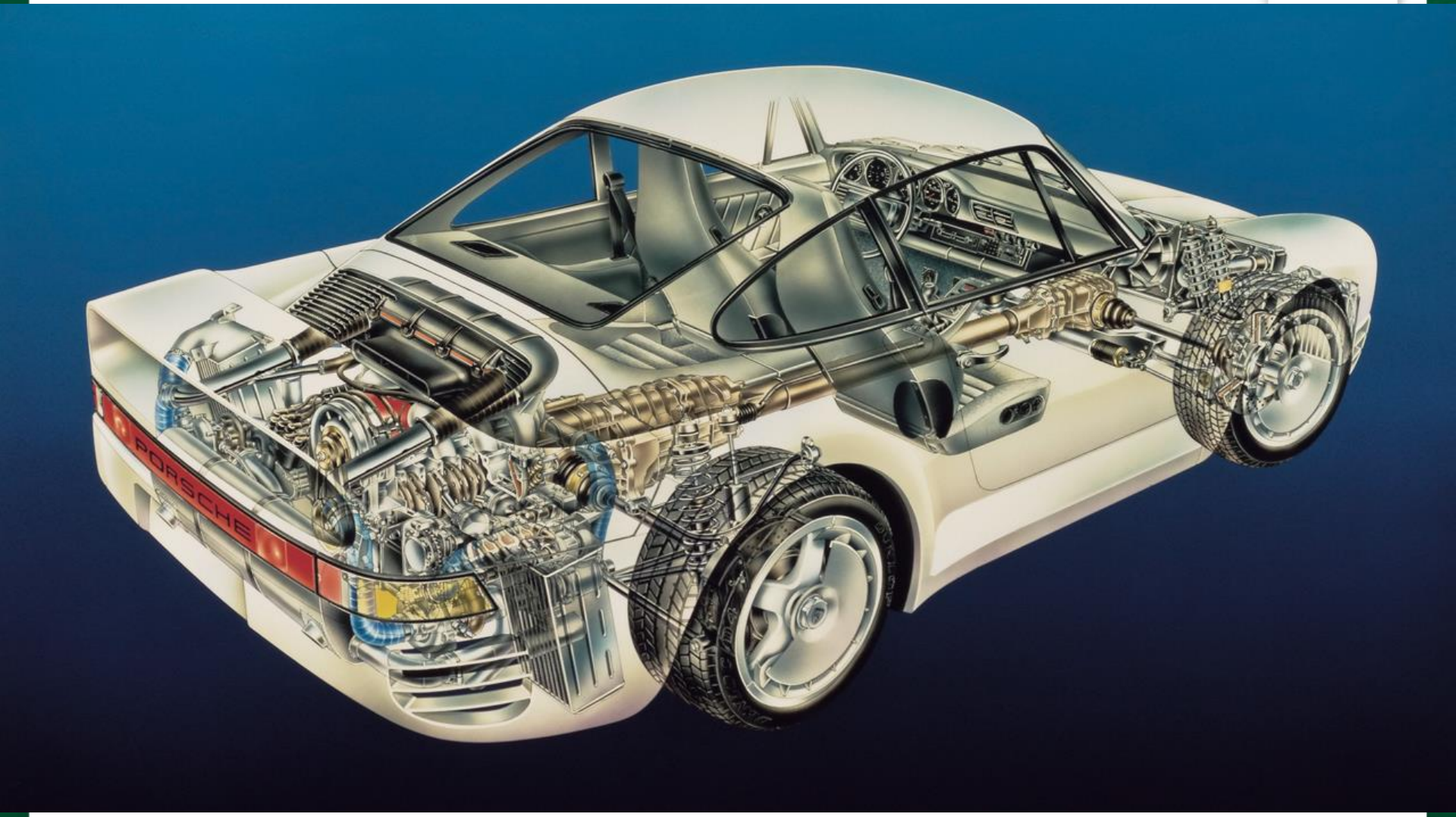

Session 2

Automotive Chassis

Speaker

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M. S. RAMAIAH SCHOOL OF ADVANCED STUDIES

Session Objectives

At the end of this session the students would have understood

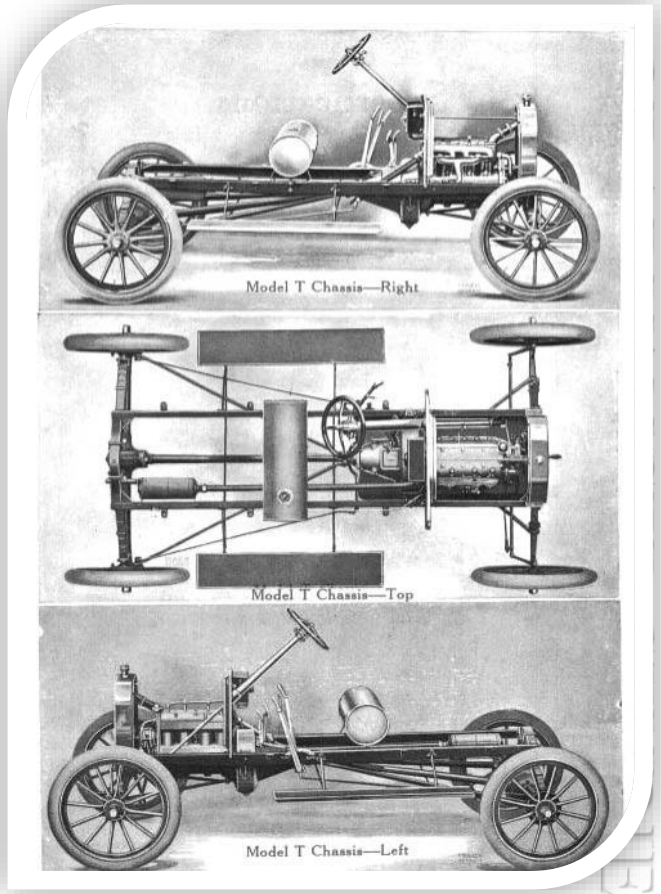
- History of automotive chassis
- Different types of automotive structures
- Basic Automotive Construction

