Agenda (3/3)

- Exercices, Training (Groups) and pre Exams-Validation (Day 4, Morning 1,2)
- Module 7 – High lift Systems (Day 4, cont. Day 5)
  - 7-1 **<u>High lift systems architecture</u>** (Day 4, Morning 3,4)
  - 7-2 High lift systems actuation (Day 4, Afternoon 1,2)
  - 7-3 Other aircraft actuation systems (Day 4 Afternoon 3,4)
  - 7-4 Future of actuation (Day 5, Morning 1,2)
- Module 8 –Wrap-Up , Exercise and Exam Session (Day 5, Day 6)
  - 9-1 Wrap-Up (Day 5, Afternoon 3,4
  - 9-2 Exam (Day 6, Morning)

7-1 High lift systems architecture

High lift devices are movable surfaces at the leading edge (Slats) and trailing edge (Flaps) of the wing. The purpose is increase of lift for low speed operation

Aircraft in “clean” confoguration

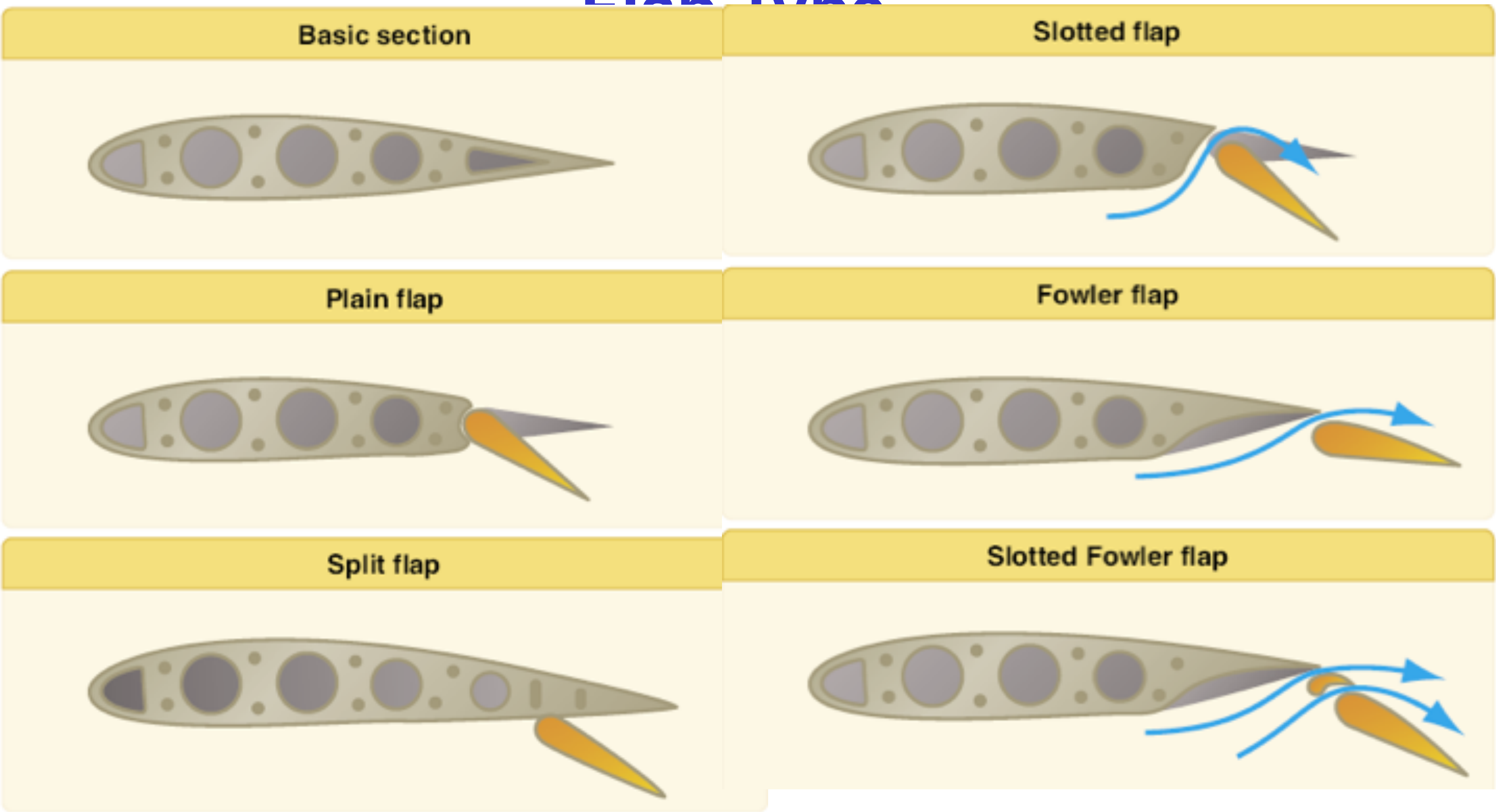
Aircraft in Low Speed configuration

FLAPS

- Flaps are high lift devices fitted at the trailing edge of the wing which:
  - increase the effective wing surface (fowler)
  - increase the camber of the wing,

Their use gives better take-off performance and permits steeper approach angles and lower approach and landing speeds.

Flap Type

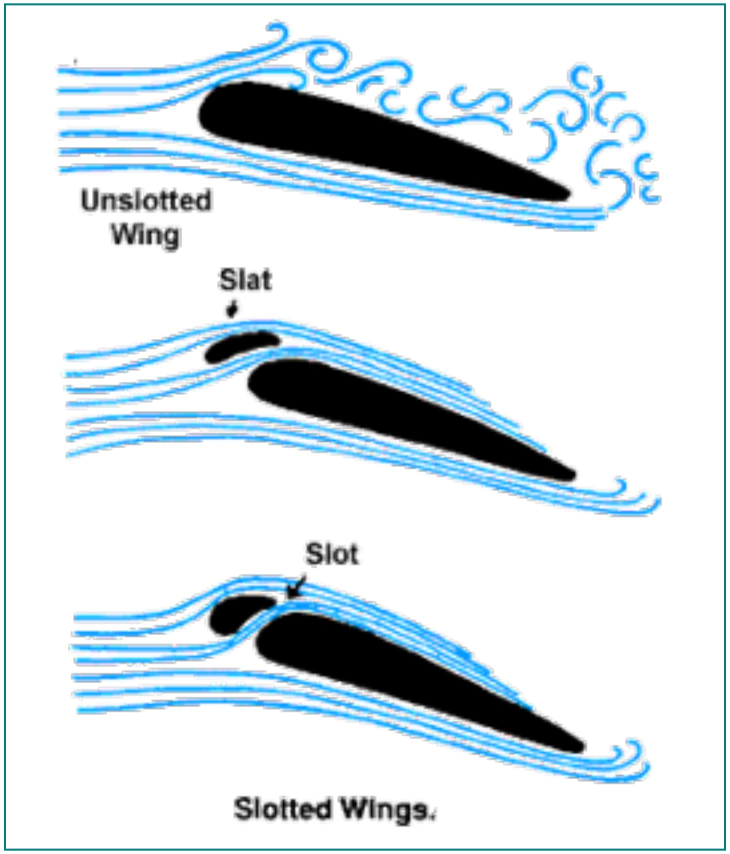

Basic section
Slotted flap
Plain flap
Fowler flap
Split flap
Slotted Fowler flap

FLAPS

- Flaps increase lift, but
- Flaps do increase drag, too.

SLATS

- **Slats are auxiliary airfoils fitted to the leading edge of the wing**. At high angles of attack, they can be moved out ahead of the wing. The angle of attack of the slat being less than that of the mainplane, there is a smooth airflow over the slat which tends to smooth out the vortex forming over the wing.
- Slots are passageways built into the wing at short distance from the leading edge in such a way that, at high angles of attack, the air flows through the slot and over the wing, tending to smooth out the turbulence due to vortex.



Effect of Flaps and Slats on Aerodynamic Performanc

Airfoil/wing :

- is optimised for cruise configuration (low angle of attack).

