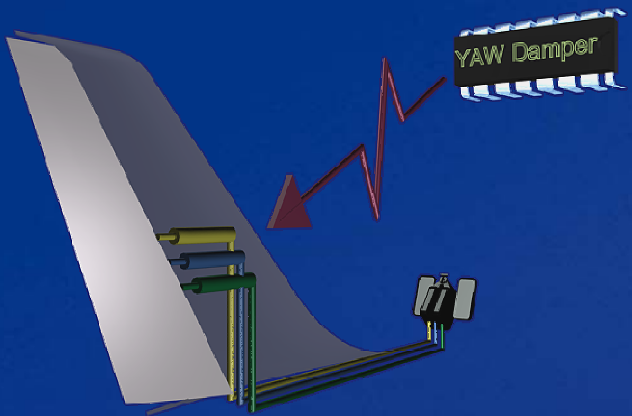
RUDDER and LOADS

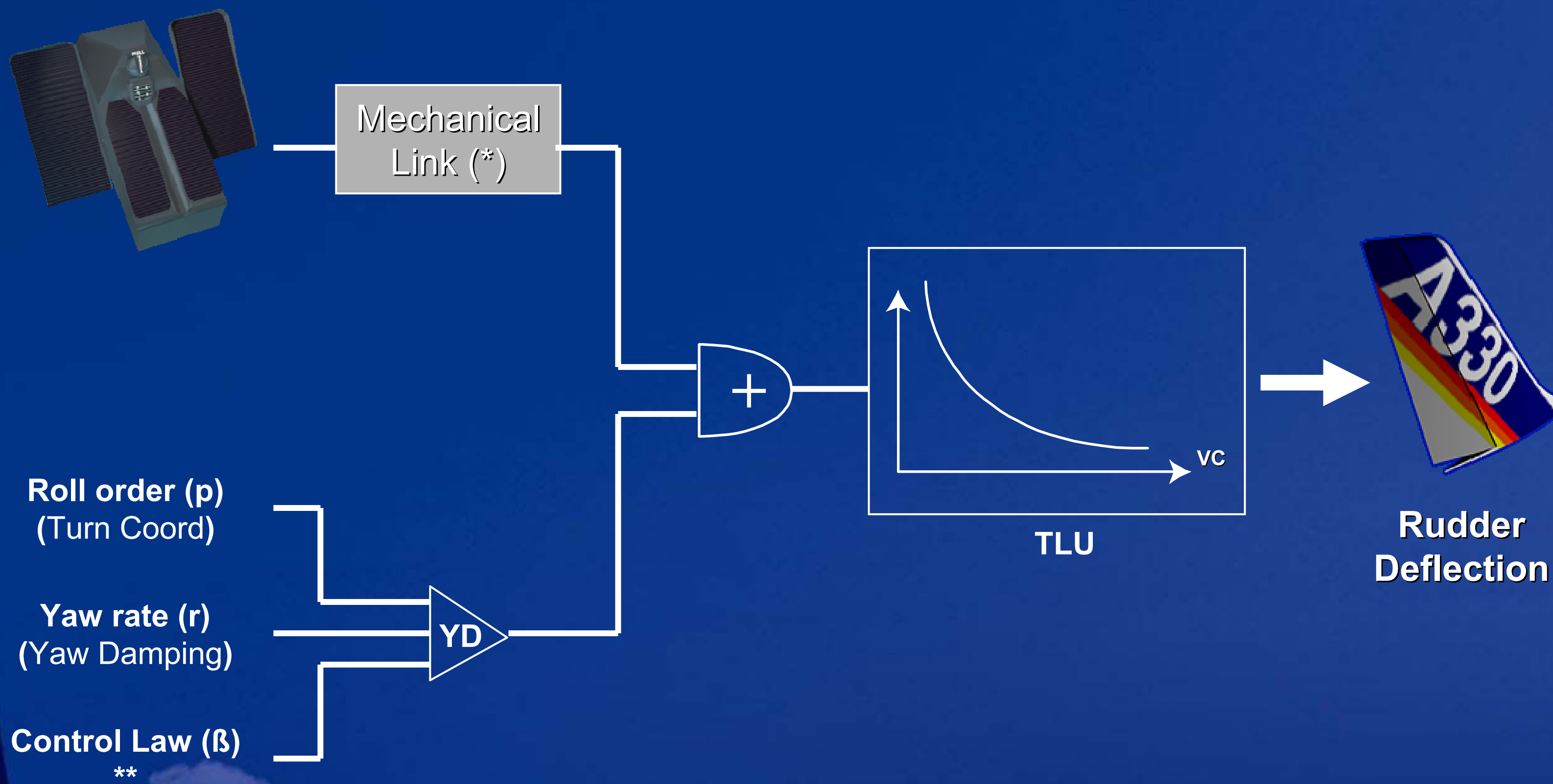
Some Rudder and Yaw Considerations

- The rudder deflection is the sum of:
  - the order from the pedal input
  - the order from the “Yaw Damper” function.



