# Aerospace Structural Mechanics

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# What is a structure?

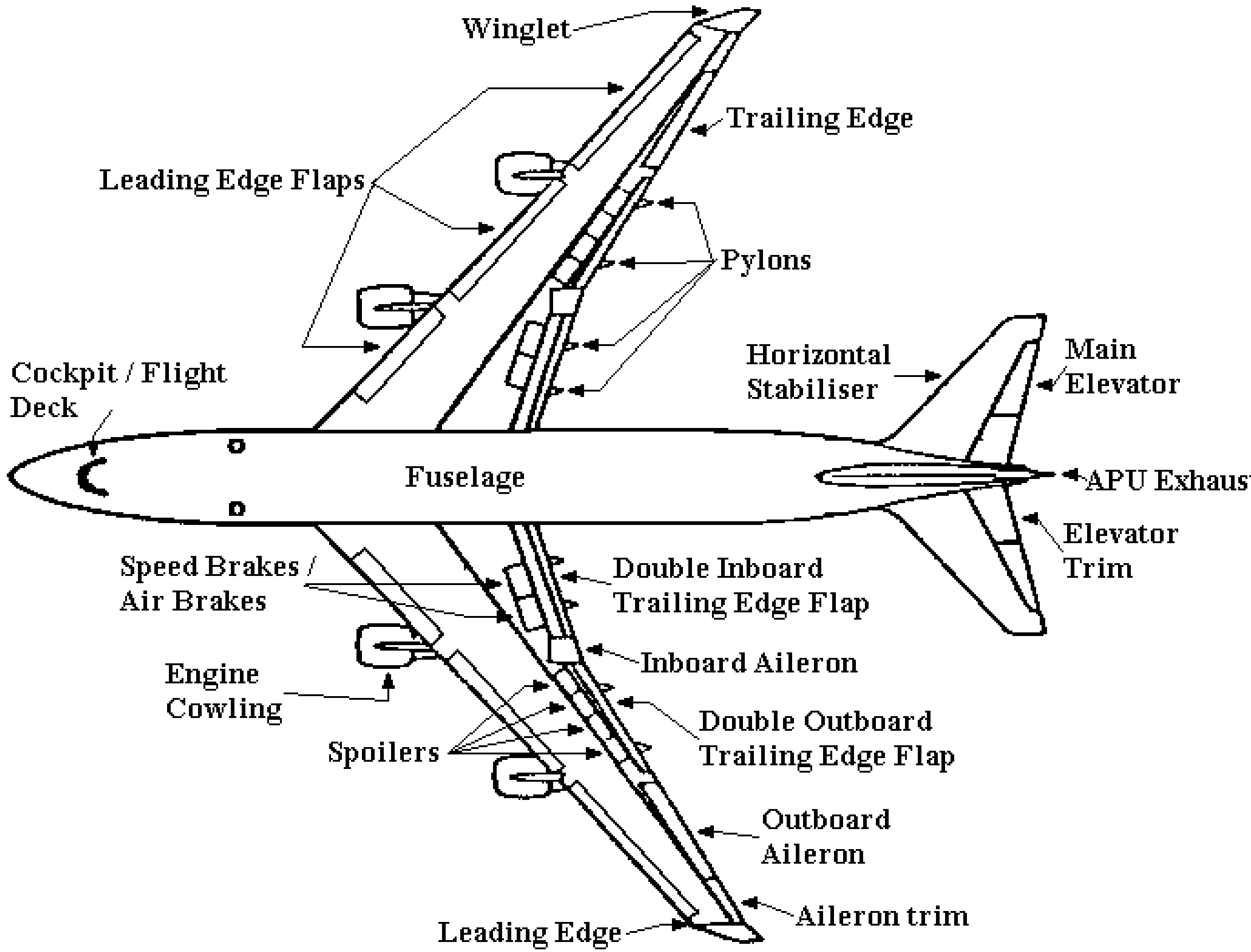
**Structure**

*The arrangement of and relations between the parts or elements of something complex – Oxford dictionay*

