A300-600R - MSN420 - AAL587
PUBLIC HEARING

Loads items

3/10/2002

Loads

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    - The investigated domains
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  - Rudder maneuvers and resulting loads
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Loads

- **Loads - General**

  - In flight, an airplane is submitted to:
    - aerodynamic loads due to pressure distribution on the external surfaces
    - inertia loads due to the gravity and accelerations applied during the flight to the items of mass distributed all along the airplane,
    - propulsion loads delivered by the engines (thrust),
    - pressure loads in pressurised areas (cabin).

  - The loads calculation considers all significant forces acting on the airplane.

  - Those loads are calculated for a number of specific conditions, called “load cases”, which are defined with reference to the regulatory requirements.

Loads

- **Loads - General** (cont'd)
  - The Airbus airplanes are designed and certified under FAR/JAR 25 Airworthiness Standards: Transport and Category Airplane.
  - Each load cases is defined by:
    - the conditions to be considered (airplane maneuvers, external atmospheric disturbances,…)

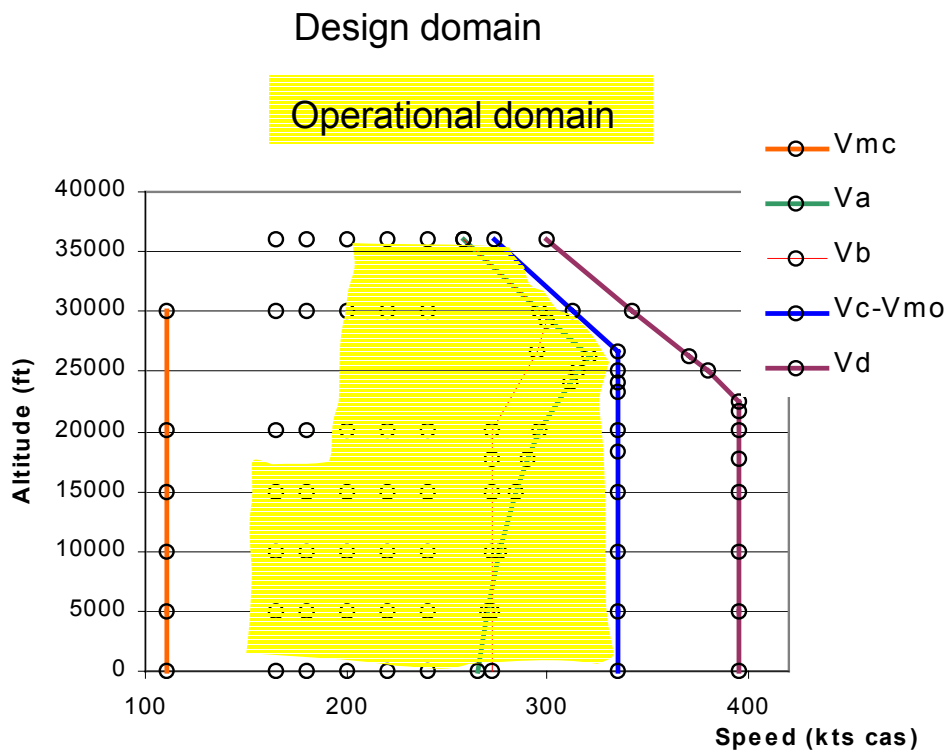
      and
    - the domain to be considered (flight conditions: speed, altitude, weight, center of gravity, for which the airplane is designed and will or may be operated)

Loads

- **Vertical tail loads - The conditions (A300-600R)**
  - Several conditions dictate the establishment of the vertical tail loads:
    - the yawing maneuver resulting from a rudder displacement condition,
    - the lateral gust resulting from the airplane encountering an external atmospheric disturbance (gust),
    - the engine failure (loss of thrust) and associated pilot corrective action,
    - the potential systems failures, with particular focus on flight control systems.

