Flight Operations Safety Awareness Seminar (FOSAS)

The Airbus Cockpit Philosophy

Airbus Flight Operations Support and Training Standards
Nairobi, 19-21 Sep. 2017

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The Airbus Cockpit Philosophy

Design Requirements

Airbus Cockpit Philosophy

Airbus Family Concept

Golden Rules

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Golden Rules

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Ten High Level Design Requirements

Airbus Design

The Airbus cockpit is design to achieve the operational needs of the pilots

The 10 high level rules dictate the Airbus operational philosophy.

+They include operational considerations

+They include human factor considerations.

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Ten High Level Design Requirements

1 + The **pilot is ultimately responsible** for the safe operation of the aircraft.

2 + If required, the **flight crew can exercise their full authority** by performing **intuitive actions**, while aiming at **eliminating the risks** of overstress or overcontrol

3 + The cockpit design **accommodates for** a wide range of **pilot skill levels** and **experience acquired on previous aircraft**

4 + The cockpit design ensures **safety, passenger comfort,** and **efficiency**, in that order of priority

5 + The cockpit design aims at **simplifying the tasks of the flight crew**, by enhancing situation and aircraft status awareness.

Ten High Level Design Requirements

6

+ The automation is considered as an **additional feature available to the crew**, who can decide when to delegate and what level of assistance they need, according to the situation

7

+ The design of the **Human Machine Interfaces** (HMI) takes into account system features together with the strengths and weakness of the flight crew

8

+ The state of the art of the **Human Factors considerations** are applied in the system design process, in order to manage potential errors of the flight crew

9

+ The overall cockpit contributes to facilitate and to enhance **the flight crew communication** (e.g. tasksharing, teamworking)

10

+ The use of new technologies and implementation of new features are **imposed by**:
  + Significant safety benefits
  + Obvious operational advantages
  + A clear response to the needs of the flight crew

The Airbus Cockpit Philosophy

Design Requirements

Airbus Cockpit Philosophy

Airbus Family Concept

Golden Rules

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The Airbus Cockpit Philosophy

Airbus Design Philosophy

- Cockpit Layout
- Automation
- FBW / Protections
- Display Units
- Alerts

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The Airbus Cockpit Philosophy

Airbus Design Philosophy

Implementation

- Cockpit Layout
- Automation
- FBW / Protections
- Display Units
- Alerts

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Overall Cockpit Layout

+ Dark Cockpit Concept

+ Color Coding

+ Panel Arrangement

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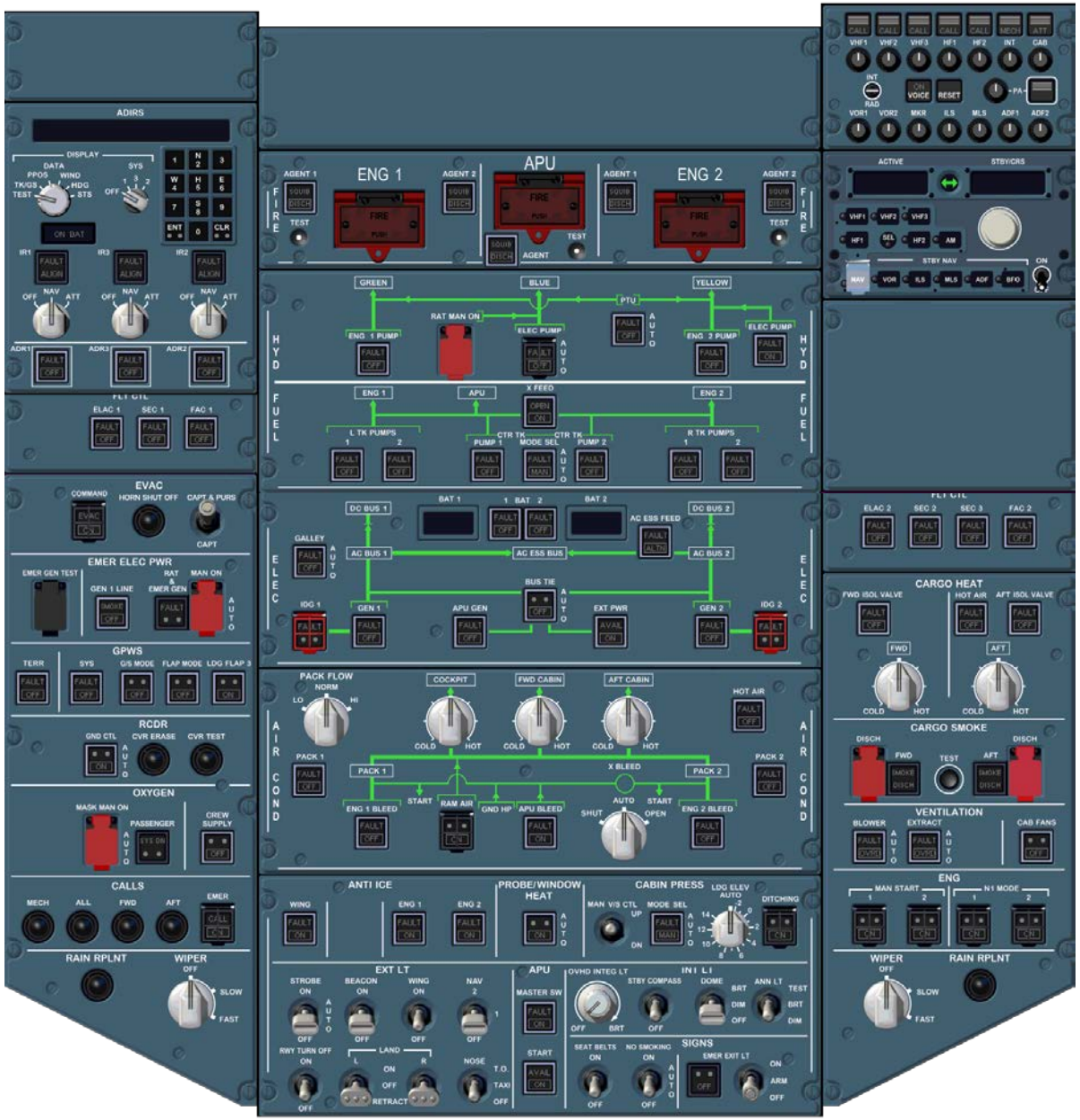
Overall Cockpit Layout

Dark Cockpit Concept

+ No White Lights

System is set

Fit to fly



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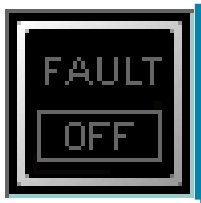
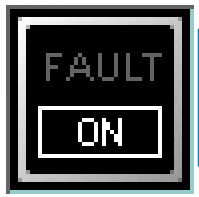
Overall Cockpit Layout

Color Coding Pushbuttons

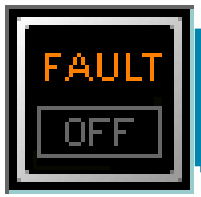
+ The state of the **Lights** and information provided on display units are **color** coded to indicate the status of the system, or the nature of the information



Normal operation configuration. Light out position

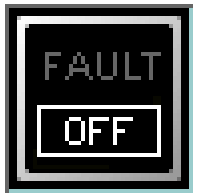


System activated



ABNORMAL Fault indication

Temporarily selected switch



System deactivated

Applicable system status

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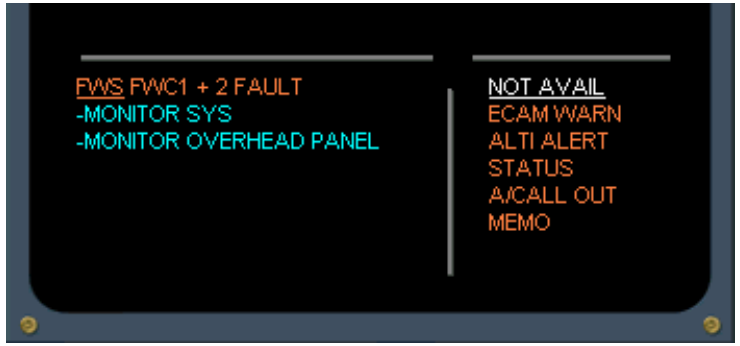
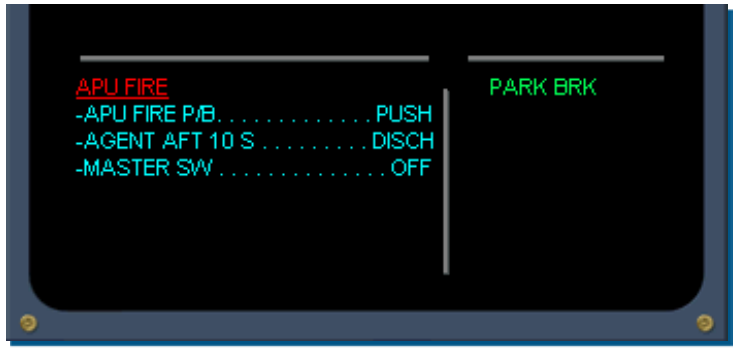
Overall Cockpit Layout

Color Coding Displays

+ Lights and information provided on display units are color coded to indicate the status of the system, or the nature of the information





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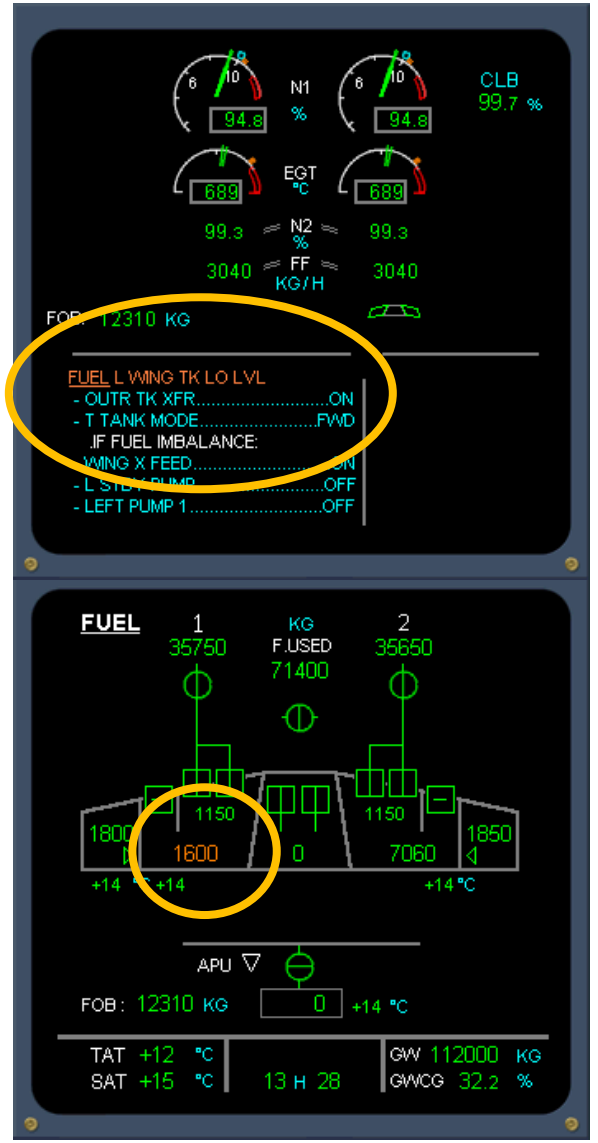
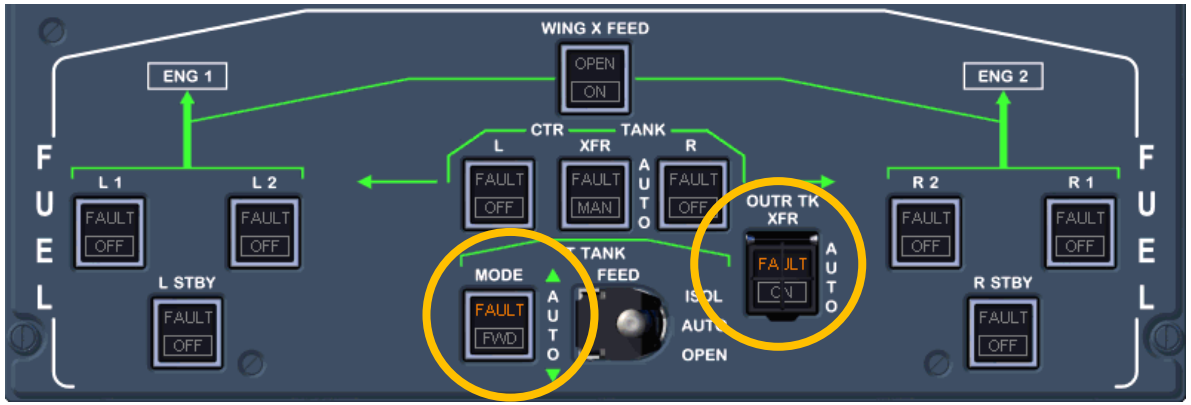
Overall Cockpit Layout