- This deflection is limited by the RTLU (Rudder Travel Limit Unit) for structural considerations.
- The Rudder trim merely moves the pedals.

Some Rudder and Yaw Considerations



* Except on A3456
** on all FBW

Role of the "Yaw Damper" on the A300/A310

- The FAC achieves following Yaw functions:
  - Dutch Roll damping (with high deflection rates)
  - Turn Coordination (minimizes side slip during turn entry/exit)
  - with AP ON, in TO and GA modes, assistance for Engine failure compensation.

Role of the “Yaw Damper” on FBW aircraft: A320

- The “Yaw Damper functions are achieved by the ELAC when handflying the Aircraft:
  - Dutch Roll Damping and Turn Coordination
  - Lateral Control Law objectives

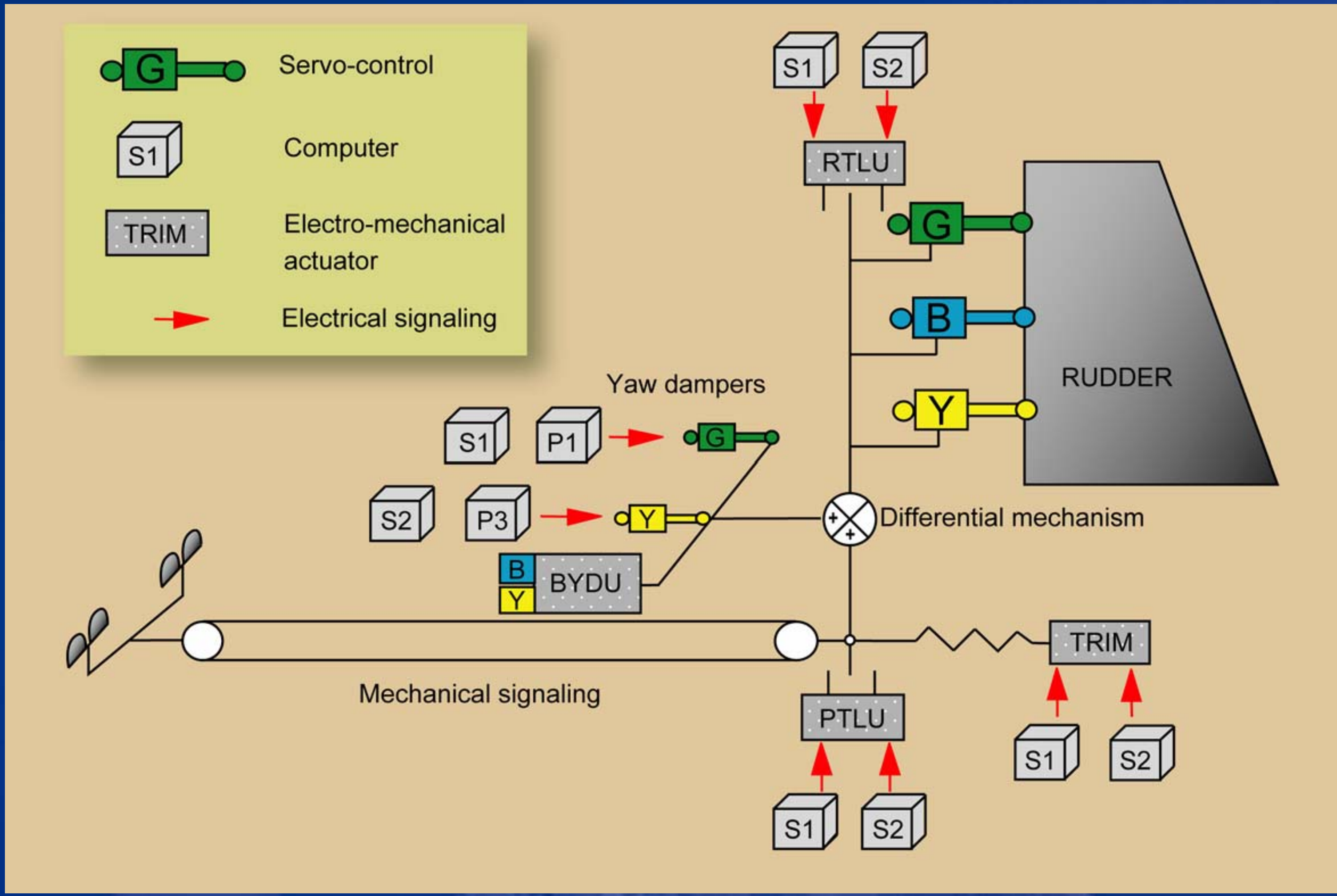
  (eg: ß = f(rudder pedal), engine out …)

- The FAC transmits the ELAC rudder deflection orders to the Y/D actuator and achieves the Rudder Travel Limit function.