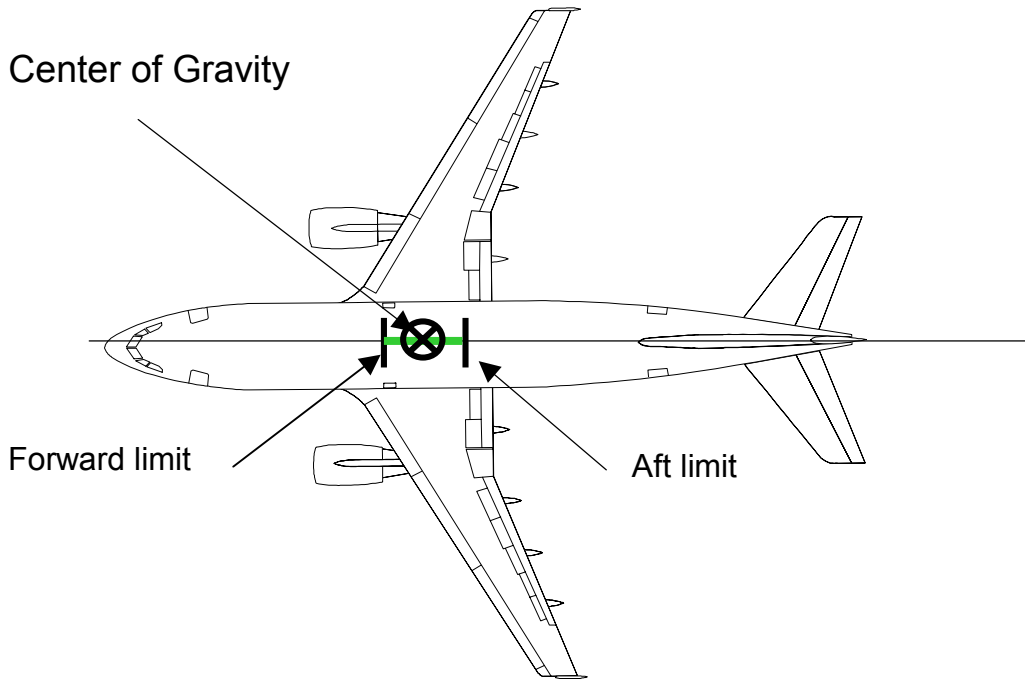
Loads

- **Vertical tail loads - The investigated domains (A300-600R)**
  - Flight domain
    - Speeds and altitudes where the different conditions are analyzed.
    - The domain investigated is expanded beyond the normal maximum operating speed Vmo (Vmo =Vc) up to the design dive speed Vd.



Loads

- **Vertical tail loads - The investigated domains (A300-600R)**
  - Weight & Balance domain
    - Fuel and payloads combinations for which the different conditions are analysed
    - 30 flight mass cases defined, covering different distributions and combination of payload and fuel. (W, CG, PL&Fuel)
      - MTOW= 375 890 lbs
      - MLW = 308 650 lbs
      - MZFW = 286 600 lbs



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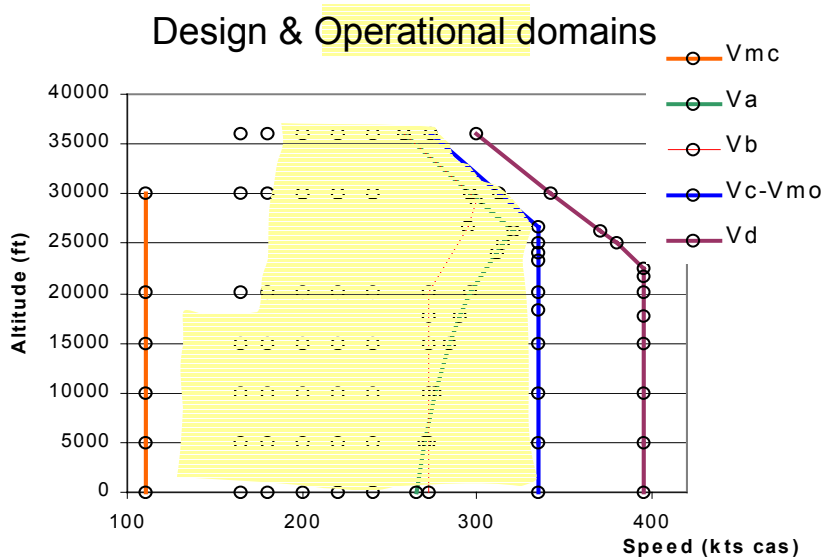
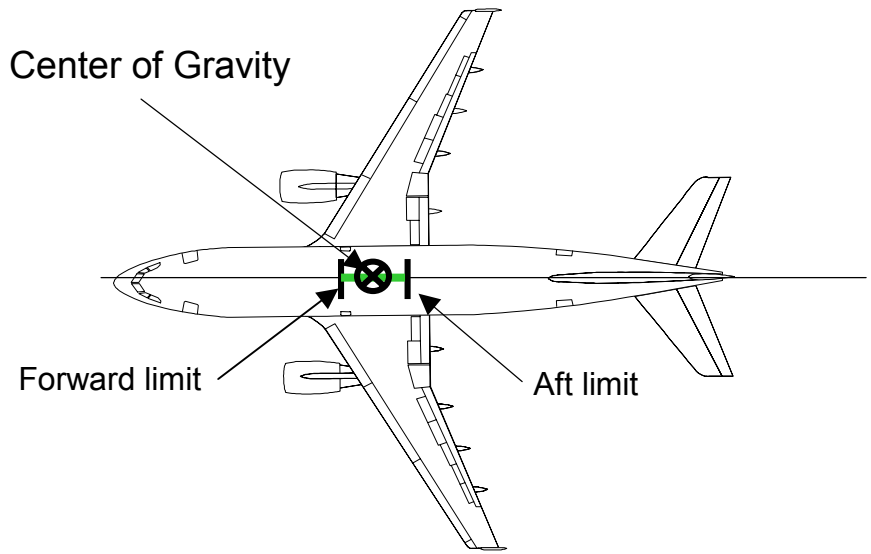
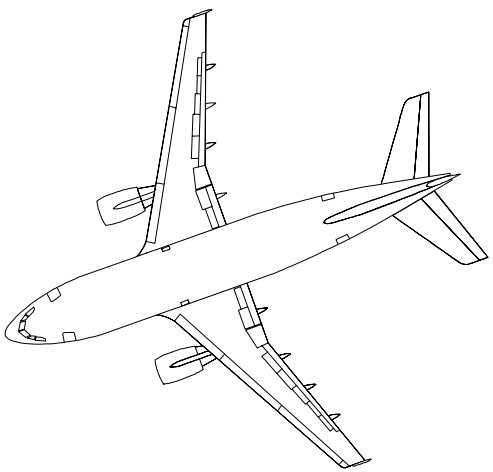




Loads

- **Vertical tail loads - Loads analysis**
  - The airplane loads assessment is performed by analysis using a theoretical model which involves aerodynamic, mass, stiffness and systems data.