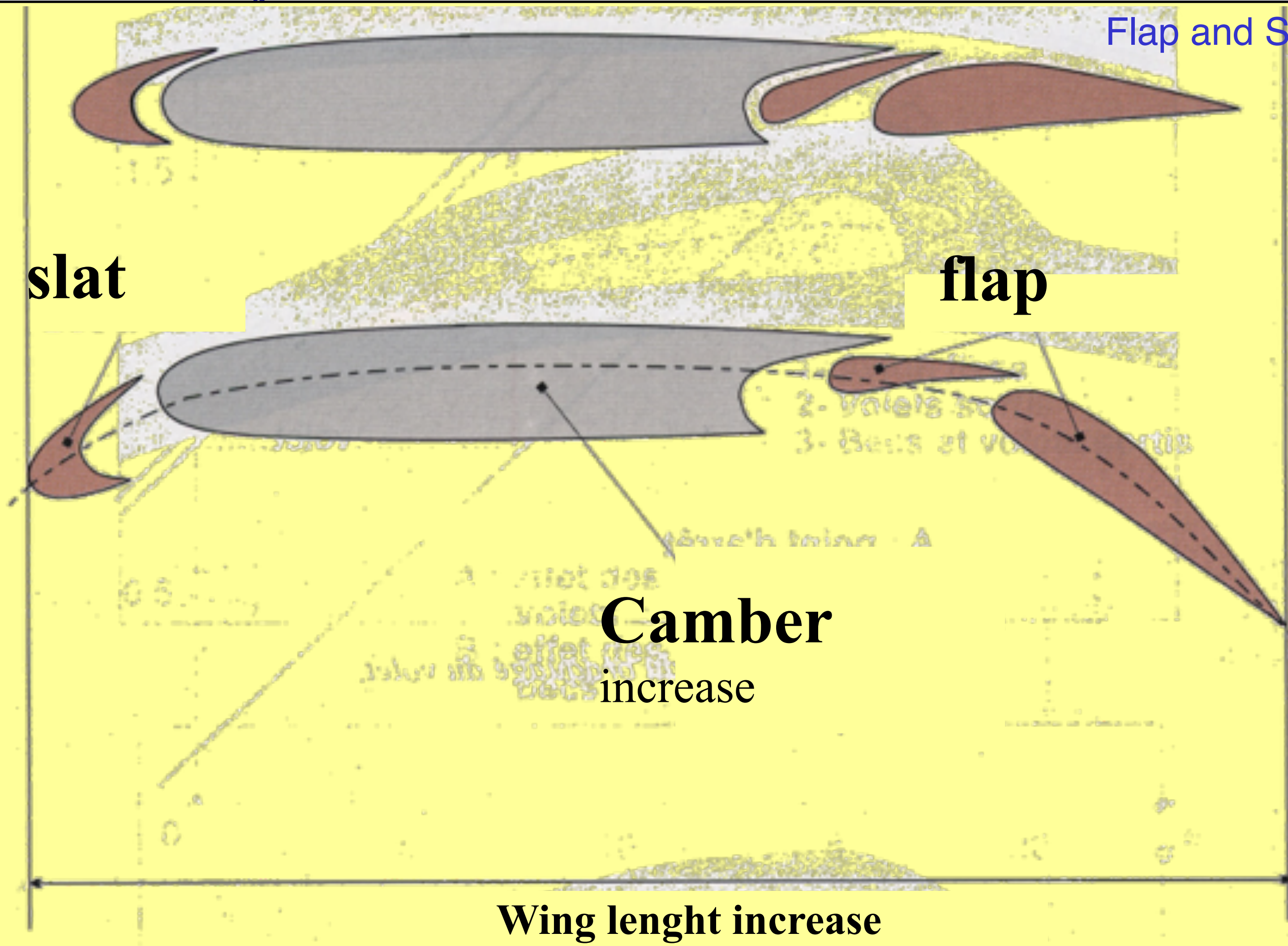
Flap :

- increase lift force for high angle of attack
  (take off and landing)

Slat :

- delayes stall configuration

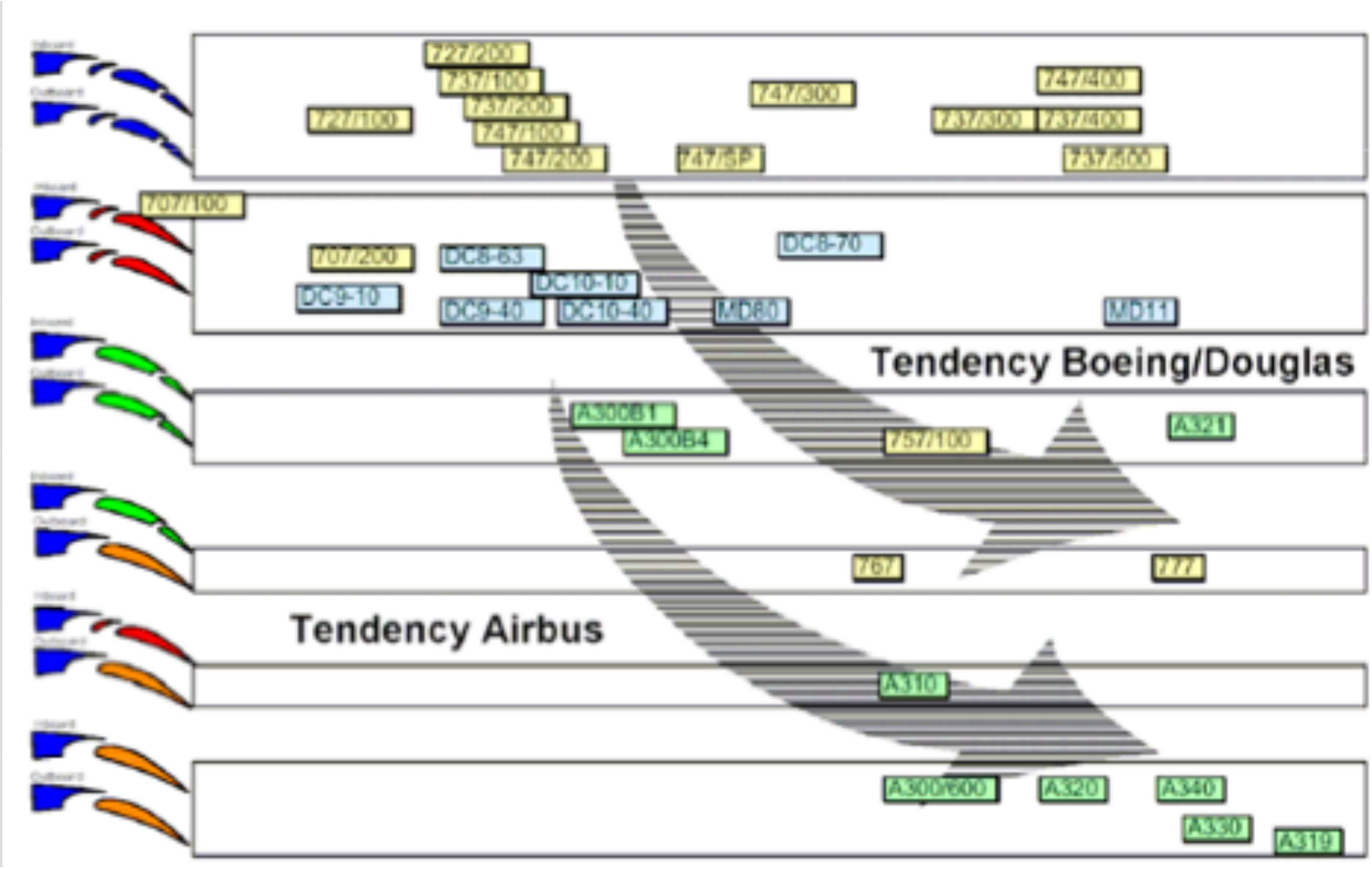
Flap and Slat effect



7-1 High lift systems architecture

- The permanent increasing requirements for wings in the high speed and in the low speed domain leads to the development of contradictory requirements for the wing design. One common wing design can not cover the full range if requirements. Therefore configuration changes are needed to cover both.
- The increase of cruise speed was accomplished by wing sweep and airfoil optimization; further performance optimizations also lead to increased wing loading.
- More powerful high lift devices were required.
- Wing trailing edge devices evolved from plan flaps to Fowler flaps with single, double, and even triple slots. The complexity of high lift systems was reached with the Boeing B747 design, which has triple slotted flaps. Since then the tendency in high lift system development has been to achieve high level of lift with simpler devices and optimized actuation systems in order to reduce complexity and therewith weight and maintenance costs