Color Coding
Displays and Pushbuttons

- Master P/Bs: Initial clue (color + audio)
- ECAM Display
- System Display for diagnosis
- Relevant P/Bs lighted





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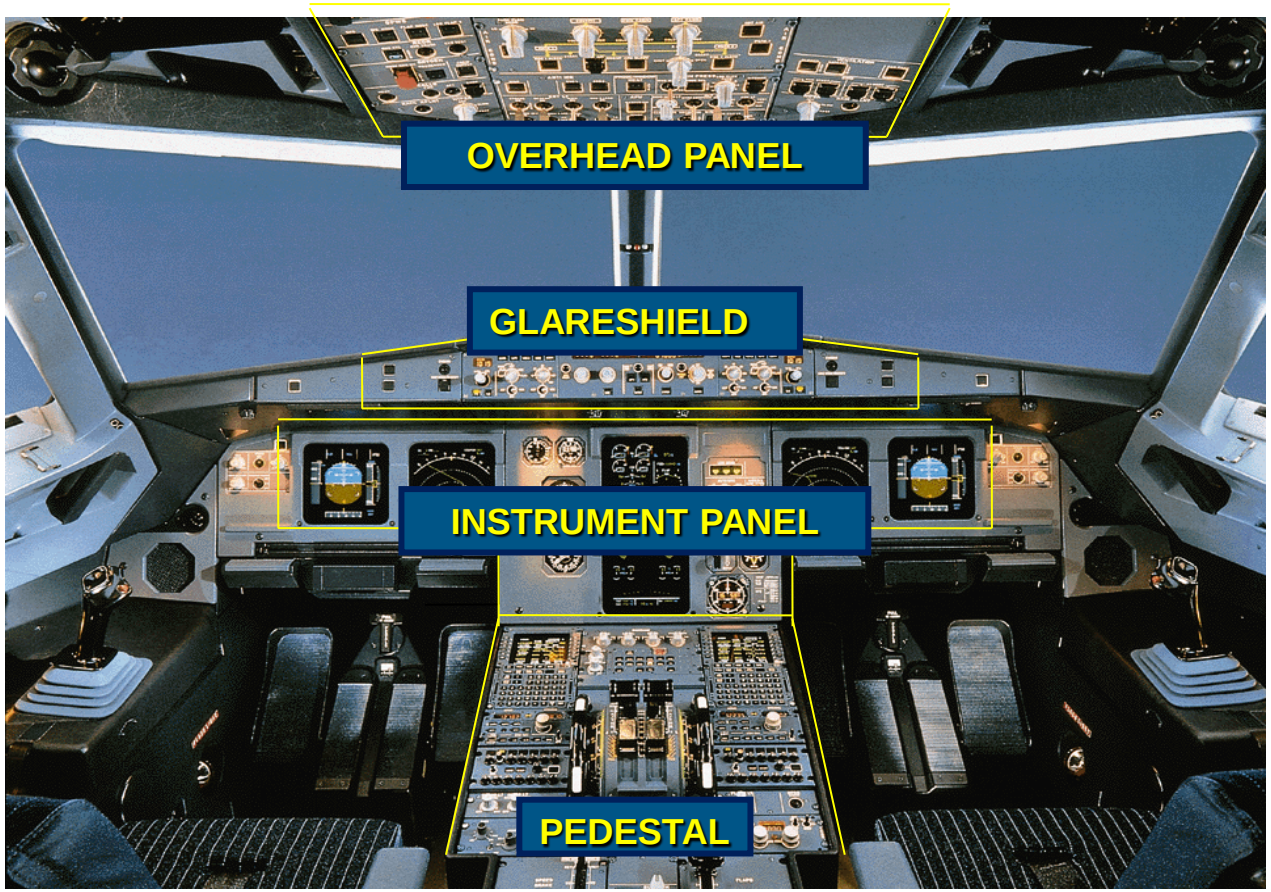
Overall Cockpit Layout

Arrangement of Panels

- **Location of the main controls takes into account:**
  - The relative **importance** of each system
  - The **frequency of operation** by the pilots
  - The **ease** with which controls **can be reached**
  - The **shape** of the control
  - The **duplication** of controls, if required



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Overall Cockpit Layout

Overall Cockpit Layout

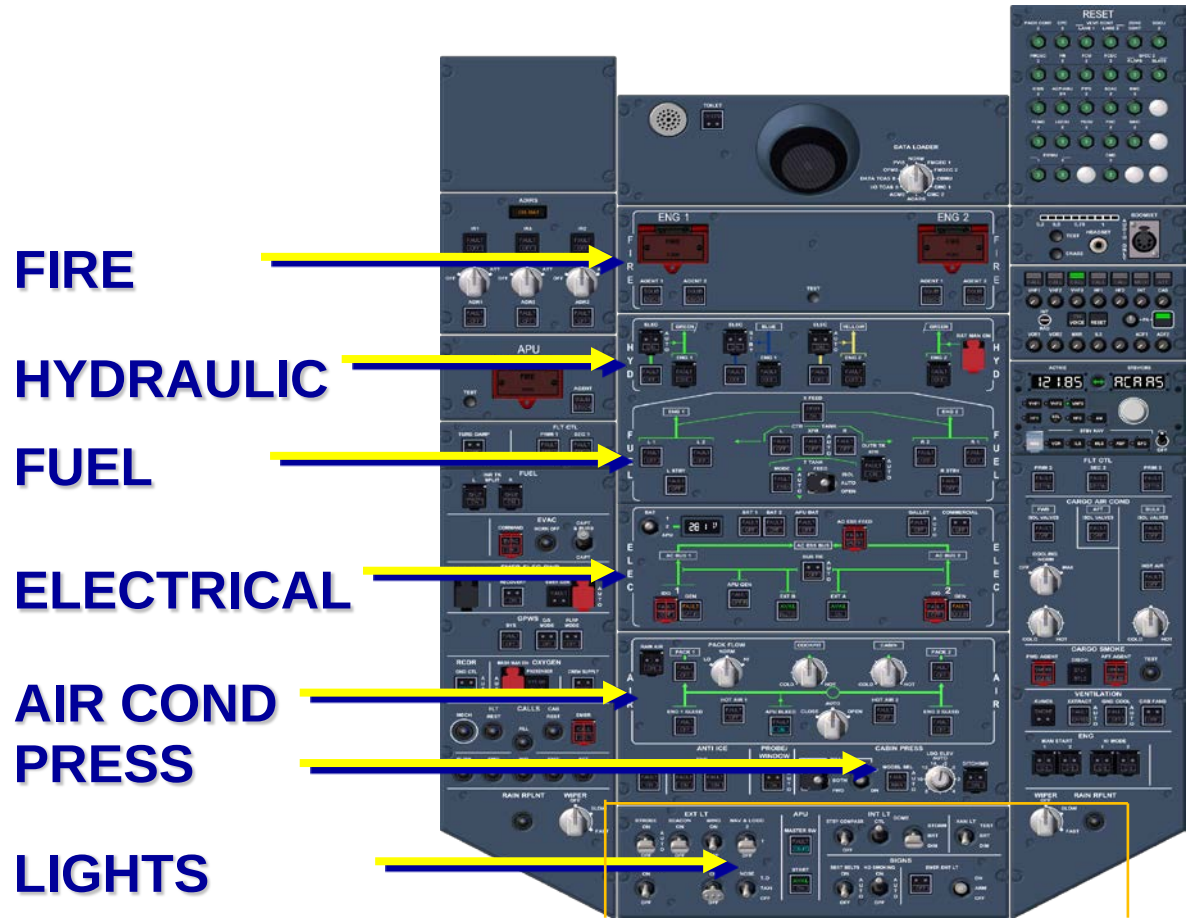
Overhead Panel

+ **Cascade arrangement on overhead panel**

  + System control panels are set one below the other

    › Minimize Errors

    › Easier for Procedures



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Overall Cockpit Layout

Glareshield - FCU /AFS CP

+ Supports the short term tactical controls for the Auto Flight System (AFS)
+ Controls operation can be achieved “Head-Up” and within easy access for both pilots

A320

A330 A340

A350 A380

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Overall Cockpit Layout

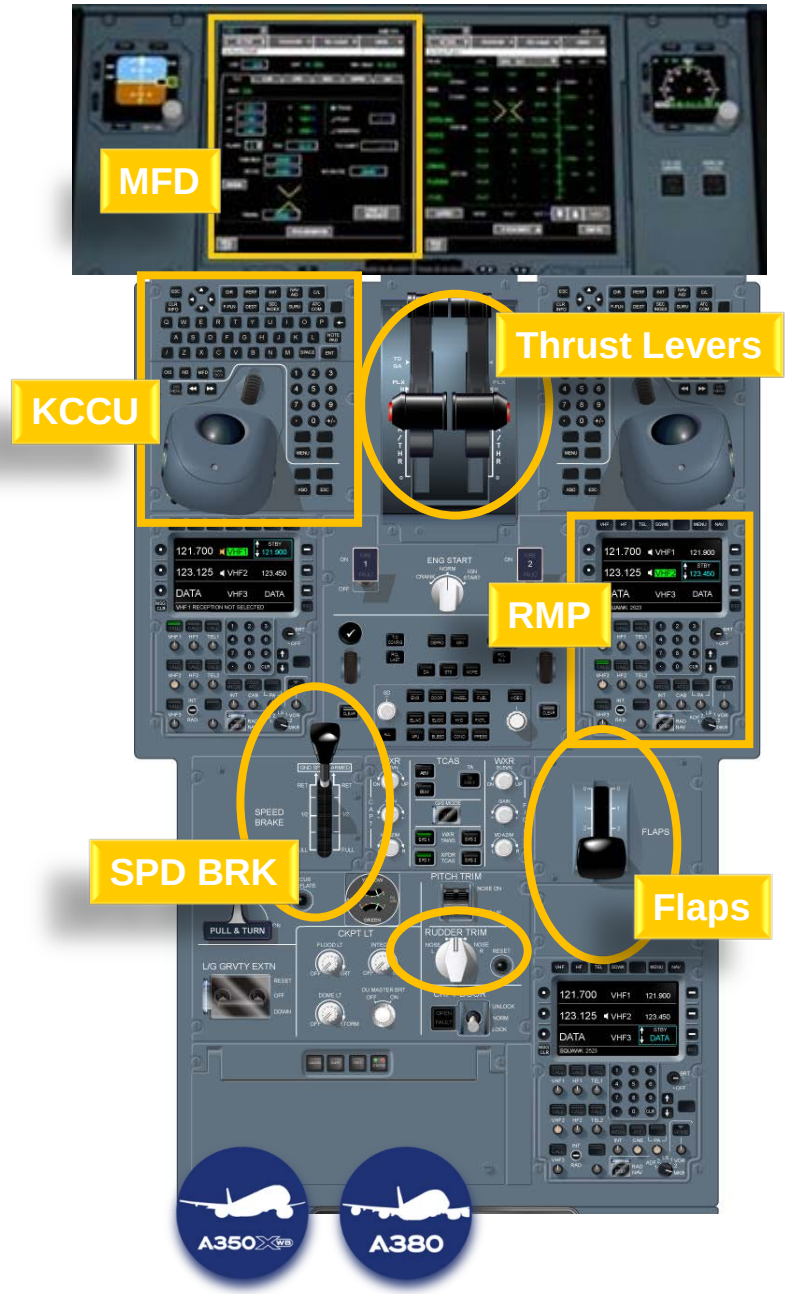
Main Instrument Panel

- Controls Display units are located to be in full view of both pilots
- Mainly supports the Display Units necessary to:
  - FLY (PFD/HUD)
  - NAVIGATE (ND)
  - COMMUNICATE (ATC)
  - MONITOR (ECAM)

