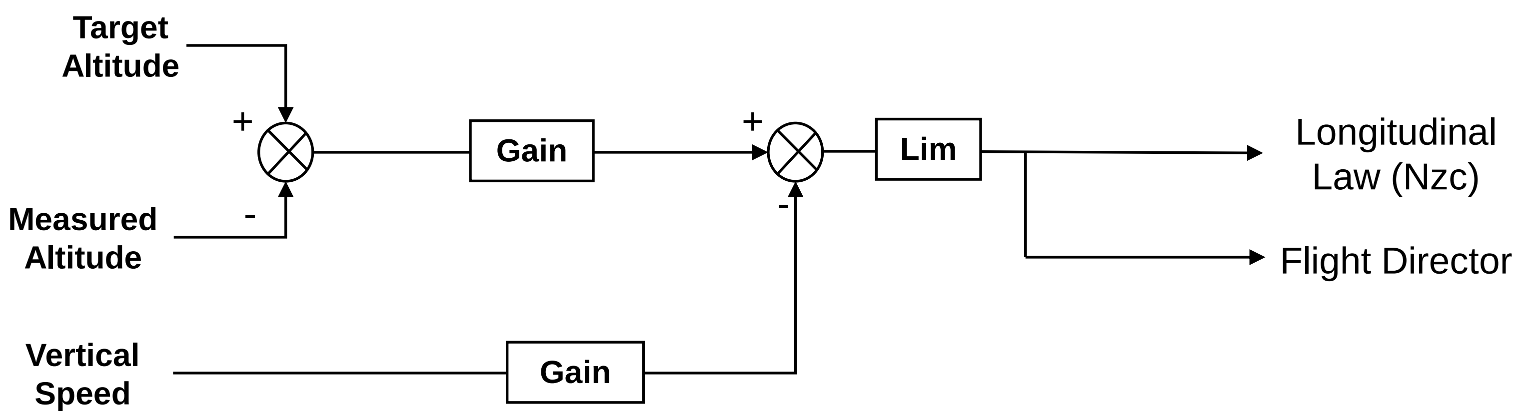
SPD/MACH	Speed hold during level change with VLS and VMO protections, combined with A/THR THR mode
V/S	acquisition and hold of a vertical speed value with VLS and VMO protections
FPA	acquisition and hold of a flight path angle value with VLS and VMO protections
ALT	hold of an altitude value
ALT star	acquisition of an altitude value
VPATH	acquisition and hold of a vertical profile
SRS	speed hold for T/O or G/A with protection against excessive pitch angle and ensuring a minimum vertical speed
Glide	acquisition and hold of a glide slope
Flare	aircraft rotation to ensure touchdown performances (autoland)
Nose down	aircraft derotation following touchdown (autoland)