Session Topics

1. History of Automotive Chassis
2. Different Types of Structures
   - Composite Construction
   - Unibody Construction
   - Tubular Space Frame
   - Glass-fiber Body
   - Carbon-fiber Monocoque Chassis
   - Aluminum Monocoque
3. Basic Automotive Construction

History of Automobile Chassis

- Body terminology (phaeton, tonneau, landaulet, wagonette) was taken from the coaches world.
- The structures were made of a wooden frame with wooden body panels mounted on it.
- Introduction of steel and aluminum sheets (1900)
- This enabled the designers to create shapes with more freedom



History of Automobile Chassis

- First high volume all steel car : Dodge Brothers (1914)
  - In 1922 the Lancia Lambda was a revolution in the evolution of chassis design.
    - Inspired by ship building
    - All steel body monocoque structure

Dodge Brothers (1914)

Source: http://www.carbodydesign.com/

Lancia Lambda (1922)

Source: http://www.news.lt/Upload/200103/Lambda1.jpg

Different type of Structures

- Composite construction (Chassis / Body-on-frame)

Composite Construction

- Composite construction was the most common type of structure used on the earliest cars of 1900's.
- The chassis and body are built as two separate units.
- The body is assembled on the chassis with mounting bracket
- These flexible mountings allow the body to move slightly when the car is in motion
- Earlier days frames were made of wood, but steel ladder frames became common in 1930s

Composite Construction

- Automobile increased complexity leads to the new weight reduction demand, made this type of structure unviable
- From 1960s most of the small passenger cars switched to unibody construction, leaving trucks and large cars using conventional frames

Composite Construction

- Composite construction for heavy duty vehicles

Still using BOF

Unibody construction

Composite Construction

- Latest trends

- The chassis structure (skateboard structure) contains the powertrain and mechanical components, while the body is a separate structure.
- There are no mechanical links between the body and chassis, which makes it easy to produce the rolling chassis in large quantities separate from the bodies, and place different body styles on top of a common structure.

Tubular Space Frame

- Consists of dozens of circular-section tubes (uses square-section tubes; for easier connection to the body panels, or circular section provides the maximum strength

Maserati Tipo 61: “Birdcage”

Source: http://www.carbodydesign.com

Tubular Space Frame

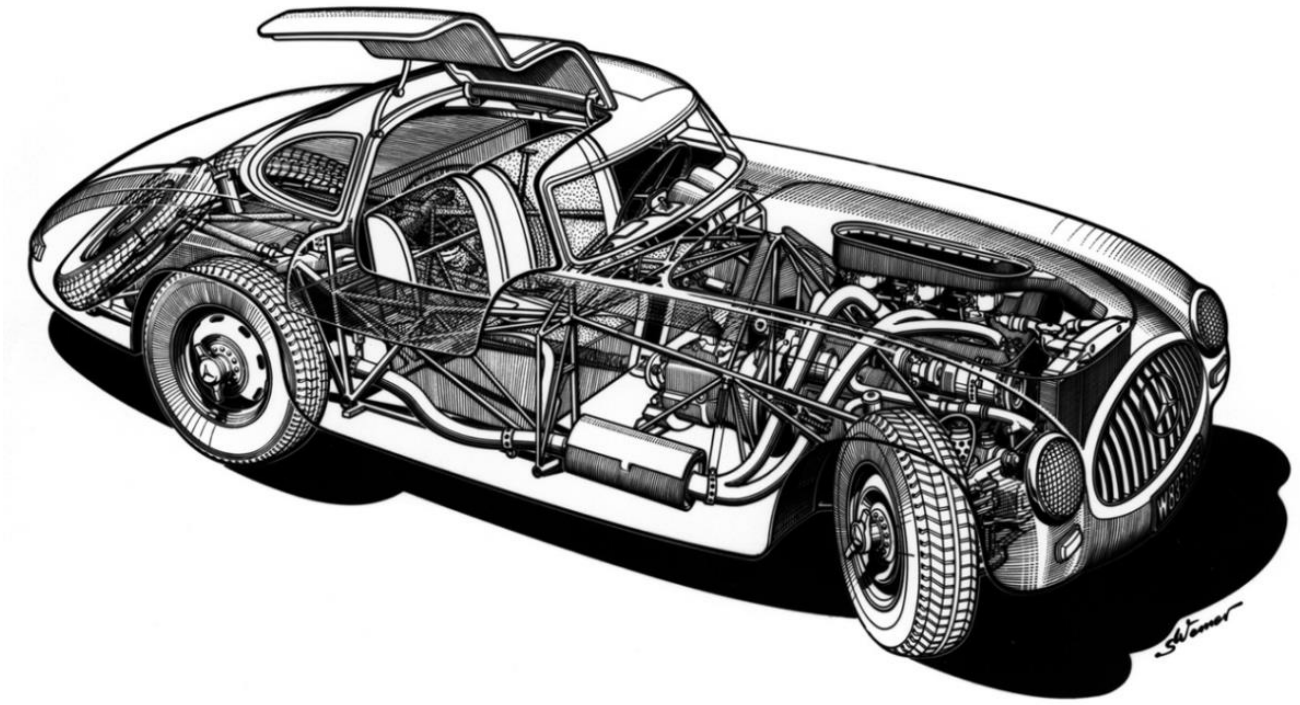
Lamborghini Countach

Source: www.autozine.org

- High performance cars require higher strength
- Tubular space frame chassis usually incorporate a strong structure under both doors
- High door sill and difficult access to the cabin