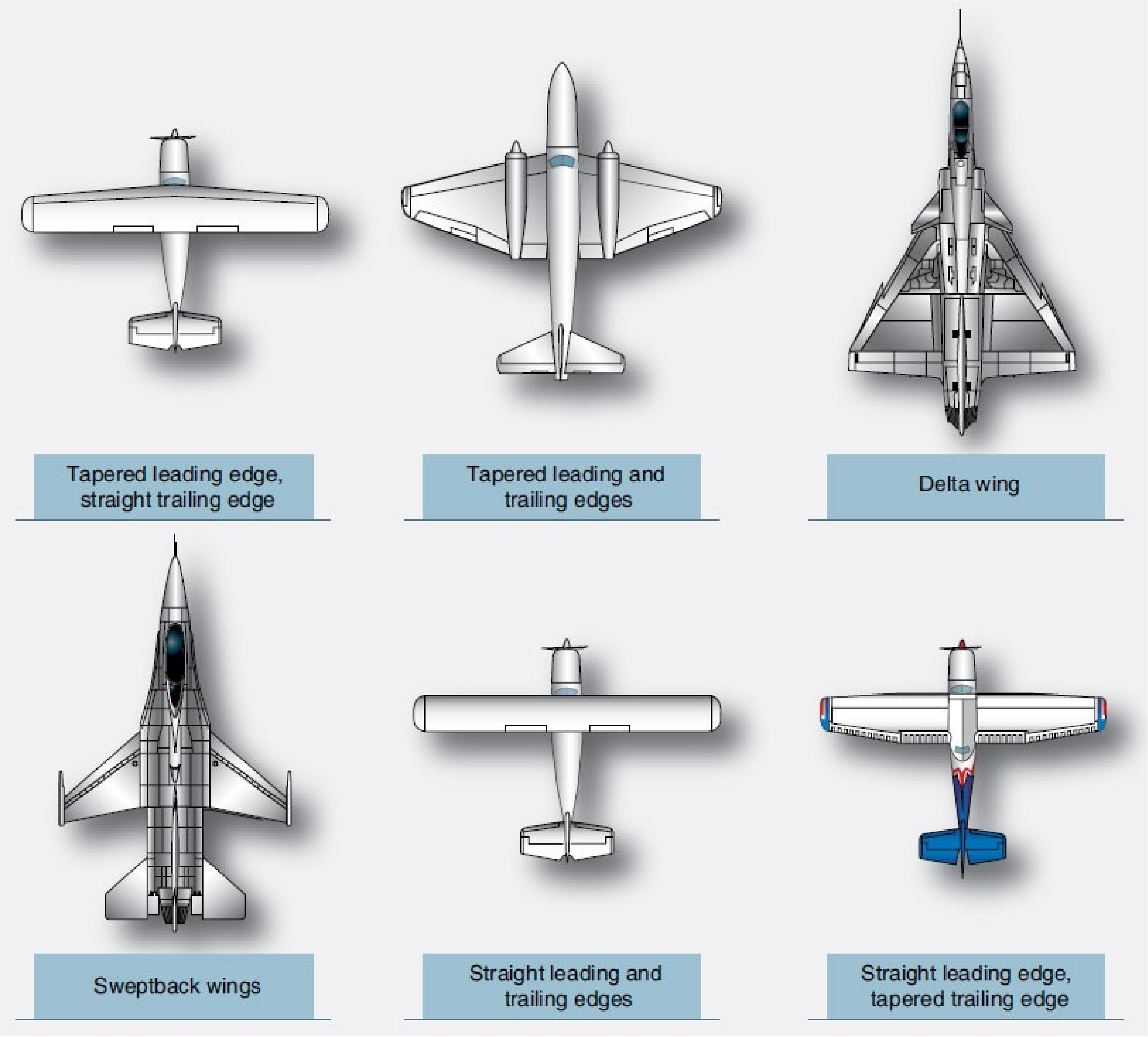
**Use of a structure**

*Maintain geometrical (not to mention ergonomical...) integrity under the action of loads impressed to ensure the efficient performance of a system it is part of*