Altitude Hold control law

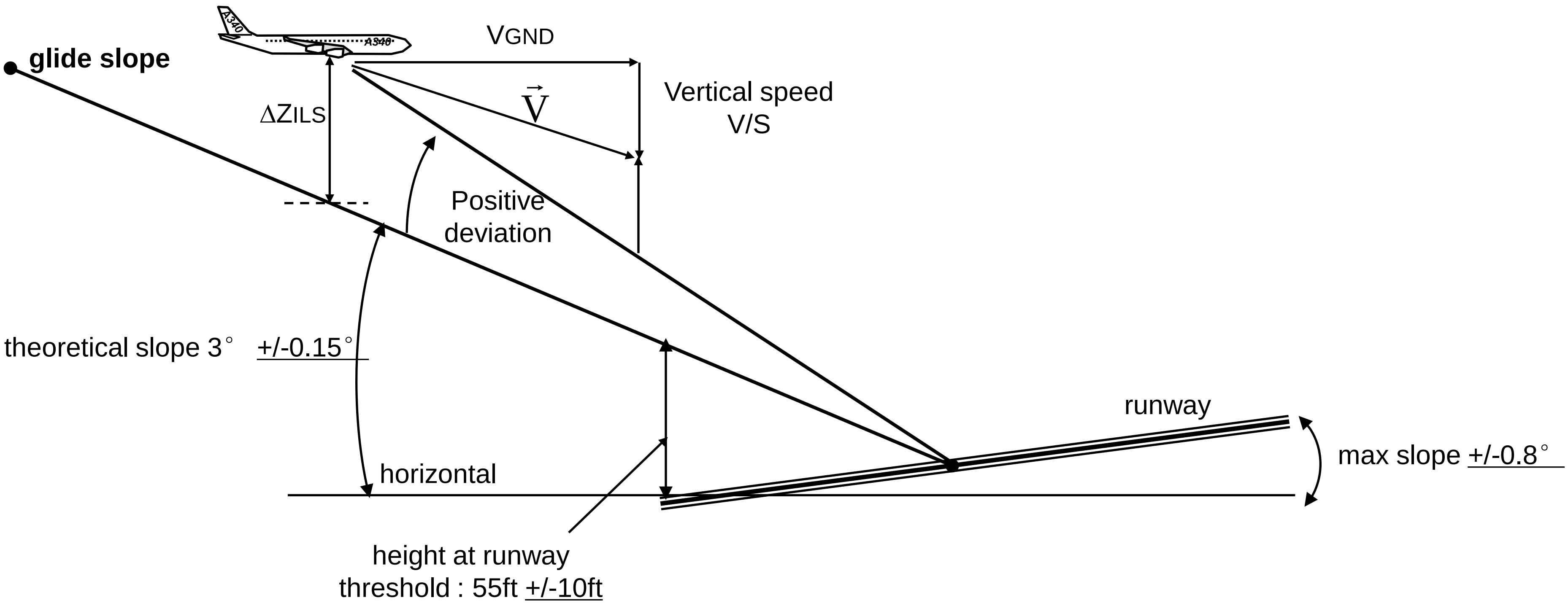
- Objectives

  The aim of the ALT control law is to hold the altitude target

- Principles



- Glide characteristics



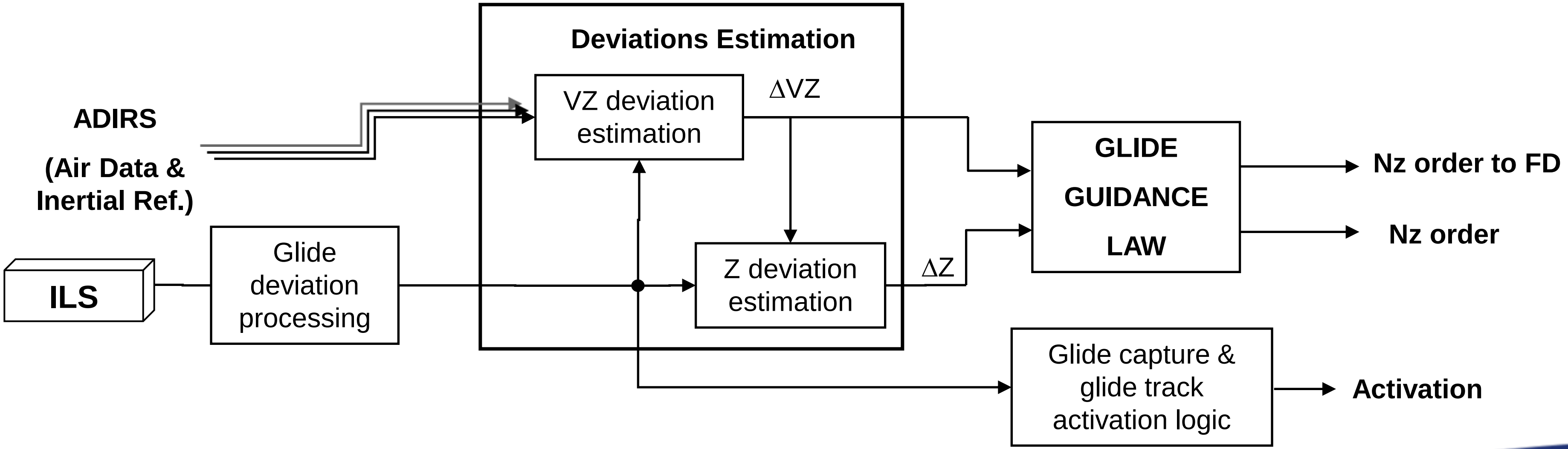
- **Objectives**

  The aim of the Glide control law is to capture and then track the ILS glide slope.

- **Principles**

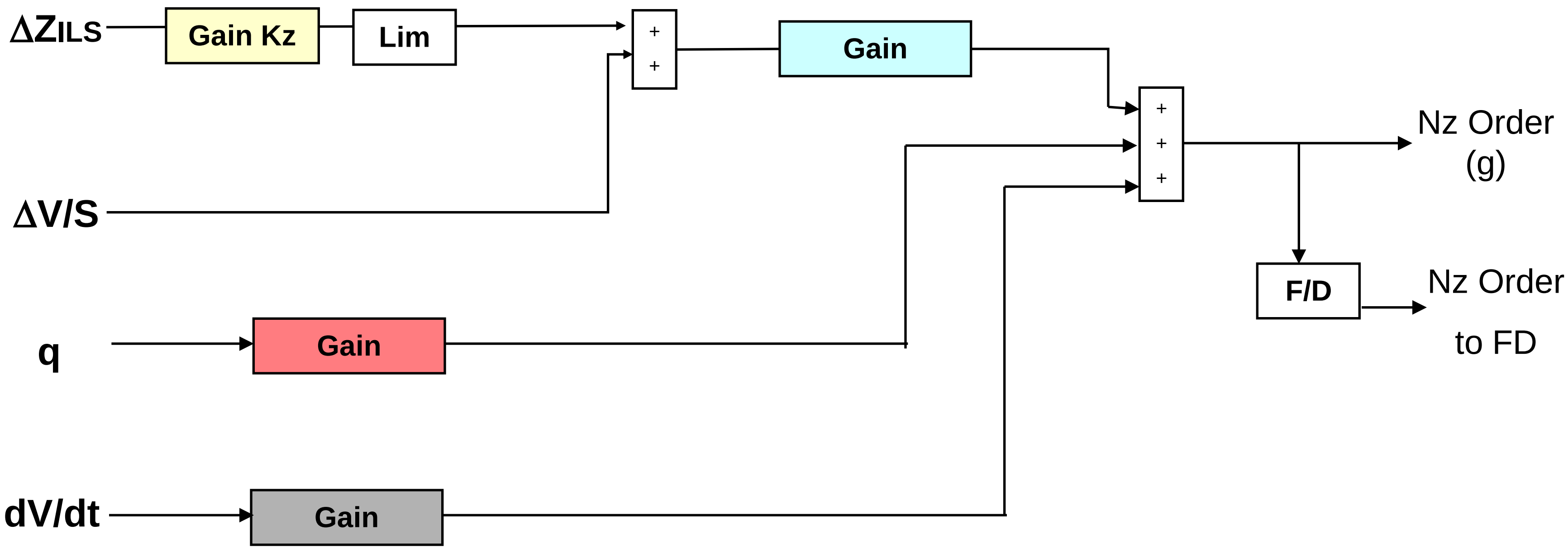
  The two main functions are :

  - estimation of Z and VZ deviation
  - guidance control law

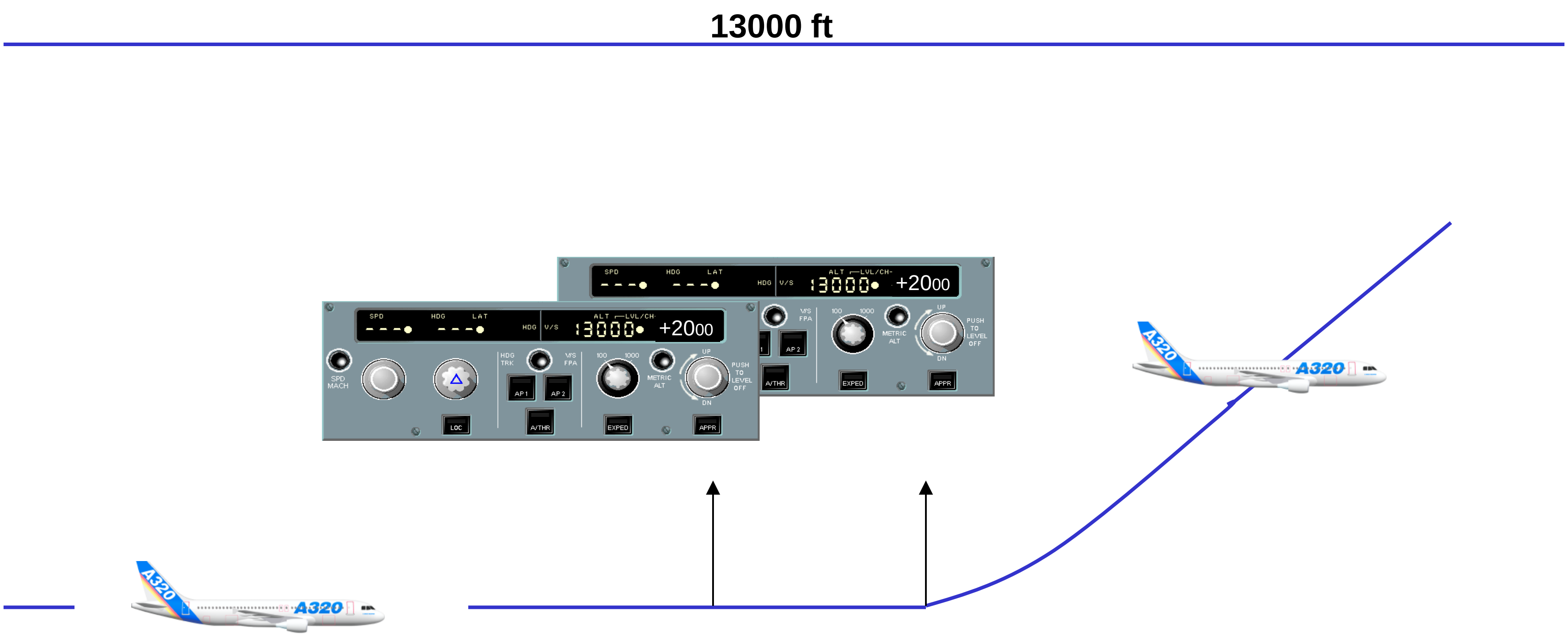


Glide control law

- Guidance law



Capture and hold of a vertical speed



TURN

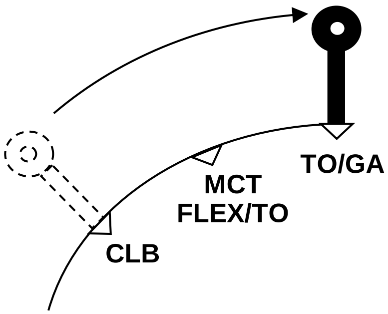
to select
a VS

PULL

to engage the
VS mode

Particular cases of TO and GA

TO and GA modes are engaged by pushing the thrust levers on TOGA detent.