Tubular Space Frame

- First tubular space frame road car, 300SL Gullwing

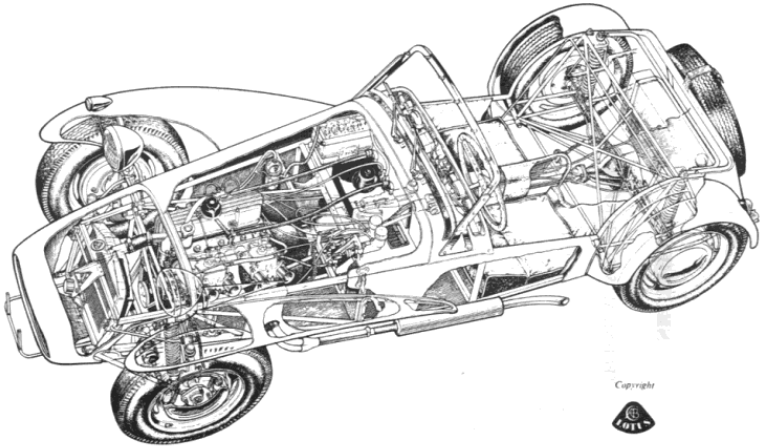


Mercedes Benz300SL Gullwing

Source: www.silverstarrestorations.com

Tubular Space Frame

Who use it??



Source: http://www.autozine.org/technical_school/chassis/tech_chassis2.htm

- From 1960s many high-end sports cars also adopted tubular space frame to enhance the rigidity / weight ratio
- Space frames for the front and rear structure and made the cabin out of monocoque to cut cost.
- All Ferrari before the 360M, Lamborghini Diablo, Jaguar XJ220, Caterham, TVR etc.

Tubular Space Frame

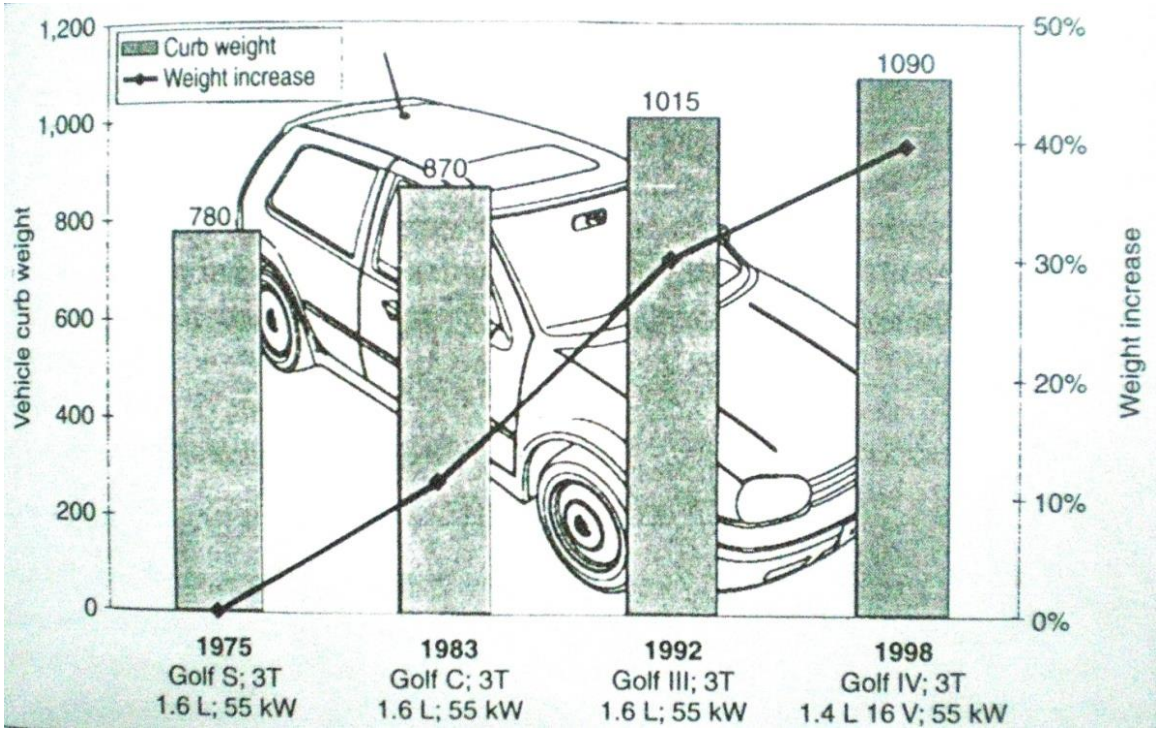
Advantages

- Very strong in any direction. (compare with ladder chassis and monocoque chassis of the same weight)

Disadvantage in tubular space frame

- Very complex, costly and time consuming to built.
- Impossible for mass production.
- Raised door sills result in difficult access to the cabin.

