DEUTSCHE GESELLSCHAFT FÜR LUFT- UND RAUMFAHRT – LILIENTHAL OBERTH E.V.
Wissenschaftlich-Technische Vereinigung

Presented by

Xavier Le tron
**Airbus**
Flight Controls


# A380 Flight Controls overview

AIRBUS

# A380 Flight Control and Guidance Systems main novelties

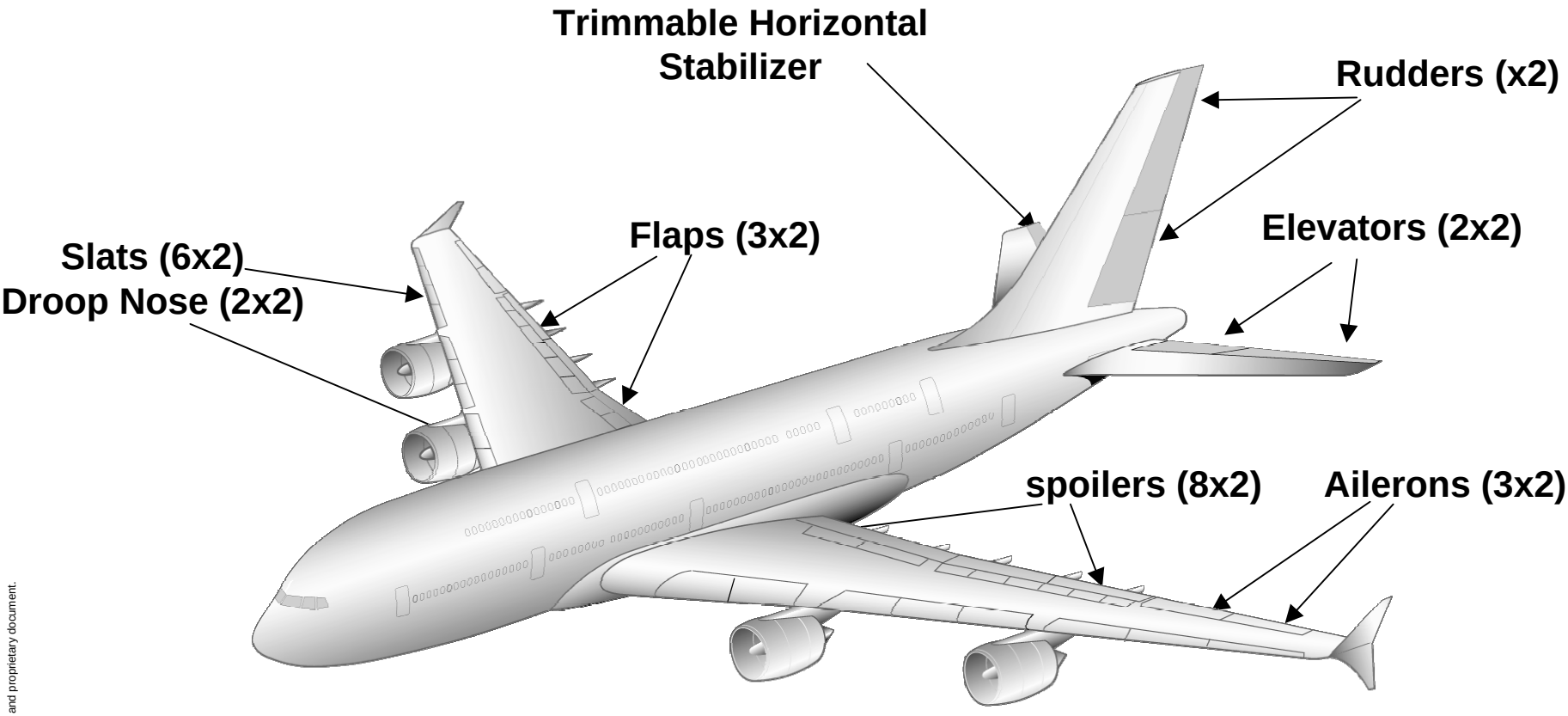
- Aircraft configuration and control surfaces
- Actuator technology
- Power sources for Flight Controls
- Flight Control Architecture and Computers
- Back-up controls
- Flight Control Laws
- Conclusion : Flight Tests Findings





AIRBUS

# Flight Control Surfaces



# Flight Controls: actuator characteristics

| | stall load | weight | *A340/330* |
|---|---|---|---|
| *stall load* | | | |
| ▸ Ailerons | 13,5 T | 35/65 kg | *15,7/10 T* |
| ▸ Spoilers | 21/14,5 T | 25/65 kg | *11/8,6 T* |
| ▸ Elevators | 18 T | 40/80 kg | *10,2 T* |
| ▸ Rudders | 22,5 T | 100 kg | *9,4 T* |
| ▸ THSa* | 85 T | 380 kg | *32,5T* |

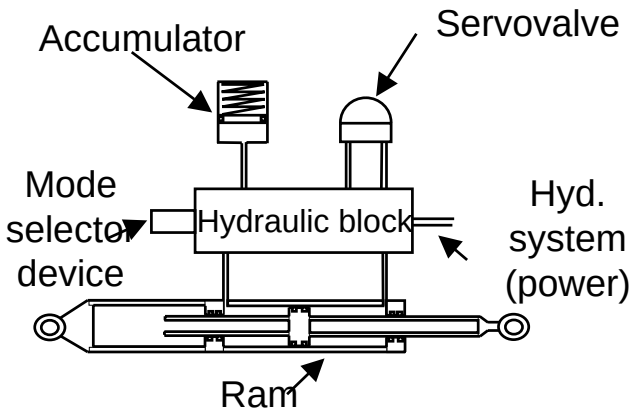
*: loads on trim screw

# A380 Flight Control and Guidance System : main novelties

- Aircraft configuration and control surfaces
- Actuator technology
- Power sources for Flight Controls
- Flight Control Architecture and Computers
- Back-up controls
- Control Laws

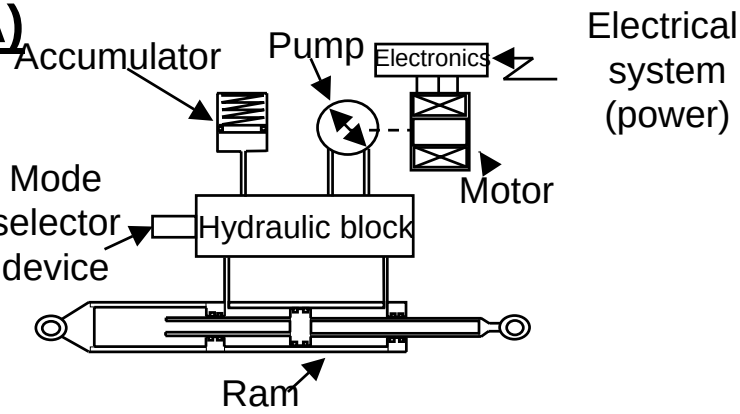
# Primary Flight Control System Actuators : E(B)HA