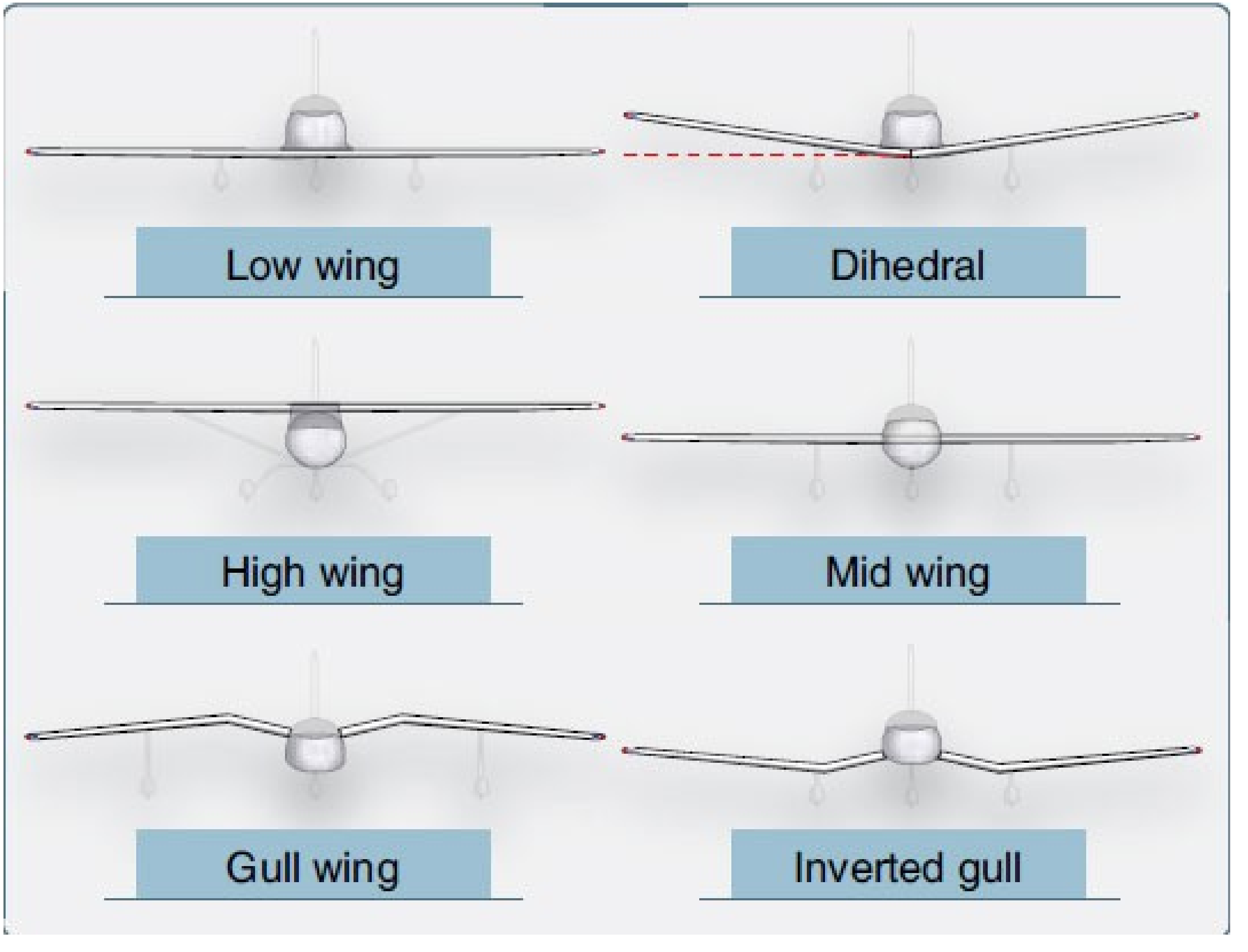
# Typical aircraft structural parts



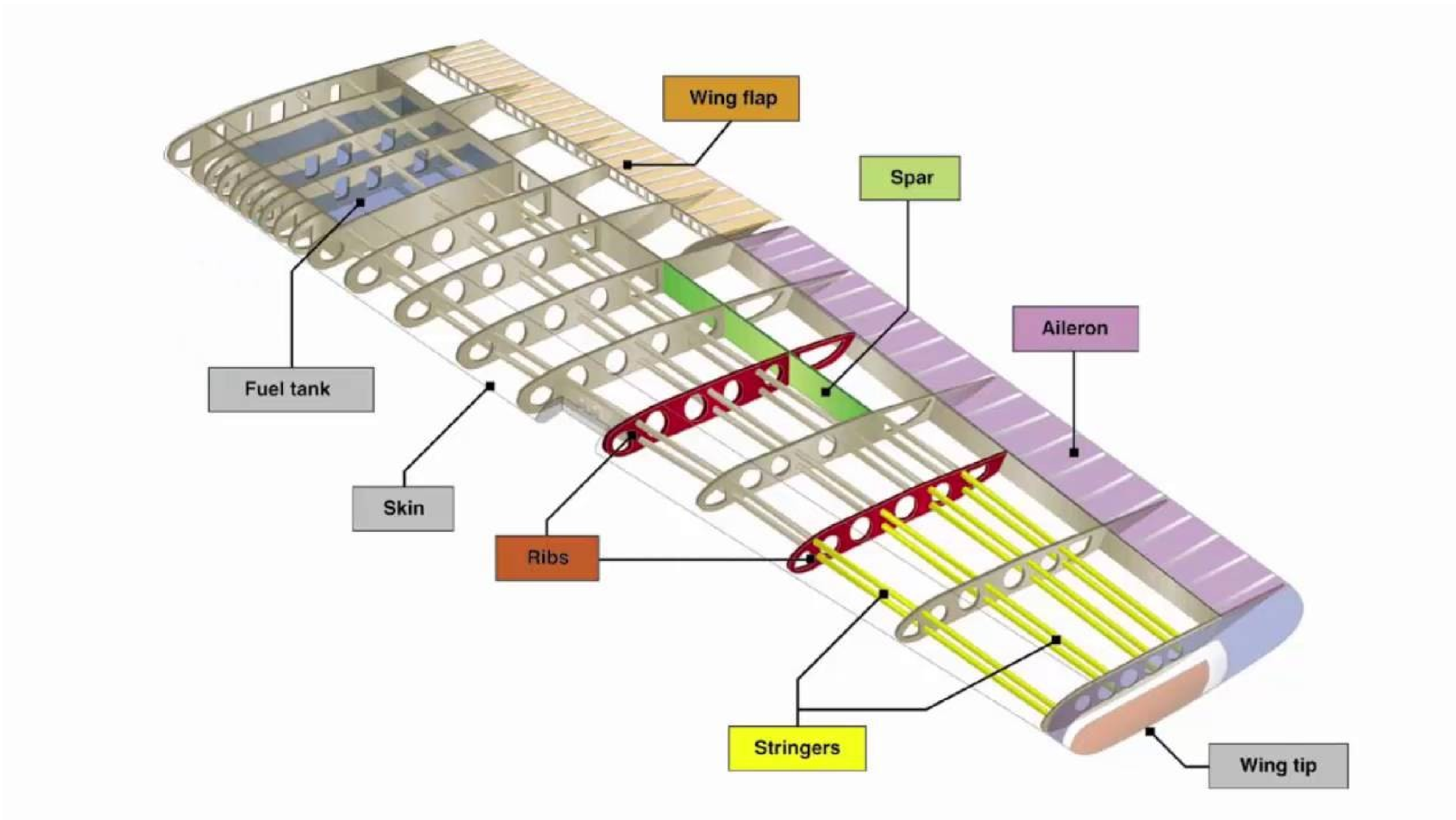
# Typical Wing configurations



# Typical Wing attach points and dihedral angle



# Typical wing sub-structures



# Role of wing sub-structures

Ribs:

a. Maintain the cross-sectional shape of the wing for all combination of loads

b. Along with skin, resist the distributed aerodynamic loading

c. Distribute concentrated loads (e.g. undercarriage and additional wing store loads) into the structure and redistribute stress around discontinuities

d. Provide end restraints and consequently increase column buckling stress of the longitudinal stiffners by establishing their column length

e. Increase plate buckling stress of skin panels

In general, light rib structure sufficient near wing tip as compared to rugged structure closer to the wing root