Monocoque (Unibody)



- World wide increase in the vehicle weight
- Depending on the vehicle type and engine configuration, a 100kg weight increase is associated with a consumption increase of 0.41 - 0.61L per 100km

Monocoque (Unibody)

- Monocoque is a one-piece structure which defines the overall shape of the car.

Source:http://www.km77.com/

Monocoque (Unibody)

- Made by welding several pieces together.
- The floorpan, which is the largest piece, and other pieces are press-made by big stamping machines.
- They are spot welded together by robot arms (some even use laser welding) in a stream production line.
- After that, some accessories like doors, bonnet, boot lid, side panels and roof are added.

Monocoque (Unibody)

- Monocoque construction was first widely used in air craft, starting in the 1920s
- Introduction of monocoque in automotive : Lancia Lambda 1922

Monocoque (Unibody)

- In 1934 Chrysler and Citroën built the first mass-produced monocoque vehicles, Chrysler Airflow and the Traction Avant

Monocoque (Unibody)

- The Ford Consul introduced an evolution of monocoque chassis, called unit body or unibody
- Rambler Classic had "uniside" door

Source: http://www.tatraplan.co.uk/

Monocoque (Unibody)

- Automotive industries

- 1940

- Military production

"Performance Cars"

1949 Ford Custom Club

lack of steel

Lighter Cars

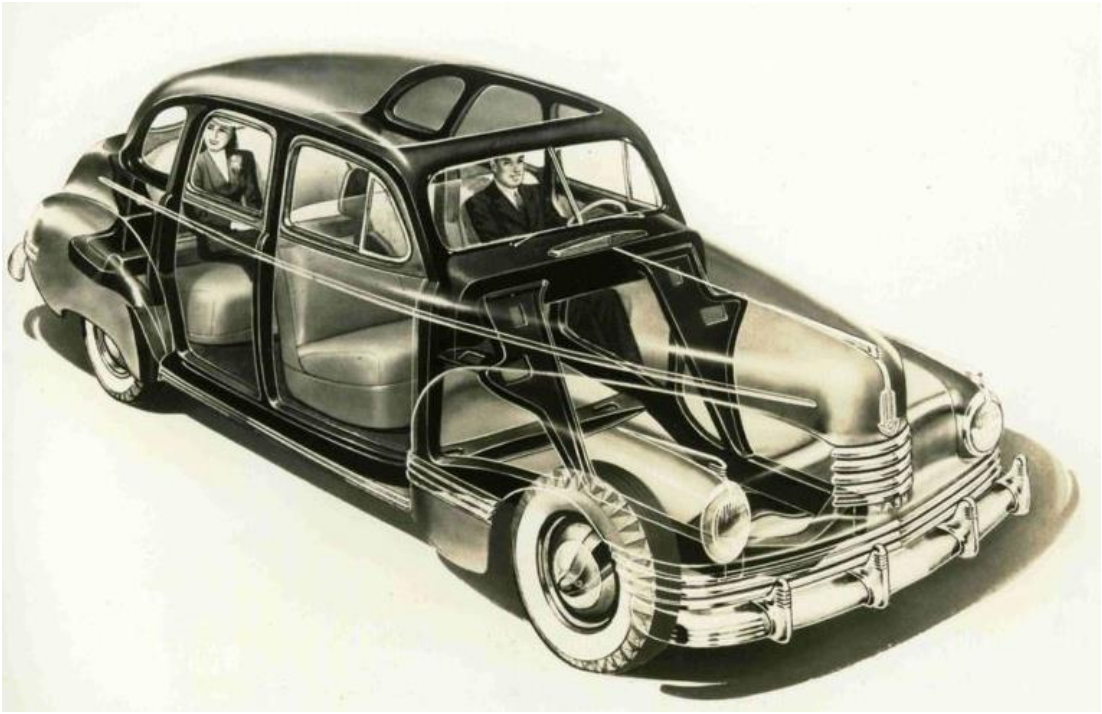
Fiat 500 Topolino 1948

Monocoque (Unibody)

www.forbes.com

- The Land Rover (1948) with its riveted aluminum body was a result of this phenomenon

Monocoque (Unibody)



- First mass-produced unibody construction in US :by Nash Motors in 600 (1951)