Role of the "Yaw Damper" on FBW aircraft: A330 and A340

- The "Yaw Damper function is actually part of the Lateral Normal Law, as achieved by the PRIM.
- The Lateral Normal Law main objective is to command a Side Slip (ß) as a function of the Rudder Pedal Input.
- It also includes the typical Yaw Damper functions (DR damping and Turn Coordination) and additional ones such as Engine Out Compensation, comfort improvement …
- The SEC's achieve the TLU functions (RTLU, PTLU …)

Electrical rudder A340-300 rudder control architecture

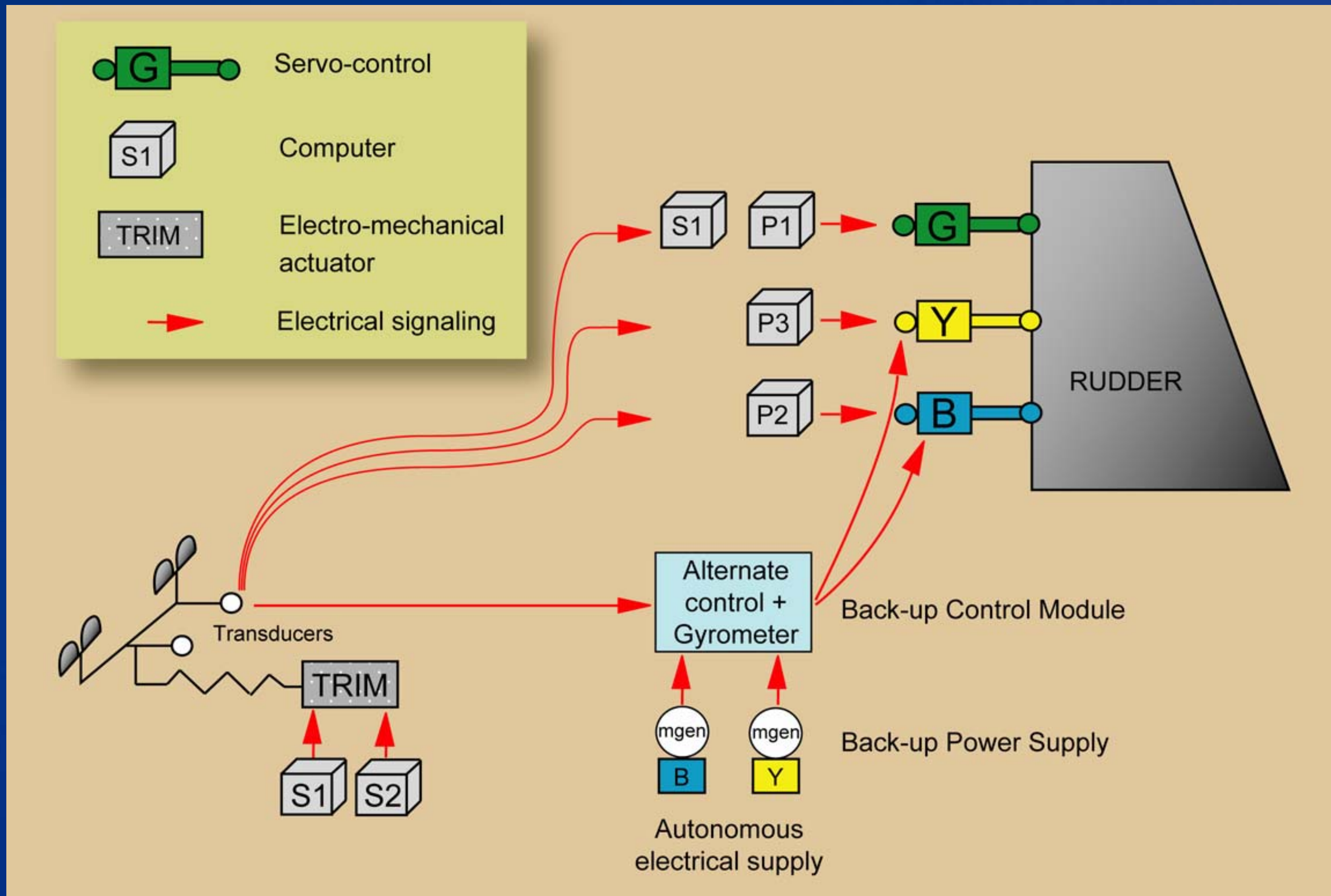


A340-500/600 Rudder Control Architecture

- On the A340-500/600, the Rudder is fully electrical.
- The Lateral Normal Law achieved by the PRIM include all the yaw functions required to properly control the A/C on the yaw axis:

  ß = f(rudder pedal), Engine Out Compensation, D.R. damping, Turn Coordination, Flexible A/C Damping, Rudder Travel Limitation …
- The FBW computers transmit all the resulting orders (including rudder pedals) to the servo actuators.
- The rudder trim moves the rudder pedals, as on all A/C.