**Why is it sufficient to have light rib structure near wing tip compared to wing root?**

# Role of wing sub-structures

Skin:

a. Form an impermeable surface for supporting the aerodynamic pressure distribution from which the lifting capability of the wing is derived.

b. Provide resistance to shear and torsional loads (typically along with spar webs)

c. Provide axial and bending resistance (typically along with stringers)

In general, aerodynamic forces are transmitted to the ribs and stringers by the skin through plate and membrane action..

# Role of wing sub-stuctures

Stringers:

a. They are attachedto skin and ribs therby dividing skin into small panles and increasing its buckling and failing stress

b. They rely on rib attachments for preventing column action in the normal direction

c. Combined with skin, they resist axial and bending loads

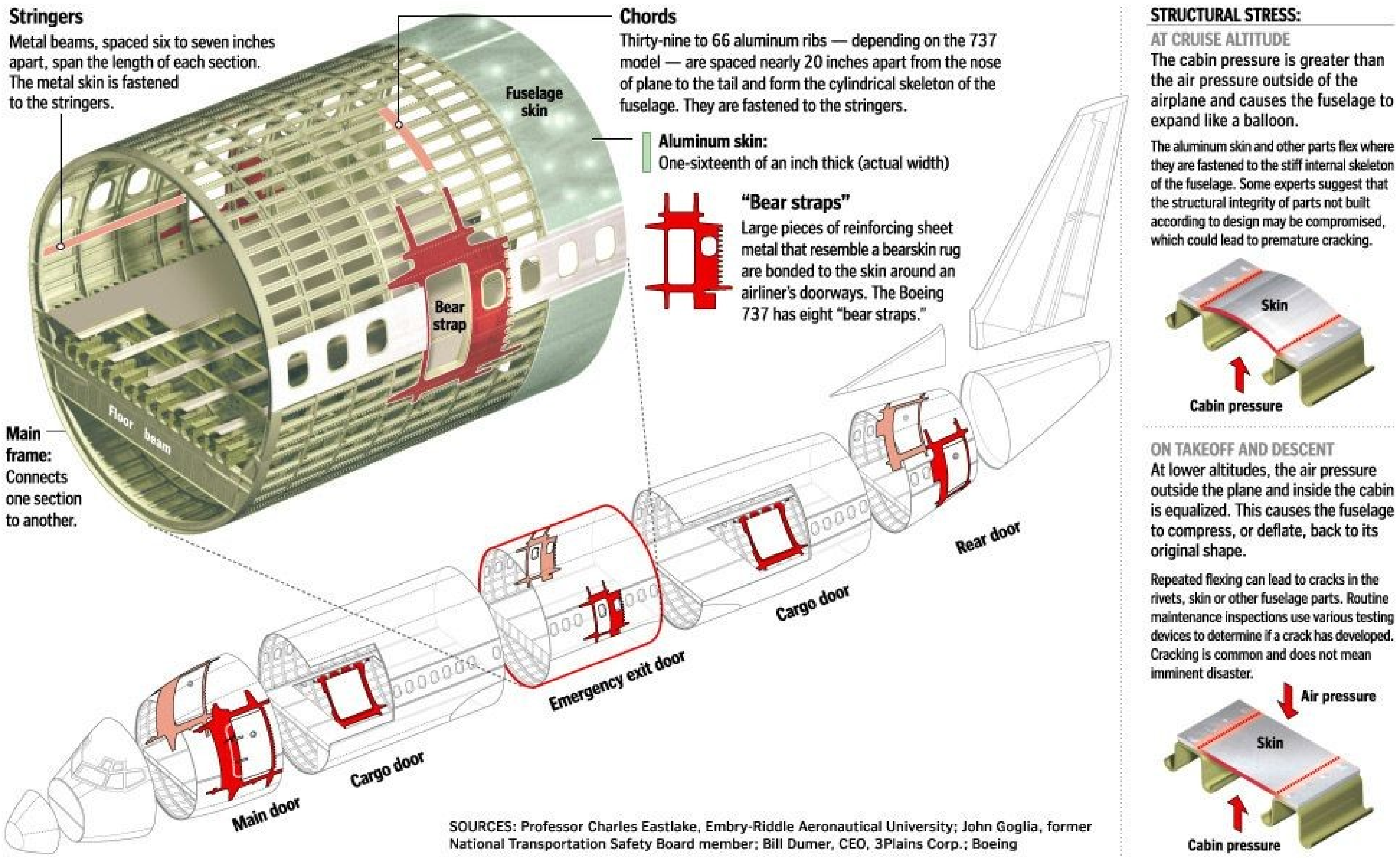
Spar webs:

a. Develop shear stress to resist shear and torsional loads

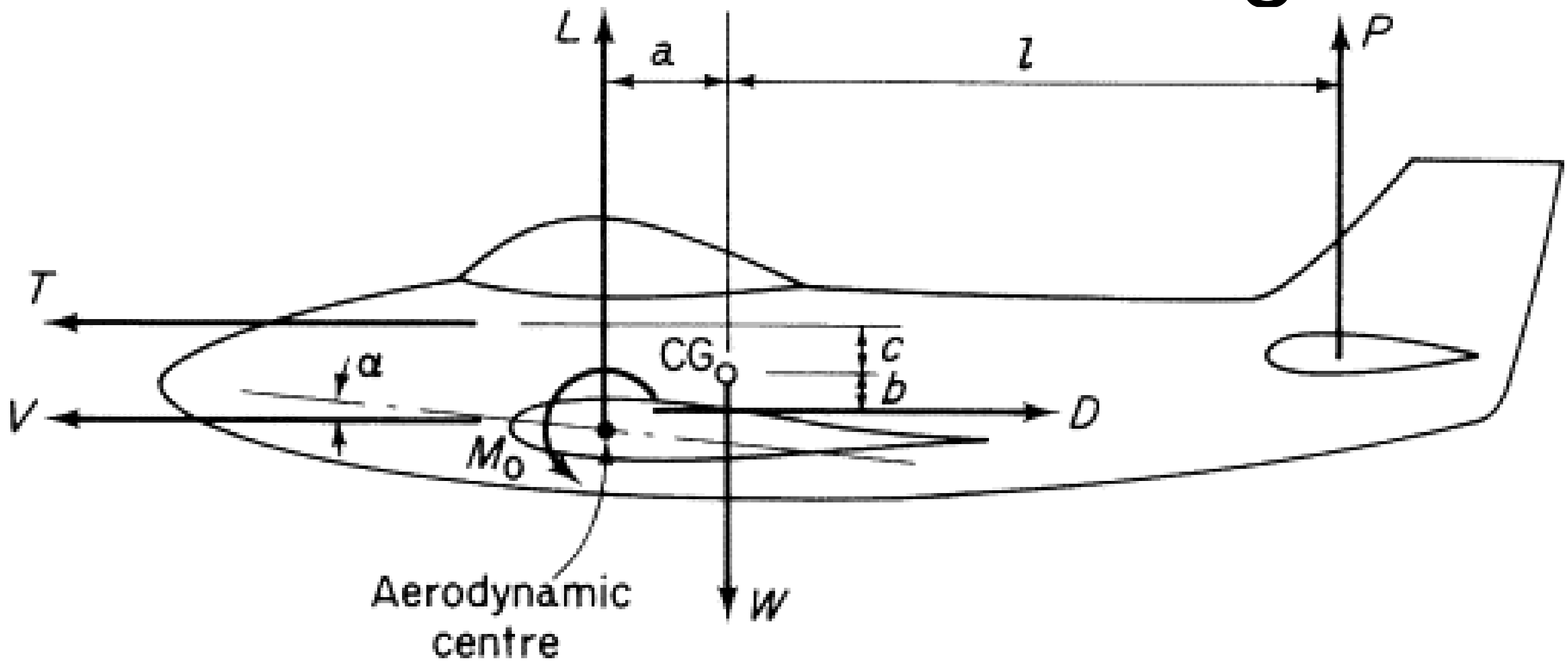
b. Help in stabilizing, with the skin, spar flanges or caps which are therefore capable of supporting large compressive loads from axial and bending effects

c. Exert a stabilizing influence on the skin in a similar manner to the stringers

# Fuselage


Stringers
Metal beams, spaced six to seven inches apart, span the length of each section. The metal skin is fastened to the stringers.
Chords
Thirty-nine to 66 aluminum ribs — depending on the 737 model — are spaced nearly 20 inches apart from the nose of plane to the tail and form the cylindrical skeleton of the fuselage. They are fastened to the stringers.
Fuselage skin
Aluminum skin:
One-sixteenth of an inch thick (actual width)
"Bear straps"
Large pieces of reinforcing sheet metal that resemble a bearskin rug are bonded to the skin around an airliner's doorways. The Boeing 737 has eight "bear straps."
Bear strap
Floor beam
Main frame:
Connects one section to another.
Main door
Cargo door
Emergency exit door
Cargo door
Rear door
SOURCES: Professor Charles Eastlake, Embry-Riddle Aeronautical University; John Goglia, former National Transportation Safety Board member; Bill Dumer, CEO, 3Plains Corp.; Boeing
STRUCTURAL STRESS:
AT CRUISE ALTITUDE
The cabin pressure is greater than the air pressure outside of the airplane and causes the fuselage to expand like a balloon.
The aluminum skin and other parts flex where they are fastened to the stiff internal skeleton of the fuselage. Some experts suggest that the structural integrity of parts not built according to design may be compromised, which could lead to premature cracking.
Skin
Cabin pressure
ON TAKEOFF AND DESCENT
At lower altitudes, the air pressure outside the plane and inside the cabin is equalized. This causes the fuselage to compress, or deflate, back to its original shape.
Repeated flexing can lead to cracks in the rivets, skin or other fuselage parts. Routine maintenance inspections use various testing devices to determine if a crack has developed. Cracking is common and does not mean imminent disaster.
Air pressure
Skin
Cabin pressure