Overall Cockpit Layout

Pedestal

- Mainly supports the controls for:
  - Engine & Thrust (ENG M/L, Thrust Levers)
  - Aircraft Configuration
    - (SPD BRK, FLAPS, Rudder Trim)
  - Navigation (FMS, MCDU/MFD-KCCU)
  - Communication (RMP)



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The Airbus Cockpit Philosophy

Airbus Design Philosophy

Implementation

- Cockpit Layout
- **Automation**
- FBW / Protections
- Display Units
- Alerts

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Automations

Automation Principles

- Reduces Workload
- Enhances Situation Awareness

- **Automation applied to assist pilots in tactical tasks:**
  - For safe and accurate aircraft operation
  - For fast and complex computation
  - For pilot's situational awareness enhancement by proper data management
- **Reliability:**
  - Redundancy
  - Proper Caution/Warning in case of failure
- **Flight Crew can always takeover**
- **Automation operation requires:**
  - Proper Interfaces
  - Crew Awareness

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Automations

Automation Principles

+ **Works within defined limits**
  + Out of these limits, it may disengage
  + Proper caution is provided before or at disconnection.
+ Must **indicate when unable to fulfill the task** requested by the flight crew
+ Minimizes and **clearly indicates the automatic mode changes**
+ Automation **concepts easy to understand**

Automations

Automation Redundancy

2 APs and 1 A/THR with 2 channels

2 FMGS with 2 or 3 MCDUs

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The Airbus Cockpit Philosophy

Airbus Design Philosophy

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- Cockpit Layout
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- **FBW / Protections**
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Airbus Fly-by Wire Concept

Non-FBW

› **Aircraft response** to pilot input varies with aircraft status (GW, CG, Speed, Altitude, Configuration, …)

› **Aircraft behaviour**
close to stall speed very dependent of CG / CONF

FBW

› **High stability and maneuverability** of the aircraft regardless of aircraft CG, GW, speed, altitude and configuration.

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Airbus Fly-by Wire Concept

Non-FBW

› **Large control column deflection** required to accurately displace the control surfaces, and overcome numerous **mechanical and friction forces.**

FBW

› The **pilot efforts** on the controls in pitch and roll are always **balanced**.

› Risks of **over-control** or **overstress** of the aircraft are minimized.

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Airbus Fly-by Wire Concept

Non-FBW

› **Emergency Maneuvers**

› (TCAS, GPWS, Windshear, Collision avoidance…) are dependent of the flight parameters and require specific training and active monitoring from the crew.

FBW

› The **aircraft is protected** against excursions outside the safe flight envelope.

› **Built-in protections** give full authority to pilots to achieve the **maximum aircraft performance**

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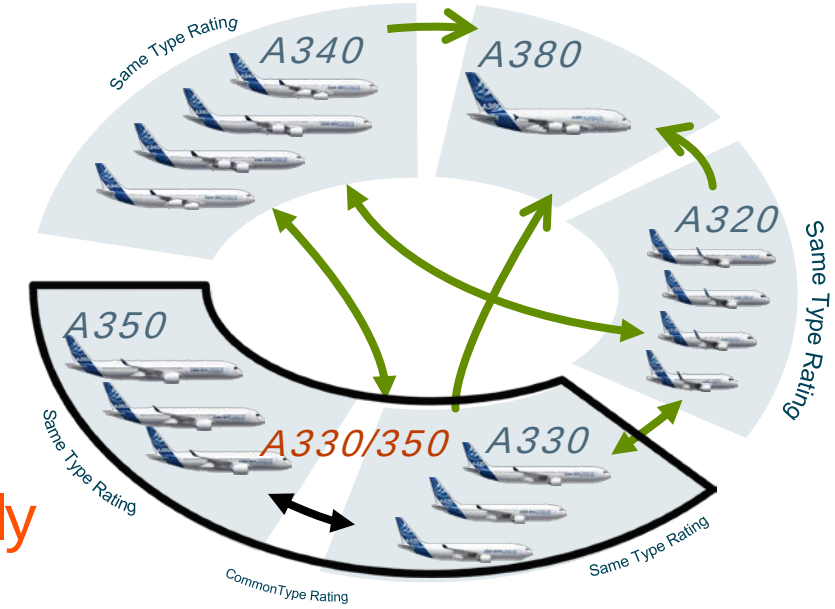
Airbus Fly-by Wire Concept

FBW is one key element for the Airbus family Concept



+ Similar **aircraft handling characteristics** within the family

+ **Minimize the transition training time** between the aircraft of the family.

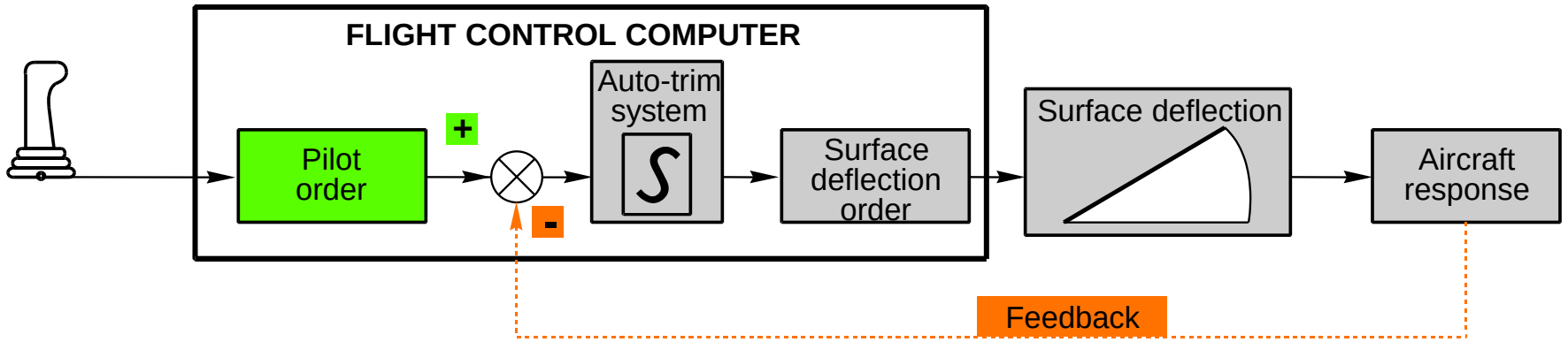
+ Allows **Mixed Fleet Flying**

+ **Enhances safety** when transitioning from one A/C of the family to another

Airbus Fly-by Wire Control Laws

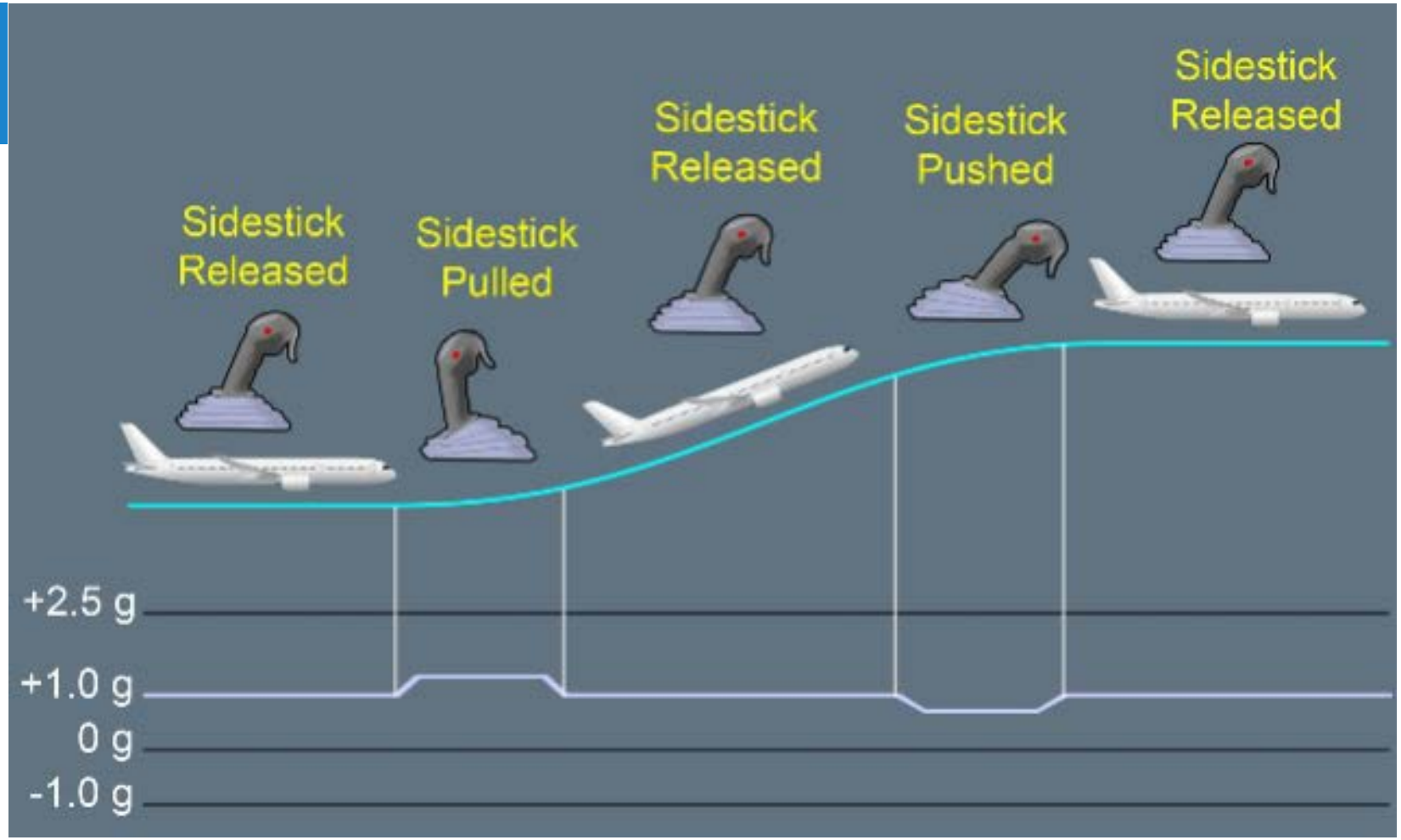
+ **Control Law:** The relationship between the pilot input on the stick and the aircraft response

+ The control law determines the handling characteristics of the aircraft



Airbus Fly-by Wire Control Laws

Pitch Normal Law



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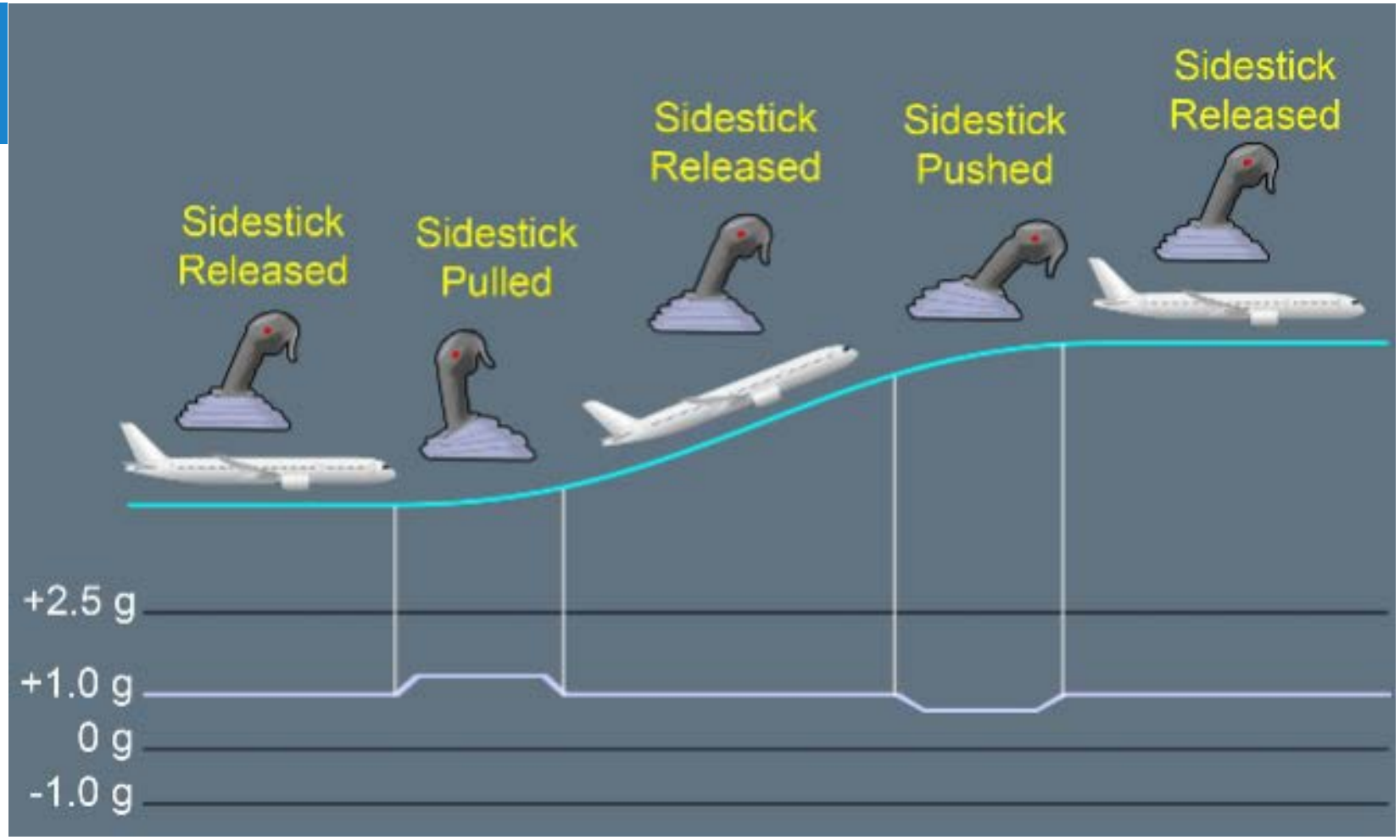
Airbus Fly-by Wire Control Laws