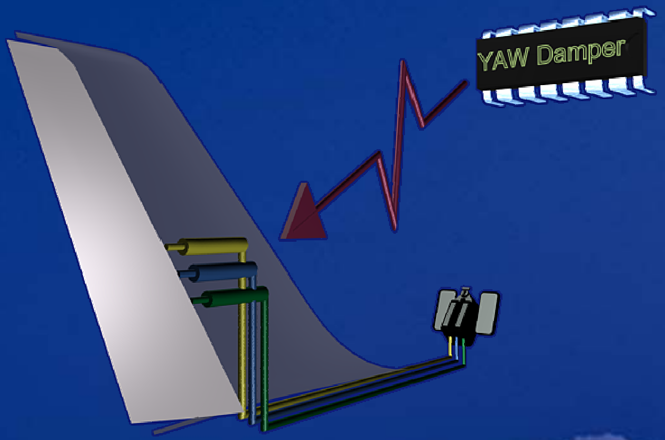
Electrical rudder A340-500/600 rudder control architecture



Some Rudder and Yaw Considerations

As a general rule, the Rudder deflection is:

Rudder deflection = Rudder from pedal input * + Rudder from YD



* either pedal moved directly by pilot, or by rudder trim.

Rudder deflection and Load considerations

- Load Limits definition

  – Limit Loads are those maximum loads expected in "normal" flight envelope

  ➔ *No deformation of the surface occurs*

  – Ultimate Loads are far beyond the limit loads:

  UL = 1.5 LL

  ➔ *No breaking of the surface occurs at least till ultimate loads*

Maneuverability and Controllability Criteria

- Those criteria are defined for Roll and Yaw axis

- When achieving those lateral axis maneuver criteria, limit loads may not be exceeded.

  ➔ *This dimensions the structural design of the surfaces such as the Fin and Rudder*

Roll Maneuver Criteria

- At the “maneuver speed VA” a full deflection of the stick (or yoke) allows to achieve a Roll Rate “p_A”

  At the “design speed VC”, the same Roll Rate “p_A”

  must be achievable (this reduces the deflection of the ailerons/spoilers accordingly)

- At the “diving speed VD”, the deflection of the surfaces must allow to achieve 1/3 “p_A”.

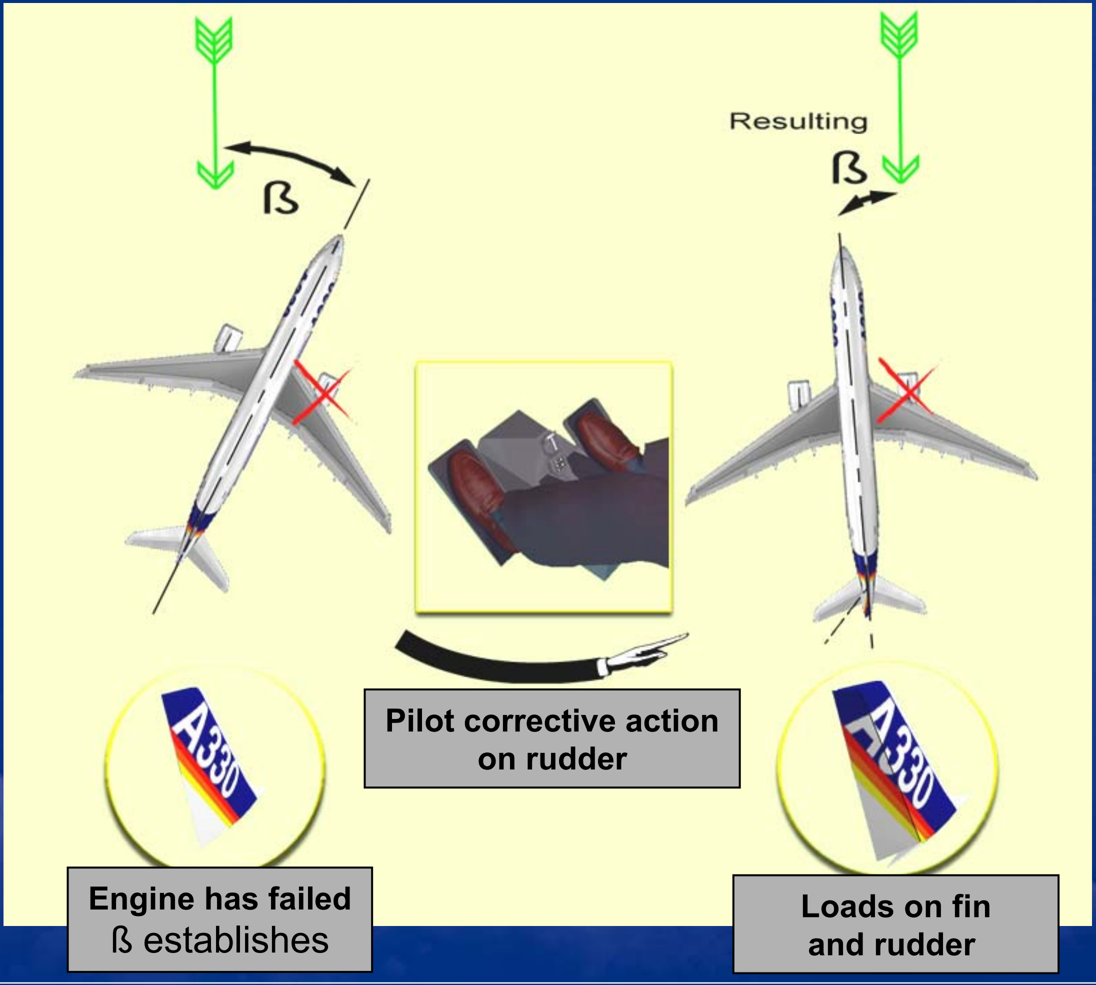
  (Typically VA = 280 kts, VC = VMO, VD = VMO + 35 - FBW)