# Loads on aircrafts during manoeuvre – Level flight




Equillibrium equations:

L + P – W = 0 (along the vertical direction)

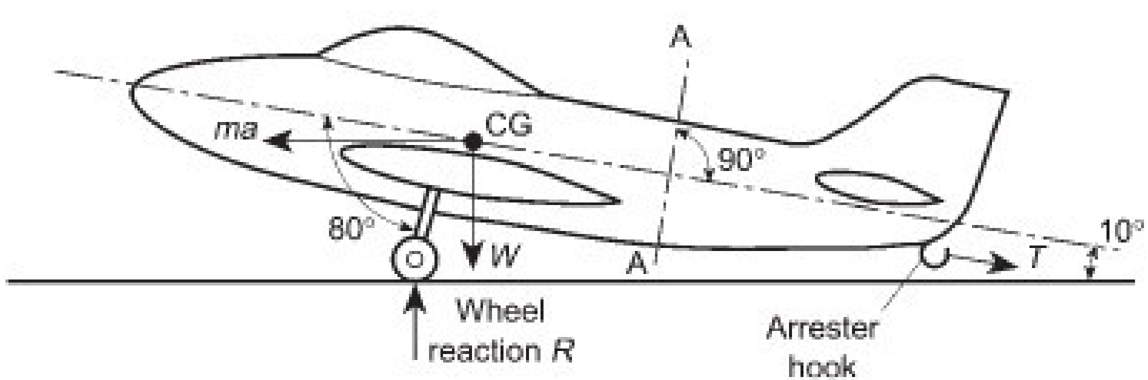
T – D = 0 (along the horizontal direction)

La – Db – Tc – $M_0$ – Pl = 0 (moment about aircraft's CG in the plane of symmetry)

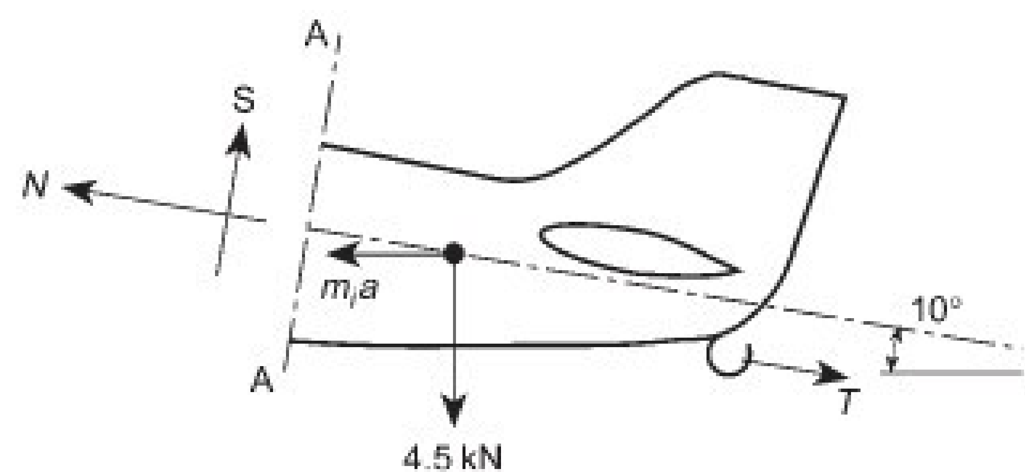
**Note: These set of equations have to solved in an iterative process**

# Forces on a landing aircraft

1. An aircraft having a total weight of 45 kN lands on the deck of an aircraft carrier and is brought to rest by means of a cable engaged by an arrester hook, as shown in the figure below. If the deceleration induced by the cable is 3 g determine the tension, T , in the cable, the load on an undercarriage strut and the shear and axial loads in the fuselage at the section AA; the weight of the aircraft aft of AA is 4.5 kN. Calculate also the length of deck covered by the aircraft before it is brought to rest if the touch-down speed is 25 m/s.