Pitch Normal Law



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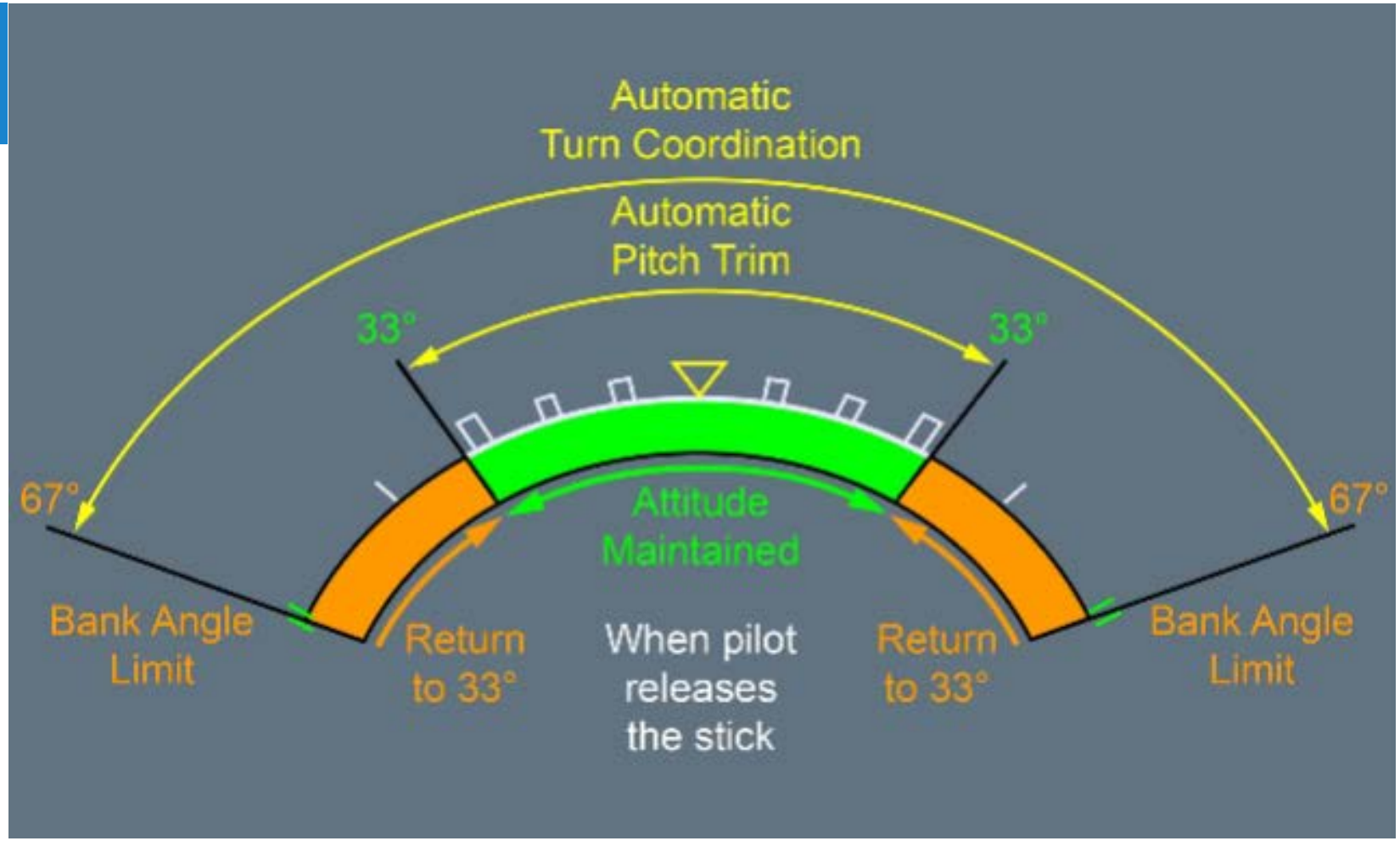
Airbus Fly-by Wire Control Laws

Lateral Normal Law



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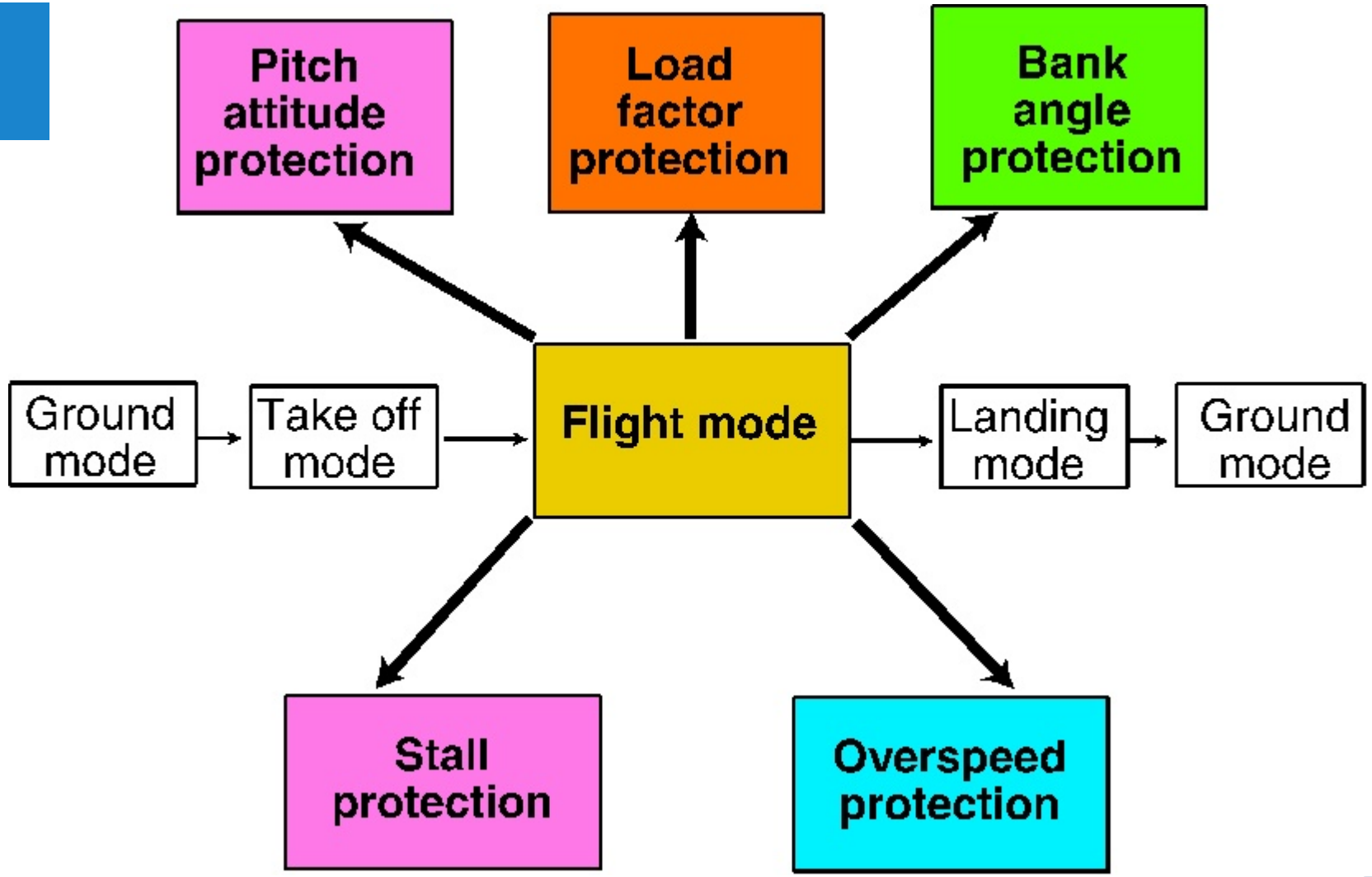
Airbus Fly-by Wire Protections

Protections



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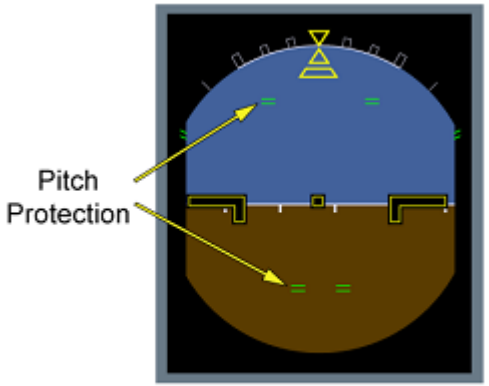
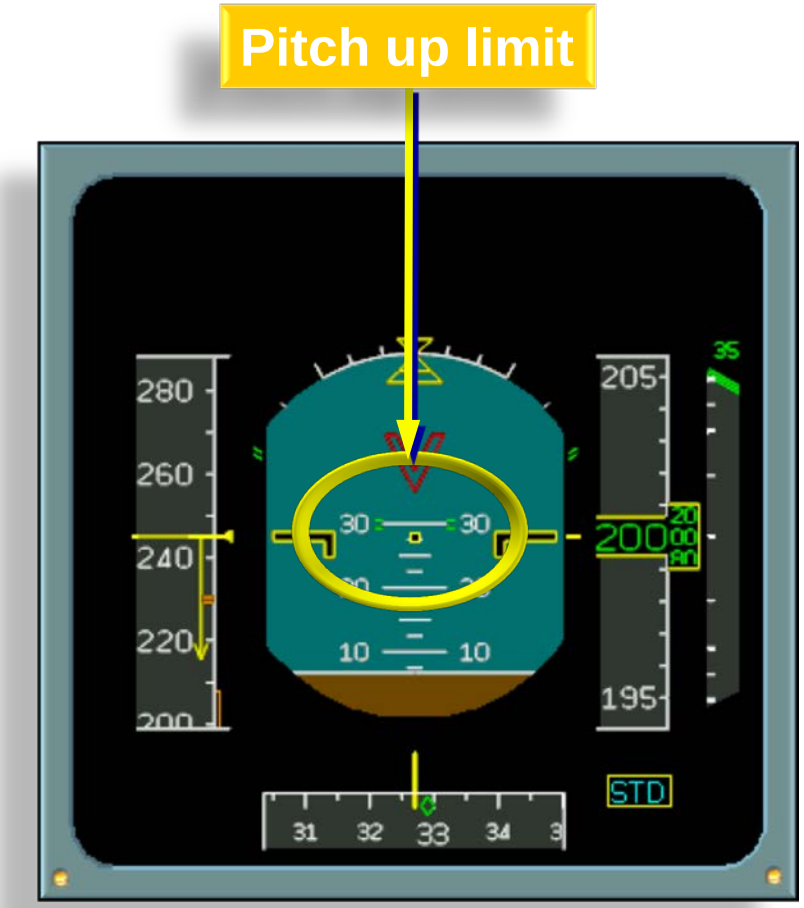
Airbus Fly-by Wire Protections