Yaw Maneuver Criteria

- "*Sudden Pedal Input till pedal stop*" (one way) must be structurally possible from VMCA to VD
- "*Sudden pedal release from full pedal input*" once <u>in steady side slip state</u>, must be structurally possible from VMCA to VD.

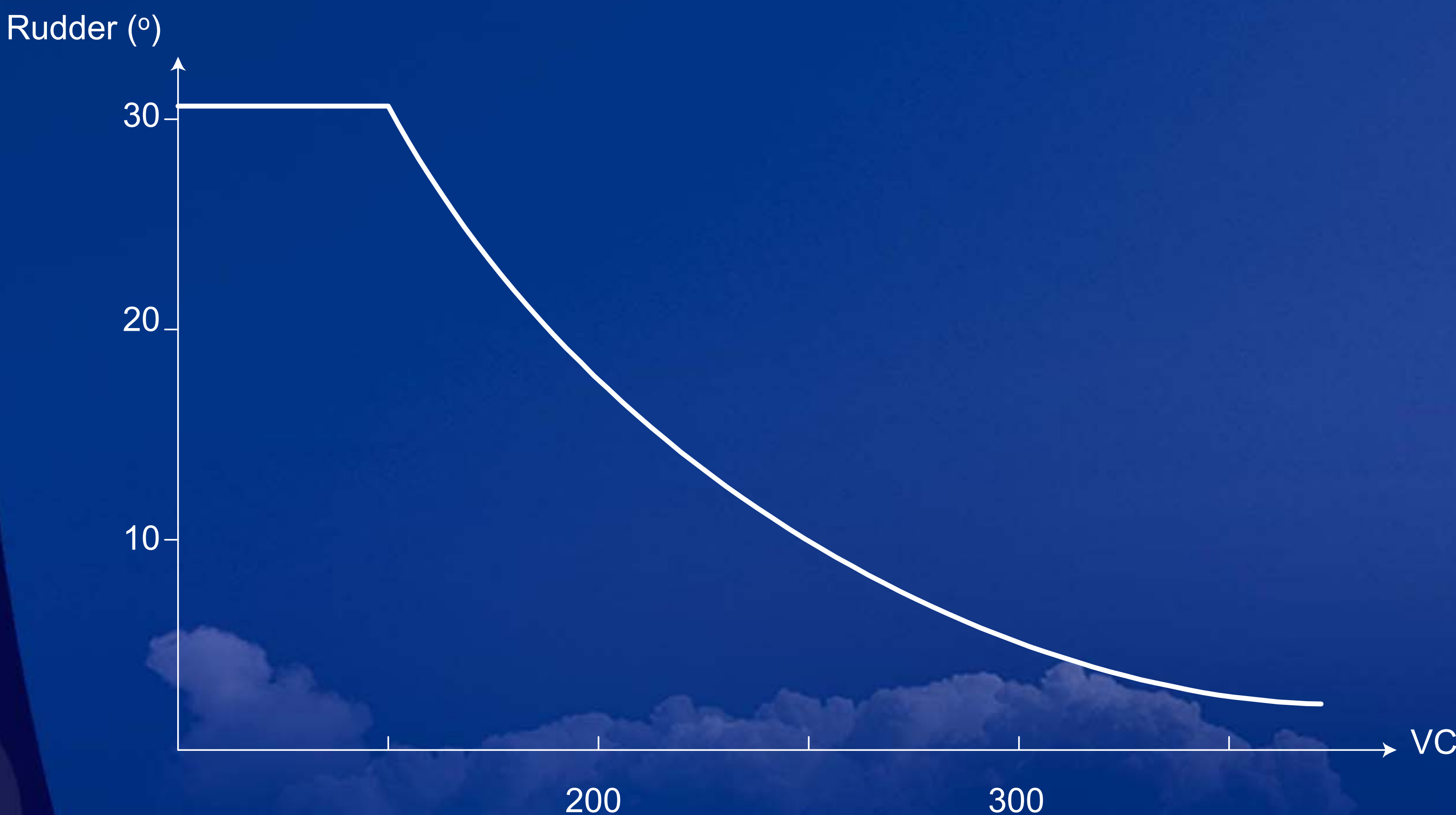
Yaw Maneuver Criteria

- In case of an engine failure, the pedal deflection required for the corrective action from the pilot after 2 sec recognition time must be possible.