Wind Tunnel Test data

Aerodynamic data

Mass data

Structural stiffness

Engine data

Systems data

Maneuvers (rudder)

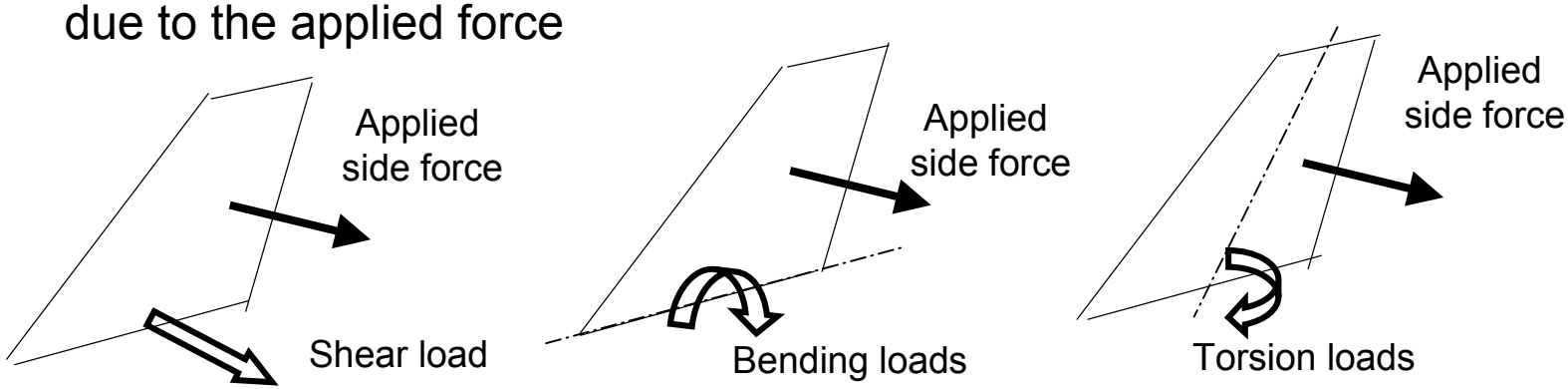
Loads Models airplane movements and associated loads

Airplane components loads

Atmospheric disturbances

Loads

- **Vertical tail loads - Loads analysis**
  - The overall model is supported and consolidated by tests (ground and flight) ensuring an accurate representation of the aircraft behavior.
  - By using this model, simulation of the aircraft movements due to controls maneuvering or external atmospheric disturbances (gusts) are performed and associated loads induced by forces on aircraft components (wing, vertical tail,…) are calculated.
  - Vertical tail loads are represented by shear, bending and torsion loads due to the applied force

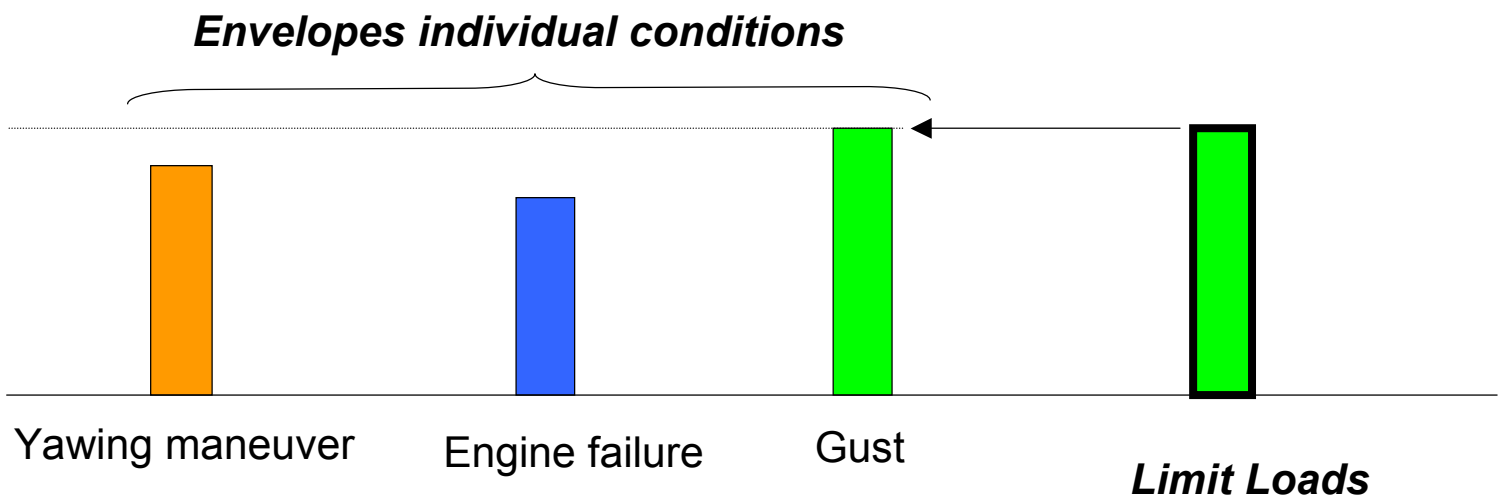


  - Those loads are used for the structural strength analysis (design and justification) and structural tests.

Loads

- **Vertical tail loads - Envelope Loads - Limit Loads**

  - For each individual condition (Yawing maneuver, gust,..), the highest loads level resulting from the most severe combination of weight & balance (payload, fuel) and flight condition (speed, altitude) is determined providing the Envelope Loads for the condition.