Longitudinal axis mode:

- SRS mode: speed capture and hold: V2+10 at take-off, current aircraft speed in go around

Lateral axis mode:

- RWY: follow LOC axis at take-off (with FD only)
- GA TRACK: current aircraft track hold in go around

Particular case of Approach

The approach modes are engaged thanks to specific push-buttons on the FCU.

LOC

To engage only lateral approach modes

APPR

To engage lateral and longitudinal approach modes

No longitudinal approach mode without lateral approach mode

Coupling AP/FD/ATHR with FM

Purpose: to follow a flight plan generated by the FM (climb, cruise, descent, approach) with AP/FD engaged.

The flight plan (lateral et longitudinal) and its parameters (speed, level off, cruise altitude, …) is entered in the MCDU on ground (can be modified in flight).

Once the managed modes engaged, the FM sends to the FGS outer loops orders:

- Φc (commanded roll angle) or HDG/TRK (depending on submode), for lateral guidance
- $\Delta\Theta c$ (commanded pitch difference) or speed/VS/FPA (depending on submode) for vertical guidance
- Speed target or thrust target.

➔ Different sharing on A400M

AIRBUS

Mode arming

Some modes are armed before being engaged :

- Lateral: RWY, NAV, LOC (F-LOC)
- Vertical: ALT, CLB, DES, GS (F-GS)

AFS components

Mode equivalence Boeing / Airbus

Lateral modes

Boeing	Airbus
TO/GA	RWY RWY TRK GA TRK
LNAV	NAV
HDG HOLD HDG SEL	HDG
TRK HOLD TRK SEL	TRACK
LOC	LOC* LOC
ROLL OUT	ROLL OUT
ATT (en option)	N/A

Longitudinal modes

Boeing	Airbus
TO/GA	SRS
VNAV SPD	CLB, DES
VNAV PTH	CLB, DES ALT CRZ*, ALT CRZ ALT CST*, ALT CST
VNAV ALT	ALT*, ALT
FLCH SPD	OP CLB OP DES
ALT	ALT*, ALT
V/S	V/S
FPA	FPA
G/S	G/S*, G/S
FLARE	FLARE

ATHR modes

- When engaged with neither AP nor FD, the ATHR works in SPEED/MACH.
- When at least one AP or FD is engaged, the ATHR mode active depend on the longitudinal AP/FD active mode.

Basic principle: to not let a same objective be controlled by 2 commands (risk of conflict or instability).

For example:

- AP/FD mode: OPEN CLB ⇒ ATHR mode: THRUST (speed hold by the elevators)
- AP/FD mode: V/S ⇒ ATHR mode: SPEED (speed hold by the engines)

ATHR modes

Name	Thrust	Speed	Mach
Display	**THR XXX**	**SPD**	**MACH**
Control law	thrust	A/THR SPEED/MACH	
Type	selected or managed	selected or managed	selected or managed

ATHR control law brief description

SPEED/MACH	acquisition and hold of a speed/Mach value
THRUST	acquisition and hold of a thrust value (idle or thrust limit), combined with SPD/MACH or SRS

Auto THRust control loop

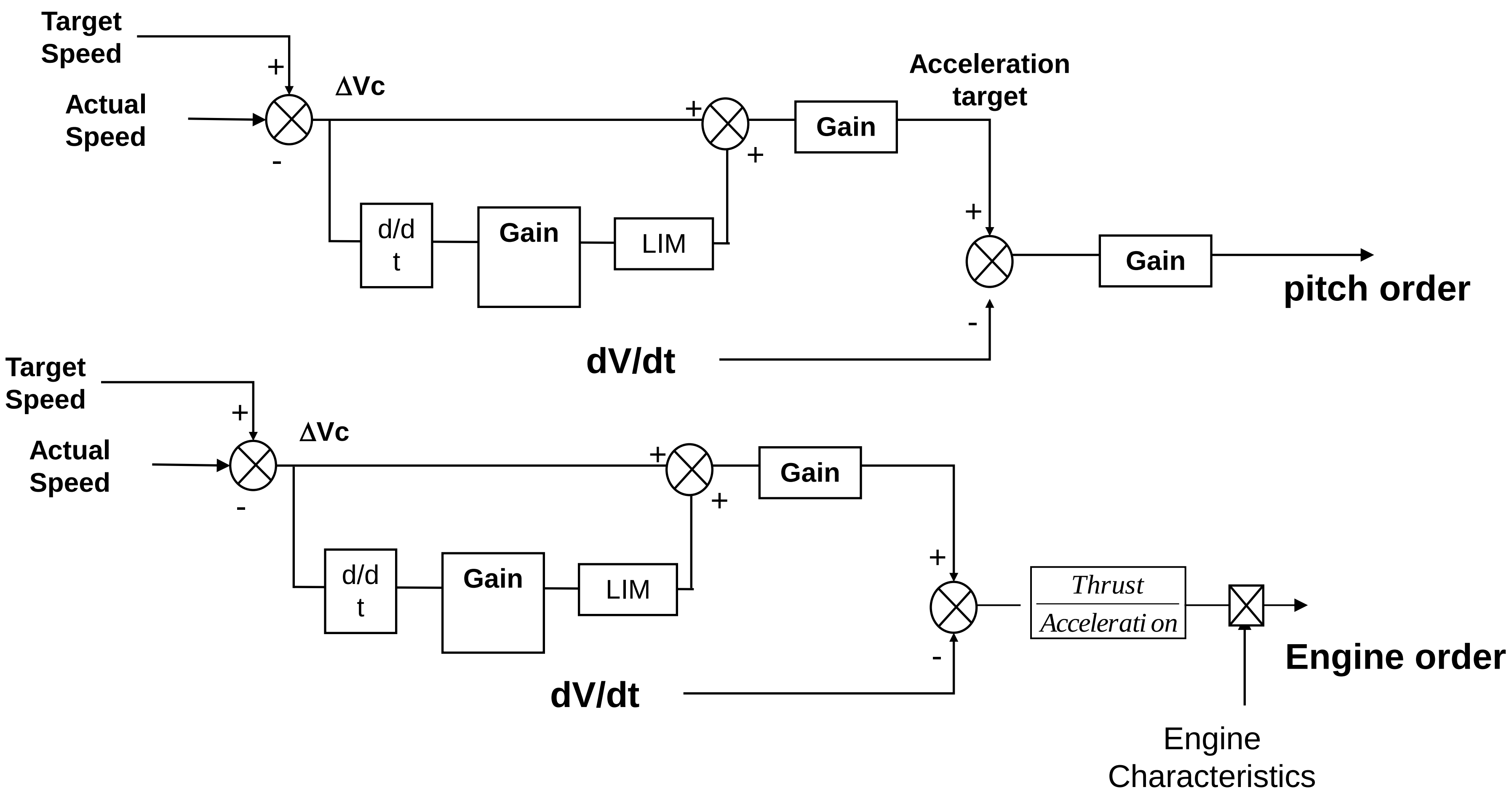
- Objectives

  The aim of the A/THR outer loop is to compute thrust variation and pitch control orders , in order to :