Evolution of high lift systems



B747 Flaps

A 330/340 Flaps


COPYRIGHT EMIL ALMESTAD
AIRLINERS.NET


DHL

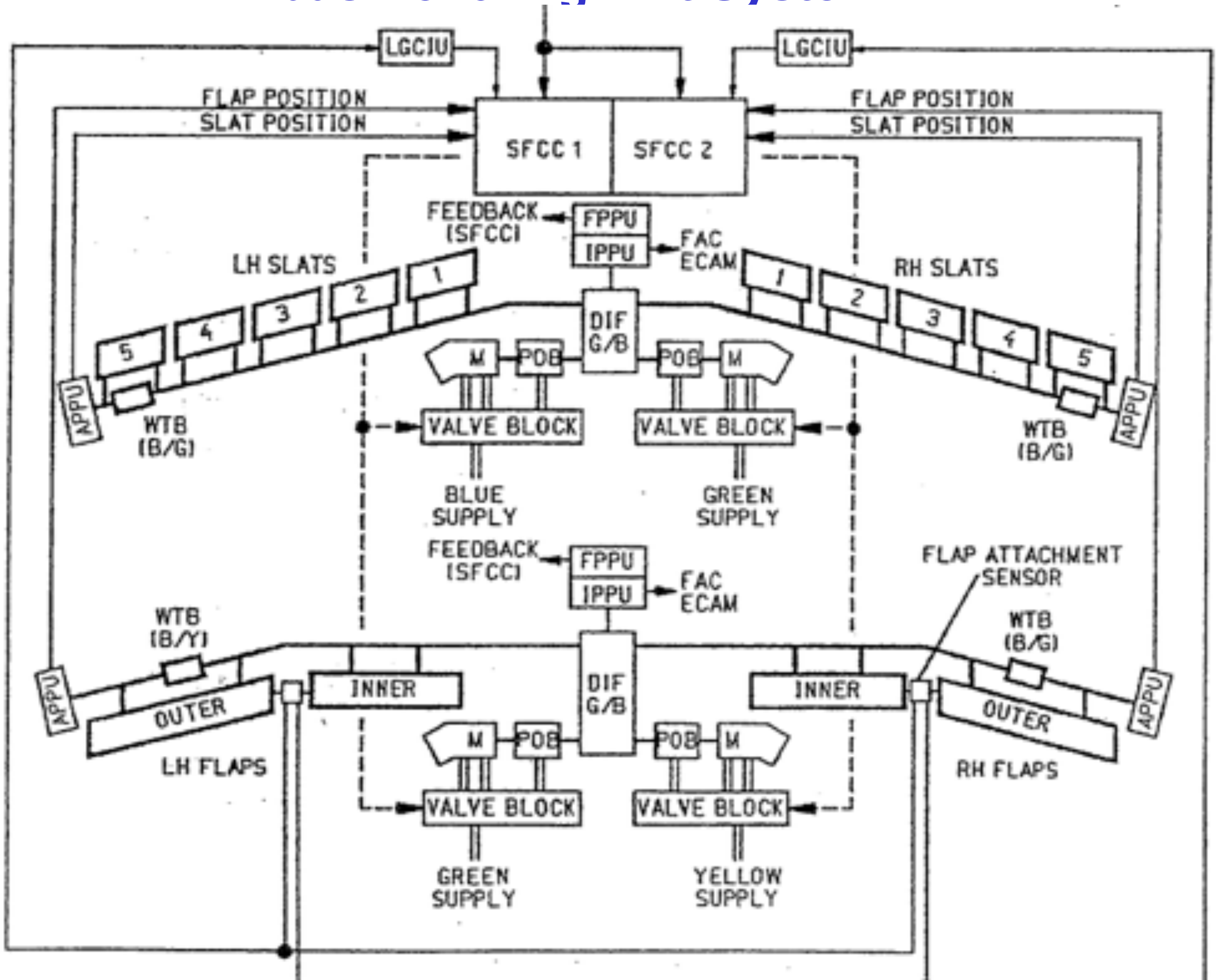
A system description of a High lift system

- State-of-the-art high lift actuation systems predominantly consist of
  - Mechanical or by wire command systems.
  - synchronised hydraulic motors with common control valves, (electrical motor as back up)
  - a mechanical transmission shaft
  - rotary or ballscrew actuators
- These architectures assure a synchronous deployment of all flap and respectively slat panels but prohibits functional flexibility.

STATE-OF-THE-ART HIGH LIFT ACTUATION SYSTEMS

- As an example the A320 flap actuation system will be shown.
- The central hydraulic power control unit (PCU) supplies the power necessary to operate the flap panels on each wing.
- A mechanical transmission shaft transmits the mechanical power to rotary actuators, which move the flaps on the tracks.
- This power transmission system consists of
  - Torque shafts (Steel, Carbon)elements
  - gearboxes necessary for larger geometrical direction changes as well as
  - universal joints, plunging joints and spline joints to accommodate wing bending and temperature effects.
- Integrated in the shaft system are essential equipment like
  - System torque limiters,
  - Brakes,
  - Position sensors

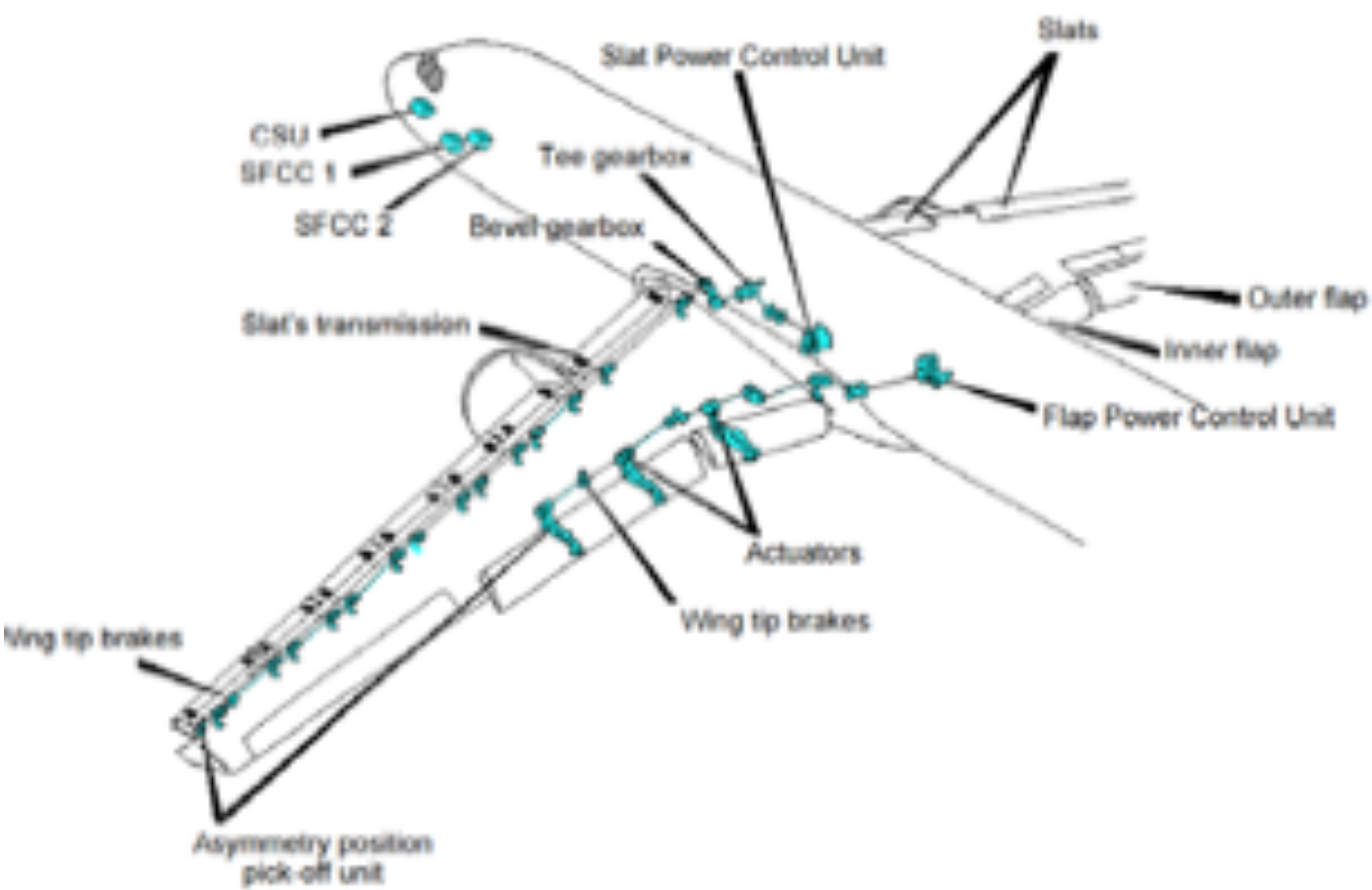
Airbus A320 High lift System



STATE-OF-THE-ART HIGH LIFT ACTUATION SYSTEMS

- The transmission system of each wing has 4 drive stations. The inboard flap has two drive stations and the outboard flap has two .
  - number of drive station is determined by failercase (loss of surface smaller than 10 minus 9
- Each drive station consists of a rotary actuator with an integrated output leaver
- An interconnection strut connects the inner flap to the outer flap on each wing and acts as an alternative load path in the event of a drive link disconnect in the drive stations 1 (inboard), 2 and 3.
- The high lift system is controlled and monitored by two slat flap control computers (SFCC) using sensor information from several analogue and discrete sensors.
- The mechanical transmission shaft assures synchronous deployment of all flap panels