## Conventional servocontrol



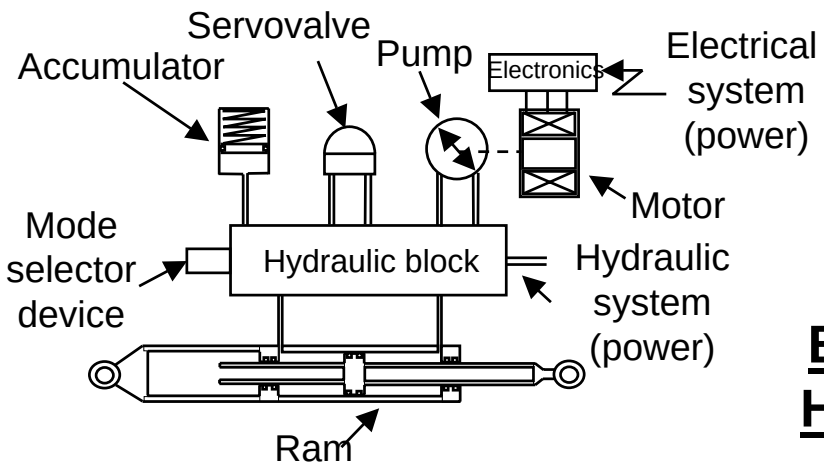

**Servovalve replaced by an electric motor Pump**

## Electro-Hydrostatic Actuator (EHA)




**EHA in back-up**

**Servocontrol in normal operation**



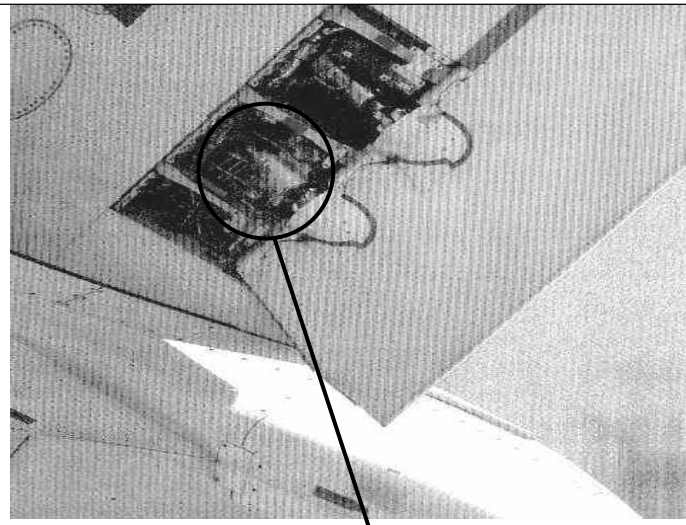

## Electrical Back-up Hydraulic Actuator (EBHA)

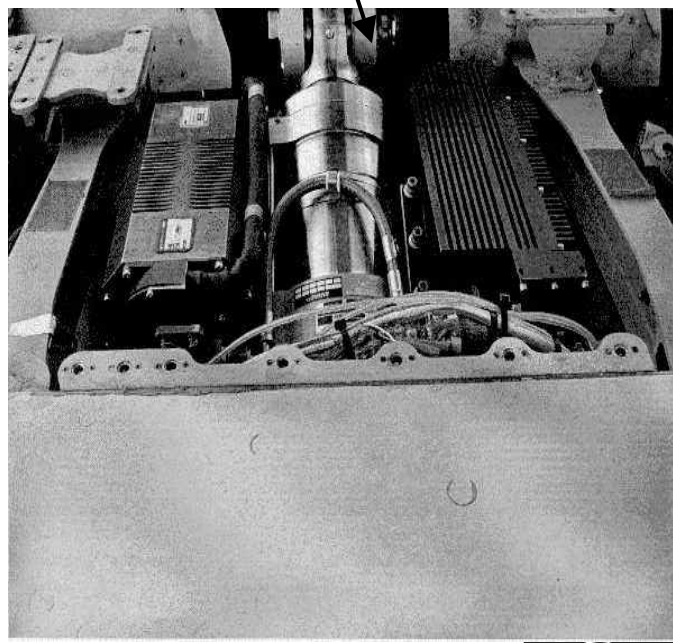