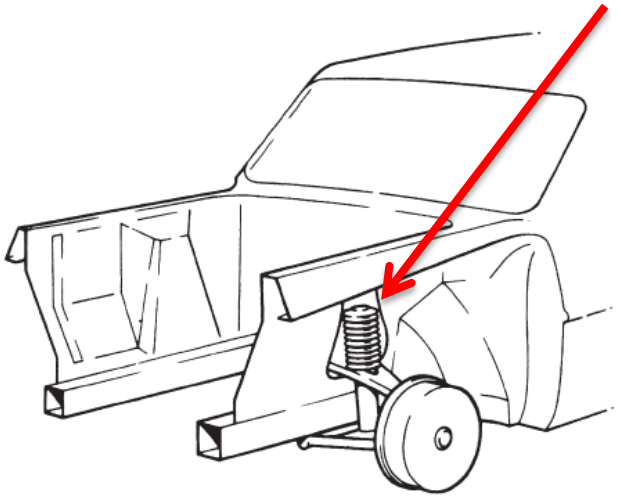
Semi Integrated Method

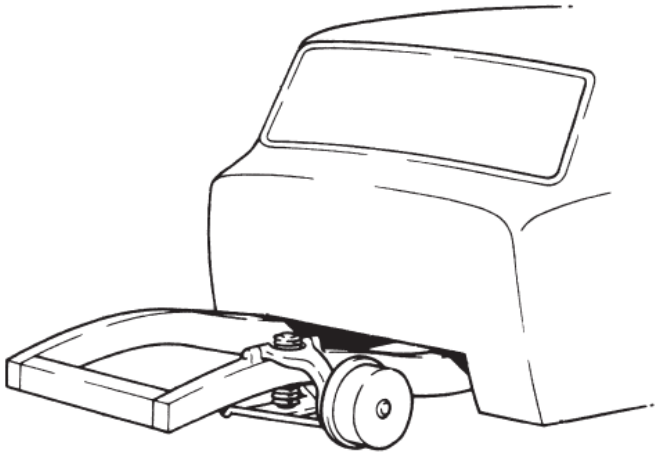
- Partial monocoque combined with a subframe carrying the front end and powertrain.
- Front end or subframe forward of the bulkhead is joined to the cowl assembly with bolts.
  - Subframe can be replaced as one assembly in the event of extensive damage
  - Isolation of noise and vibration of power train and suspension components

Chevrolet Camaro (1967-81)

How Monocoque differs from Composite Construction?

- Suspension member is incorporated to the body





- Floor pan area: In integral body this is usually of heavier gauge metal than in the composite body
- Upper body :Construction will be heavier in the areas like rear seat, attaching members for front wing, bulk head and floor assembly for better strength

Monocoque (Unibody)

- Advantages
  - Cheap for mass production
  - Inherently good crash protection
  - Space efficient

- Disadvantages
  - It's very heavy
  - Impossible for small-volume production

Aluminum Space Frame and ULSAB monocoque

In early 1990s

Traditional steel monocoque

Safety regulations

ULSAB monocoque

ASF

Ultra Light Steel Auto Body (ULSAB)

- Advantages:
- Stronger and lighter then conventional
- Disadvantages:
- Not strong or light enough for the best sports cars.
- Same structure as that of conventional monocoque
- Use of "Hydroform" parts, sandwich steel and laser beam welding

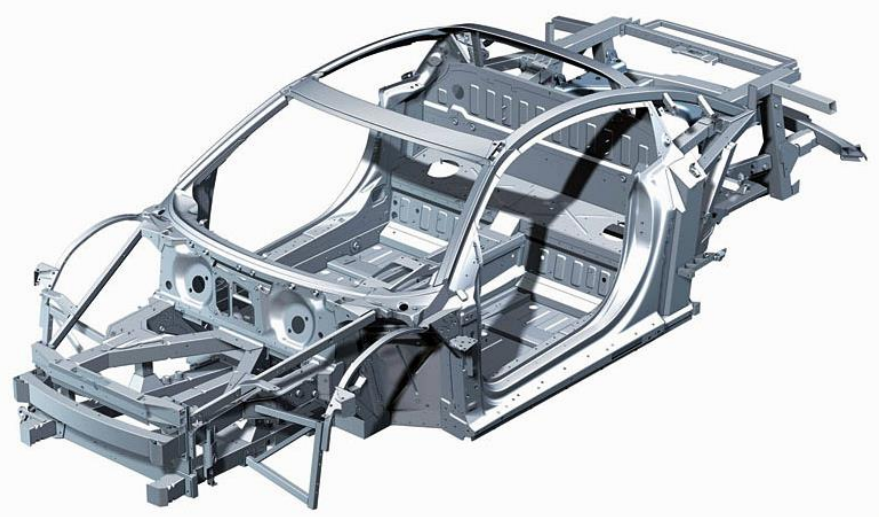
Ultra Light Steel Auto Body (ULSAB)

BMW 3 series

- Conventional pressing-creates inhomogeneous thickness - the edges and corners are always thinner than surfaces
- Leads to use of thicker sheet metal
- Hydroform – high pressure fluid are used to create uniform thin steel tube
- Designers can use the minimum thickness steel to reduce weight

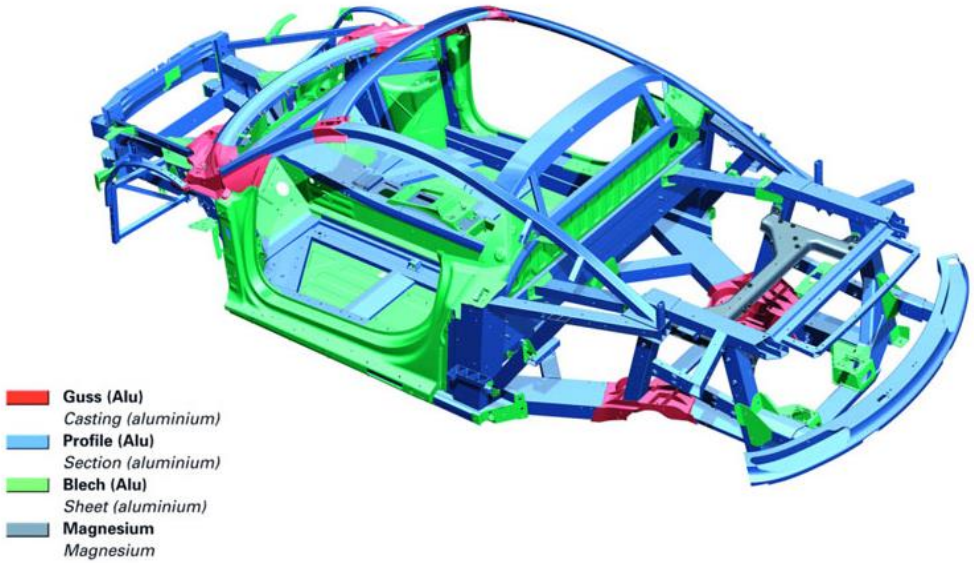
Aluminum Space Frame

Audi ASF



- Audi A8 is the first mass production car featuring Aluminium Space Frame chassis.
- Developed in conjunction with US aluminium maker Alcoa, ASF is intended to replace conventional steel monocoque mainly for the benefit of lightness.
- Audi claimed A8's ASF is 40% lighter yet 40% stiffer than contemporary steel monocoque.