A320 high lift actuation system installation



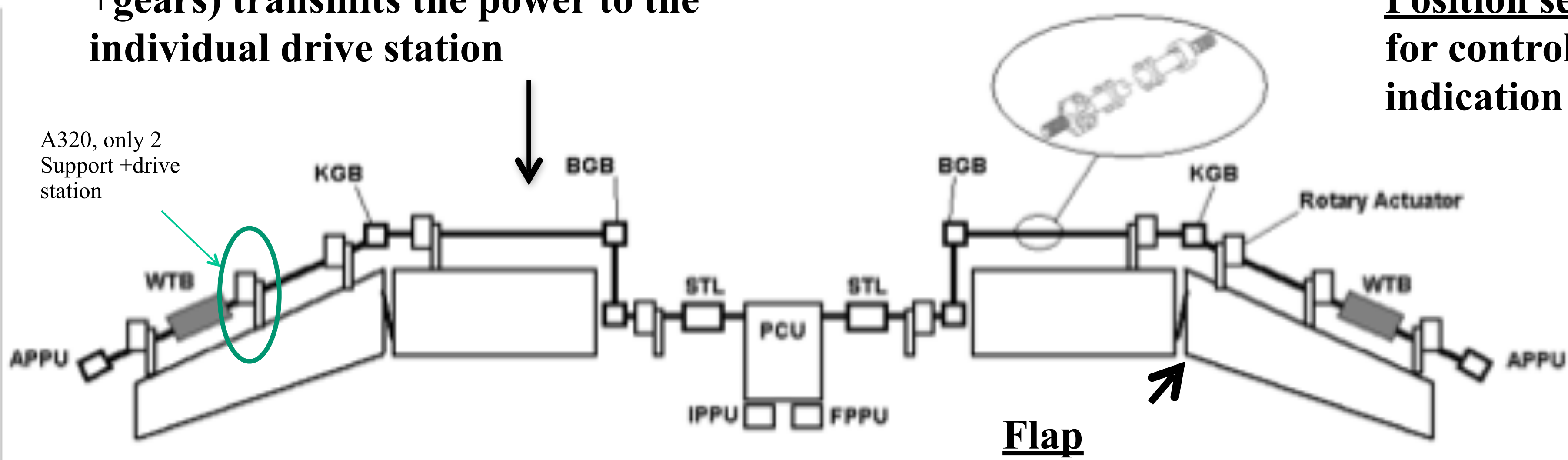
Principal of a Flap actuation system, (Example A330)

Mechanical actuator (screw or rotary type) actuate the surface

A transmission system (torque shafts +gears) transmits the power to the individual drive station

Position sensors for control and indication

A320, only 2 Support +drive station



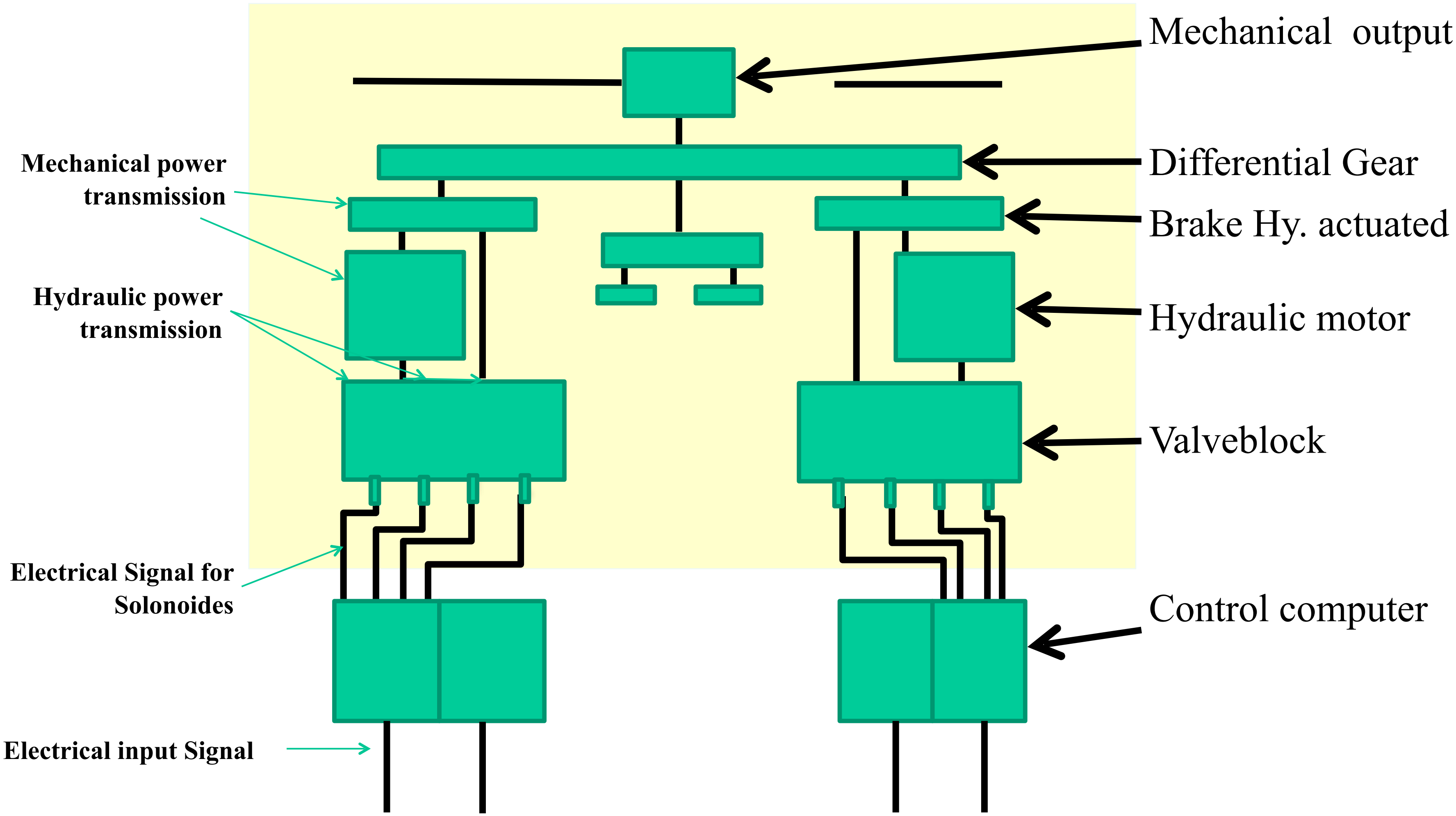
Flap inteconnection

Torque limiter and brakes protect the system against failure

The Power control unit provides and control the power

ACTUATION FOR FLAPS AND SLATS, THE PCU

Power Control Unit architecture



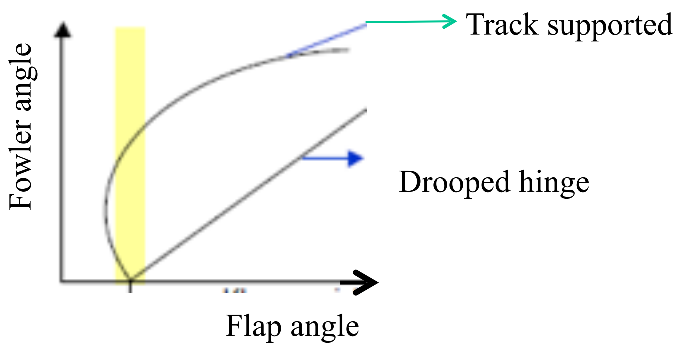
WING TRAILING EDGE DEVICES (CALLED FLAPS)

Functional requirements

- Airfoil configuration
  - Single slot
  - Double slot
- Aerodynamic Performance
  - Fowler for take of (High lift increase)
  - Large Angle for landing (High lift+drag increase
  - Limit AOA for landing
- System complexity

Aero requirements

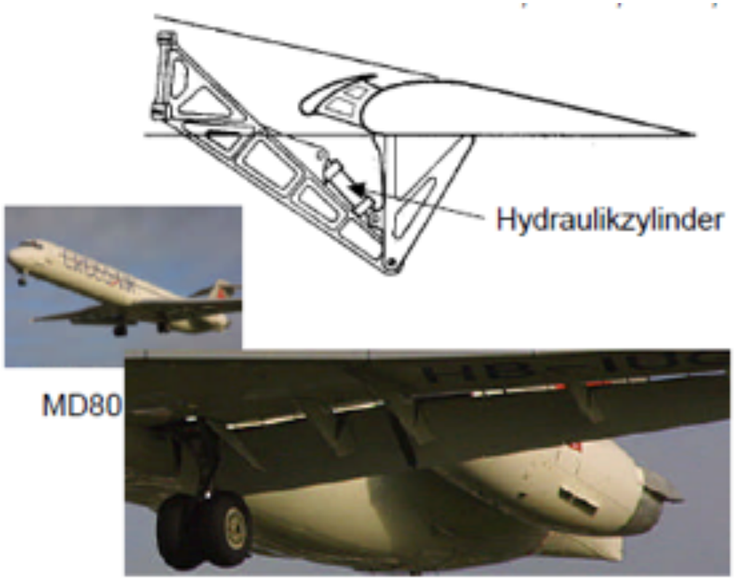
- Track supported flaps allow optimisation of fowler
- Drooped hinge system allow big flap angle