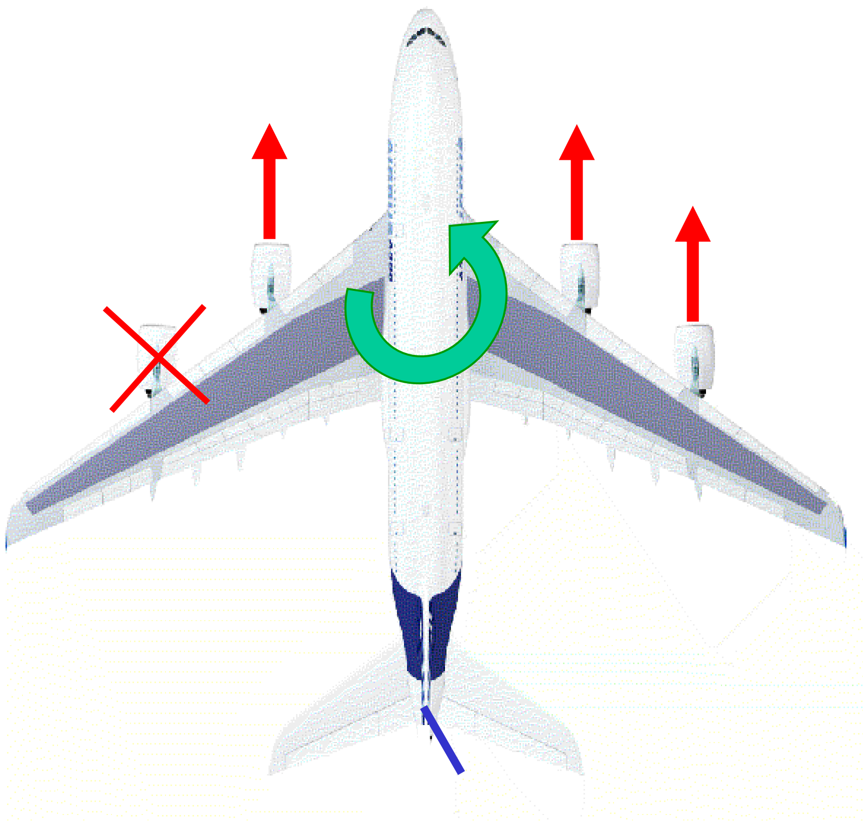
  - control the A/C speed/mach according to Target
  - While keeping coordination with AP longitudinal control (slope) and compensating engine pitching moment

Auto THRust control loop

- Principles: pitch & thrust control for A/THR

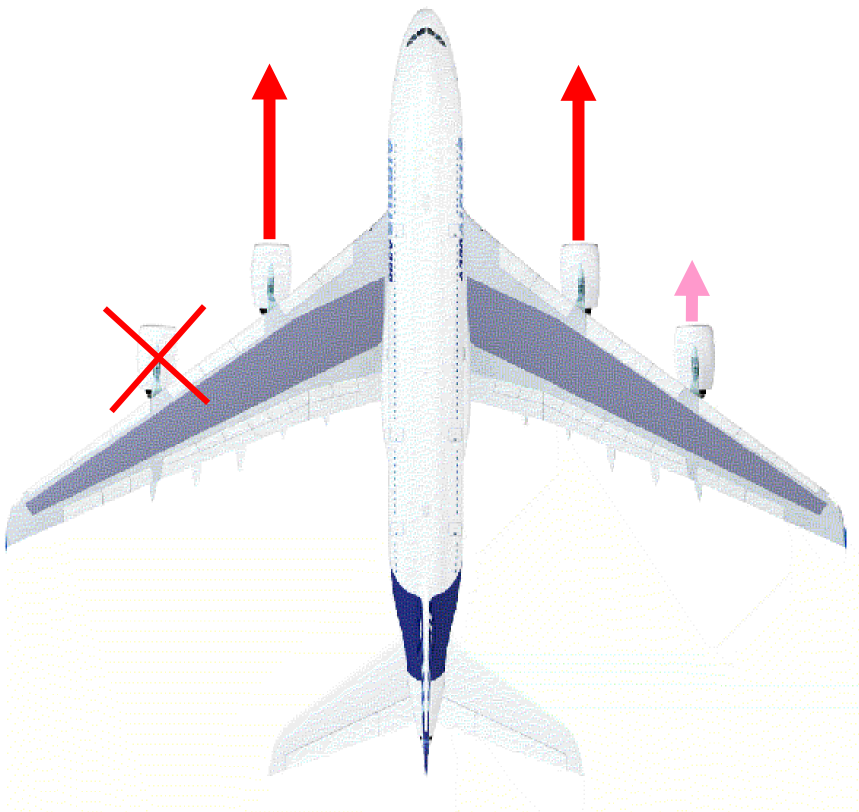


The ATHR is able to manage Engine failures :



AFS components
ATHR modes

The ATHR is able to manage Engine failures :



AP speed protections

Purpose: to avoid speed excursion outside AP/FD operational envelope: VLS - VMAX (VMO, VFE, VLE).

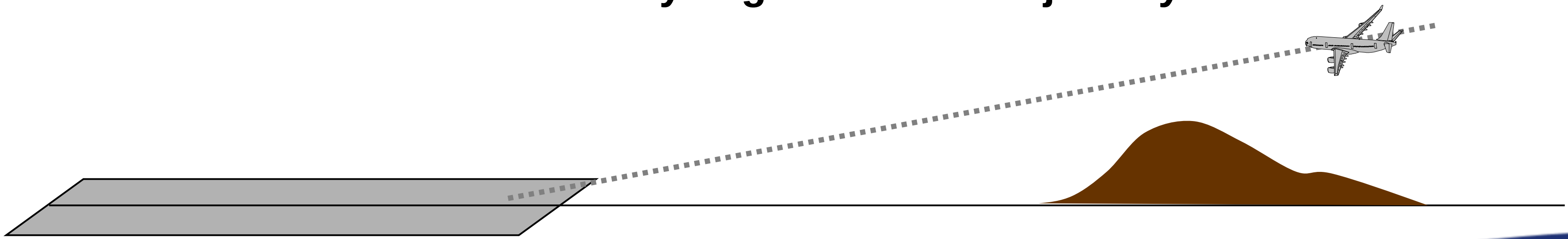
Protected AP/FD modes: V/S, FPA, CLIMB, DESCENT, OPEN CLIMB, OPEN DESCENT, ALTITUDE ACQUIRE, SRS.