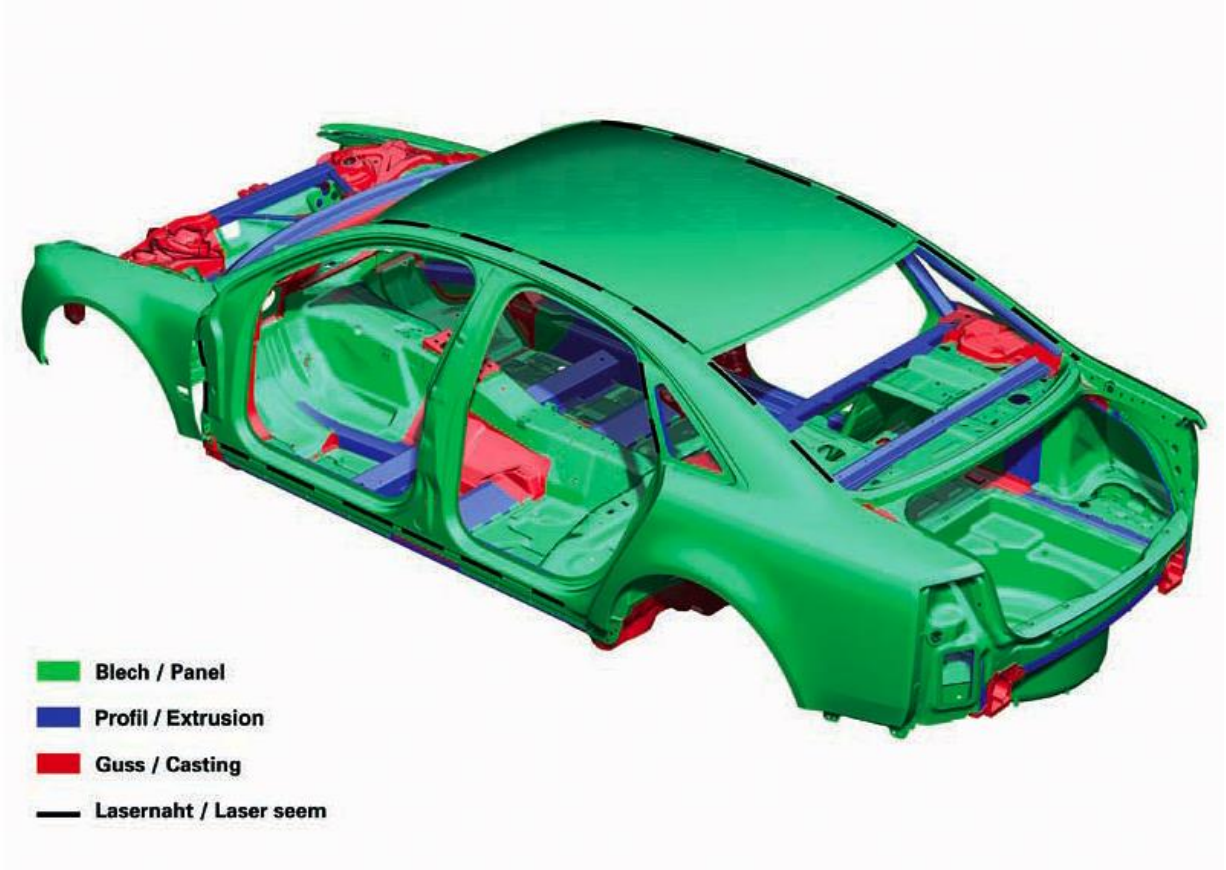
Aluminum Space Frame



- ASF consists of extruded aluminum sections, vacuum die cast components and aluminum sheets of different thicknesses.
- At the highly stressed corners and joints, extruded sections are connected by complex aluminum die casting (nodes)

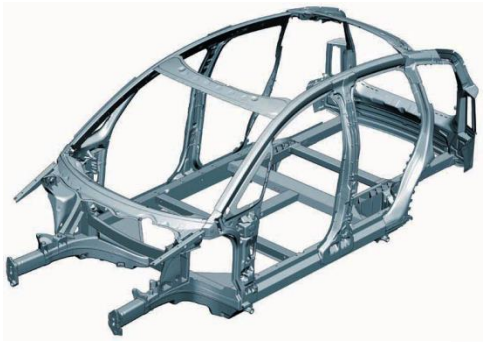
Aluminum Space Frame

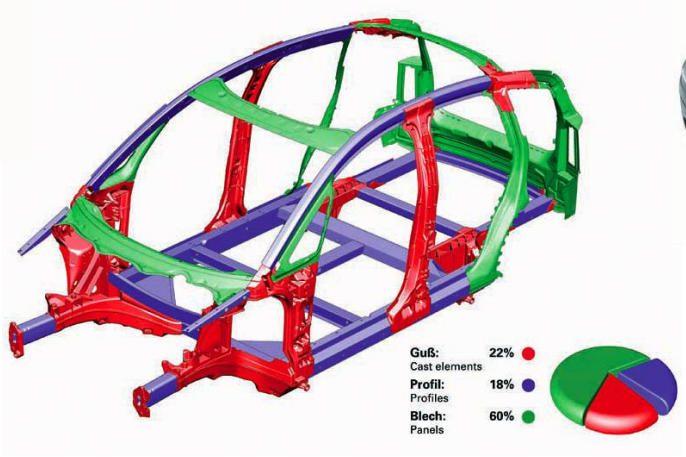
First generation ASF technology



Aluminum Space Frame

Second generation ASF technology





- Advantages
  - Lighter than steel monocoque. As space efficient as it.
- Disadvantages
  - Still expensive for mass production

