A380 Flight Controls overview
A380 Flight Control and Guidance Systems
main novelties

• Aircraft configuration and control surfaces

• Actuator technology

• Power sources for Flight Controls

• Flight Control Architecture and Computers

• Back-up controls

• Flight Control Laws

• Conclusion : Flight Tests Findings
Flight Control Surfaces

- Slats (6x2)
- Droop Nose (2x2)
- Flaps (3x2)
- Ailerons (3x2)
- spoilers (8x2)
- Elevators (2x2)
- Rudders (x2)
- Trimmable Horizontal Stabilizer
- Elevators (2x2)
## Flight Controls: actuator characteristics

<table>
<thead>
<tr>
<th></th>
<th>stall load</th>
<th>weight</th>
</tr>
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<tbody>
<tr>
<td>Ailerons</td>
<td>13,5 T</td>
<td>35/65 kg</td>
</tr>
<tr>
<td>Spoilers</td>
<td>21/14,5 T</td>
<td>25/65 kg</td>
</tr>
<tr>
<td>Elevators</td>
<td>18 T</td>
<td>40/80 kg</td>
</tr>
<tr>
<td>Rudders</td>
<td>22,5 T</td>
<td>100 kg</td>
</tr>
<tr>
<td>THSa*</td>
<td>85 T</td>
<td>380 kg</td>
</tr>
</tbody>
</table>

*: loads on trim screw
A380 Flight Control and Guidance System: main novelties

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- Control Laws
Primary Flight Control System Actuators: E(B)HA

Conventional Servocontrol

- Accumulator
- Servovalve
- Mode selector device
- Hydraulic block
- Hyd. system (power)
- Ram

Servocontrol in normal operation

Electro-Hydrostatic Actuator (EHA)

- Servovalve replaced by an electric motor pump
- Accumulator
- Pump
- Mode selector device
- Hydraulic block
- Hyd. system (power)
- Motor

Electrical Back-up Hydraulic Actuator (EBHA)

- Electrical system (power)
- Motor
- Hydraulic block
- Ram
Primary Flight Controls

equipment status - overview

EHA experience

• 1989: first prototypes EHA/EMA

• 1992: EBHA aileron first flight on A320 test aircraft (more than 100 fh)

• 1993/2000: full qualification process, development of large EHA

• 2000/2002: One EHA (inboard aileron) constantly flight tested on A340 MSN 1 (200 FH, 61 flights), in active and standby modes, start phases, thermal behaviour...
Example: A380 EHA aileron

Hydraulic pump + elec. motor

Electronic module
Electro-Hydrostatic Actuator features

- EHA hydraulically autonomous in flight:
- EHA includes a fluid reservoir in order to compensate thermal dilatation and small external seepage
- EHA fluid reservoir refilling rare, but possible through a connection between each EHA and one centralised circuit
  (Filing operation only possible on ground)
THSA DESIGN MAIN FEATURES

- End stop
- Primary Nut
- Secondary Nut
- Electric Controller
- Gearbox
- Hydraulic Valve Block
- Hydraulic Motor
- Upper Attachment
- Lower Attachment
- Ballscrew

Total length: 2.9 m
THSA DESIGN MAIN FEATURES
A380 Flight Controls: High Lift system

A380 High Lift movables and system mechanical components (similar concept as A340 Long Range)
A380 Flight Controls: High Lift system

- 2 Drooped Nose Devices per wing (INBD wing) to improve aerodynamic performance (lift to drag ratio)
- 6 Leading Edge Slats per wing (MIDBD & OUTBD wing)

DROOPED NOSE DEVICES:
Supported by hinged arms; driven by rotary actuators via link & lever

SLATS:
supported by curved tracks; driven by rotary actuators via rack & pinion
High Lift main novelties

• Electric motor for SLAT PCU: due to 2H/2E concept

• Hydraulic Variable Displacement motors: flow consumption

• Fail-Safe Control Lever & Sensor: to improve S/F availability
  (no Clean Wing Landing design objective)
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**A380 Hydraulic and electrical power sources**

**Green System**
- Reservoir and main generation components (within pylon)
- 2 Engine Driven Pumps
- 1 Ground Electric Motor Pump (within pylon)
- 2 Engine Driven Pumps

**Yellow System**
- Reservoir and main generation components (within pylon)
- 2 Engine Driven Pumps
- 1 Ground Electric Motor Pump (within pylon)
- 2 Engine Driven Pumps

**Electrical System 1**
- Power center
- Generator 2
- Generator 1

**Electrical System 2**
- Power center
- Generator 4
- Generator 3

**Emergency System**
- Power center
- E.RAT (Flap Track Fairing)
• Survivability/robustness improvement:
  ‣ good fuse function
  ‣ recovery facility in case of power generation failure
  ‣ good segregation of distribution
  ‣ dissimilarity on surface actuators power supplying
Redundancy improvement (2 electrical systems replace 1 hydraulic system)

• Reduction of both hydraulic and electrical power consumption

From Blue Hydraulic system to electro-hydraulic actuators
Electro-hydraulic actuators use

• Performances
  ‣ EHA: same performances as adjacent servocontrol,
  ‣ EBHA: same performances in hydraulic mode, reduced deflection rate in electrical mode.

• Electrical mode Activation logics:
  ‣ In Normal flight:
    ‣ No EHA or EBHA operation (damping & hydraulic mode)
  ‣ in case of High surface deflection or deflection rate:
    ‣ double pressurisation of hydraulic actuators or E(B)HAs
  ‣ Failure cases with possible use of EHA and/or EBHA:
    ‣ Single or double hydraulic failure,
    ‣ One engine inoperative,
    ‣ Total engine flame-out (with electrical RAT),
    ‣ Engine burst
    ‣ ...
A380 Flight Control and Hydraulic System: main novelties

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A380 Flight Control System Architecture

• 2H/2E architecture
  ‣ 4 dissimilar power systems to actuate the moving surfaces
  ‣ Aircraft controllable from one power system
  ‣ robust architecture (engine rotor burst, structural damages …)

• Electrical RAT supplying EHA and EBHA in case of total engine flame-out.