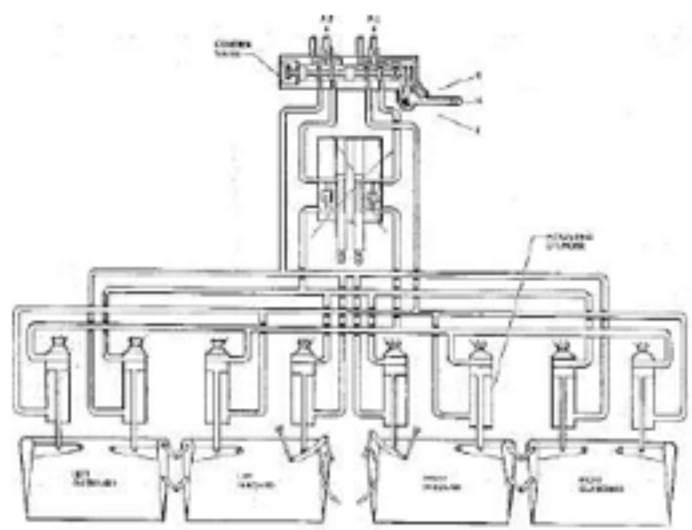


HOW TO ATTACH AND MOVE A MOVABLE SURFACE ON A WING?

Flap Wing attachment system examples

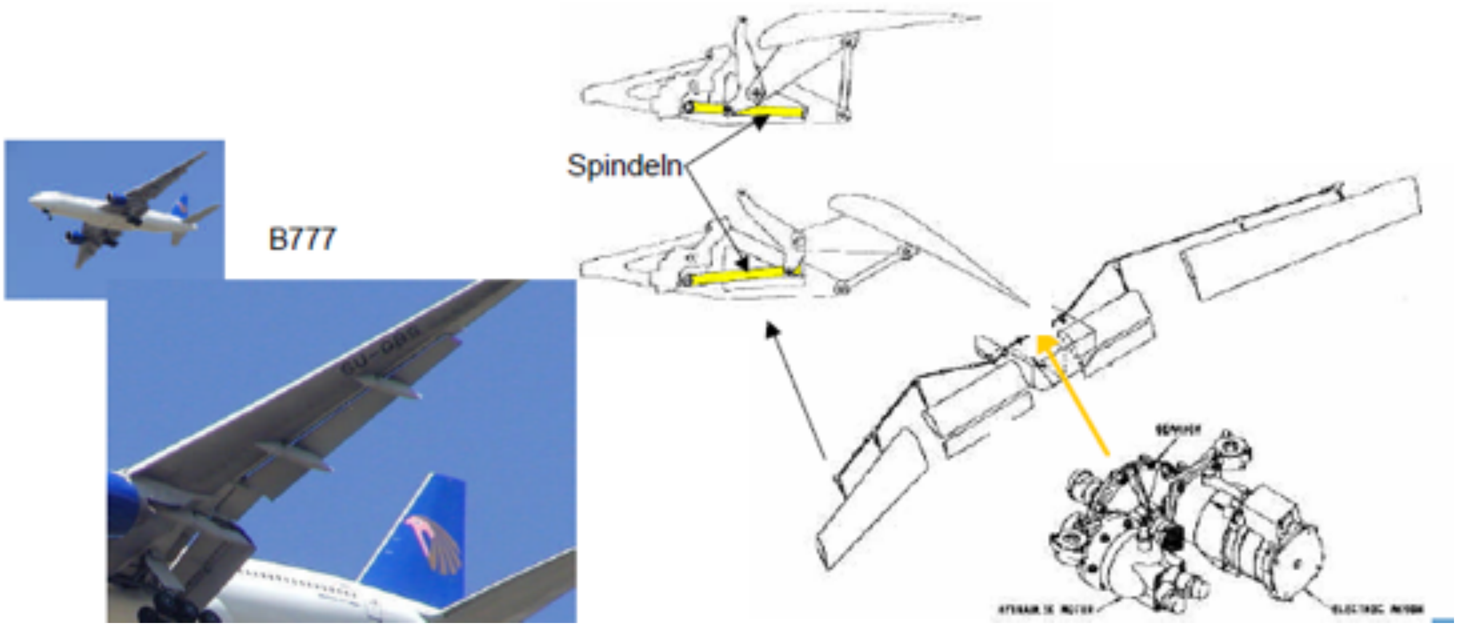
- **Drooped hinge**
    - Simple solution with limited Aero performance
    - Actuated via hydraulic actuators or screw jacks
    - Typical solution for MD aircraft





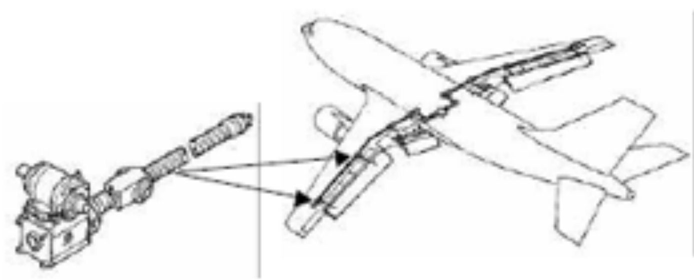
4 Bar Linkage System

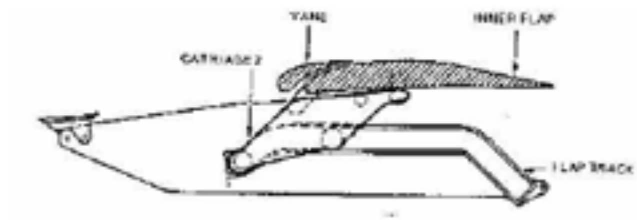
- Design principal allows addaption to individual performance requirements
- High aerodynamic performence
- Actuation by screw jack or rotary actuator
- Complex and costly system, high maintenance efforts requirred



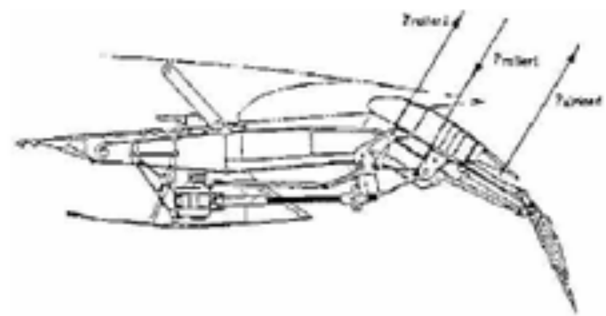
Curved Flap Beam (flap track)

- Design principal very flexible to fulfil aero requirements
- Actuation by screw jacks
- Realised for B727/737,747 , A300, 310, RJ70
- Medium Complexity, Production cost and maintenance



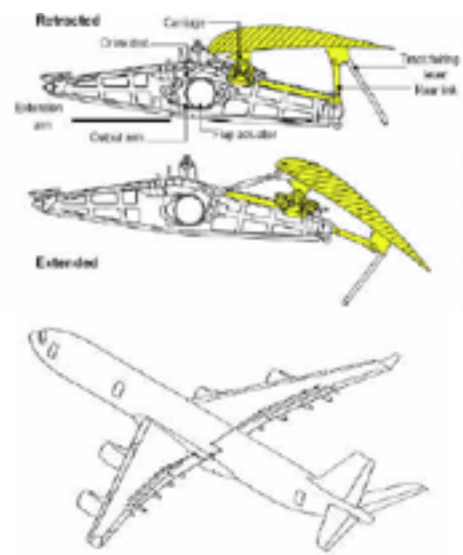


A310



Strait support Beam (Flap track)

Good aero performance,
Simple design, (relative to linkage solution)
Lower cost, lower maintenance effort
Realised for A320, A330, A380......



Link/track mechanisms-

The link/track flap mechanism, with it low overturning moment from the flap loads creates a couple between the roller carriage and the front link or aft link and drive rod. This setup reduces roller loads and provides good roller track wear characteristics .

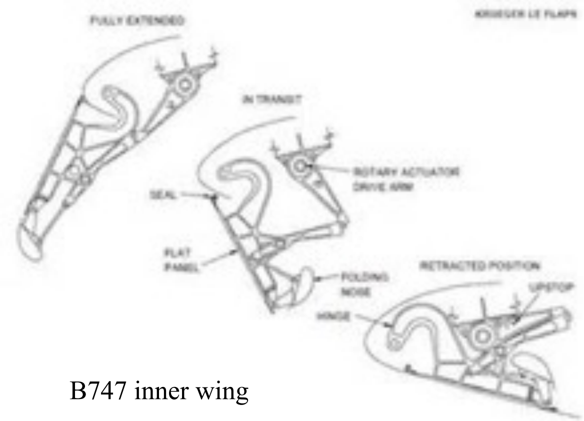
Airbus is using two of these concepts on the Airbus A320/321 and A330/340 airplanes.