Lotus Aluminum Space Frame

- Chassis is made of extruded aluminium sections joined by glue and rivets
- Aluminium extruded sections can be made much thinner than traditional welding technique
- Welded joints are weak, so the thickness of material should be increased throughout a member just to make a joint strong enough
- Advantages:

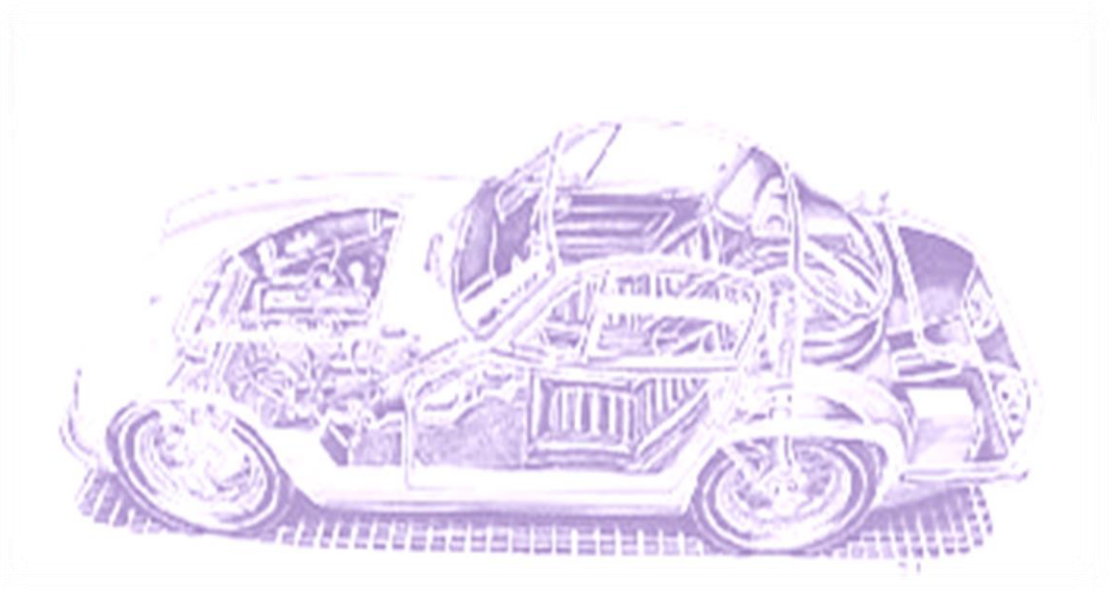
  Cheap for low-volume production. Offers the highest rigidity-to-weight ratio besides carbon fiber monocoque
- Disadvantages:

  Not very space efficient

Glass-Fiber body

- The Chevrolet Corvette (1953) was the first production car with a fiberglass body (46 components in total)

Glass-Fiber body

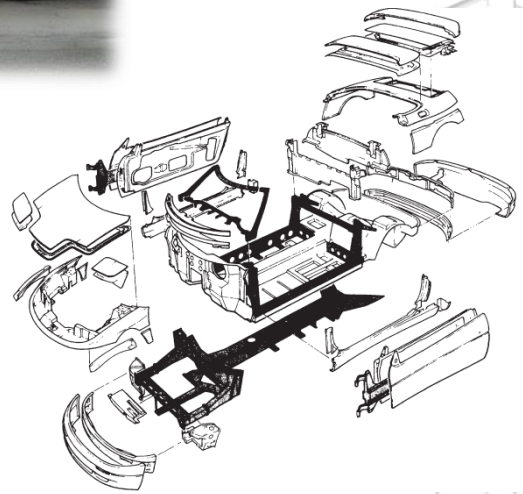


- In 1957, Lotus pioneered Glass-Fiber Monocoque chassis in Elite
- Engine, transmission and suspensions were bolted onto the glass-fiber body
- The stressed chassis are usually backbone, tubular space-frame, aluminium space-frame or even monocoque.
- Whole car weighed as light as 660 kg

Glass-Fiber body

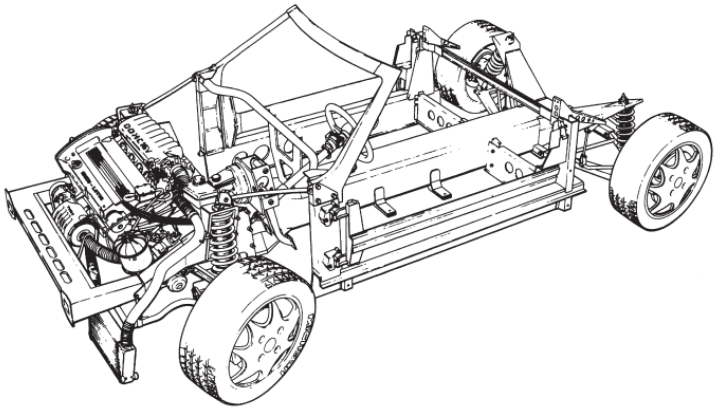
- Advantages
  - Lightweight.
  - Cheap to be produced in small quantity.
  - Rust-proof.
- Disadvantages
  - Lower visual quality.
  - Unable to act as stressed member.