Pitch Protection





Limits the pitch attitude to 30 degrees nose-up

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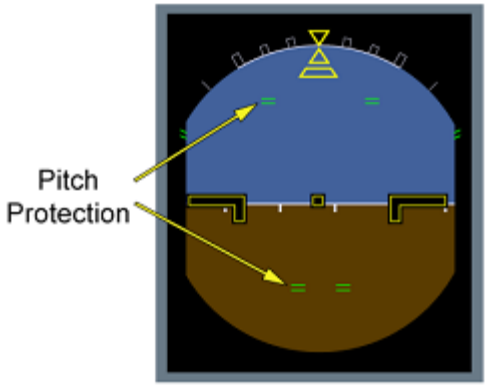
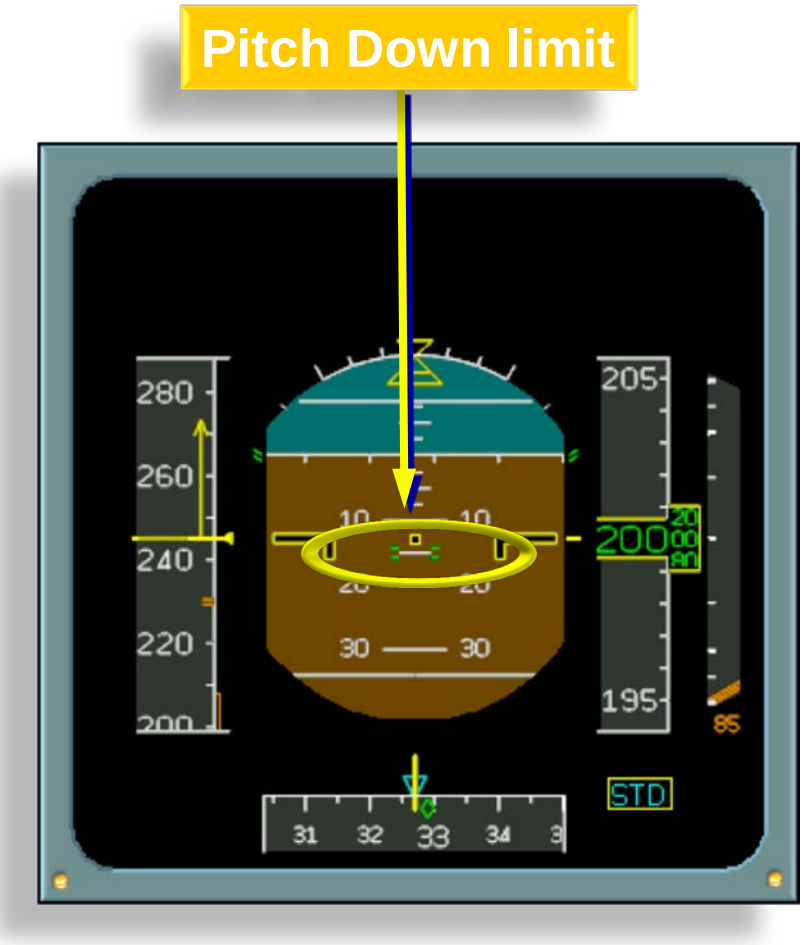
Airbus Fly-by Wire Protections

Pitch Protection





Limits the pitch attitude to 15 degrees nose-down

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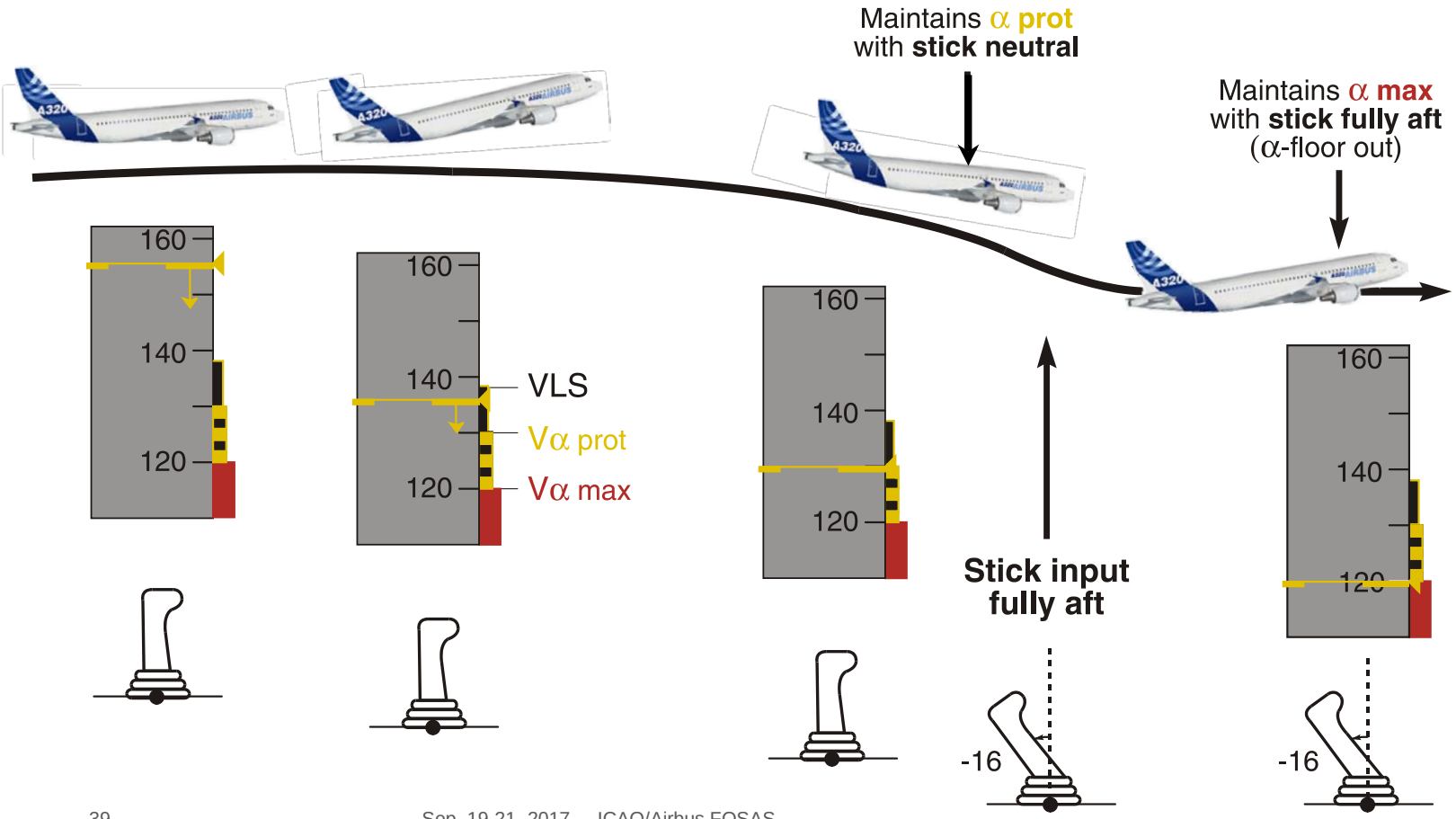
Airbus Fly-by Wire Protections

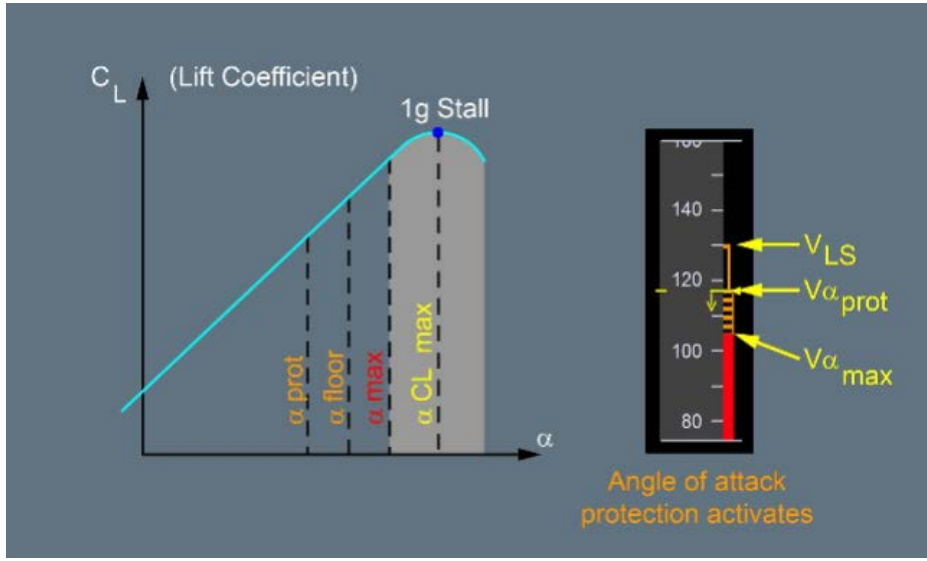
Load Factor Protection

Should a sudden evasive maneuver be necessary, the G-load protection limits the load factor to +2.5 g

Airbus Fly-by Wire Protections

High Angle-of-Attack





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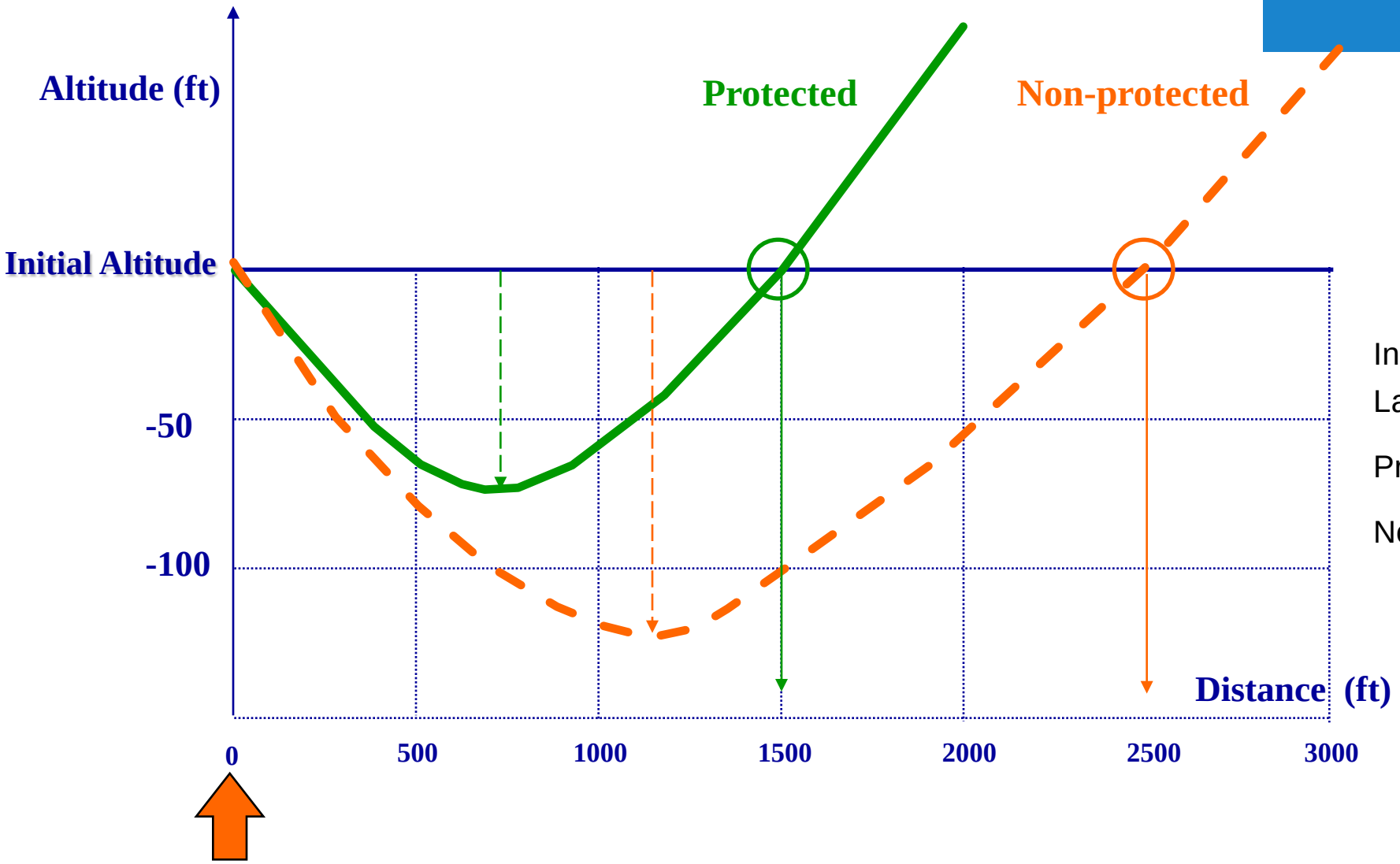
Airbus Fly-by Wire Protections