- Airbus A320 flaps use an upside-down forward link in conjunction with **a** straight track on **a** fixed structure as aft support . The motion of this mechanism is very favorable for:
  - Fowler motion at lower takeoff flap angles and requires very low actuation power.
  - In addition, the mechanism is adaptable to stream wise conical motion.

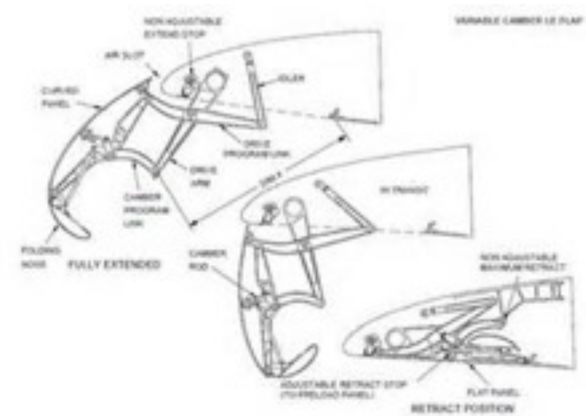
WING LEADING EDGE DEVICES (CALLED SLATS)

Krueger Flap

- Used for inner wing application (B747 full wing)
- Actuated by screw jacks, rotary actuator, hydraulic ,



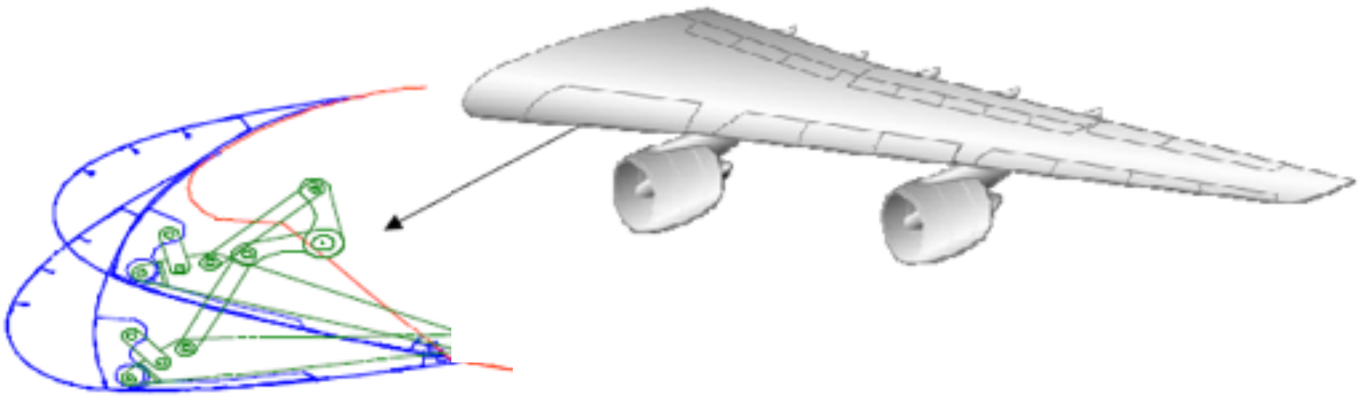
B747 inner wing



B747 mid and outer wing wing

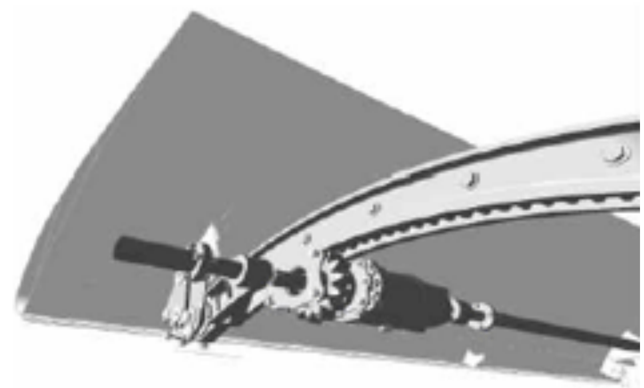
Droop nose

- Applied for the A380 inner wing
- Actuated by rotary achtuator



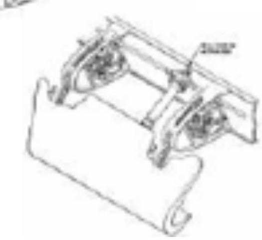
Slat supported by curved moving Tracks

- Simple design solution
- Design principal flexible for aero requirements
- Actuated by many means depending on aircraft typ



Actuated by hydraulic
B727, B737 (outer W)

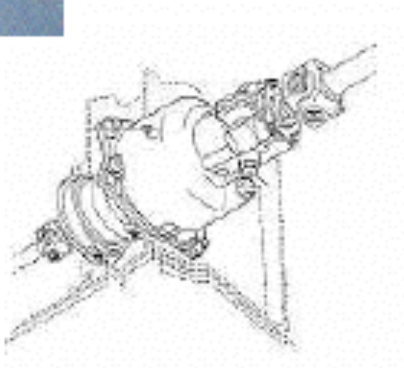
Actuated by Rotary A
A320, A330, ...



Actuated by scrw jack
L1011, A300, A310

Actuators

- Typical design for wing leading edge devises (Slats, Droop nose)

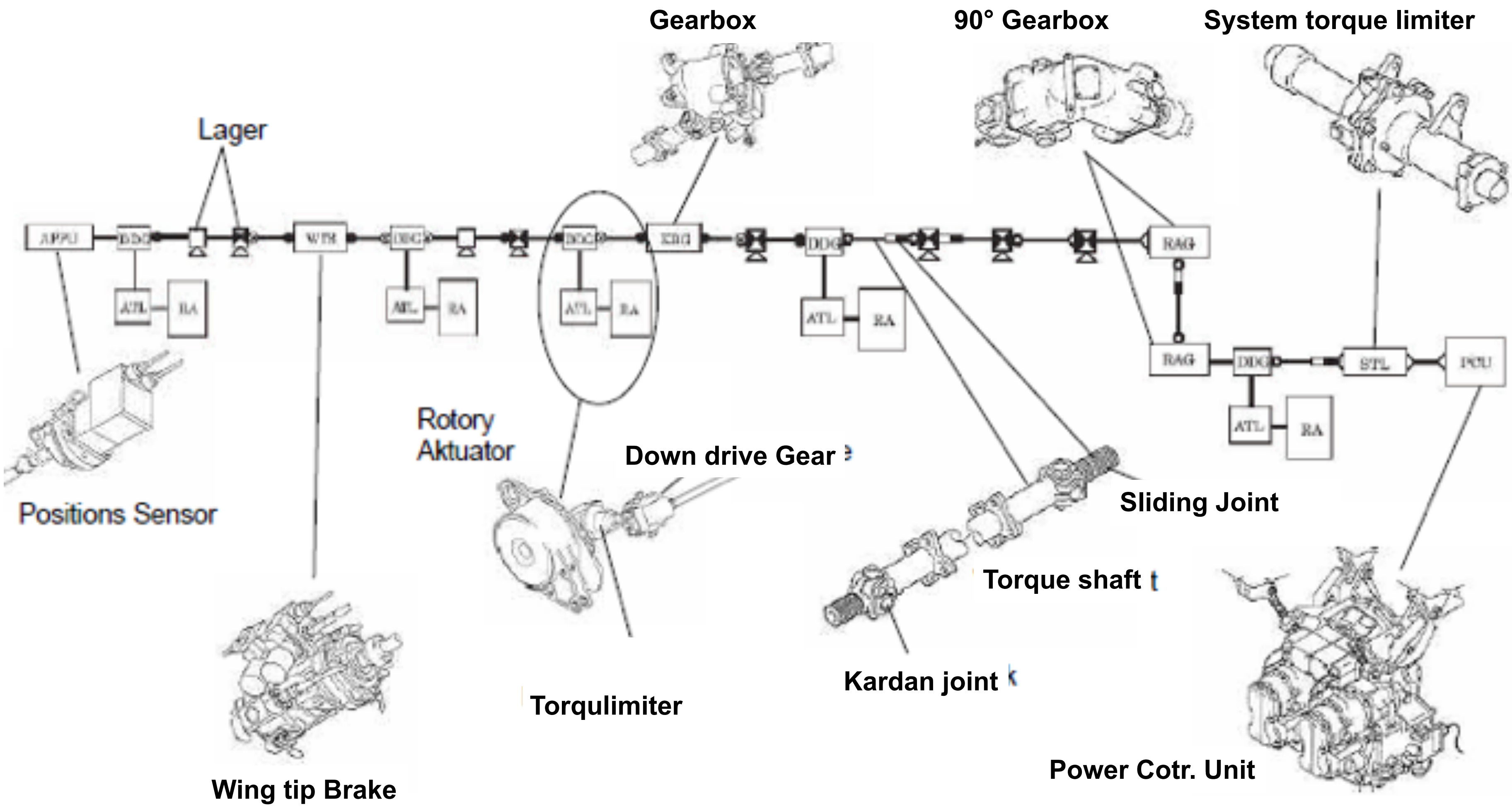


- Typical design for wing trailing edge devices (Flaps)

Why a torque shaft system?