The objectives of the protections are to maintain:

- in climb, at least VLS + 5 (or VLS if the initial speed target was near VLS)
- in descent, at the most VMO (ou VLE) in full conf or VFE + 4 slat extended

Not protected modes: ALTITUDE, G/S CAPT or G/S TRACK, FINAL DES

Priority is given to the trajectory



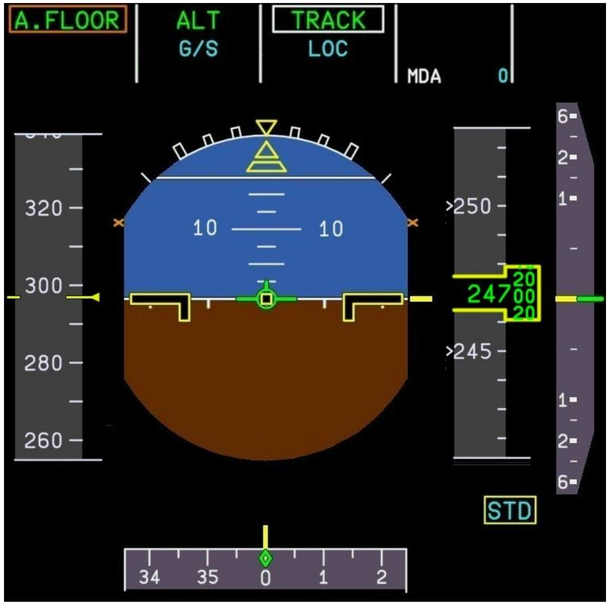
ATHR protection "Alpha Floor"

Purpose: to avoid stalling in case of aircraft low energy.

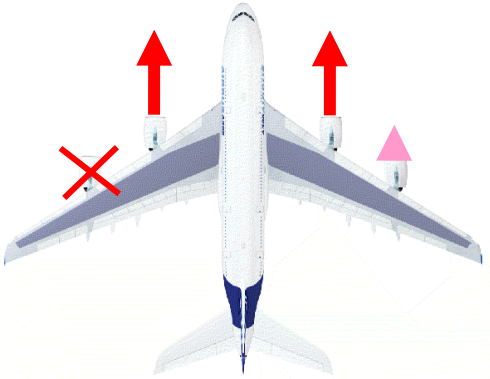
Upon angle of attack condition:

- the ATHR automatically engages in Alpha Floor mode,
- Full thrust is commanded to the FADEC.

Exit of Alpha Floor mode by ATHR disengagement.



Management of engine failures



AP authority (longitudinal axis)

The maximum longitudinal authority of the AP (=maximum load factor that the AP can order) depends on the longitudinal active mode:

- 0,3 g in SRS (TO and GA), G/S CAPT, G/S TRACK,
- 0,05 g in clean/0,1 g in hyper in ALT, V/S, FPA
- 0,1 g in ALT ACQ, OPEN
- 0,15 g in level off
- authority increased to 0,15 g when :
  - airbrakes extension
  - slope reversion
  - transition VMO/MMO

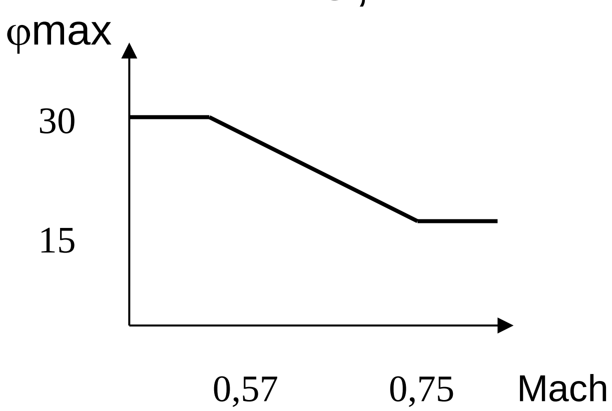
In speed protection, the authority if increased to 0,3 g.

AP authority (lateral axis)

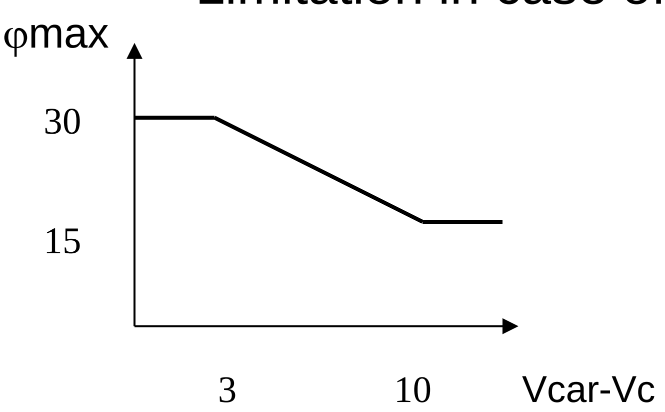
The maximum lateral authority of the AP (φmax commanded) depends on the lateral active mode:

- 30° in LOC CAPT
- 10° in LOC TRACK below 700 ft
- between 15° and 30° (depending on the Mach) in NAV, TRK, HDG

In HDG, TRK



Limitation in case of EO



AFS components
Warnings

Warnings

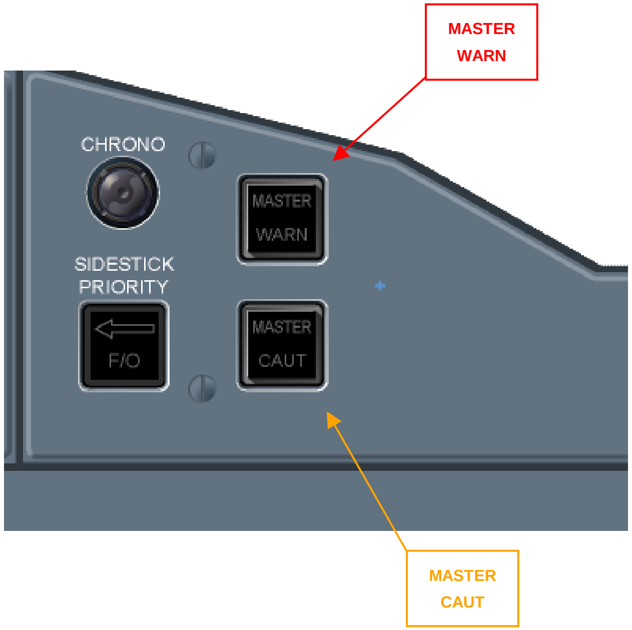
AP OFF warning:
- message on EWD: AP OFF
- sound: CAVALRY CHARGE
- light: MASTER WARNING

ATHR OFF warning:
- message on EWD: A/THR OFF
- sound: GONG
- light: MASTER CAUTION
- THR LK on FMA (frozen thrust)