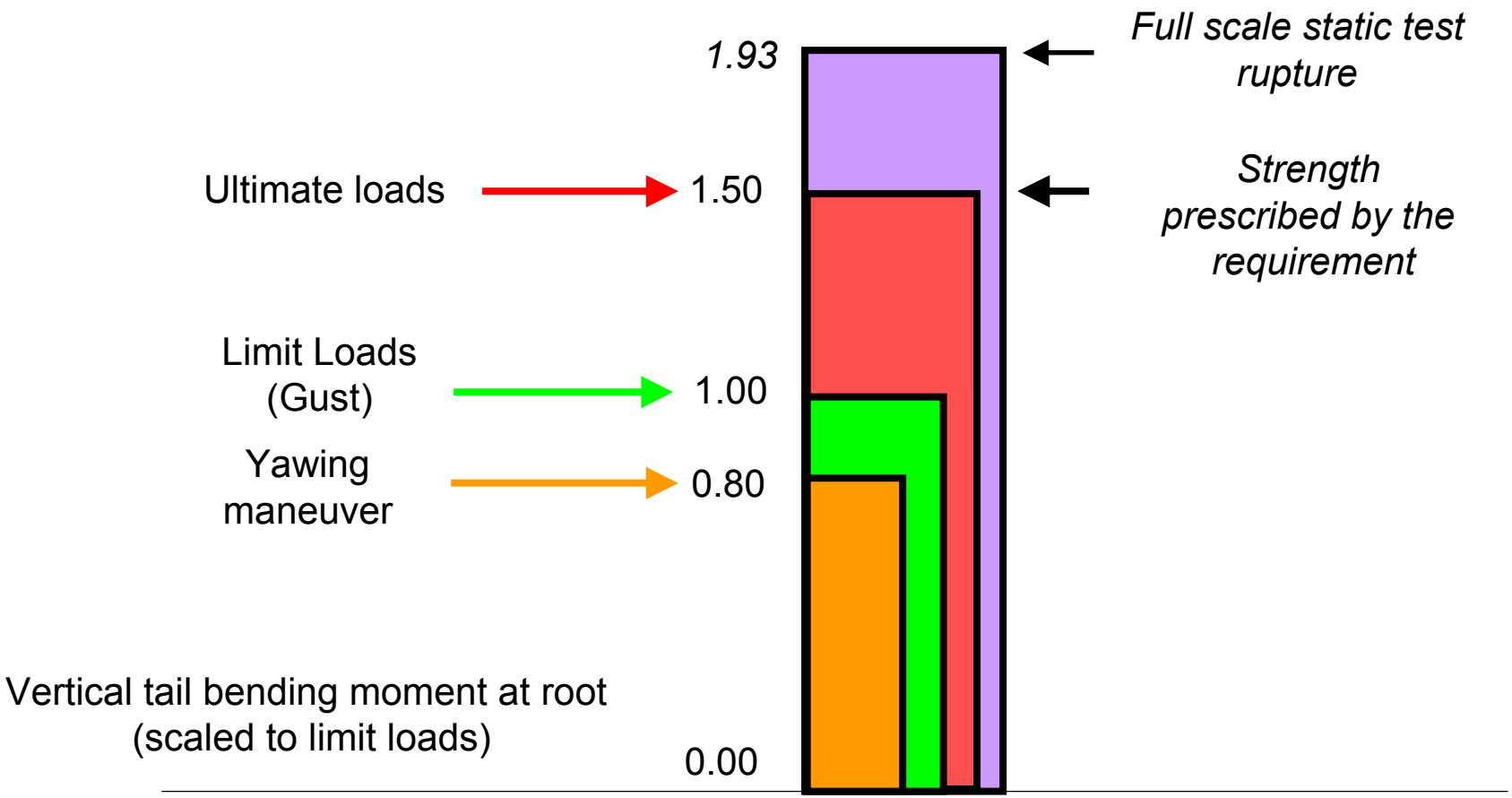
  - The highest loads from all the individual above envelope conditions dictates the Limit Loads
    - Limit Loads = the most severe case from a large number of cases .

Loads

- **The structural conditions - General**
  - Strength requirements are specified in terms of:
    - limit loads (the maximum loads to be expected in service)
    - ultimate loads (limit loads multiplied by prescribed factors of safety, generally 1.5).
  - The structure must be able to support limit loads without detrimental permanent deformation.
  - The structure must be able to support ultimate loads without failure.
  - As a result, the full set of required conditions provides an appropriate level of structural strength (through the coherency between usage aims, requirements, design, tests and finally operational usage).