FBW – CFIT Escape Trajectory Summary



Initial Conditions:

Landing CONF - V/S= -1500 ft/min

Protected aircraft - MLW -aft Cg - Vref+5

Non protected: Gw- Cg unknown

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Airbus Fly-by Wire Protections

FBW – CFIT Escape Trajectory Summary

Parameter	Non-protected	Protected
Duck-under (ft)	125	80
Bucket distance (ft)	2 500	1 500
Bucket time (sec)	12	7
Safety margin (sec)	**3**	**8**

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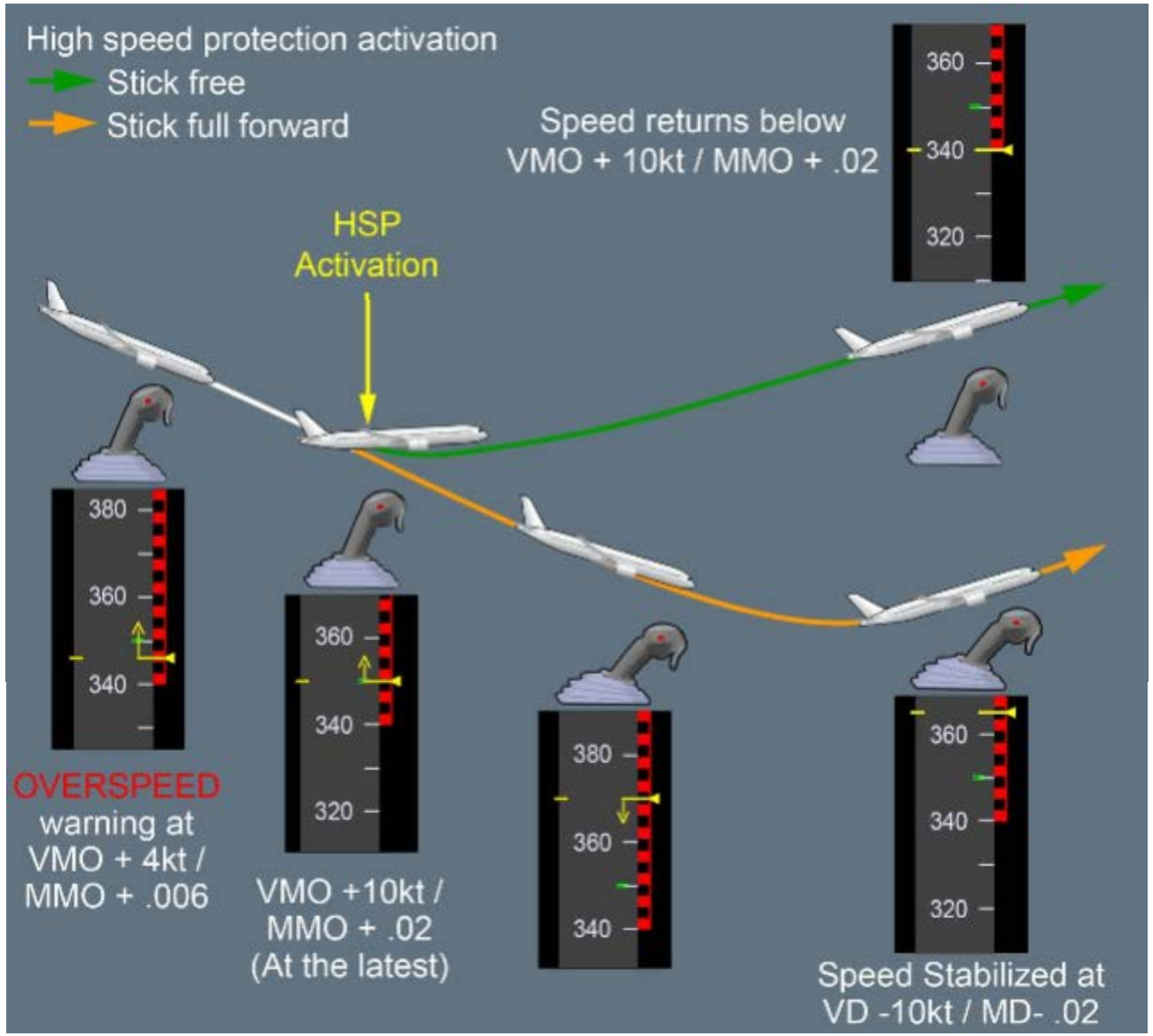
Airbus Fly-by Wire Protections

High Speed Protection



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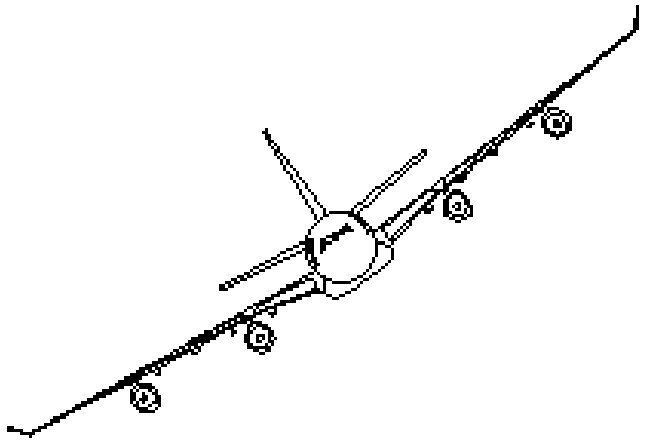
Airbus Fly-by Wire Protections

Bank Angle Protection



Bank angle limits

Bank angle protection limits the bank angle to 67°

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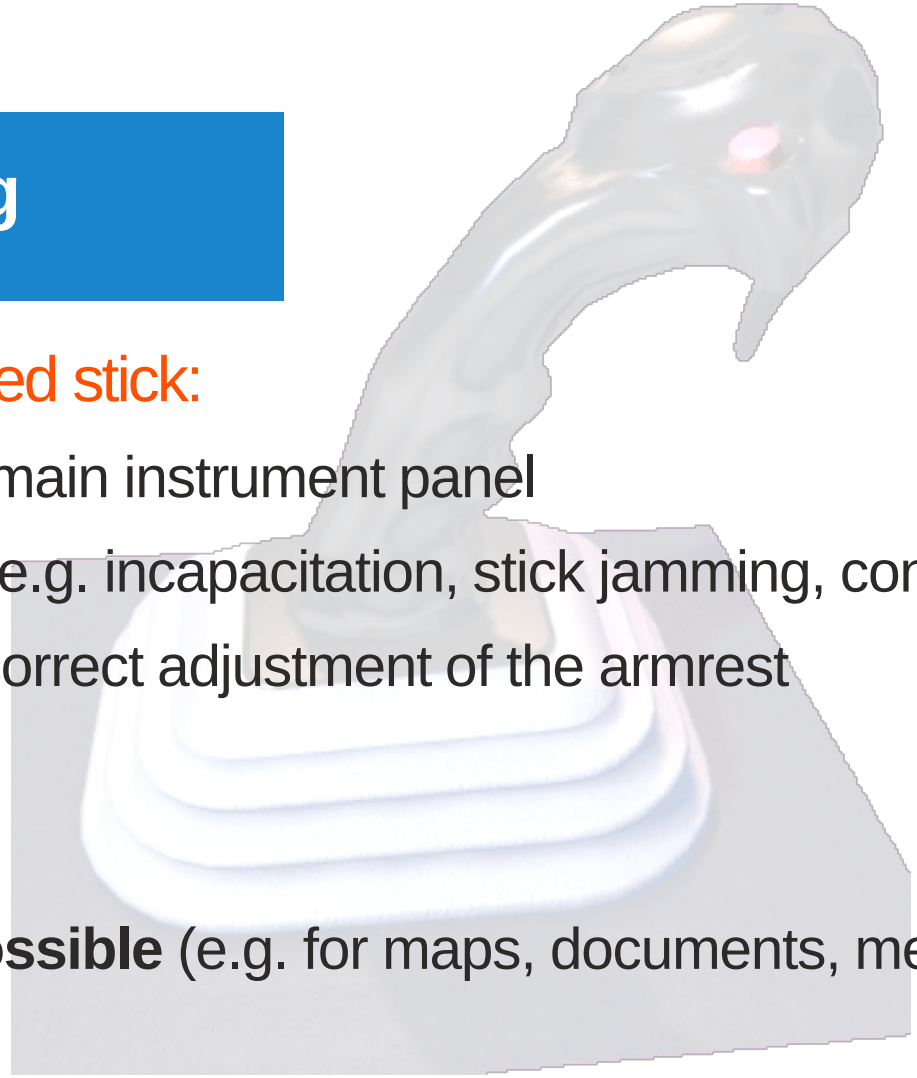
Airbus Fly-by Wire - Sidestick

Sidestick Operation: Hand Flying

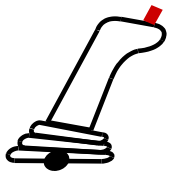


- Main **Operational Benefits** of a side-mounted stick:
  - It enables a **non-obstructed view** of the main instrument panel
  - It is **adapted for emergency situations** (e.g. incapacitation, stick jamming, control failures)
  - It **fits comfortably into the hand** with a correct adjustment of the armrest
  - It facilitates the pilot **seat** access.
  - It increases pilot **comfort in flight**.
  - It makes the **sliding table installation possible** (e.g. for maps, documents, meals)

Airbus Fly-by Wire - Sidestick

Sidestick Operation: Hand Flying

- **Only One Pilot flies at the time**
- For safety reason, the Pilot Monitoring (PM) can make an input on the side-stick.
  - PM **must clearly announces "I HAVE CONTROL"**
  - **Annunciators illuminate** on the glare shield with an aural warning.
  - PM **presses & maintain** his/her **sidestick P/B**
- Either pilot can cancel the inputs of the other pilot's stick by pressing the sidestick P/B.



Cpt priority P/B pressed

F/O sidestick deflected

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Airbus Fly-by Wire - Sidestick

Sidestick Operation: Autopilot

- When the Autopilot (AP) is engaged:
  - The sidesticks are **locked in neutral position** (Immediate tactile feedback)
  - **No** possibility of **simultaneous inputs** from autopilot and pilot
  - It can be **disconnected** by **pressing** the priority P/B
  - It can also be **disconnected instinctively** at any time by a **firm action** on the stick : typically 5kg in pitch, 3.6kg in roll.

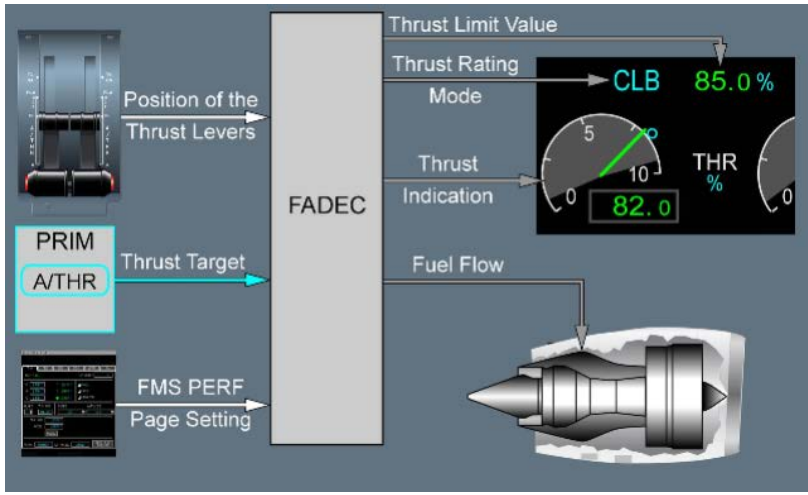
Airbus Fly-by Wire - A/THR

Auto-Throttle versus A/THR

+ The first automatic thrust control was achieved with an **auto-throttle** system (**back-driven, moving** throttles) because the **Thrust Lever Angle (TLA)** was **essential** for thrust control.