# Primary Flight Controls

**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 stand-by modes, start phases, thermal behaviour...**



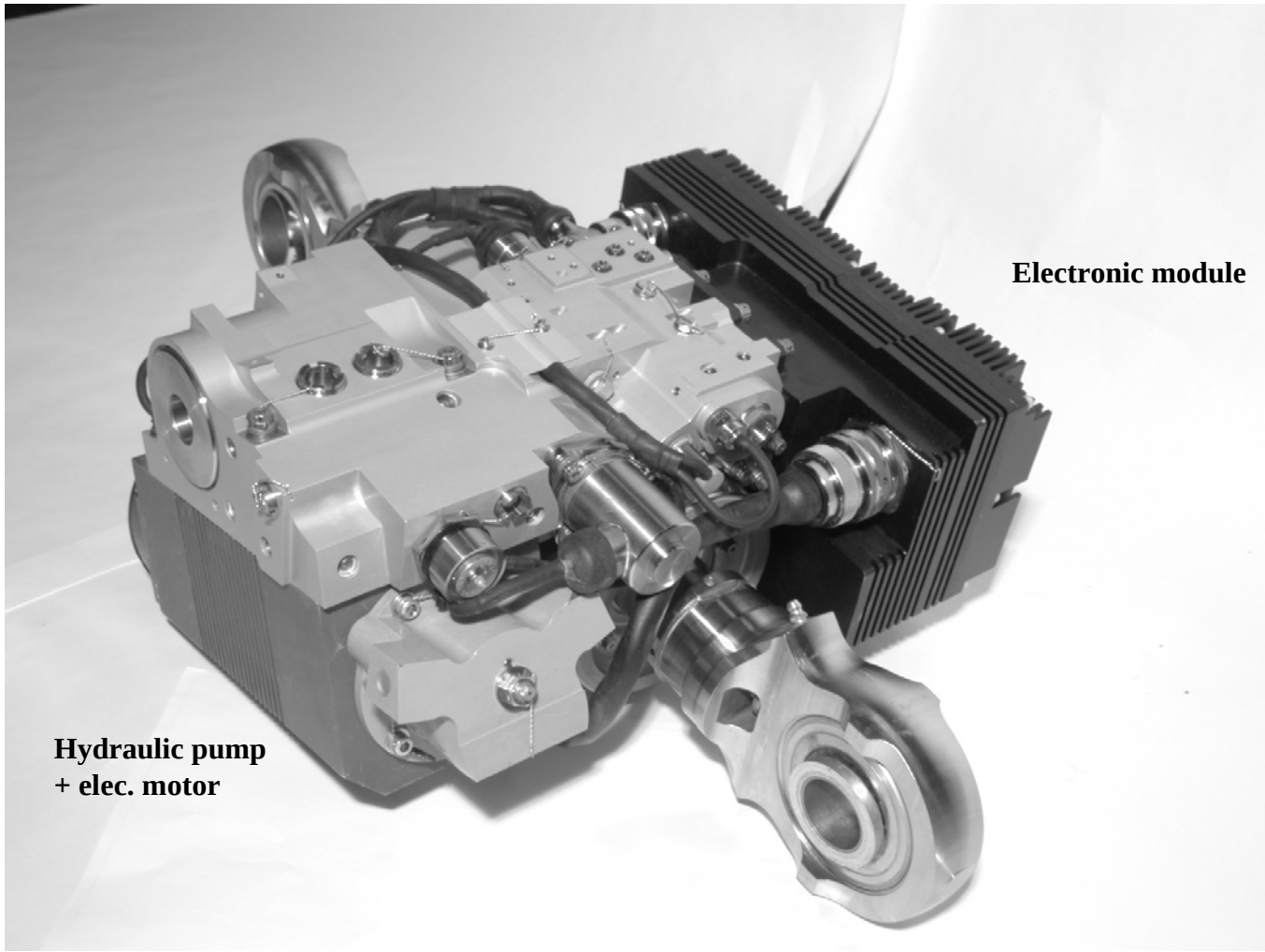






AIRBUS

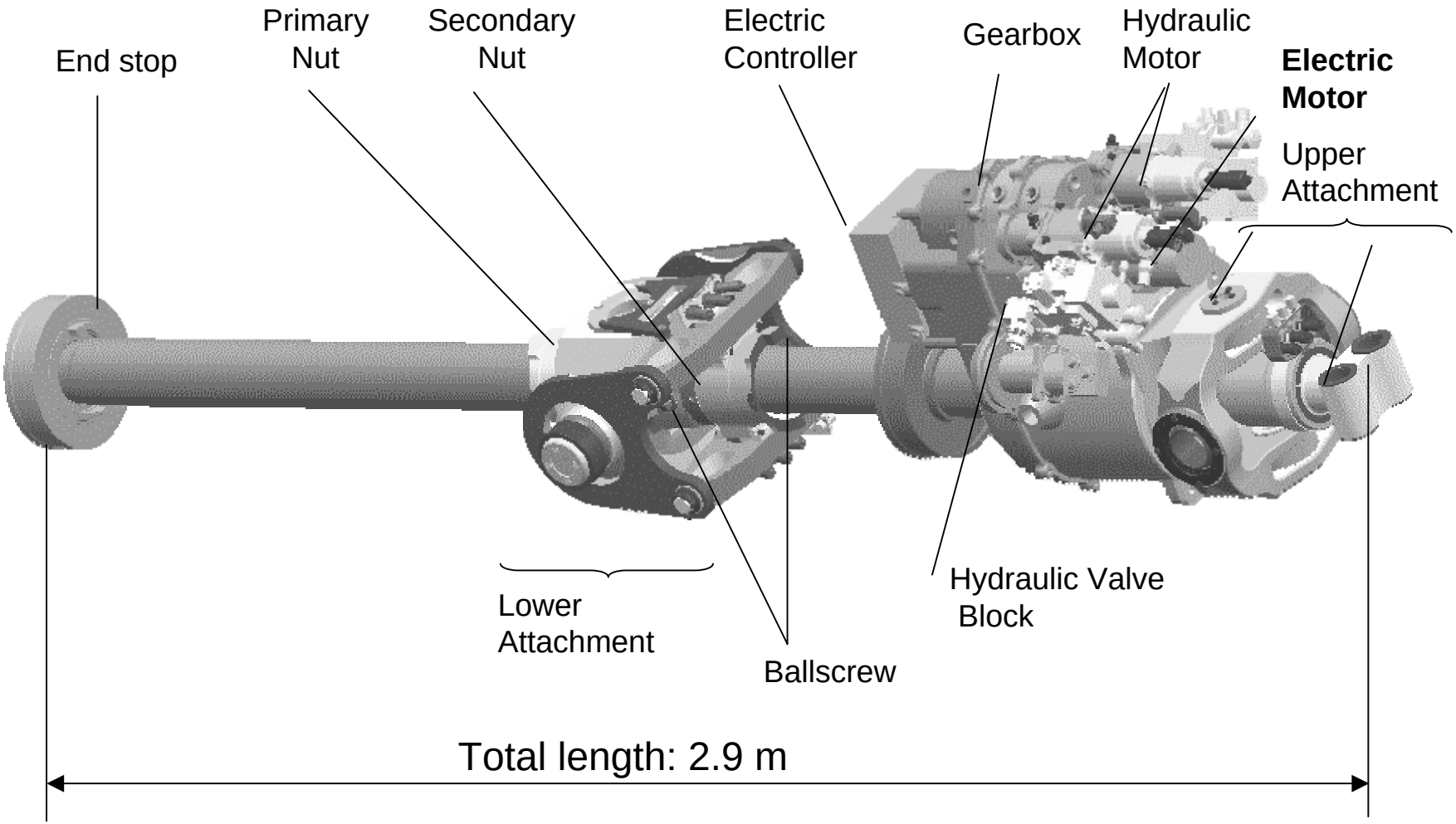
# Example: A380 EHA aileron



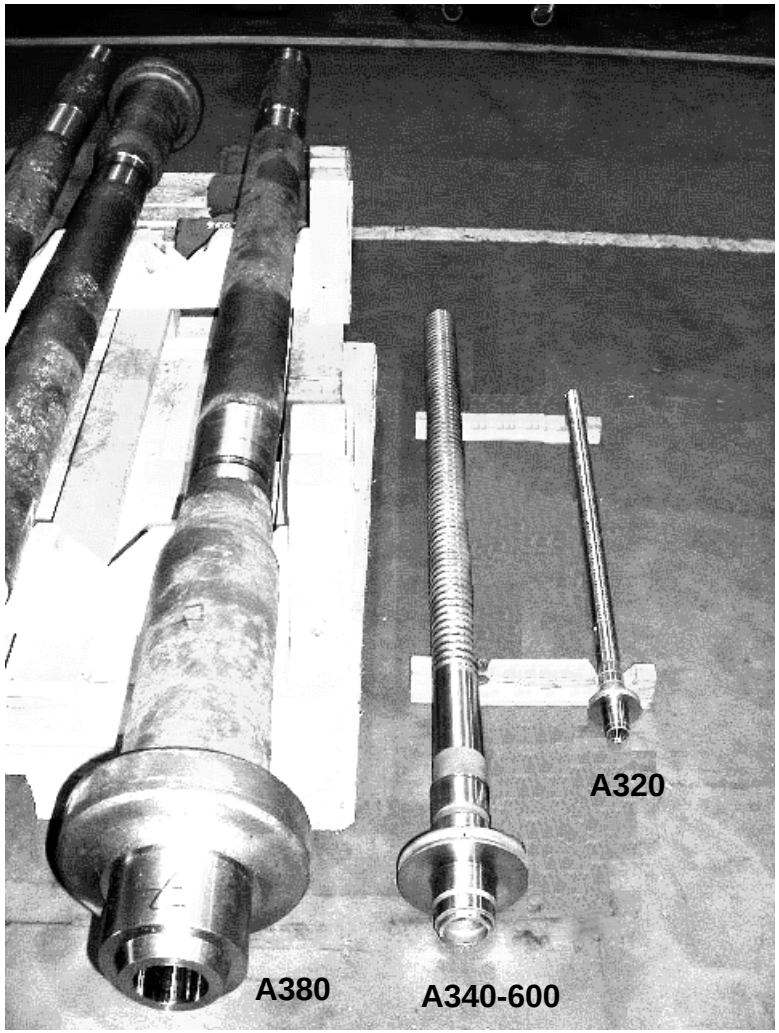