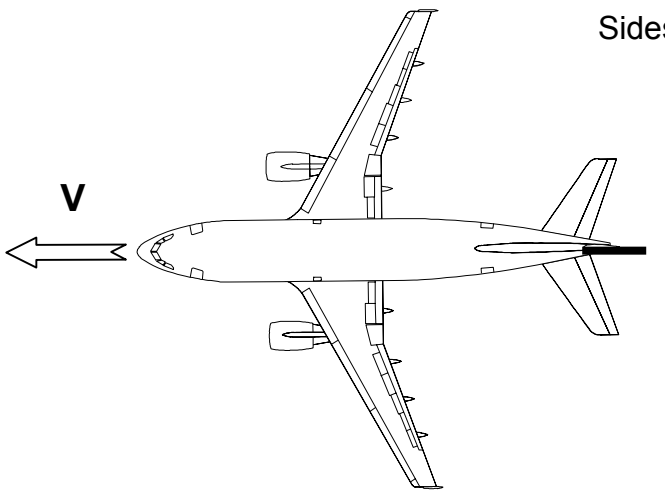
Loads

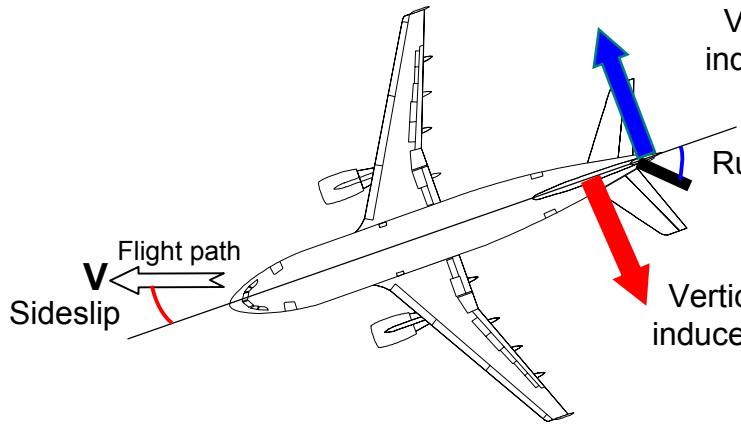
- **Vertical tail loads - Envelope loads figure**
  - A300-600R vertical tail envelope & limit loads:



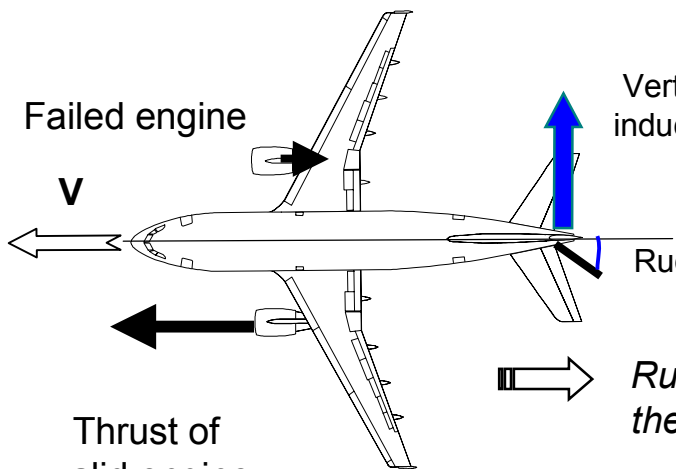
Loads

- **Rudder usage and resulting vertical tail forces**





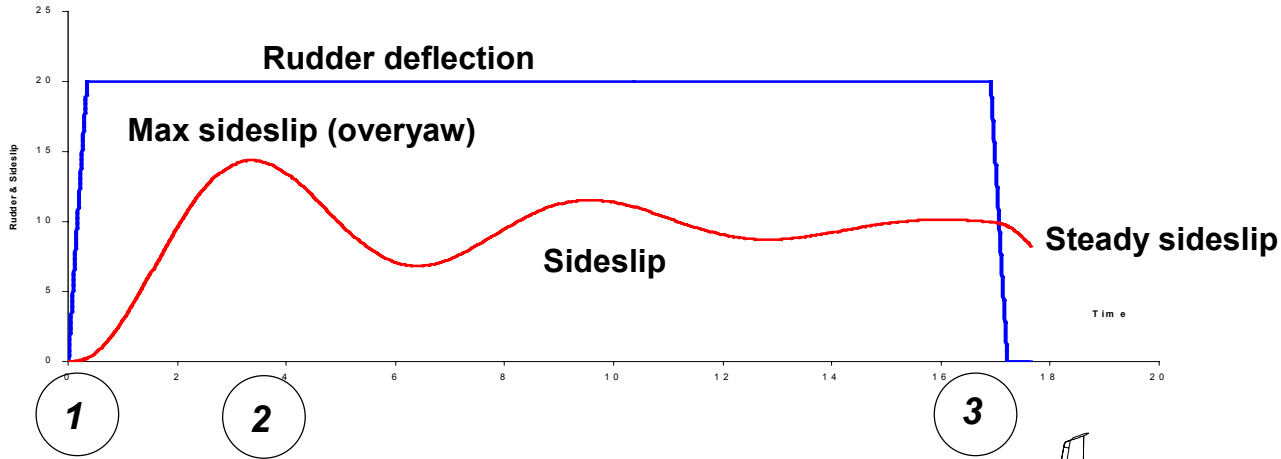
Rudder maneuver will result in an airplane yaw response which will generate sideslip.
Sideslip and rudder induced forces are opposite.