Loads and Rudder Travel Limitation Unit

- The role of the RTLU is to limit the loads so as to allow the A/C to fulfill the Yaw Maneuver Criteria.



Loads and Rudder Travel Limitation Unit

- In other words, the structure and the load limits are dimensioned so as to match the yaw maneuver criteria with adequate rudder deflection limited by a judicious RTLU.

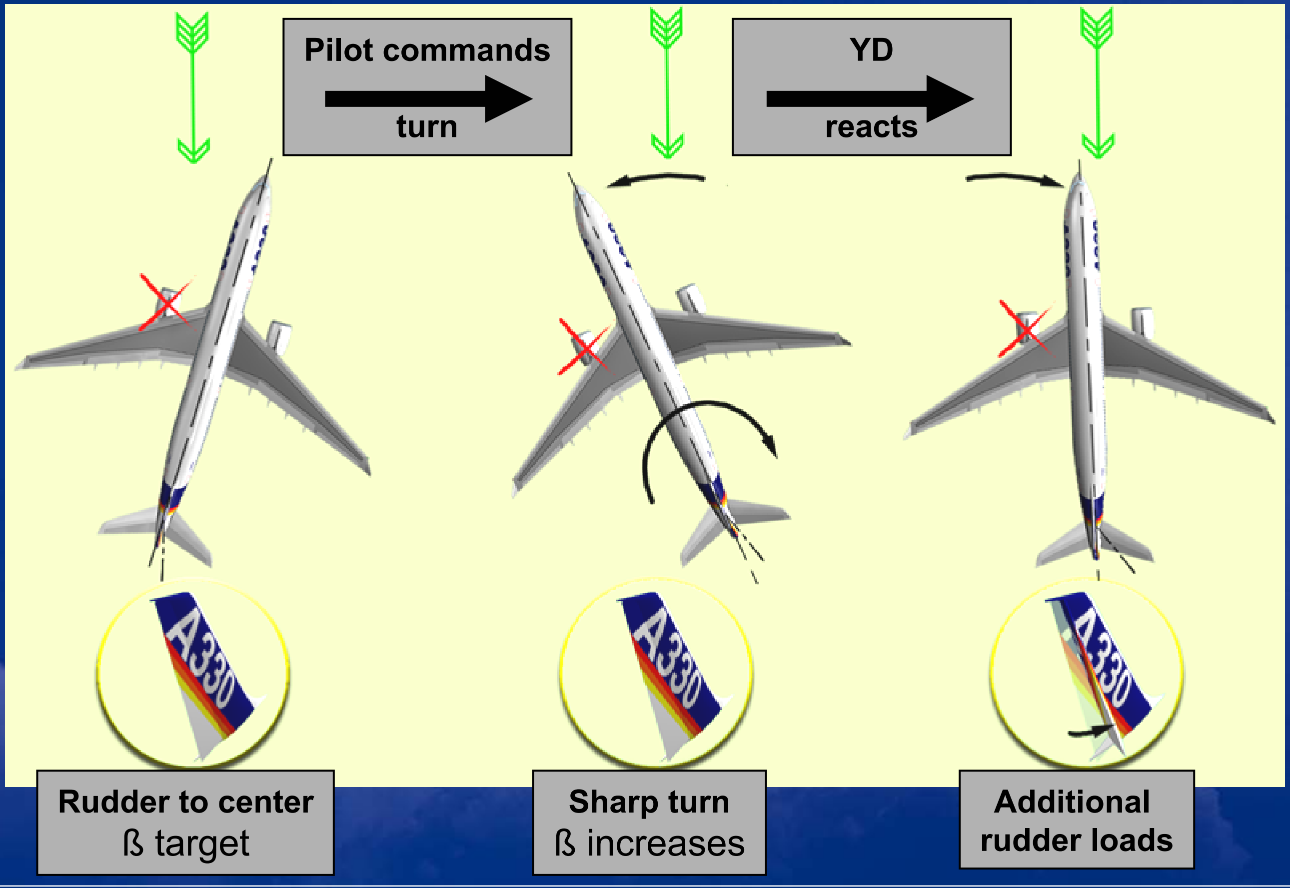
- However, the RTLU is not designed to protect the Rudder Structure for any “unrealistic” action of the pilot on the rudder pedals.

- Finally, the Certification Criteria do not address “all” possible asymmetry cases for load considerations (typically 2 same side engine out configuration on a quad, sharp roll maneuvers with rudder deflected …)

Typical Cases including high loads

- Engine failure case:

If, once the pilot has centered the $ß_{target}$, he then commands a sharp turn unto the live engine, the side slip increases rapidly. Thus the Yaw Damper abruptly reacts, which induces high loads.