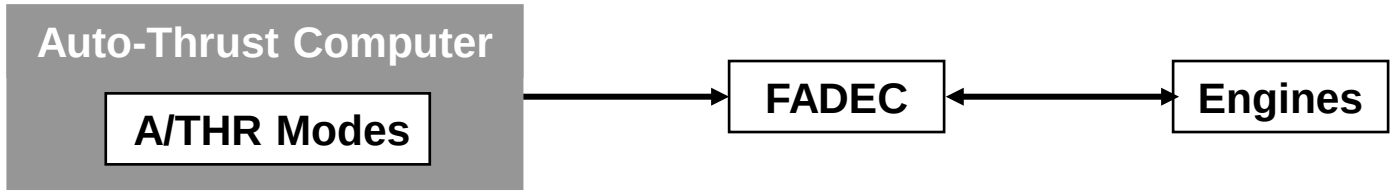
+ The auto throttle computer commanded a **Thrust Lever Angle**, and consequently a **thrust level**

Airbus Fly-by Wire - A/THR

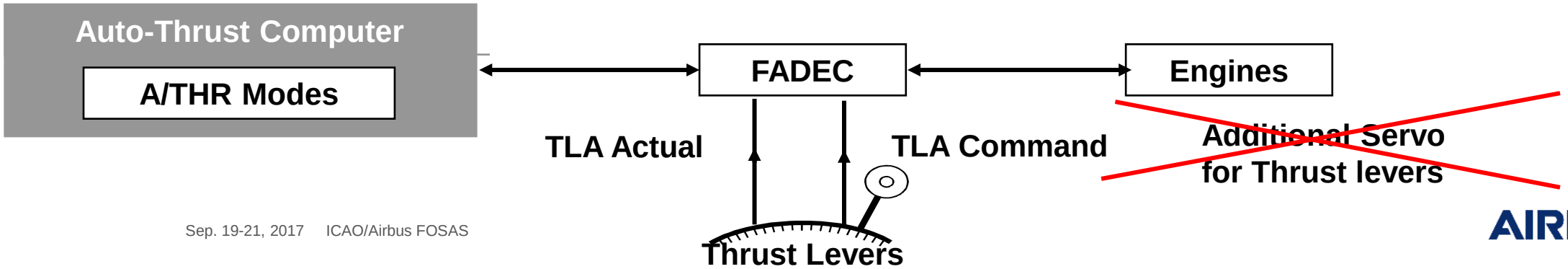


A/THR with FADEC Engines

+ Today, the latest engines are driven by a **FADEC** (Full Authority Digital Engine Control) which **no longer requires** the **Thrust Lever Angle** to control thrust



+ When the ATHR is active, an **additional servo loop** for the thrust lever control is **not necessary**.



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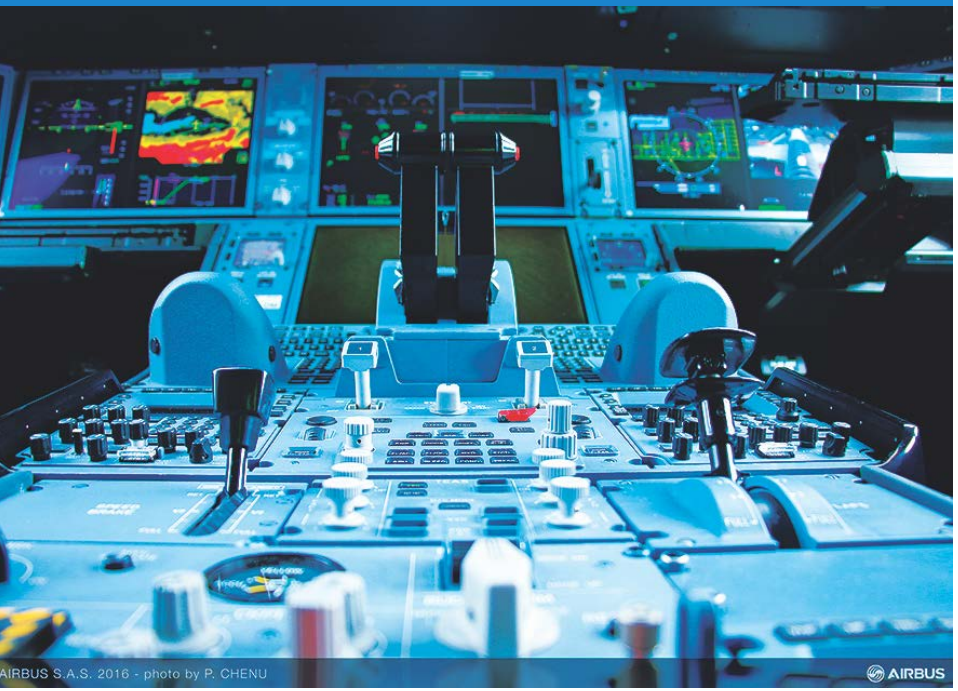
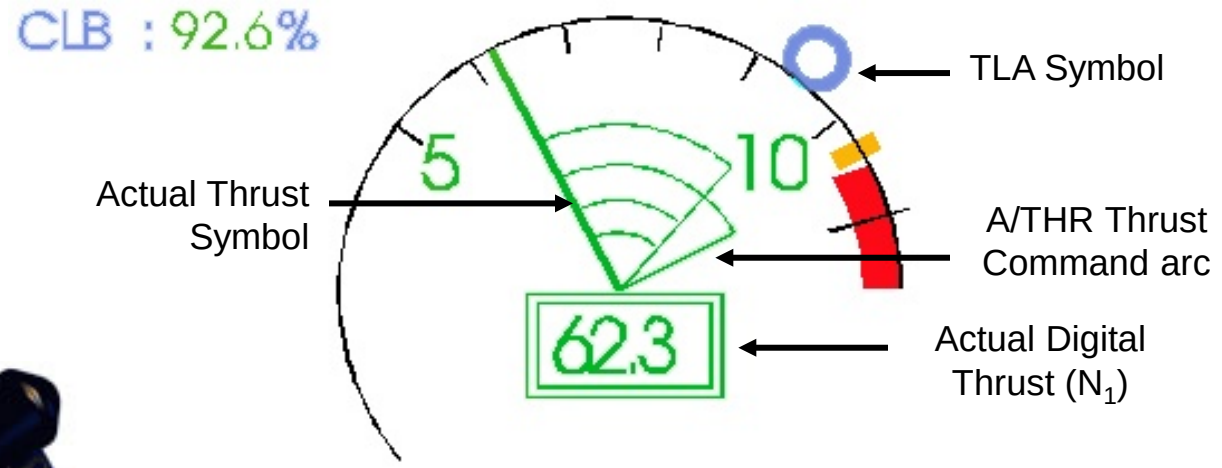
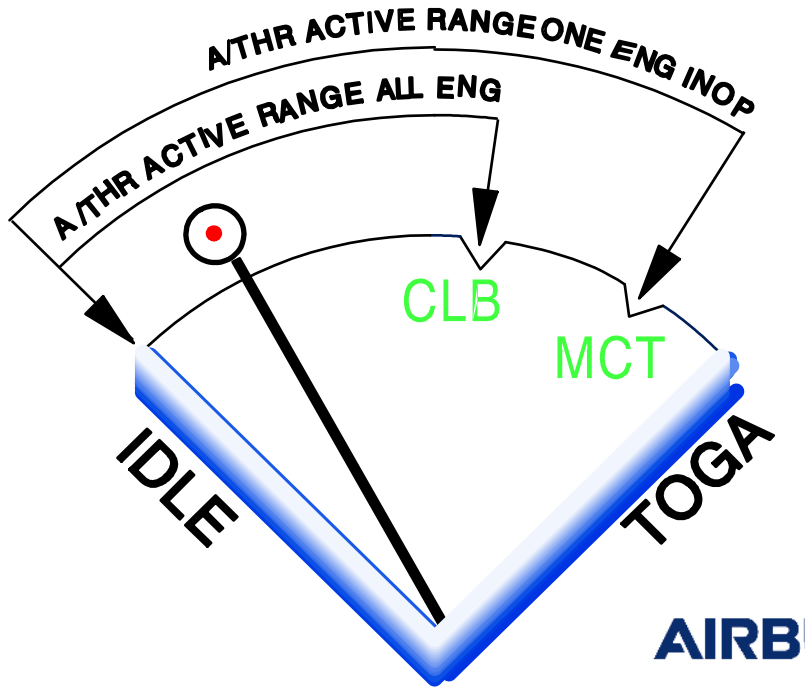
Airbus Fly-by Wire - A/THR

A/THR Controls & Indicators







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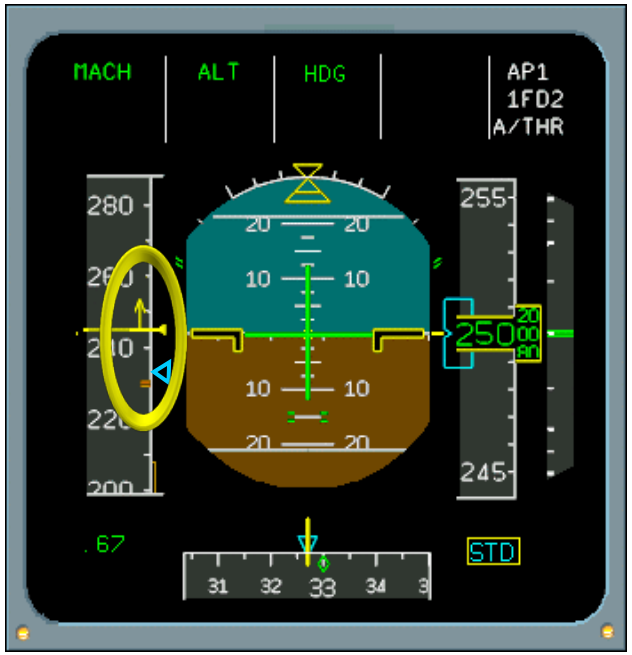
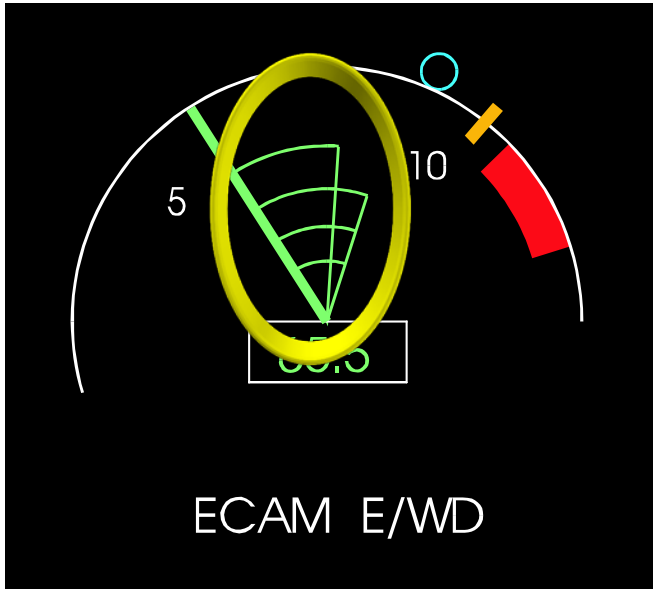
Airbus Fly-by Wire - A/THR

A/THR Monitoring

Monitoring A/THR with active energy cues

Energy cues :





Speed versus speed target

Speed trend vector

Low energy warning in approach

Actual / commanded engine thrust

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The Airbus Cockpit Philosophy