- Centrally powered and synchronized actuation systems use screw jacks, rotary hinges, rotary actuators, or rack and pinion drives as actuators.
- The shaft drive system has become the one most frequently used for trailing-edge and leading-edge flaps because it is the surest and safest way to synchronize flap deployment Figure
- Such a system has been used on the trailing-edge flaps on all Airbus airplanes. (and a large number of other AC)
- A similar drive system has been used for leading-edge actuation on all Airbus airplanes. And other manufacturer also)
- The synchronizing nature of the shafts, the high reduction ratios of the gearboxes make the system self-locking.
- Shafting is generally designed to withstand jam failures.
- Brakes or no-backs and symmetry-sensing devices are redundant safety features.
- This way to actuate flape and slats is the safest one against asymmetric and passive failures. Dual motors on PDUs guarantee functional reliability on demand.

Power Transmission system

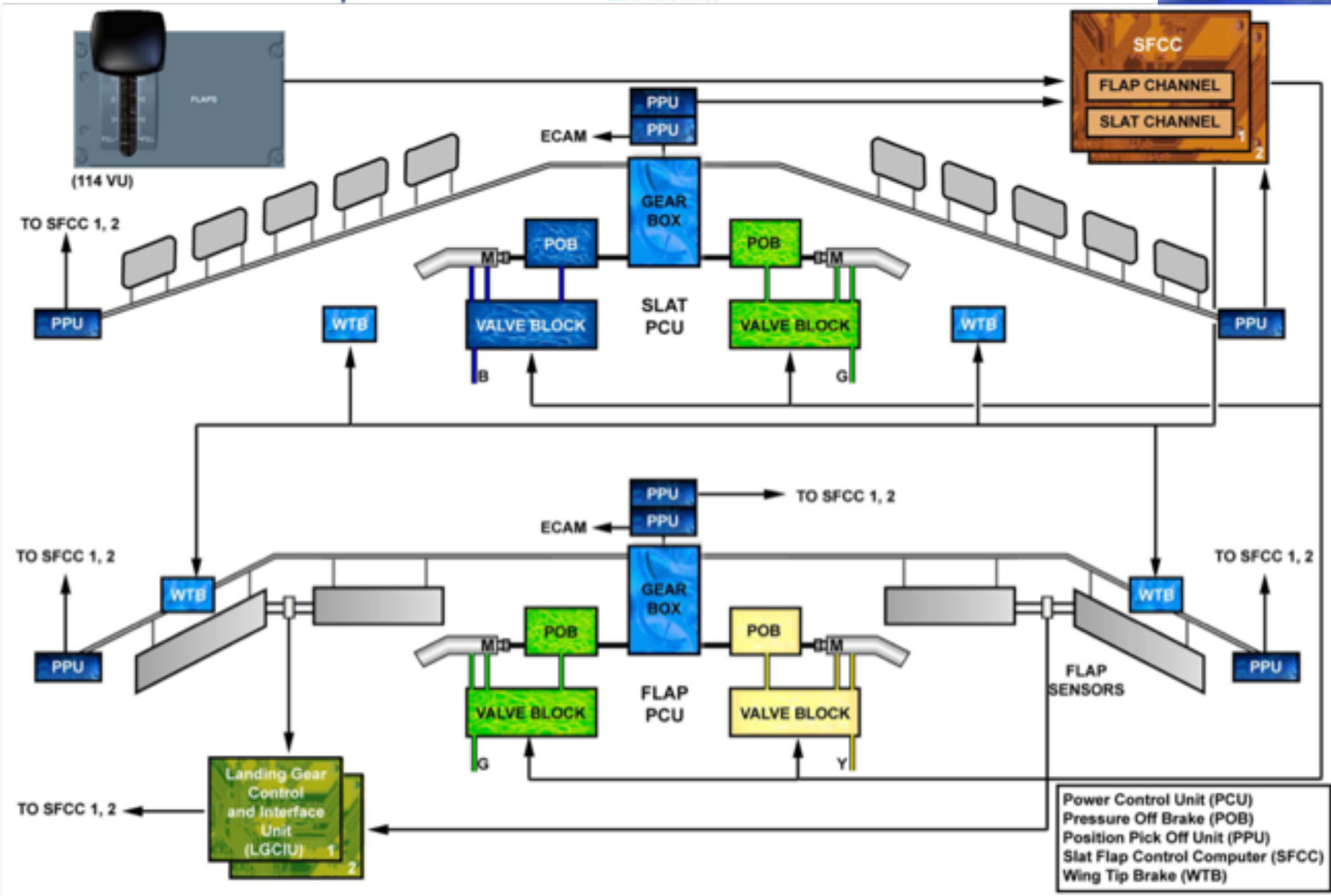


Requirements

- As part of the secondary flight control, the high-lift drive system has to be:
  - fault-tolerant and
  - fulfill high requirements regarding the reliability.
  - While the power drive unit and the slat flap control computer are of redundant design, the shaft transmission system offers a single load path only.
  - Sufficient mechanical strength of all elements in the actuation system is required for all possible system states.
  - Peak loads occurring as a result of a system failure are often a design case for the mechanical components of the drive system. Thus, the analysis of transient system behavior is of uttermost importance for the determination of strength requirements for the drive train's mechanical elements.
  - As aerospace applications require certified system and components compliant to part 25