ENGx A/THR OFF
- sound: Single Chime
- light: MASTER CAUTION
- THR lever x: Man adjust

ATHR Limited
- sound: single chime
- light: MASTER CAUTION
- THR CLB flashing on FMA

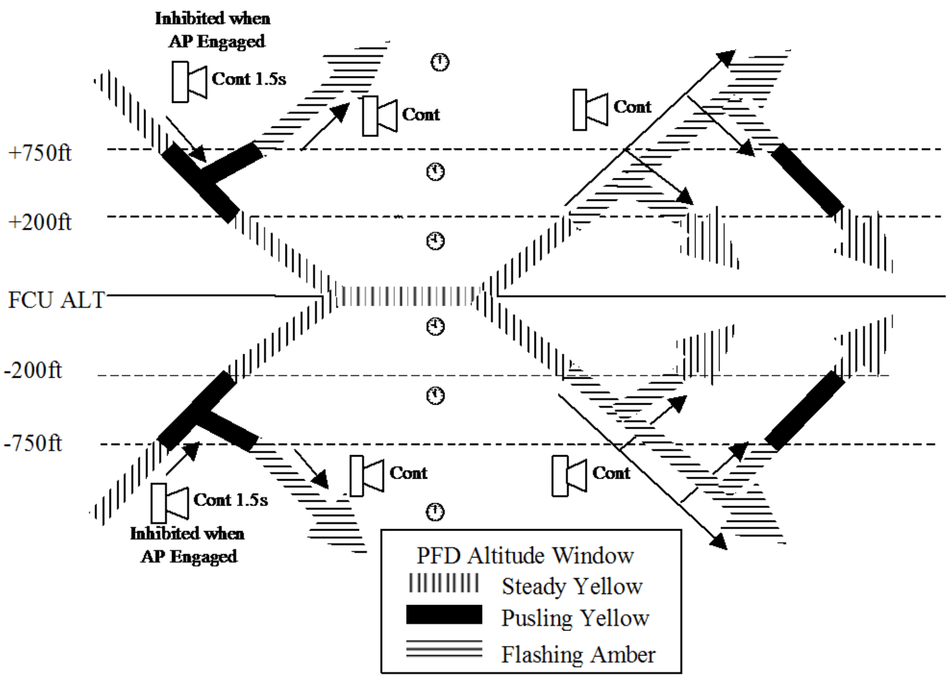
Triple click
- FMA change not commanded (landing cat or mode)



Warnings

Altitude Alert

- sound: C. CHORD
- flashing Altitude window on PFD

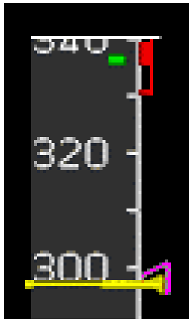


Excess dev warning

- blinking of LOC and GLIDE scales on PFD

Autoland warning

- AUTOLAND light below 200 ft if
  - excess dev warning
  - both AP disengagement
  - RA difference 15 ft (2 RA only)



VMO/MMO (Max Op. Speed)

VLS (Lowest Selectable Speed)

$V\alpha$ prot (neutral stick)

α floor

$V\alpha$ max (full back stick)

Main interfaced systems with AFS

- ADIRS = ADR ➔ CAS, Mach, TAS, AOA, SS, Zp, TAT, ...

  + IRS ➔ Nx, Ny, Nz, p, q, r, hdg, trk, Vgnd, Zbi, Vzbi, ...
- Multi Mode Receiver (MMR) ➔ deviation VS xLS axis
- Radio Altimeter (RA) ➔ height below the aircraft
- Fuel Quantity and Mesurment System (FQMS) ➔ weight and CG
- Slat and Flap Control Computer (SFCC) ➔ aircraft configuration
- Landing Gear Extraction and Retraction System (LGERS) ➔ LG position

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AIRBUS

Approach type

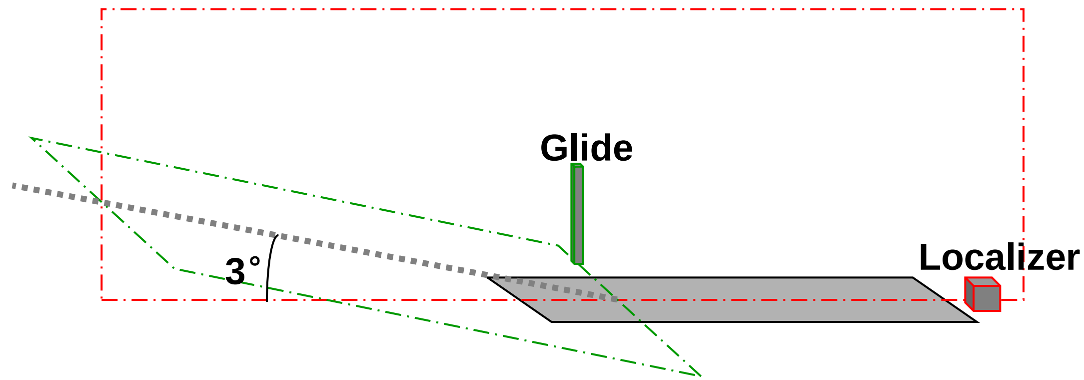
2 different approach types:

Precision approach:
The guidance is performed on a ILS or MLS beam or GLS signal. Under particular conditions, it can lead the aircraft to autoland with automatic roll out.

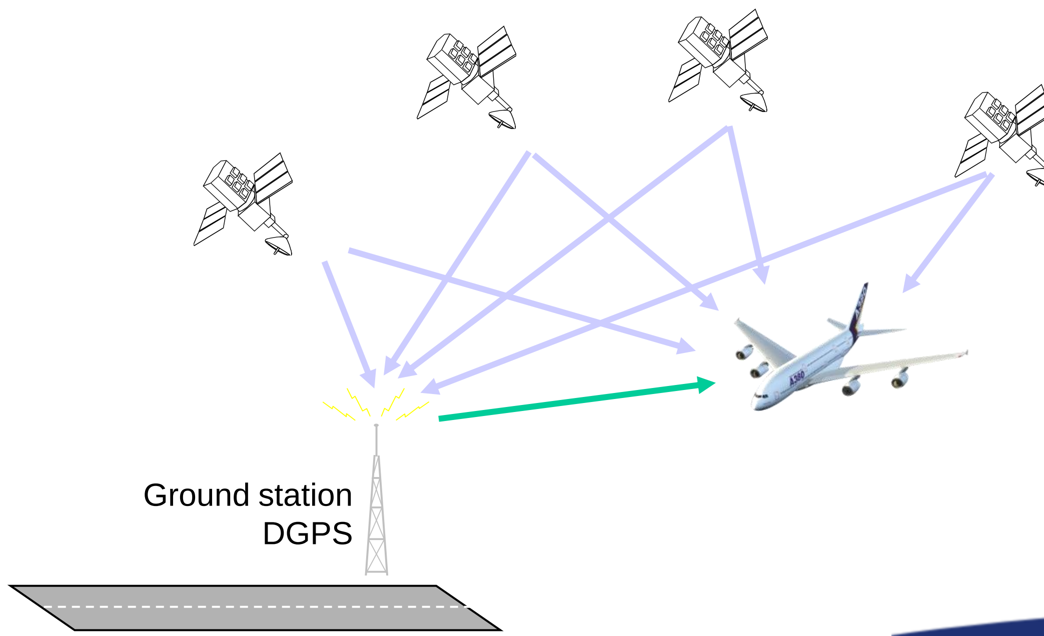
Mid term perspective: FLS (FM)

Non precision approach:
The guidance is performed on a theoretical profile computed by the FM until the MDA/MDH (Minimum Descent Altitude/Height), height at which the pilot must take over to finish manually the landing (selected modes/FM modes/FLS approach).