# Electro-Hydrostatic Actuator features

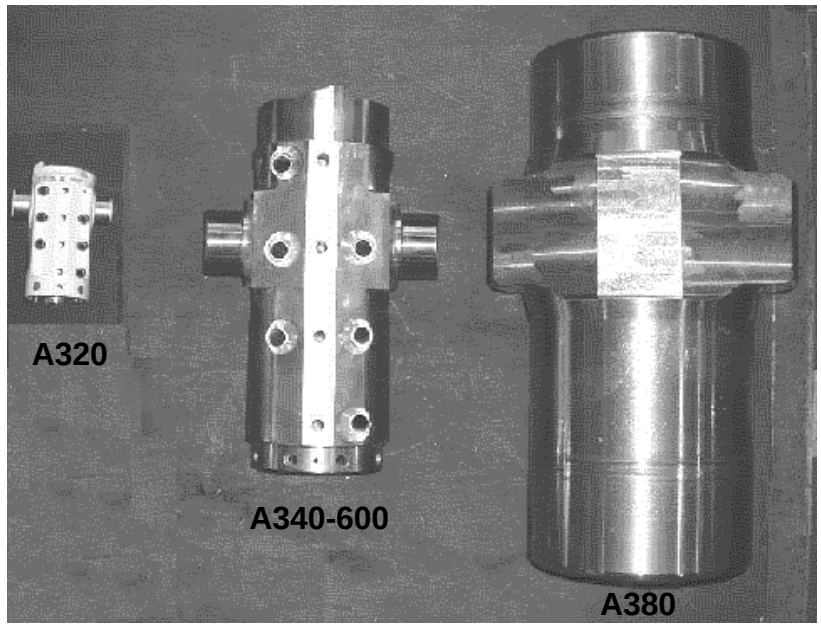
- EHA hydraulically autonomous in flight:
- EHA includes a fluid reservoir in order to compensate thermal dilatation and small external seepage
- EHA fluid reservoir refilling rare, but possible through a connection between each EHA and one centralised circuit
  (Filing operation only possible on ground)