A real system

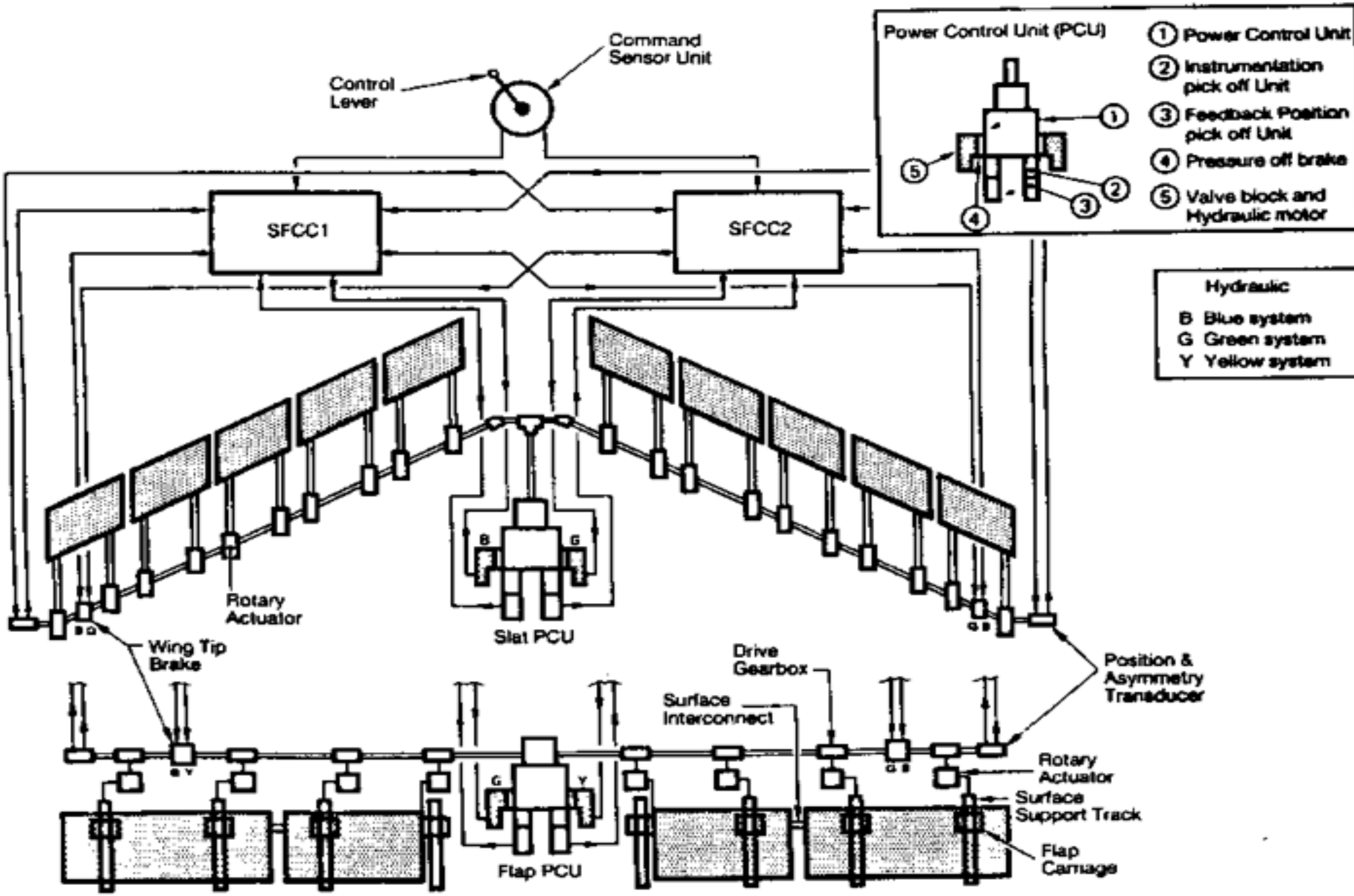
- Again A320 as and example



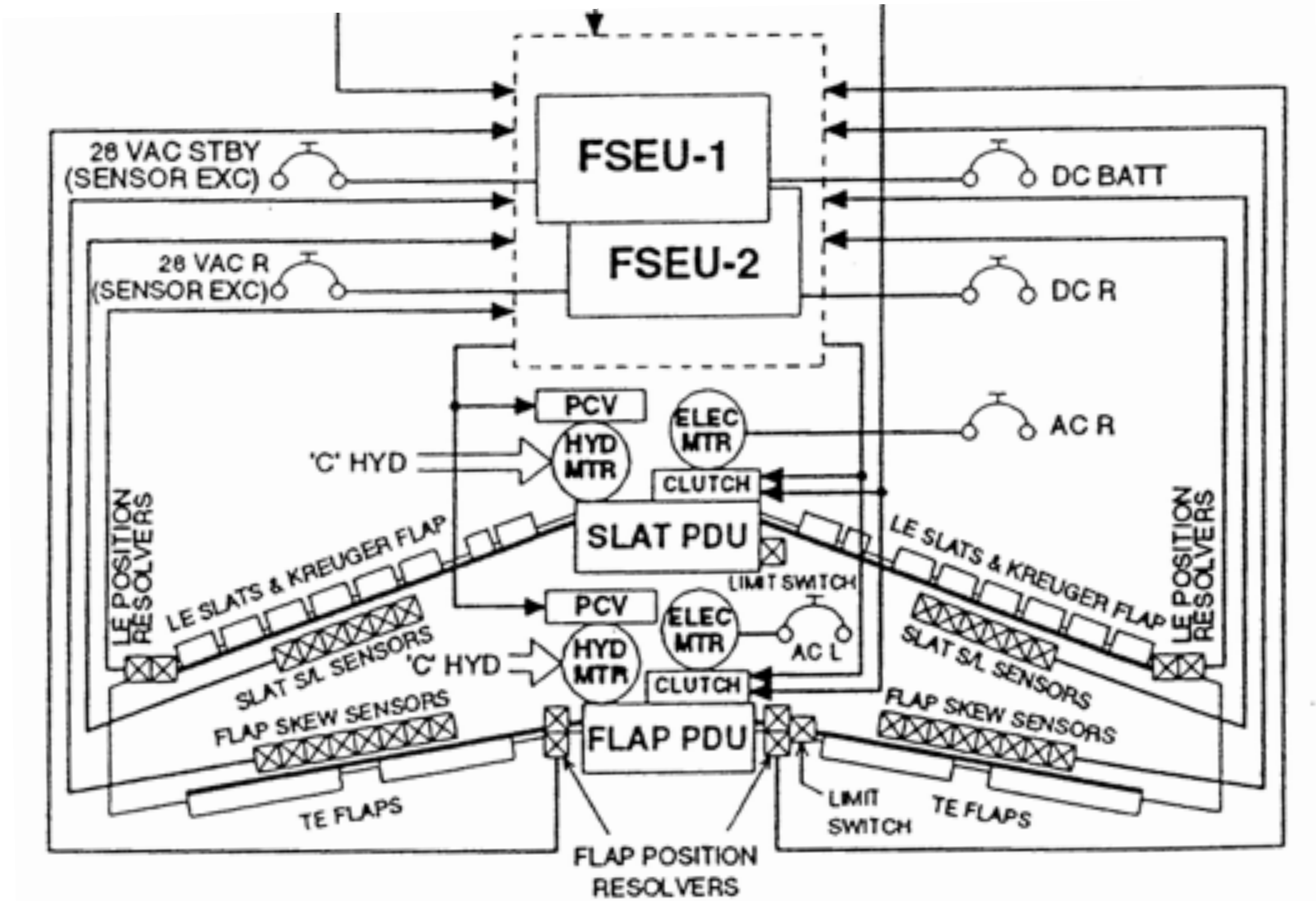
SLAT AND FLAP SYSTEM

- End of session , thanks
- Questions?

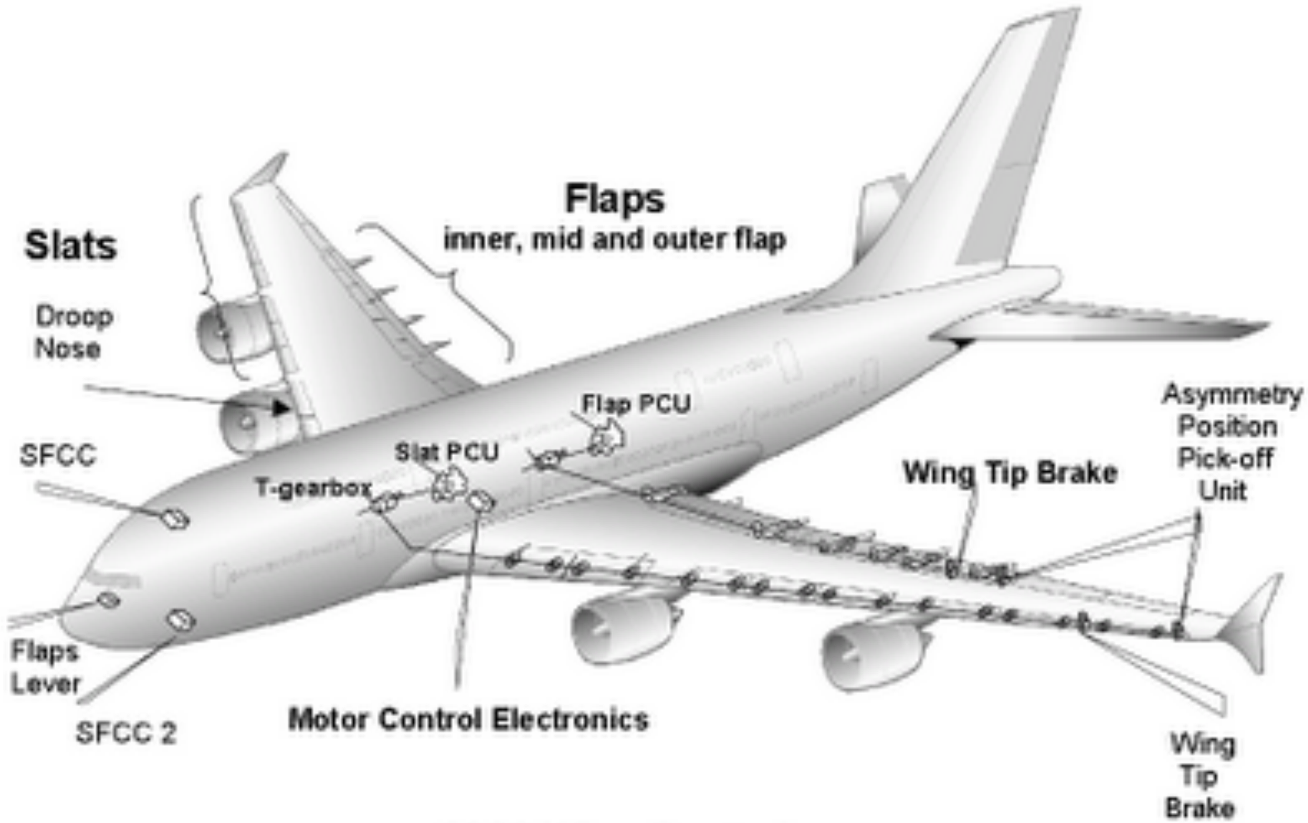
- Back up material
- Other Aircraft sysems
- Equipment details
- Test rig


Command
Sensor Unit
Control
Lever
Power Control Unit (PCU)
1 Power Control Unit
2 Instrumentation pick off Unit
3 Feedback Position pick off Unit
4 Pressure off brake
5 Valve block and Hydraulic motor
SFCC1
SFCC2
Hydraulic
B Blue system
G Green system
Y Yellow system
B
G
Rotary
Actuator
Slat PCU
Wing Tip
Brake
Drive
Gearbox
Surface
Interconnect
Position &
Asymmetry
Transducer
G
Y
Rotary
Actuator
Surface
Support Track
Flap
Carriage
Flap PCU

B777 high lift system architecture



A380 high lift architecture



A380 Wing Controls

A380 Flap Track structural Test (photo IMA)