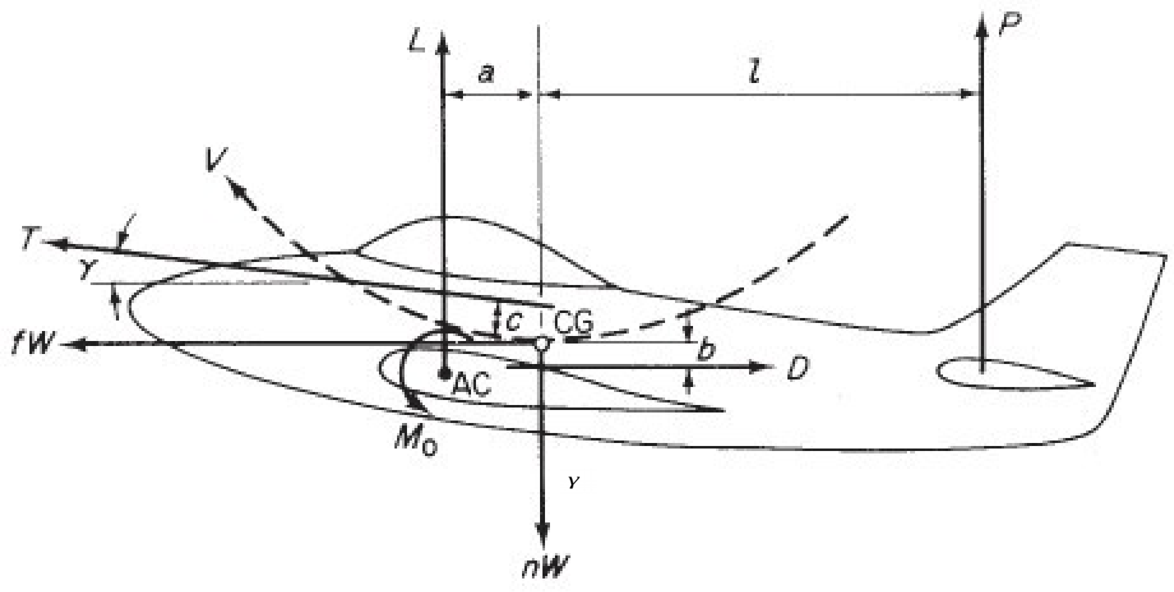



Schematic of loading on a landing aircraft




Shear and axial load on section A-A

# Loads on aircrafts during manoeuvre – General symmetric manoeuvre




Equillibrium equations (aircraft is at lowest point of pull-out):

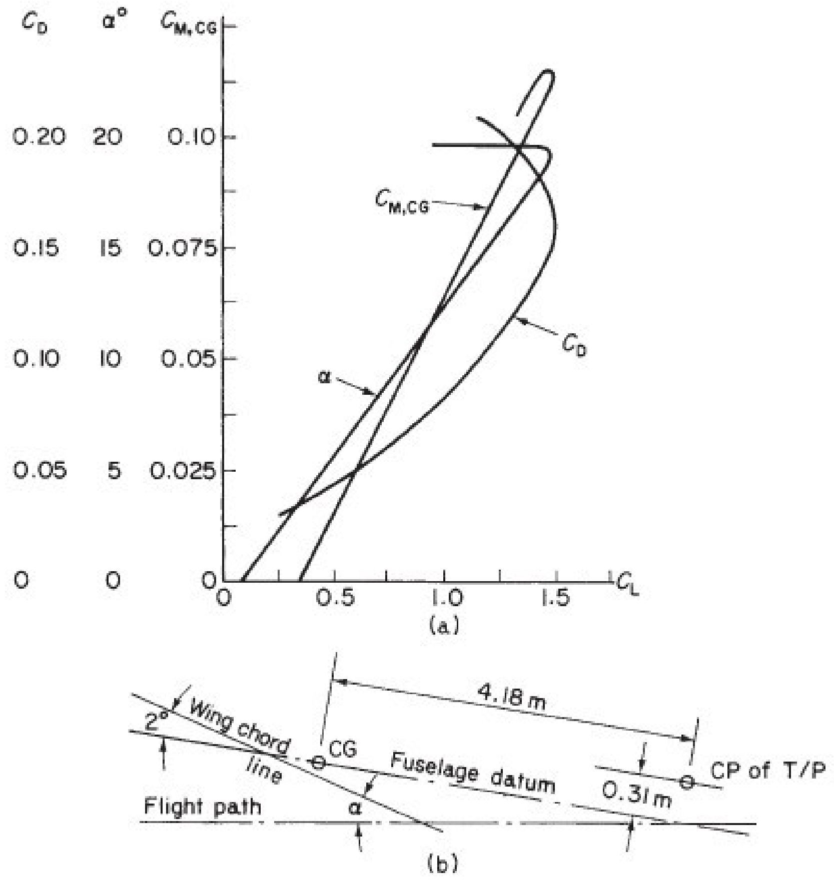
L + P + T sin $\gamma$ – nW = 0 (along the vertical direction)

T cos $\gamma$ + fW - D = 0 (along the horizontal direction)

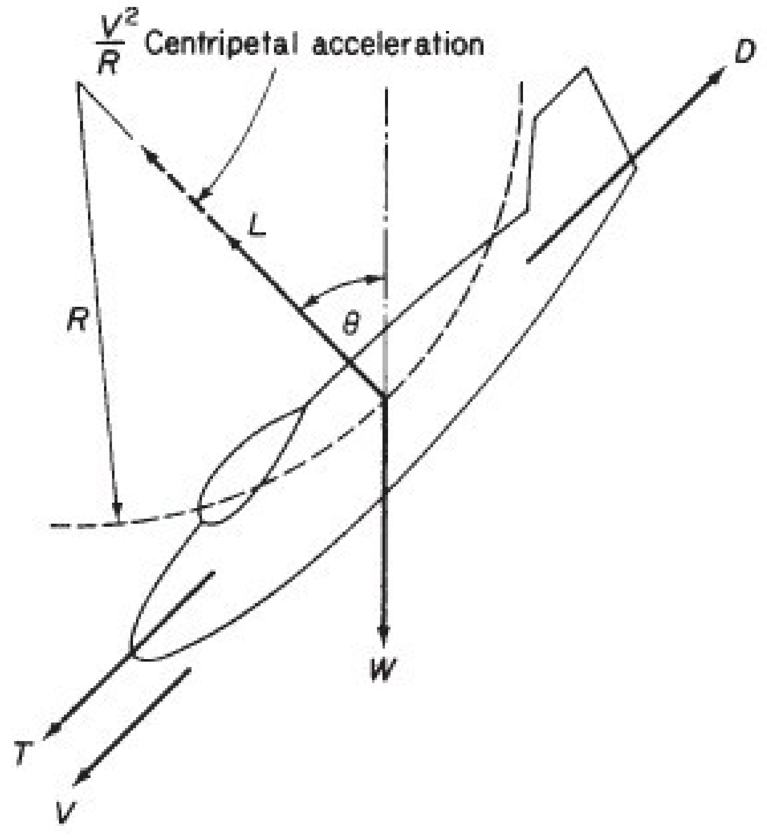
La – Db – Tc – $M_0$ – Pl = 0 (moment about aircraft's CG in the plane of symmetry)