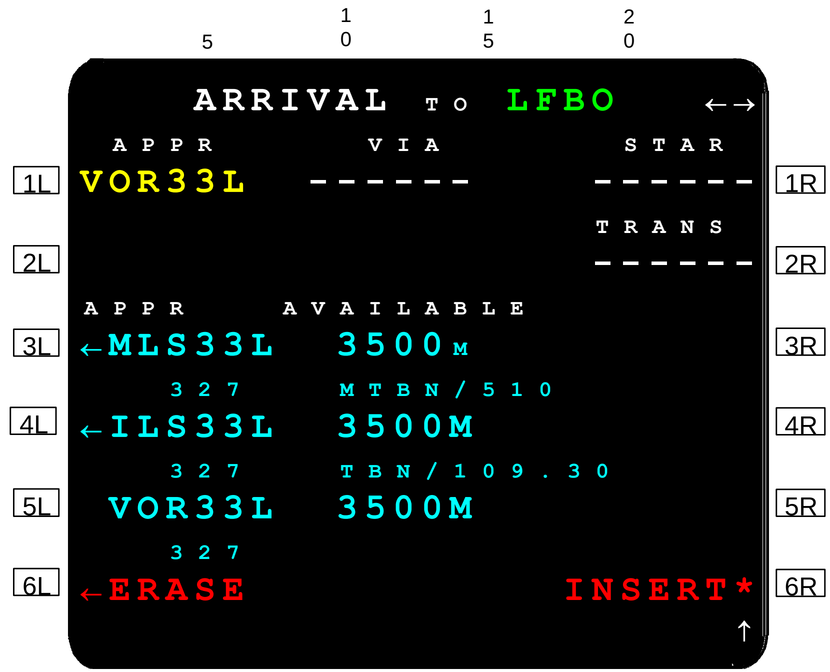
ILS / MLS



GLS (GPS / DGPS)



Approach selection

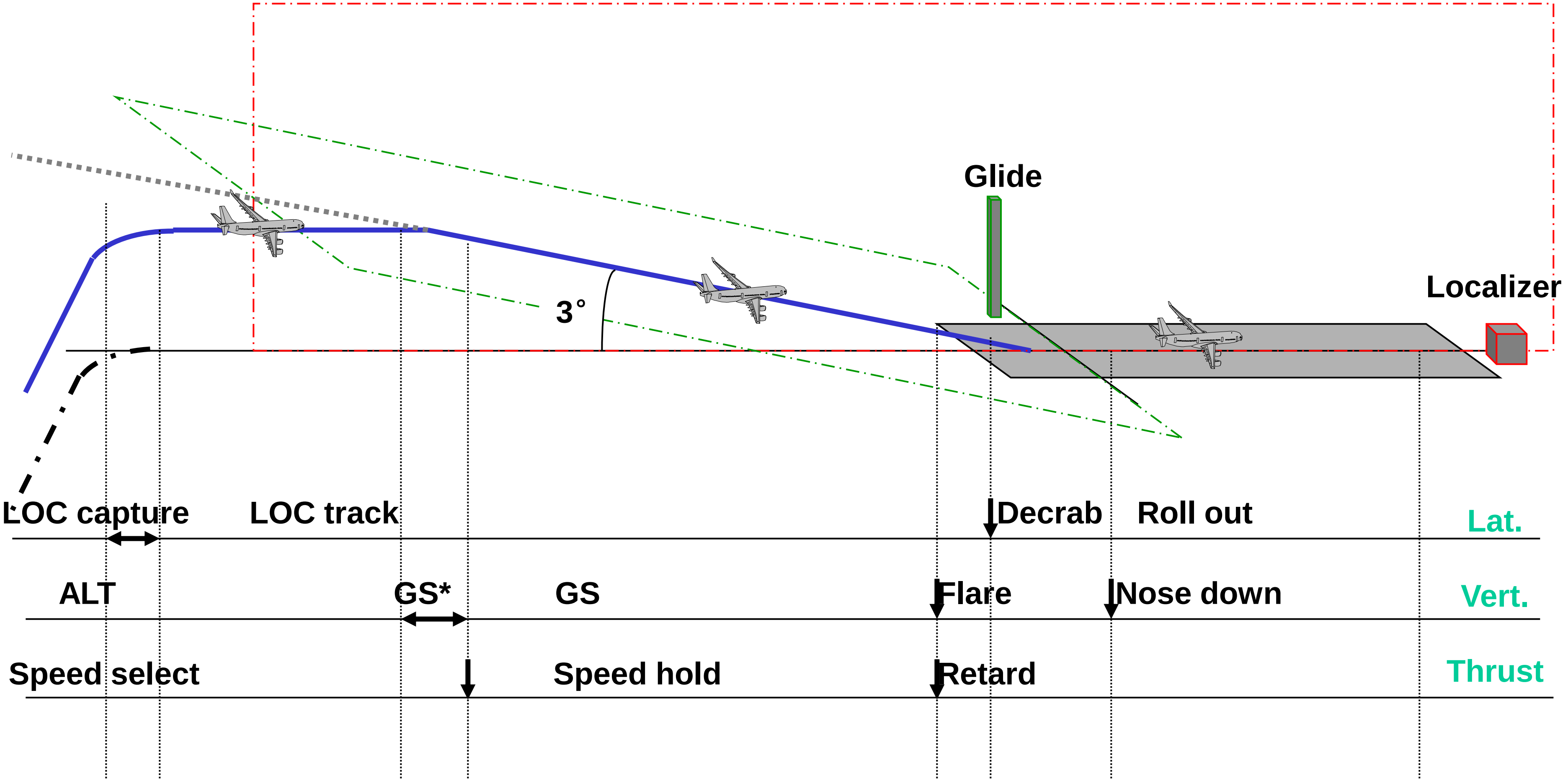


Autoland

- Capability to perform an approach and to land an aircraft in Instrument Meteorological Conditions (IMC)

Requires 3 elements

- A crew qualified for this specific operation
  - Role of the airline and its local authority
- An airfield configured for this specific operation
  - Role of the airport
- An aircraft certified for this specific operation
  - Role of the aircraft manufacturer
  - Detailed herefater



Mode sequence realized automatically by the FGS

Category I

- Conditions
  - Decision height (DH) down to 200ft
  - Runway Visual Range of 800m
- Regulations
  - No specific ones in Europe, CS 25.1329
  - AC 120-29A in the US