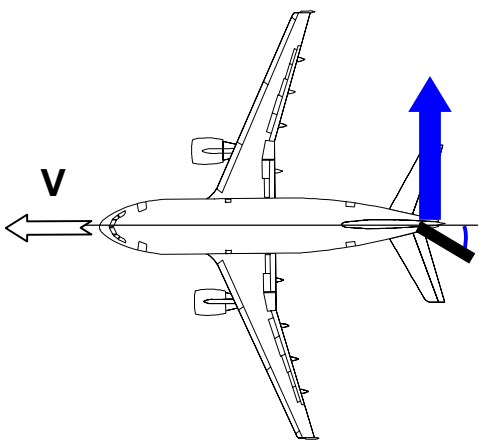
Rudder maneuver to oppose the effect of an engine failure (loss of thrust)

Loads

- **FAR/JAR Requirements Rudder maneuvers - General**

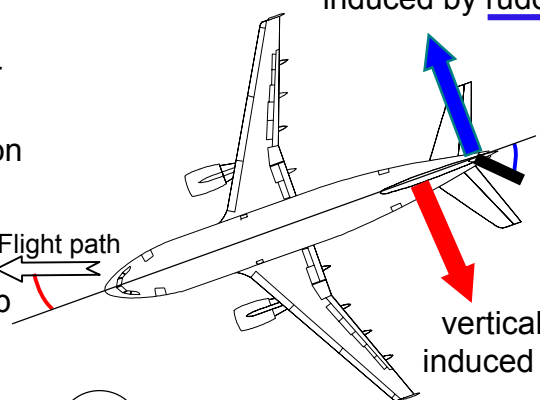


vertical tail force induced by rudder

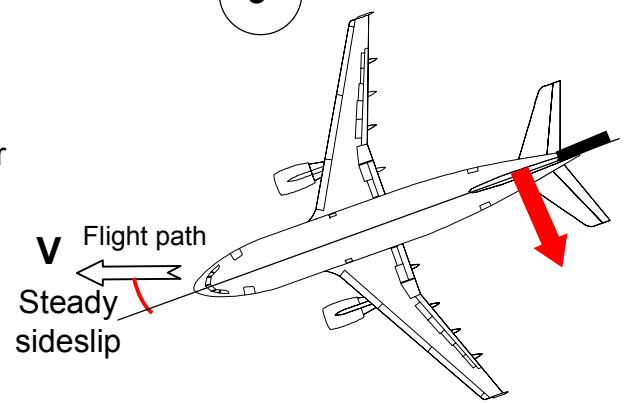


Rudder max deflection

vertical tail force induced by rudder



vertical tail force induced by sideslip



vertical tail force induced by sideslip

1 *Rudder suddenly to max deflection*

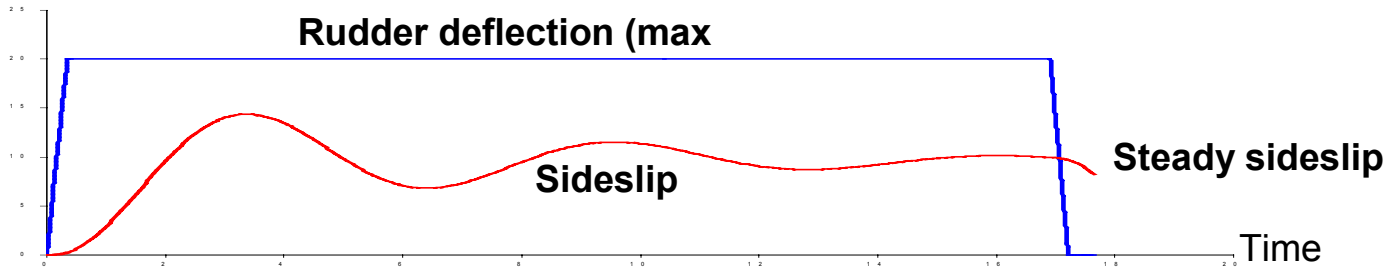
2 *Airplane yaws to resulting sideslip*

3 *At steady sideslip rudder suddenly return to neutral*

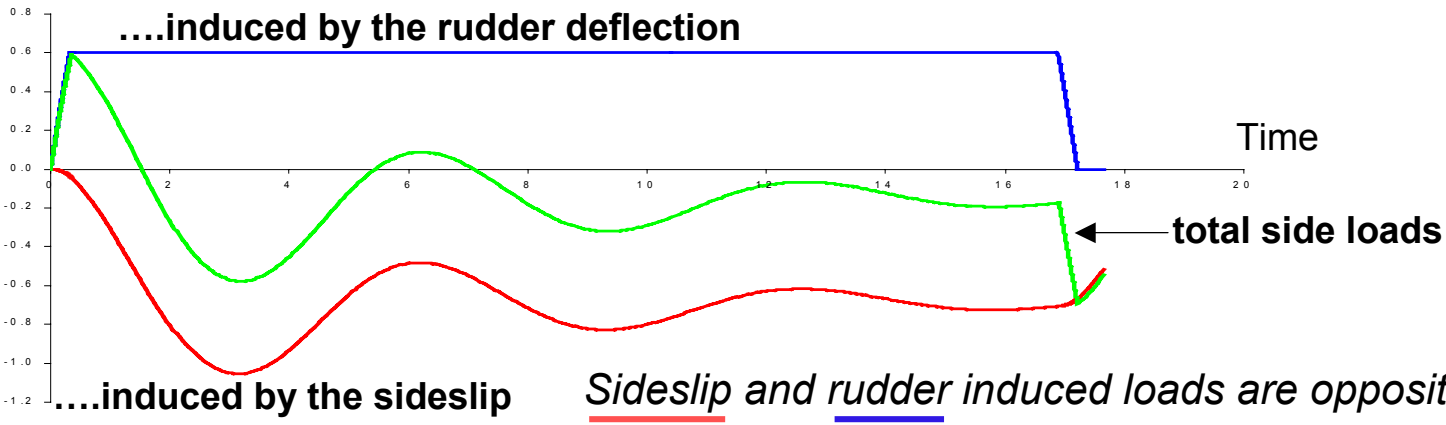
Loads

- **FAR/JAR Rudder maneuvers - Vertical tail loads development**

Rudder deflection & sideslip