Typical Cases including high loads

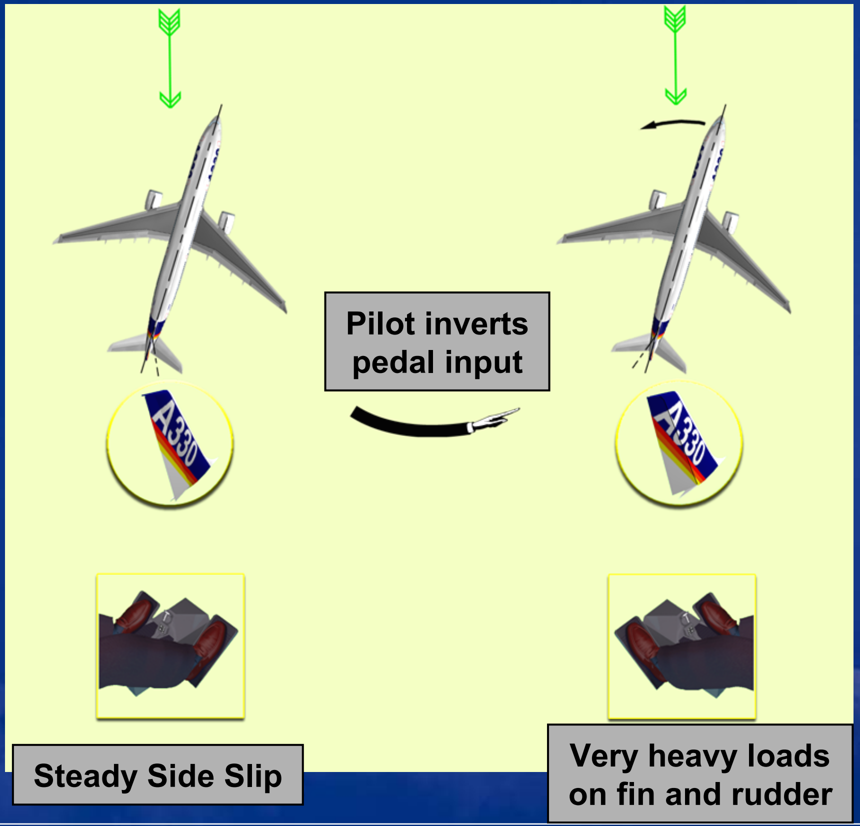
- Engine failure case (cont'd)
  - Be aware that there is no restriction to roll the aircraft with an engine failure (no additional rudder input required)
  - Furthermore with an engine failed, the maximum roll rate is limited to 7.5 ^{o} / sec (on FBW A/C at low speed, typically 160 kts).
  - At VMCA and V2 min, the certification requires to demonstrate adequate roll capability, with full roll input; the maximum ß reached is around 10 ^{o} and loads are Ok.

Typical Cases including high loads

- Rudder Pedal “Doublets”

  If, from a steady side slip state, the rudder is inverted, this induces very high loads on the fin and rudder.

  (The “doublets” technique is no more used during flight tests to induce dutch roll)



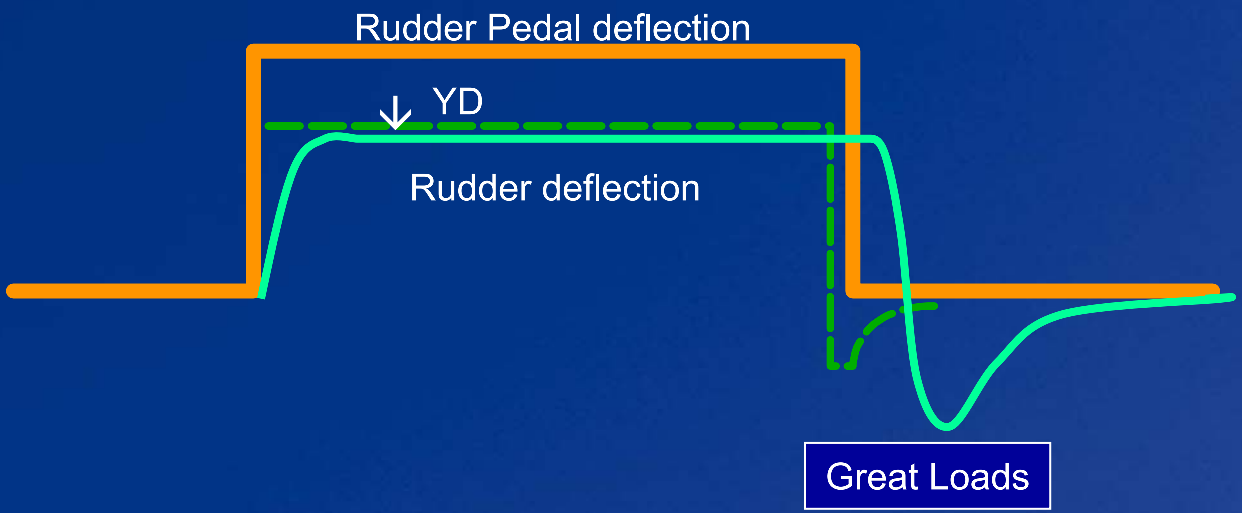
Reason for a PTLU on A330/A340

- The “Yaw Damper” has a great authority in terms of rudder deflection and rudder deflection rate, on A330/A340 as compared to A310/A320 …

- Thus, in case of a steady state side slip maneuver, the Yaw Damper decreases the initial rudder deflection so as to minimize the Side Slip

- The PTLU is the Pedal Travel Limit Unit which limits the pedal deflection as a function of the A/C CAS.