• No Mechanical Control (Trim Hand Wheel replaced by Switches)

• Improvement of Auto-Pilot availability (computers + Control Unit)
A380 Flight Controls architecture

**AILERONS**
- O/B
- Med
- I/B

**SPOILERS**
- G
- Y
- S3
- S2
- P3
- P2
- P1
- S1
- S2
- S3

**Speed brakes, Ground spoilers**

**Roll surfaces**

**ailerons O/B Med I/B**

**ELEVATORS**
- O/B
- I/B

**E1**
- GREEN hydraulic system

**E2**
- YELLOW hydraulic system

**E3**
- 28VDC

**Flight Controls architecture**

**Conventional hydraulic servocontrol.**

**EHA, Electro Hydrostatic Actuator.**

**EBHA, Electrical Backup Hydraulic Actuator.**

**Pedals, Feel and Trim Unit**

**Vertical Stabilizer**

**Upper Rudder**

**Lower Rudder**

**S2 P1 S3 P2**

**B BCM ultimate backup control**

**Reconfiguration arrow**

**(Colors on E1, E2 and E3 for representation purposes only, no engineering).**

**E1 AC power (AC1ess side 1)**

**E2 AC power (AC2ess side 2)**

**E3 AC power (AC1 side 1)**
Primary Flight Controls: Computers

- 3 PRIMary Flight Control and Guidance Computers
  - integration of Auto Flight (ex FGEC) and Flight Control (ex FCPC)
    => 3 Auto-Pilots
- 3 SECondary Flight Control Computers
  - dissimilar Software and Hardware, simpler Control Laws
- 2 Slats & Flaps Control Computers (SFCC)

- Implementation with IMA:
  - Flight Controls Data Concentrator
  - Weight & Balance monitoring
  - Flight Control Unit back-up
  - Interface through AFDX:
    - Software dataloading,
    - Maintenance and warning data,
    - Partial inter-system communication
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Primary Flight controls: Back-up Control

Logical evolution of A320 / A340 / A340-600 family:

Full Fly-By-Wire, with a “Back-up” as an additional precaution to keep control of the aircraft during temporary loss of:

- all Primary Flight Control computers
- all Electrical power supply

- A320: full FBW controls, mechanical Back-up (Pitch Trim & Rudder)
- A340/A330: like A320, additional Yaw Damper to improve Dutch Roll damping even in Back-up mode (BYDU with hydraulic micro generator)
- A340-600: like A340 for pitch, Rudder becomes fully Electrical (BPS + BCM: Back-up Power Supply + Control Module)
- A380: like A340-600 for Yaw control + BPS+BCM also power
  - Electrical Pitch Back-Up (elevators) linked to side-stick
  - Electrical Roll Back-Up (ailerons) linked to side-stick
  - Pitch Trim (Wheel is replaced by Switches).
Electrical Back-up control

- Side stick
- Pitch trim switches
- BPS Yellow
  - BCM Gyro
  - Outboard Elevators
  - Ailerons
  - SPOILERS
  - SPOILERS
- BPS Green
  - Outboard Elevators
  - Inboard Elevators
  - Rudder
  - Upper
  - Lower

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Electrical Back-up: BPS / BCM

Back-up Power Supply / Back-up Control Module

BPS contains:
- A hydraulic motor
- An electrical power generator

The BCM consists of:
- 2 rate gyrometers,
- Analog electronics performing:
  - acquisition of pilot controls
  - pitch, yaw and roll control law
  - actuator control
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Flight Controls Laws : main features

Same design philosophy as Airbus FBW:

• Normal Law with auto-trim, Flight Envelope protection
• Alternate Laws with ‘Prot Lost’, but still with auto-trim
• “Direct” law

Active Stability Control functions:

• All levels of control laws (Normal, Alternate, “Direct” and even Back-up) include a Yaw and Pitch damping function
Flight Controls Laws : main features

A380 is the continuation of FBW developed since A320:
- normal load factor demand in pitch
- roll rate demand in roll, with automatic turn coordination & yaw damping
- with flight envelope protections (Stall, attitudes, over-speed)

Main A380 novelties compared to A340 family:
- Y* law as lateral normal law: use of Side-Slip probes
- Load Alleviation functions specific to A380
- Use of voters instead of “switches” for protections (AoA, High Speed, attitudes, …)
- Closer integration with Auto-Pilot (same computers)
Conclusion: Flight Test findings

• Generally the aircraft aerodynamics in the flight domain explored (VD & MD, aft & forward CG, light/heavy) are close to predictions

• Use of E(B)HA:
  ‣ Checked gradually via Flight Test Instrumentation
  ‣ “All Electrical Flight” performed (Hydraulic pumps depressurised)

These achievements were enabled by early use of simulators (Aircraft –1, Aircraft 0) and continuous R&D.

A400M, A350 XWB and future Programmes will benefit from these achievements, plus R&T activities
Conclusion: Future R&T activities

- More Electrical Aircraft:
  - use of EMA (Electro-Mechanical Actuators)
  - Use of High Voltage DC network

- Guidance Navigation & Control:
  - Ground Automation: Brake-to-Vacate, Airport Navigation & Auto-Pilot...
  - Multi-Objective design (handling qualities, comfort, loads, fatigue, …)
  - ATM 4D including specific approach patterns
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