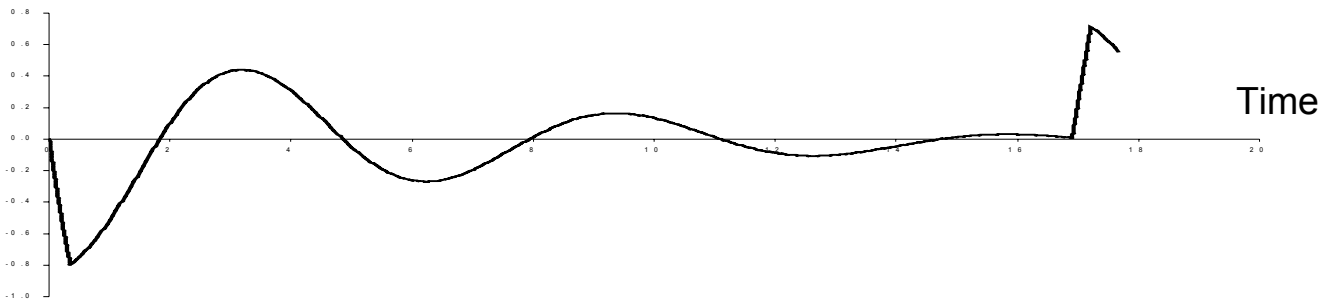


Vertical tail side forces
(scaled to LL)



Sideslip and rudder induced loads are opposite

Vertical tail load bending moment at root
(scaled to LL)

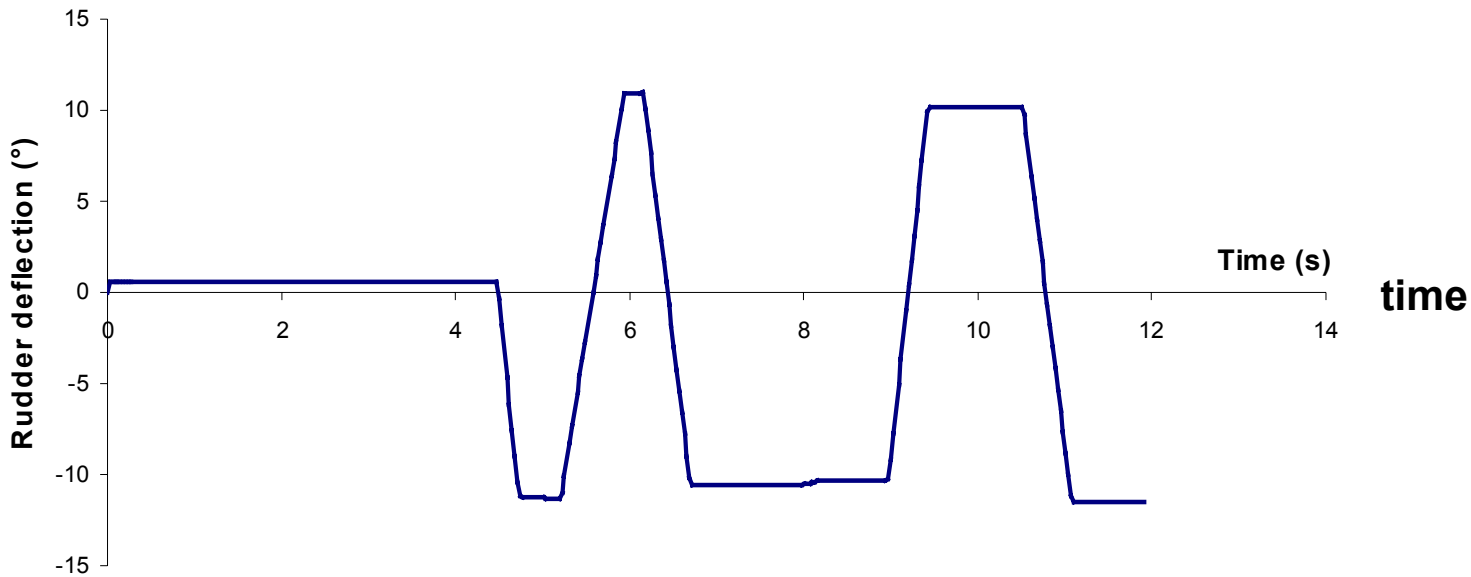


Loads

- **AAL587**
  - Since November 12th 2001, a large amount of work has been done to gather all possible/necessary information and to analyze, understand the accident.
  - One of the main tasks was to assess the vertical tail loads development during the last 12 seconds when the airplane parameters are recorded on the DFDR.
  - The loads are computed from time history of control surfaces positions (rudder,…) and associated motion of the airplane (sideslip,…) as obtained from DFDR and subsequent analysis.