**Note: These set of equations have to solved in an iterative process**

2. The curves $C_D$, $\alpha$ and $C_{M,CG}$ for a light aircraft are shown in figure. The aircraft weight is 8000 N, its wing area 14.5 $m^2$ and its mean chord 1.35 m. Determine the lift, drag, tail load and forward inertia force for a symmetric manoeuvre corresponding to n = 4.5 and a speed of 60 m/s. Assume that engine-off conditions apply and that the air density is 1.223 $kg/m^3$ . Figure shows the relevant aircraft dimensions.



# Loads on aircrafts during manoeuvre – Steady pull-out

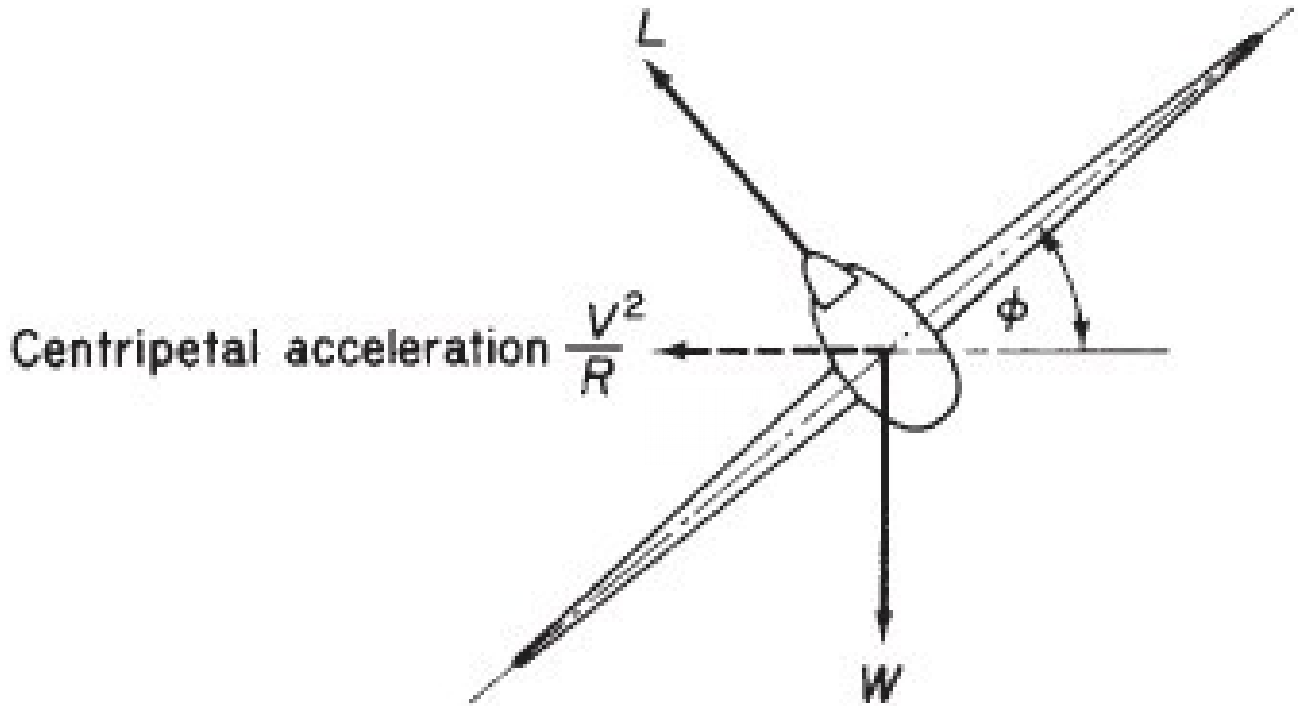



Aircraft has just begun its pull-out from a dive so that it is describing a curved flight path but is not yet at its lowest point.

$L = (WV^2/gR) + W \cos\theta$ or since $L = nW$; we can write

$n = (V^2/gR) + \cos\theta$

# Loads on aircrafts during manoeuvre – Correctly banked turn




The aircraft flies in a horizontal turn with no sideslip at constant speed

$L \sin\Phi = (WV^2/gR)$ (for horizontal equilibrium)

$L \cos\Phi = W$ ; simplifying we get $n = \sec\Phi$