Flight Operations Safety Awareness Seminar (FOSAS)

The Airbus Cockpit Philosophy

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

Design Requirements

Airbus Cockpit Philosophy

Airbus Family Concept

Golden Rules
The Airbus Cockpit Philosophy

- Design Requirements
- Airbus Cockpit Philosophy
- Airbus Family Concept
- Golden Rules
The Airbus cockpit is designed 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.
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
The Airbus Cockpit Philosophy

Cockpit Layout

Automation

FBW / Protections

Display Units

Alerts
The Airbus Cockpit Philosophy
Overall Cockpit Layout

+ Dark Cockpit Concept
+ Color Coding
+ Panel Arrangement
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
Lights and information provided on display units are color coded to indicate the status of the system, or the nature of the information.
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
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
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
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
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)
The Airbus Cockpit Philosophy

Airbus Design Philosophy

Implementation

Cockpit Layout
Automation
FBW / Protections
Display Units
Alerts
Automations

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

Automation Principles

- Reduces Workload
- Enhances Situation Awareness
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
The Airbus Cockpit Philosophy

Airbus Design Philosophy

Implementation

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

High stability and maneuverability of the aircraft regardless of aircraft CG, GW, speed, altitude and configuration.
The pilot efforts on the controls in pitch and roll are always balanced.

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

Non-FBW

- Large control column deflection required to accurately displace the control surfaces, and overcome numerous mechanical and friction forces.
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.
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
Airbus Fly-by Wire Control Laws

Pitch Normal Law
Airbus Fly-by Wire Control Laws

Lateral Normal Law
Airbus Fly-by Wire Protections

Protections

- Pitch attitude protection
- Load factor protection
- Bank angle protection

Flight mode:
- Ground mode
- Take off mode
- Landing mode
- Ground mode

Protecting modes:
- Stall protection
- Overspeed protection
Airbus Fly-by Wire Protections

Pitch Protection

Limits the pitch attitude to 30 degrees nose-up
Airbus Fly-by Wire Protections

Pitch Protection

Limits the pitch attitude to 15 degrees nose-down
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

- Maintains $\alpha_{prot}$ with stick neutral
- Maintains $\alpha_{max}$ with stick fully aft ($\alpha$-floor out)

Stick input fully aft

Graph: $C_L$ (Lift Coefficient) vs. $\alpha$ (Angle of attack)

- $V_{\alpha_{prot}}$
- $V_{\alpha_{max}}$
- $V_{LS}$
- 1g Stall
- Angle of attack protection activates

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Airbus Fly-by Wire Protections

Initial Conditions:
- Landing CONF - V/S = -1500 ft/min
- Protected aircraft - MLW - aft Cg - Vref+5
- Non protected: Gw - Cg unknown

"TERRAIN - PULL-UP"
Airbus Fly-by Wire Protections

FBW – CFIT Escape Trajectory Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Non-protected</th>
<th>Protected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duck-under (ft)</td>
<td>125</td>
<td>80</td>
</tr>
<tr>
<td>Bucket distance (ft)</td>
<td>2 500</td>
<td>1 500</td>
</tr>
<tr>
<td>Bucket time (sec)</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Safety margin (sec)</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>
Airbus Fly-by Wire Protections

**High Speed Protection**

- **High speed protection activation**
  - Stick free
  - Stick full forward

**HSP Activation**

- **OVERSPEED warning at**
  - VMO + 4kt / MMO + .006

- **VMO +10kt / MMO + .02**
  - (At the latest)

- **Speed returns below**
  - VMO + 10kt / MMO + .02

- **Speed Stabilized at**
  - VD - 10kt / MD - .02
Bank angle protection limits the bank angle to 67°
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)
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.
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.
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.
When the ATHR is active, an additional servo loop for the thrust lever control is not necessary.

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.
Airbus Fly-by Wire - A/THR

A/THR Controls & Indicators

TLA Symbol

A/THR Thrust Command arc

Actual Digital Thrust (N₁)

CLB : 92.6%

Actual Thrust Symbol

A/THR ACTIVE RANG ONE ENG INOP

A/THR ACTIVE RANG ALL ENG

CLB

MCT

IDLE

TOGA
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
The Airbus Cockpit Philosophy

Implementation

Cockpit Layout
Automation
FBW / Protections
Display Units
Alerts
The ECAM system will automatically display the WHEEL SD page after the engines have been started.
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
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Display Units
Alerts
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
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
Airbus Family & Commonality Concept

› Improve Safety through Similarity

› Improve pilot’s Skills (MFF)

› Rationalize Transition Training (CCQ)
Airbus Family & Commonality Concept

- Enhanced working environment

Respect Airbus family concept and principles
Airbus Family & Commonality Concept

Enhanced working environment

Respect Airbus family concept and principles
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.
The Airbus Cockpit Philosophy

Design Requirements

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Airbus Family Concept

Golden Rules
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

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
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
1. **Fly, navigate and communicate:**

   * in this order and with appropriate tasksharing.
   
   + Fly the Aircraft, Fly the Aircraft, Fly the Aircraft…
   + 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.
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.
3. Understand the FMA at all times.

- Monitor your FMA.
- Announce your FMA.
- Confirm your FMA.
- Understand your FMA.
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.
Airbus SOPs are designed to:

- Enhance flight safety
- Ensure consistent safe operation
- Adhere to Airbus Operational Golden Rules
- Favor adequate task sharing and CRM
- Optimize inter crew communication