# THSA DESIGN MAIN FEATURES



# THSA DESIGN MAIN FEATURES



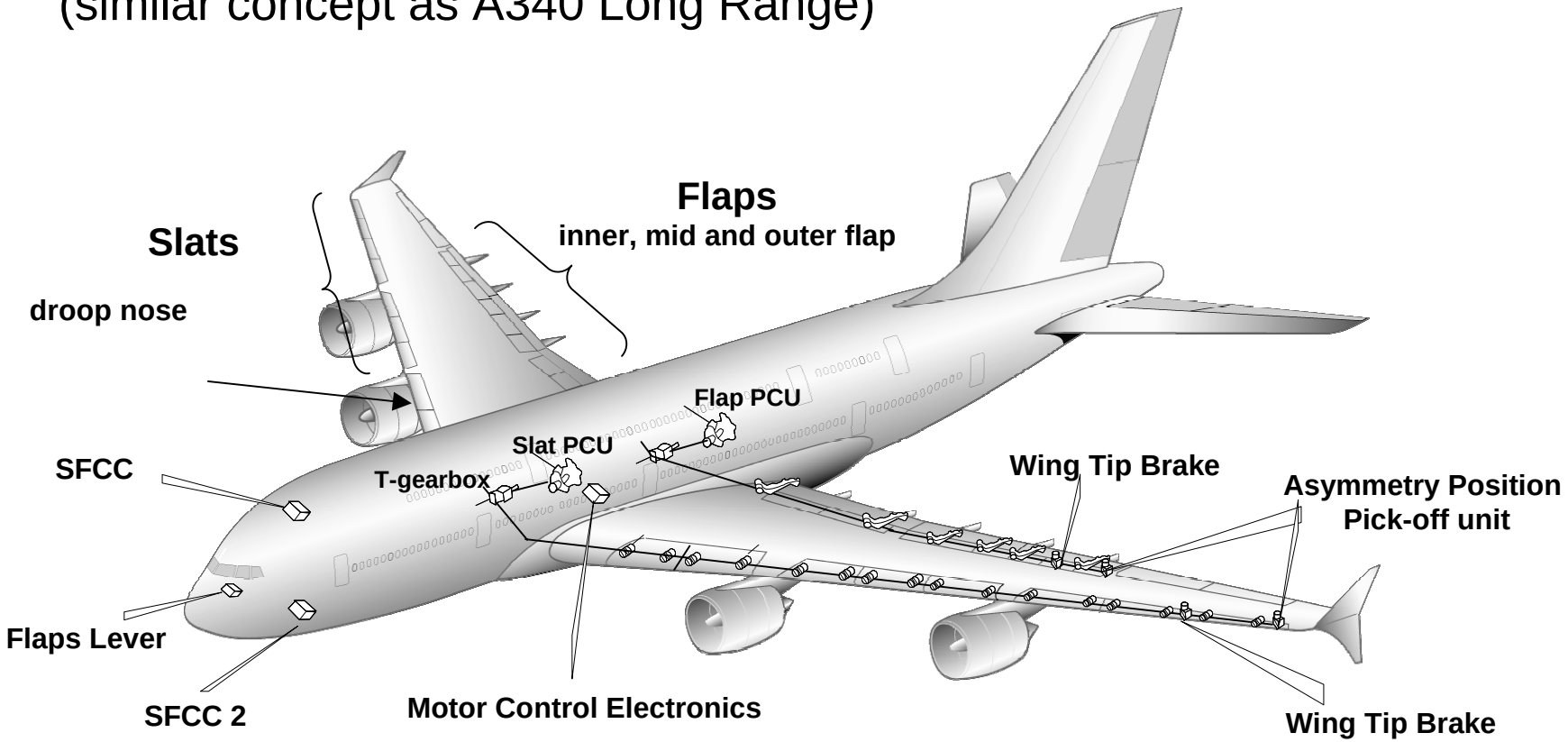





AIRBUS

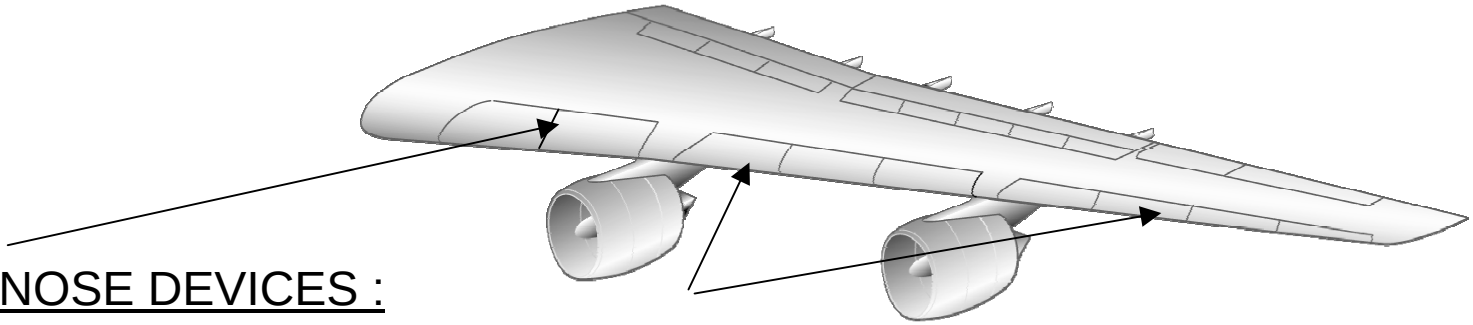
# A380 Flight Controls: High Lift system

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)

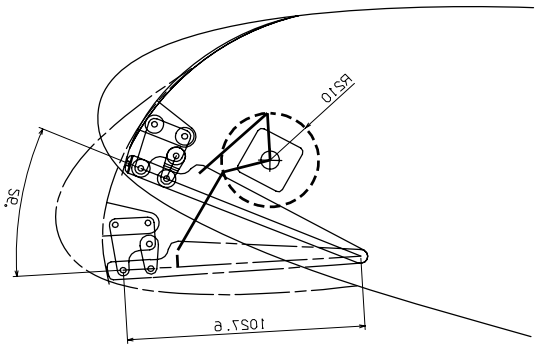


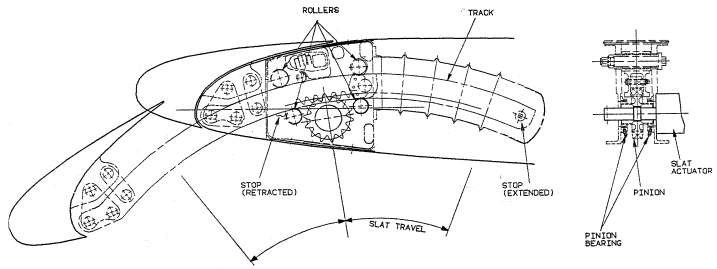
DROOPED NOSE DEVICES :

Supported by hinged arms ; driven by rotary actuators via link & lever

SLATS :

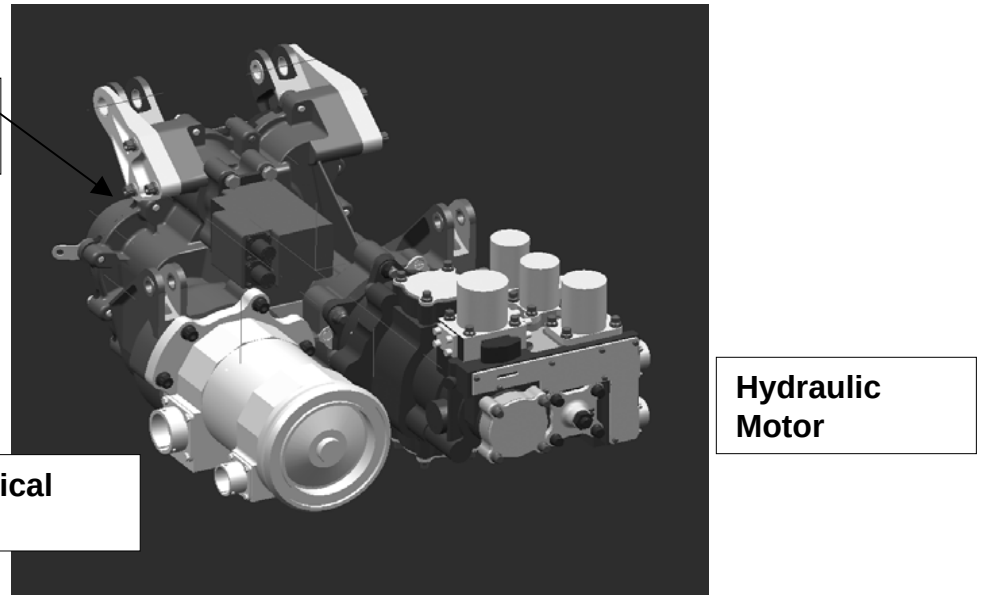
supported by curved tracks ; driven by rotary actuators via rack & pinion