Loads

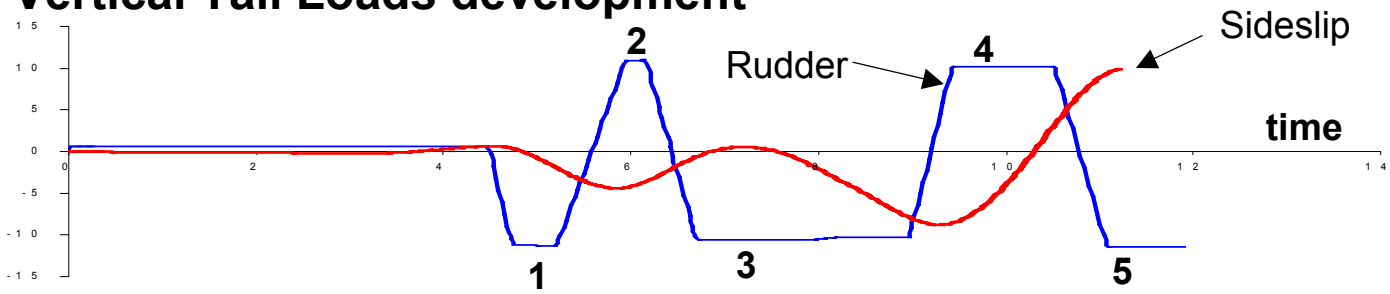
- **AAL587 - Rudder movements**
  - Ruder movements before the accident are rapid cyclic movements, with full back-to-back reversal deflections



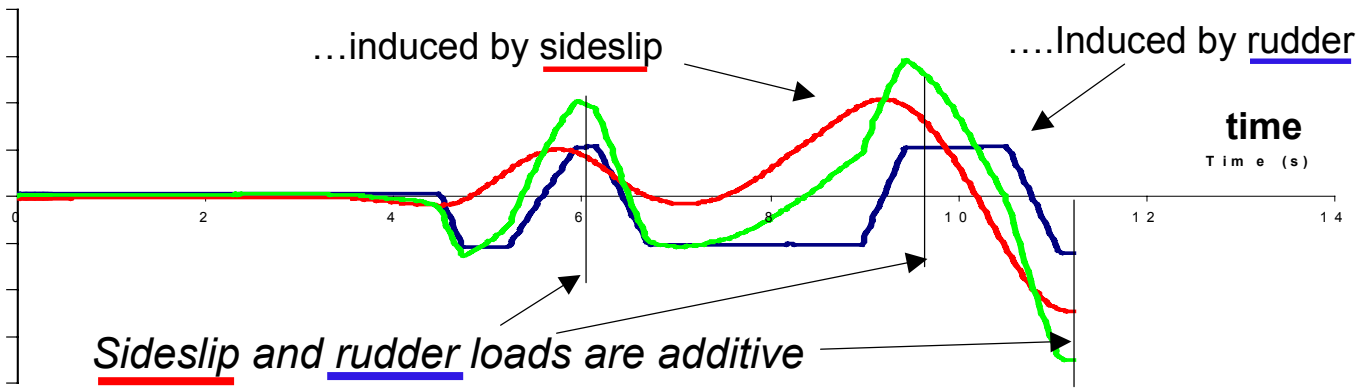
Loads

- **AAL587 - Vertical Tail Loads development**

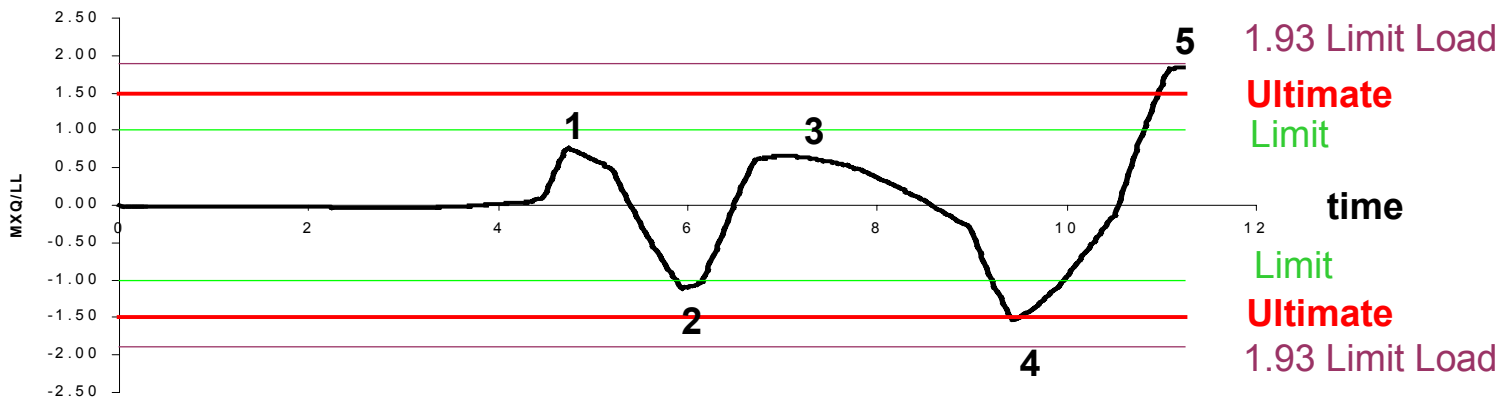
Rudder deflection & sideslip



Vertical Tail side forces...



Vertical Tail Bending loads at root



Sideslip and rudder loads are additive

AIRBUS

Loads

- **Loads summary:**
  - The A300-600R vertical tail loads have been established in agreement with the transport category airplane specified requirements.
  - The A300-600R vertical tail shows structural margin above the requirements (full scale testing demonstrated that structural failure occurred at loads in excess of the FAR 25 requirement).

Loads

- **American Airline 587 Loads summary**

  - The aircraft rudder movements during flight AAL587 create vertical tail loads largely in excess of the required design loads due to the cyclic nature of these movements, ie several rapid alternate rudder deflections from max to max.