Airbus Design Philosophy

Implementation

- Cockpit Layout
- Automation
- FBW / Protections
- **Display Units**
- Alerts

AIRBUS

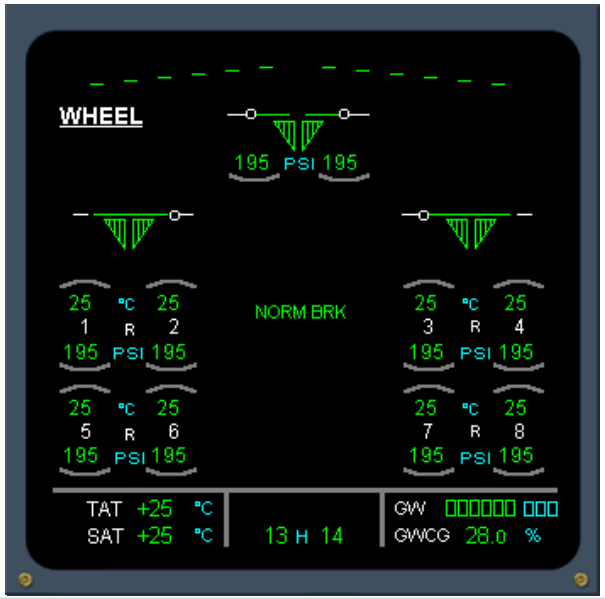
Display Units

Display Units: ECAM

+ Need to see concept

+ Flight Phase related

+ System synoptic Display



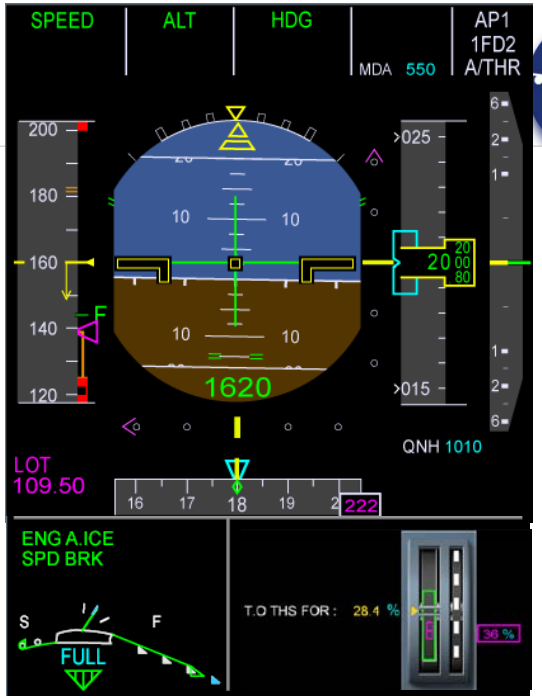
The ECAM system will automatically display the WHEEL SD page after the engines have been started

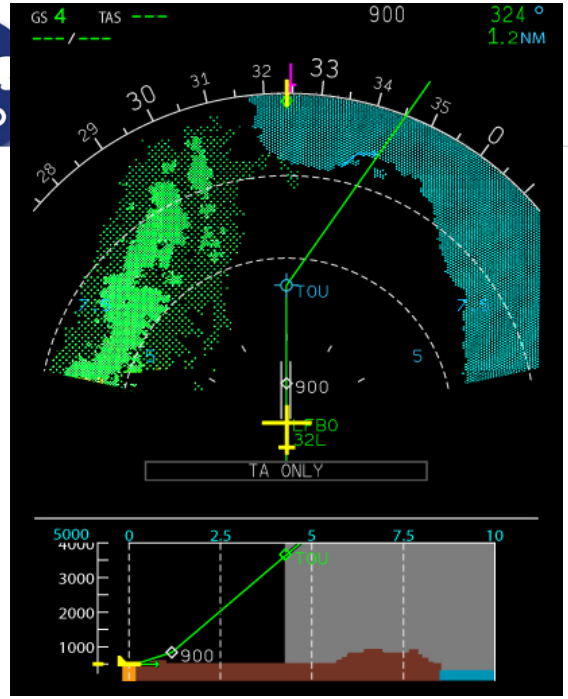
AIRBUS

Display Units

Display Units: EFIS

+ **PFD / ND**
+ Information need to
  FLY / NAVIGATE the aircraft





The Airbus Cockpit Philosophy

Airbus Design Philosophy

Implementation

- Cockpit Layout
- Automation
- FBW / Protections
- Display Units
- **Alerts**

AIRBUS

Alerts

Alert Triggering

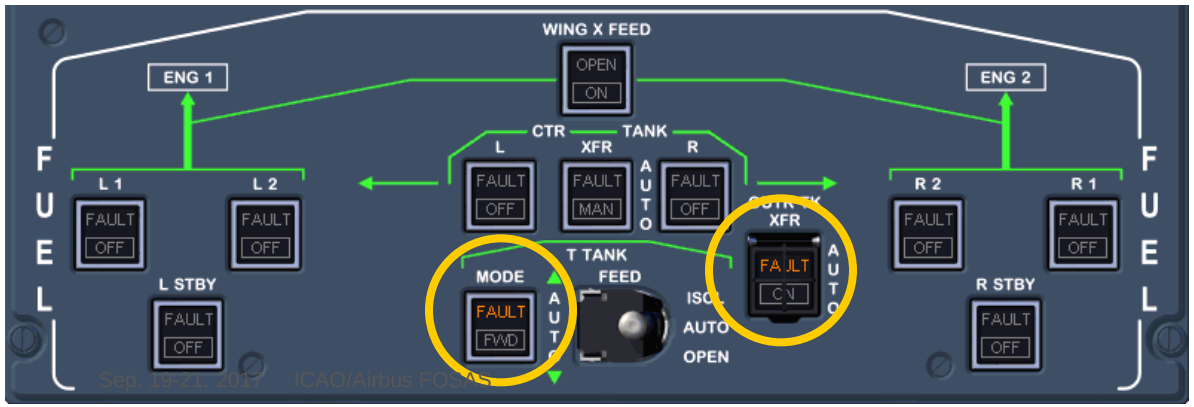
- **Unexpected events** cause an alert
  - Alerts are classified by severity and priority.
  - Some alerts are inhibited during a given flight phase
  - Alerts do not conflict each other
  - Alerts trigger visual and/or aural warnings

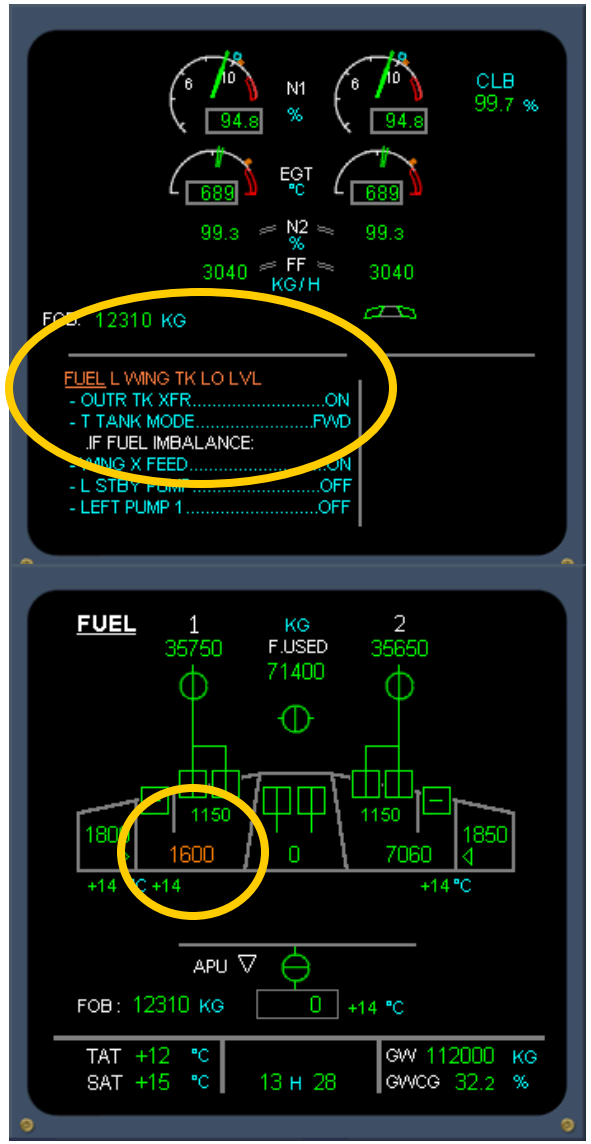
AIRBUS

Alerts

Alert Indications

- In case of failure, the flight crew is provided with:
  - All information data necessary to analyze the situation,
  - Required actions,
  - Resulting limitations, inoperative systems
  - Specific procedures according to aircraft status





The Airbus Cockpit Philosophy

Design Requirements

Airbus Cockpit Philosophy

Airbus Family Concept

Golden Rules

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Airbus Family & Commonality Concept

› Improve Safety through Similarity

› Improve pilot's Skills (MFF)

› Rationalize Transition Training (CCQ)

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Airbus Family & Commonality Concept

A380

› Enhanced working environment

Respect Airbus family concept and principles

AIRBUS

Airbus Family & Commonality Concept

A350XWB

› Enhanced working environment

Respect Airbus family concept and principles

AIRBUS

Airbus Family & Commonality Concept

Commonality thanks to :

- Fly-By-Wire and FADEC (control laws and protections, thrust control):
  - Similar airplane and thrust handling
- Cockpit layout, system integration and automation
- Dark cockpit and illuminated push buttons
- Same control location for emergency procedures
- EFIS & ECAM: similar information and phase related display rules
- Flight management and guidance system (FMGS)
- Same normal procedure (EFIS, ECAM, FMGS)
- Similar procedures and crew discipline for abnormal and emergency situations (ECAM)
- Same task sharing.

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The Airbus Cockpit Philosophy

Design Requirements

Airbus Cockpit Philosophy

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Golden Rules

AIRBUS

Airbus Golden Rules

Introduction

- The Airbus “GOLDEN RULES” are operational guidelines, based on all the following:
  - **Basic flying principles**
  - The **adaptation** of these basic flying principles **to modern-technology aircraft**
  - The **provision of information** about **required crew coordination** for the operation of the Airbus aircraft

- The **Objective** of these Golden Rules is also to **take into account** the **principles** of **flight crew interaction with automated systems**, and the principles of **CRM**, in order to:
  - **Help prevent the causes** of many accidents or incidents
  - Ensure **flight efficiency**

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Airbus Golden Rules

General Golden Rules

+ The Airbus cockpit philosophy and resulting design leads to the following operational golden rules:

+ **FLY, NAVIGATE, COMMUNICATE**
  + In that order and with appropriate tasksharing
  + Back-up each other
+ **Use the appropriate level of automation at all times***
+ **Understand the FMA at all times**
+ **Take action if things do no go as expected**

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Airbus Golden Rules

Detailed Golden Rules

AIRBUS

GOLDEN RULES

1. Fly, navigate and communicate:

in this order and with appropriate tasksharing.

- **Fly the Aircraft**, **Fly the Aircraft**, **Fly the Air**craft…
- **Don't allow** anything to **distract** you from your role as PF or PM!
- **PM** must **ACTIVELY MONITOR** the flight parameters and highlight any excessive deviations.
- **Both pilots** must **maintain** their **Situational Awareness** and **immediately resolve** any uncertainty **as a crew.**

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Airbus Golden Rules

Detailed Golden Rules

AIRBUS **GOLDEN RULES**

2. Use the appropriate level of automation at all times.

- The **appropriate level of automation** depends upon the situation and the task. **Pilot judgment prevails**, including **selecting manual flight**.
- **Understand** the implication of the intended level of automation.
- **Select** the **intended** level.
- **Confirm** the **expected** aircraft **reaction**.

Airbus Golden Rules

Detailed Golden Rules

AIRBUS **GOLDEN RULES**

3. Understand the FMA at all times.

- \+ Monitor your FMA.
- \+ Announce your FMA.
- \+ Confirm your FMA.
- \+ **Understand your FMA.**

AIRBUS

Airbus Golden Rules

Detailed Golden Rules

AIRBUS **GOLDEN RULES**

4. Take action if things do not go as expected.

- By PF changing the level of automation.
- By PF reverting to manual flight.
- By PM taking action,
  - Question.
  - Challenge.
  - **Take-over.**

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Airbus SOPs are designed to:

Airbus SOPs

Enhance flight safety

Ensure consistent safe operation

Adhere to Airbus Operational Golden Rules

Favor adequate task sharing and CRM

Optimize inter crew communication

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