# 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)**



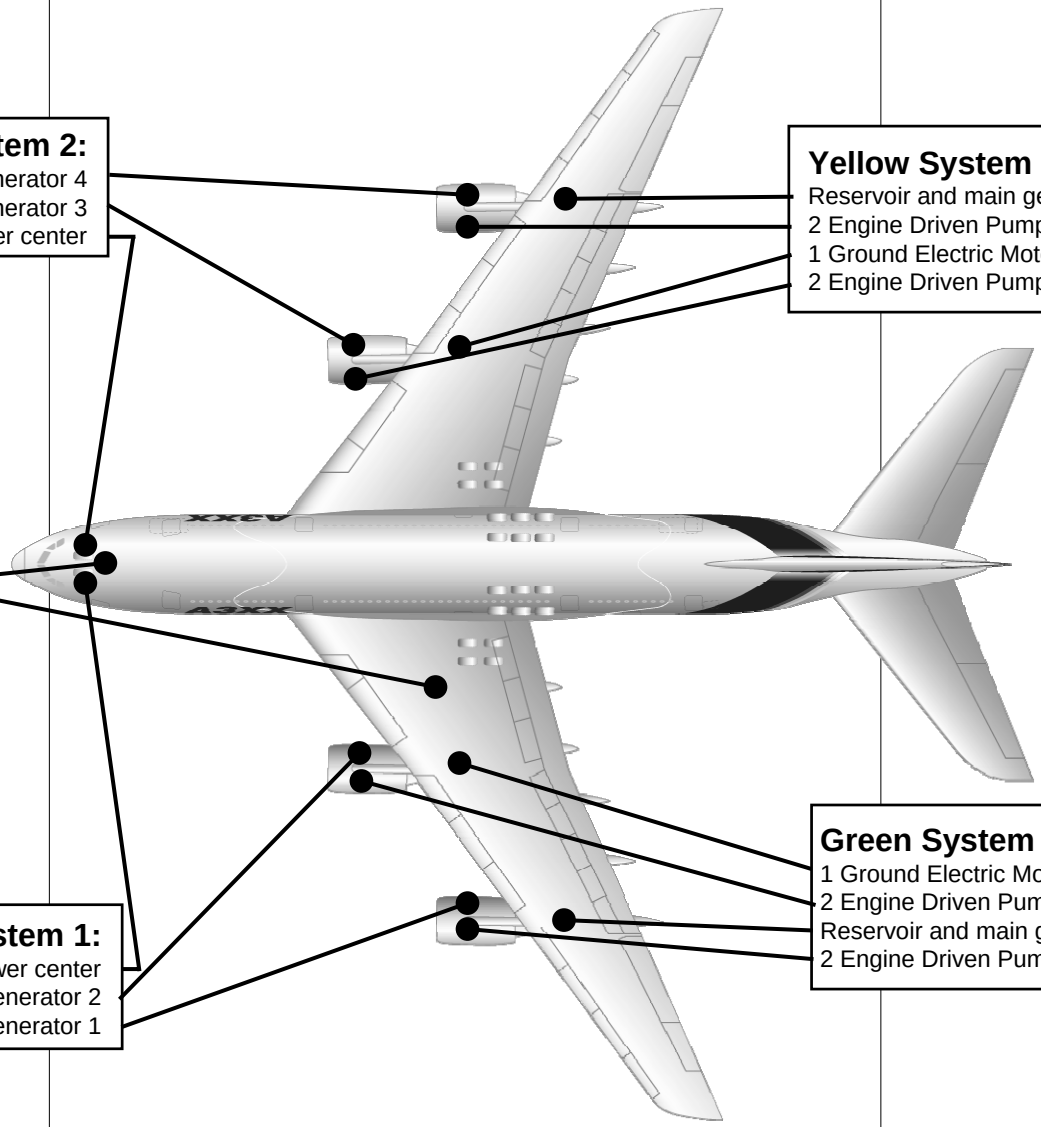


AIRBUS

# A380 Flight Control and Guidance System : main novelties

- Aircraft configuration and control surfaces
- Actuator technology
- Power sources for Flight Controls
- Flight Control Architecture and Computers
- Back-up controls
- Control Laws

# A380 Hydraulic and electrical power sources



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

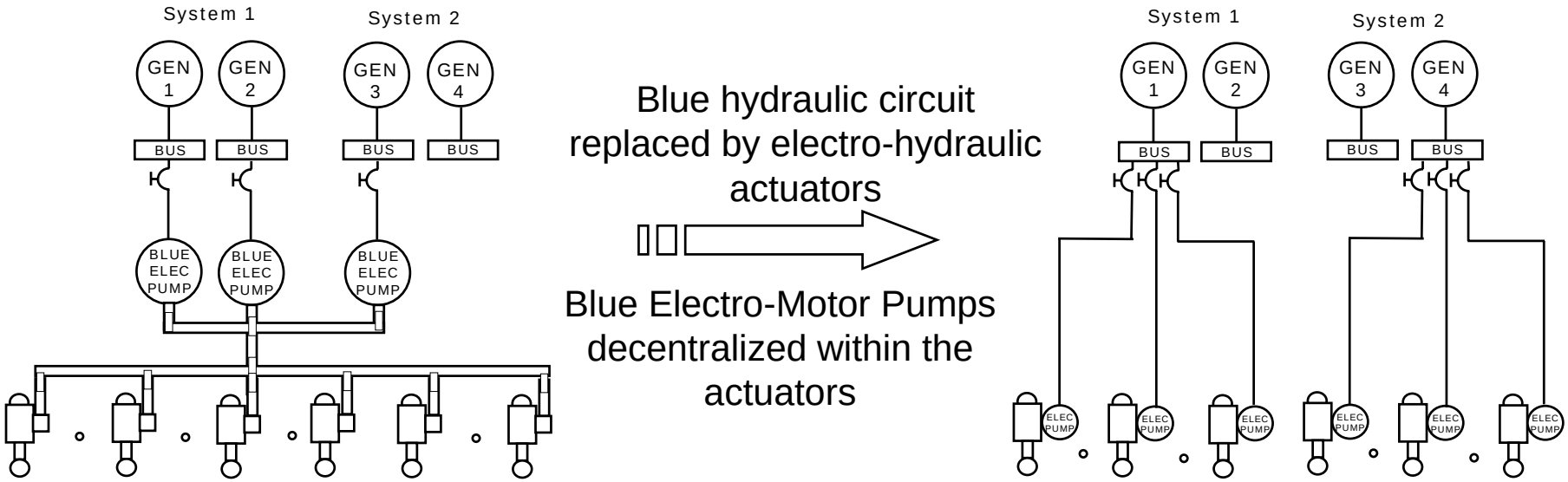
**Yellow System**
Reservoir and main generation components (within pylon)
2 Engine Driven Pumps
1 Ground Electric Motor Pump (within pylon)
2 Engine Driven Pumps