Reason for a PTLU on A330/A340



When the pilot releases the rudder pedals suddenly to neutral, as requested by certification criteria, a peak of high loads can be reached (since the rudder pedal release is equivalent to a mechanical rudder movement of same amplitude) leading to a rudder deflection on opposite side.

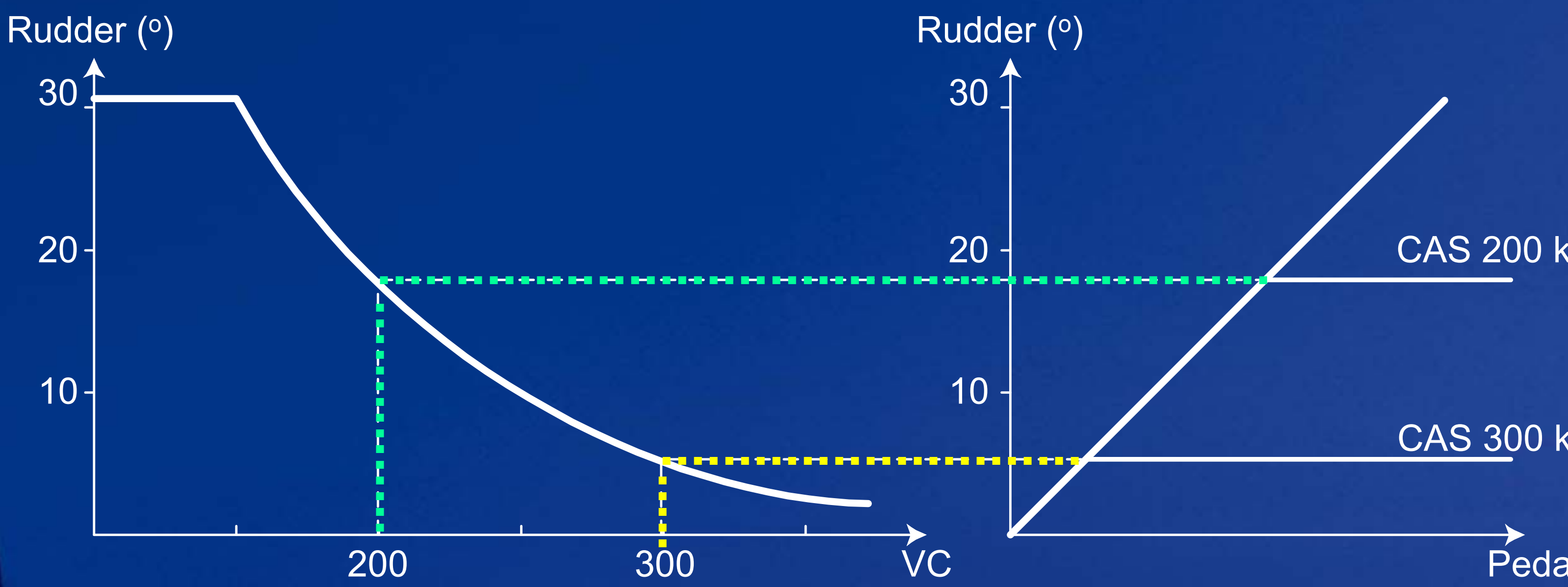
Reason for a PTLU on A330/A340

- In order to minimize the high loads caused by such rudder pedal abrupt commands, the Rudder Pedal Travel is limited.

- Actually the PTLU and RTLU have the same shape.

Why no PTLU on A340-500/600

- The rudder channel is fully electric on the A3456
- Thus the rudder pedal directly commands the amount of rudder as a function of the IAS and pedal deflection



- At a given IAS, the rudder pedals are able to command a maximum rudder deflection, as per TLU. Any additional pedal input has no effect on the rudder (PTLU and RTLU built in the lateral law).

Operational Consequences

- On most commercial A/C, the rudder ***MUST NOT BE USED:***
  - to induce Roll,
  - to counter Roll induced by any type of turbulence,
  - for turn coordination (exceptionally in Direct Law, with a double hydraulic failure where YD is lost).

Operational Consequences

- On most commercial A/C, the rudder ***IS ACTUALLY USED ONLY:***
  - during T/O and LANDING Roll,
  - in case of Engine Out, as a yaw corrective action,
  - during the last phase of a flare with crosswind for decrab purpose.

Operational Consequences

- On most commercial A/C:
  - there is no need to act on the rudder abruptly,
  - in case of failure leading to a loss of TLU, the rudder is to be used with care, as per ECAM,
  - there is no roll control restriction with an engine failed.