Category II

- Conditions
  - Decision height between 100ft and 200ft
  - Runway Visual Range of 300m
- Regulations
  - CS AWO subpart 2 in Europe
  - AC 120-29A in the US

Category IIIA

- Conditions
  - Decision height between 50ft and 100ft
  - Runway Visual Range of 200m
- Regulations
  - CS AWO subpart 3 (and 1 if automatic landing) in Europe
  - AC 120-28D in the US

Category IIIB

- Conditions
  - Decision height below 50ft or no DH
  - Runway Visual Range of 75m
- Regulations
  - CS AWO subparts 1 & 3 in Europe
  - AC 120-28D in the US

Approach / Autoland
Detailed regulation

- **Constraints on the system architecture**
  - Depending on the capability to be achieved
    - Fail passive / fail operational (+ fail-passive after 1^{st} failure)
  - Imposed failure rate for approach abortion
    - 5% of go around rate
  - Imposed AP loss failure rate
  - Imposed minimum installed equipments
  - Application of 25.1309
  - Developments standards for ILS/MLS receivers

- **Constraints on the interface with the crew**
  - Excessive deviations
    - Required from a given height
    - Proposed thresholds

- **Constraints on the performance of the Guidance**
  - Demonstrated in two cases
    - Mean risk (all elements according to their occurrence)
    - Limit risk (all elements according to their occurrence, except one at its most stringent value)
  - Evaluation of the following parameters
    - X and Y at touch-down
    - Vertical speed at impact
    - Bank angle
    - Lateral velocity or side slip angle
  - Thresholds and acceptable probability
    - Defined (range from 10^{-5} to 10^{-8})
    - Link to mean/limit risk

- **Wide range of requirements …**
  - Very specific and critical operation

Table of Content

- **Today requirements for Large Airplanes**
    - Similar regulation in Europe and in the US
    - Harmonisation still on-going

    - For general rules and cruise FGS:
        - CS 25 replacing JAR 25 for EU states
        - FAR 25 in the US

    - For autoland:
        - JAR AWO (***All Weather Operations***) Part 1 for automatic landing
        - JAR AWO Part 2 and 3 for precision approaches and autoland in reduced visibility conditions.

- **General requirements examples**
    - Applicable to AFS
    - System level
        - 25.1301 for “design appropriate to its intended function”
        - 25.1309 for safety criteria (drives the architecture)
        - 25.1322 for warnings and cautions
        - 25.1329 for FGS systems
    - Equipment level
        - 25.1431 for hardware qualification

25.1329 Automatic pilot system & 1335 Flight director

CS 25.1329 Automatic pilot system
(See AMC 25.1329.)

(a) Each automatic pilot system must be approved and must be designed so that the automatic pilot can be quickly and positively disengaged by the pilots to prevent it from interfering with their control of the aeroplane.

(b) Unless there is automatic synchronisation, each system must have a means to readily indicate to the pilot the alignment of the actuating device in relation to the control system it operates.

(c) Each manually operated control for the system must be readily accessible to the pilots.

(d) Quick release (emergency) controls must be on both control wheels, on the side of each wheel opposite the throttles.

(e) Attitude controls must operate in the plane and sense of motion specified in CS 25.777 (b) and 25.779 (a) for cockpit controls. The direction of motion must be plainly indicated on, or adjacent to, each control.

(f) The system must be designed and adjusted so that, within the range of adjustment available to the human pilot, it cannot produce hazardous loads on the aeroplane, or create hazardous deviations in the flight path, under any condition of flight appropriate to its use, either during normal operation, or in the event of a malfunction, assuming that corrective action begins within a reasonable period of time.

(g) If the automatic pilot integrates signals from auxiliary controls or furnishes signals for operation of other equipment, there must be positive interlocks and sequencing of engagement to prevent improper operation. Protection against adverse interaction of integrated components, resulting from a malfunction, is also required.

(h) Means must be provided to indicate to the flight crew the current mode of operation and any modes armed by the pilot. Selector switch position is not acceptable as a means of indication.

(i) A warning must be provided to each pilot in the event of automatic or manual disengagement of the automatic pilot. (See CS 25.1322 and AMC 25.1322.)

CS 25.1335 Flight director systems

Means must be provided to indicate to the flight crew the current mode of operation and any modes armed by the pilot. Selector switch position is not acceptable as a means of indication.

Specific requirements for ILS approach

- ***Depending on the Decision Height, the regulation imposes to have*** :
  - 50 ft < DH < 100 ft : autoland fail passive, automatic thrust control; automatic Go Around
  - DH < 50 ft : autoland fail operative, automatic thrust control, fail passive automatic Go Around, automatic rollout
  - no DH : autoland fail operative, automatic thrust control, fail passive automatic Go Around, fail passive automatic rollout, anti-skid braking

  And requirements on the number of equipment : ILS, RA, PFD, FWS, …

- ***Autoland fail passive:***
  An autoland is fail passive if, in the event of a failure, there is no significant out-of-trim condition or deviation of flight path or attitude but the landing is not completed automatically.
  i.e. **"Loss of the function, but safety ensured"**

- ***Autoland fail operative:***
  An autoland is fail operative if, in the event of a failure, the approach, flare and landing can be completed by the remaining part of the automatic system.
  i.e. **"No function loss, performance and safety ensured"**

AIRBUS

- **Autoland**

  ~100 autolands in various conditions

  • weight / CG
  • wind: head, cross, back
  • runways: at least 3 different runways (altitude runways depending on certification)

- **Go around**

  ~10 go around

  • at various height
  • with engine failure (established or at go around)

- **Roll out**

  ~ 20 roll out in autoland conditions (thrust dissymetry)

All of the above complemented with Simulation results (Monte-Carlo), whose statistics have to pass AWO Criteria.

The required conditions to allow CAT III are defined in the **Aircraft Flight Manual (AFM)** which is document approved by airworthiness authorities.
For the autoland, it contains:

- **The limitations use**
  - wind limits (head, cross, back)
  - values of DH, RVR

- **The required equipments**
  - list of airctaft systems depending on the operational category

- **The procedures**
  - normal procedures to be applied during the autoland
  - procedures to be applied in case of failure

This document is used by the companies to write the **Flight Crew Operating Manual (FCOM)** which is used by the crew.

Procedures and rules of the FCOM can be more conservative than whose approved in the AFM.

Airworthiness

International standards

- Compliance is also shown
  - By application of international standards
  - Not specific to Airbus

- Some examples
  - Software development

    ED 12B or DO 178B
  - Hardware development

    ED 14D or DO 160D
  - Complex components development

    ED 80 or DO 254
  - Certification considerations for highly integrated or complex aircraft systems

    ED 79 or ARP 4754

AIRBUS

- CRI : Certification Review Item (JAA/EASA)

  Discussed and agreed between authorities and Airbus

- Some examples
  - CRI B-10

    Human factors evaluation of flight deck and novel design

  - CRI F-22

    Software formalised requirements validation and verification

  - …

Airworthiness

Validation and Verification