**Emergency System:**
Power center
E.RAT (Flap Track Fairing)

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

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

# *From Blue Hydraulic system to electro-hydraulic actuators*




- **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**





AIRBUS

# 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**
    - **...**

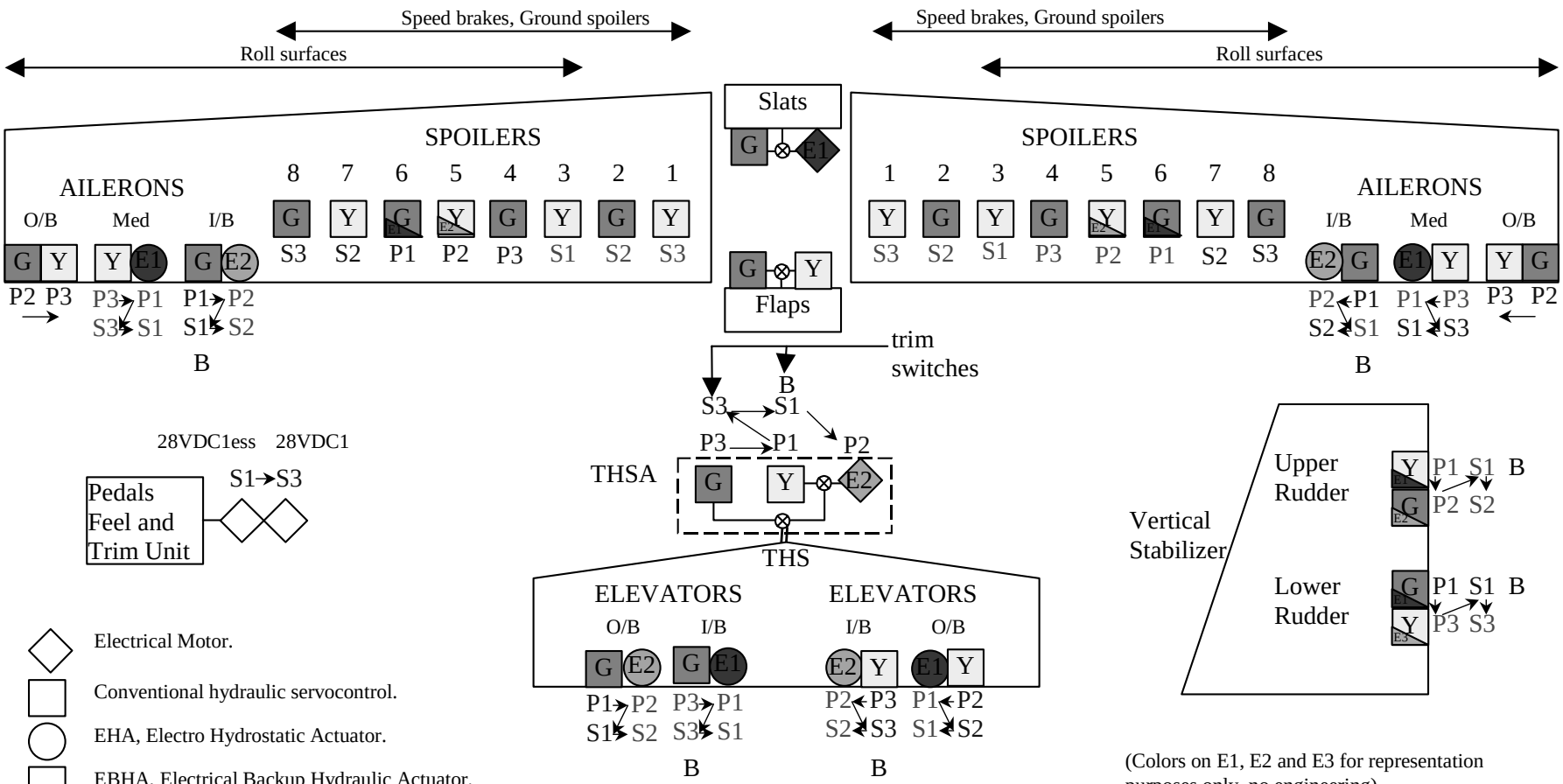
# A380 Flight Control and Hydraulic System : main novelties

- Aircraft configuration and control surfaces
- Actuator technology
- Power sources for Flight Controls
- Flight Control Architecture and Computers
- Back-up controls
- Control Laws

# A380 Flight Control System Architecture

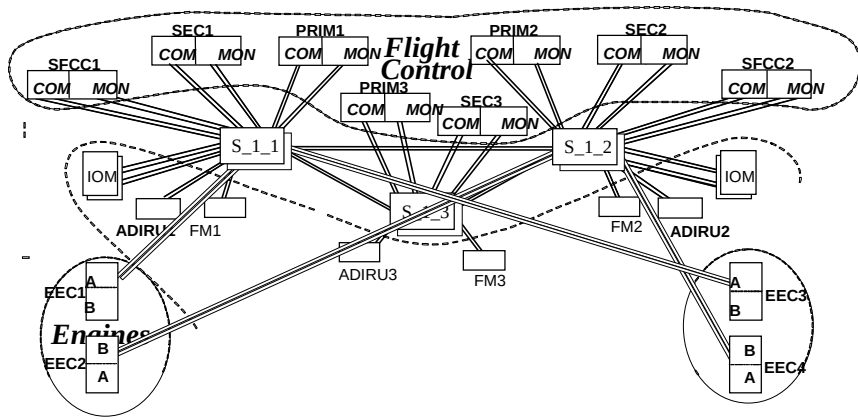
- **2H/2E architecture**
  - **4 dissimilar power systems to actuate the moving surfaces**
  - **Aircraft controllable from one power system**
  - **robust architecture (engine rotor burst, structural damages …)**
- **Electrical RAT supplying EHA and EBHA in case of total engine flame-out.**
- **No Mechanical Control (Trim Hand Wheel replaced by Switches)**
- **Improvement of Auto-Pilot availability (computers + Control Unit)**

# A380 Flight Controls architecture



# 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








AIRBUS

# A380 Flight Control and Hydraulic System : main novelties

- Aircraft configuration and control surfaces
- Actuator technology
- Power sources for Flight Controls
- Flight Control Architecture and Computers
- Back-up controls
- Control Laws

# 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**

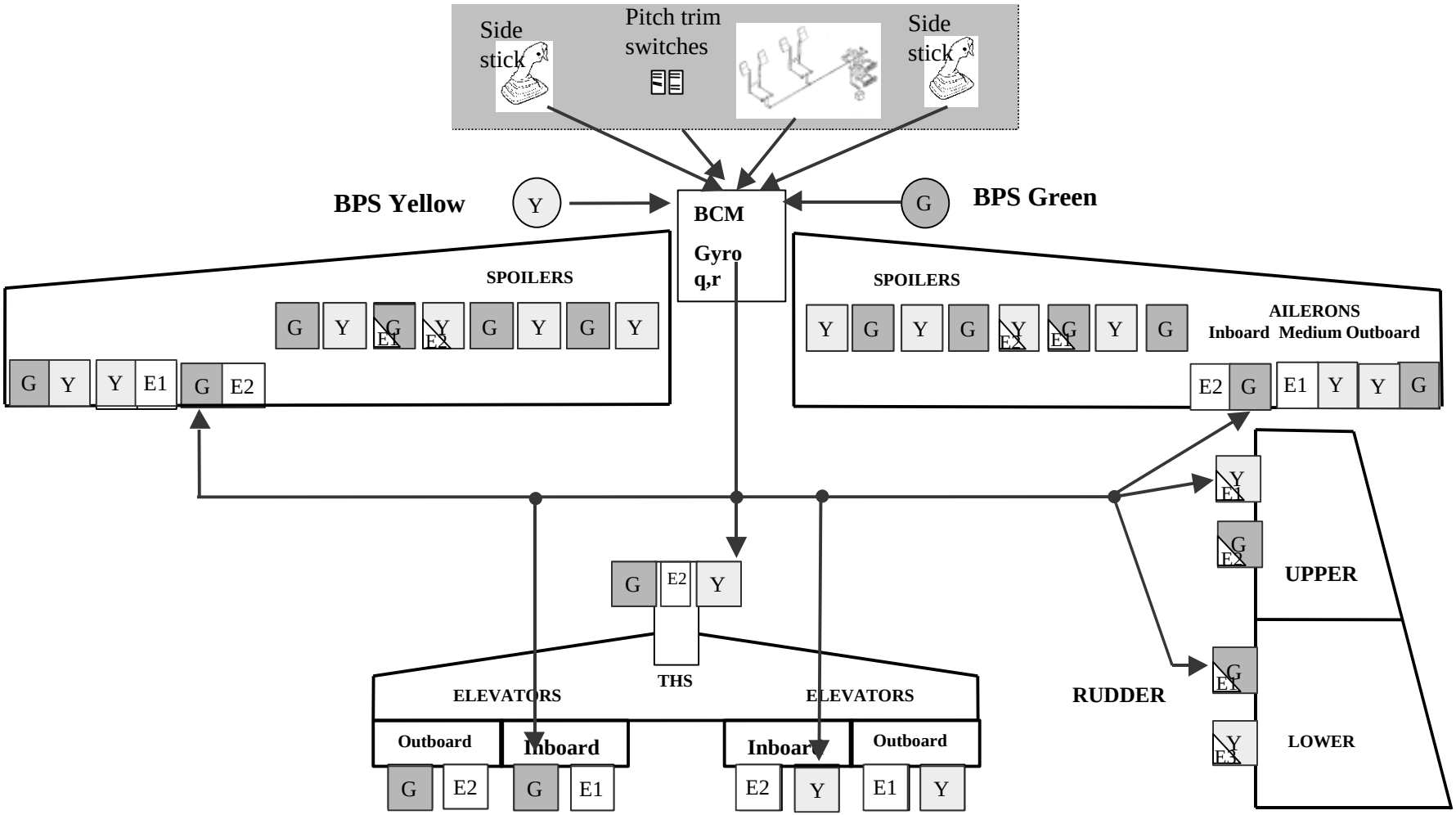
  **(BPS + BCM : Back-up Power Supply + Control Module)**
- **A380 : like A340-600 for Yaw control + BPS+BCM also power**
  - **Electrical Pitch Back-Up (elevators) linked to side-stick**
  - **Electrical Roll Back-Up (ailerons) linked to side-stick**
  - **Pitch Trim (Wheel is replaced by Switches).**





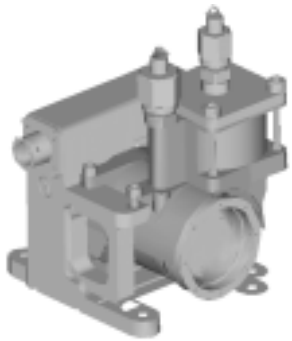
AIRBUS

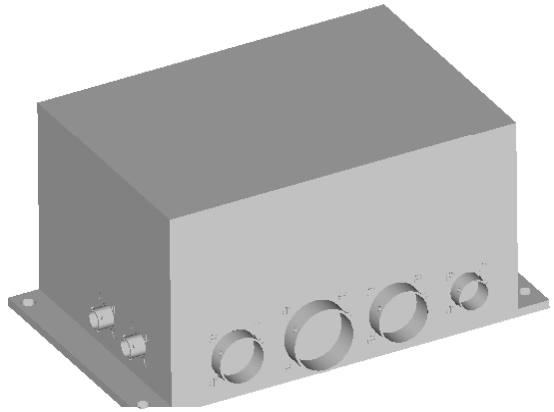
# Electrical Back-up control



# Electrical Back-up : BPS / BCM

## **B**ack-up **P**ower **S**upply / **B**ack-up **C**ontrol **M**odule





**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**

# A380 Flight Control and Hydraulic System : overview

- Aircraft configuration and control surfaces
- Actuator technology
- Power sources for Flight Controls
- Flight Control Architecture and Computers
- Back-up controls
- Control Laws

# 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

# Thank you for your attention


AN EADS JOINT COMPANY
WITH BAE SYSTEMS