Lotus Elan



- Body panels are secured by self-tapping bolts which offer very positive location and a useful saving in assembly time

Backbone Chassis



1962 Lotus lunched the Elan

- Colin Chapman, the founder of Lotus, invented backbone chassis in his original Elan roadster.
- A strong tubular backbone (usually in rectangular section) connects the front and rear axle and provides nearly all the mechanical strength
- Inside which there is space for the drive shaft in case of front-engine, rear-wheel drive layout like the Elan
- The body is built on the backbone, usually made of glass-fibre.

Backbone Chassis

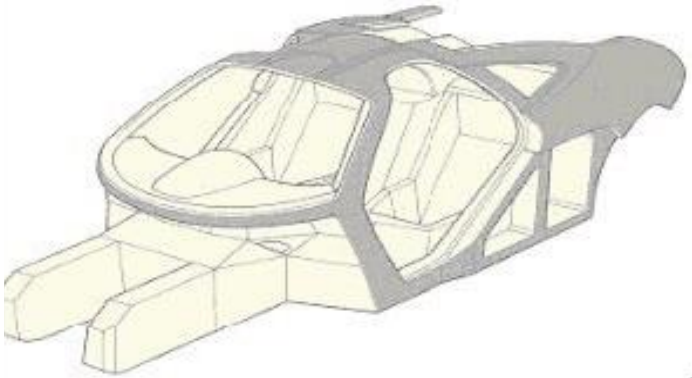
- Advantages:
- Strong enough for smaller sports cars.
- Cheap for low-volume production.
- The most space-saving other than monocoque chassis.
- Disadvantage:
- Not strong enough for high-end sports cars.
- The backbone does not provide protection against side impact or off-set crash.

Carbon-Fiber Monocoque

- Superior rigidity-to-weight ratio
- In the early 80s, FIA established Group B racing category, which allowed the use of any technology available as long as a minimum of 200 road cars are made.
- As a result, road cars featuring Carbon-Fiber body panels started to appear, such as Ferrari 288GTO and Porsche 959.

Carbon-Fiber Panels Vs Carbon-Fiber Monocoque Chassis?

- Carbon Fiber Monocoque was first introduced in 1981 with McLaren's MP4/1 Formula One racing car
- Carbon-fiber monocoque chassis, which had only ever appeared in McLaren F1, Bugatti EB110SS and Ferrari F50
- Superior rigidity with optimize weight.



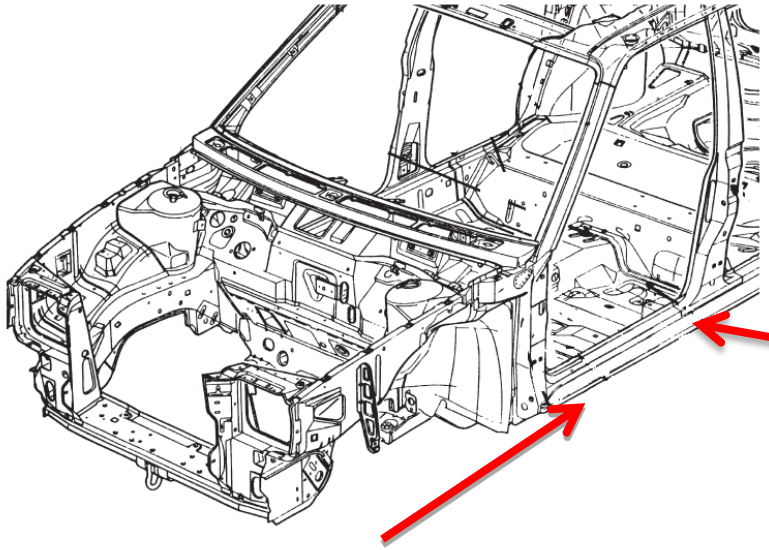
Carbon-Fiber Panels Vs Carbon-Fiber Monocoque Chassis?

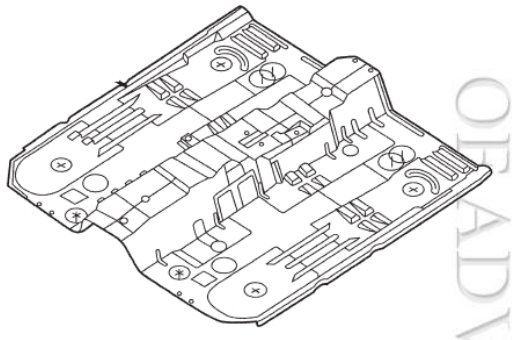
Car	Body	Chassis
Ferrari 288GTO (1985)	carbon fiber panels	steel tubular space frame
Porsche 959 (1987)	carbon fiber panels	steel monocoque
Ferrari F40 (1988)	carbon fiber panels + doors	steel tubular space frame
McLaren F1 (1993)	carbon fiber panels	carbon fiber monocoque
Ferrari F50 (1996)	carbon fiber panels + doors	carbon fiber monocoque
Lamborghini Diablo SV (1998)	mostly aluminium panels, with carbon fiber bonnet + engine lid	steel tubular space frame
Lamborghini Diablo GT (1999)	mostly carbon fiber panels + aluminium doors	steel tubular space frame

- Advantages
  - The lightest and stiffest chassis
- Disadvantages
  - By far the most expensive

Chevy Corvette Z06-Manufacturing Process

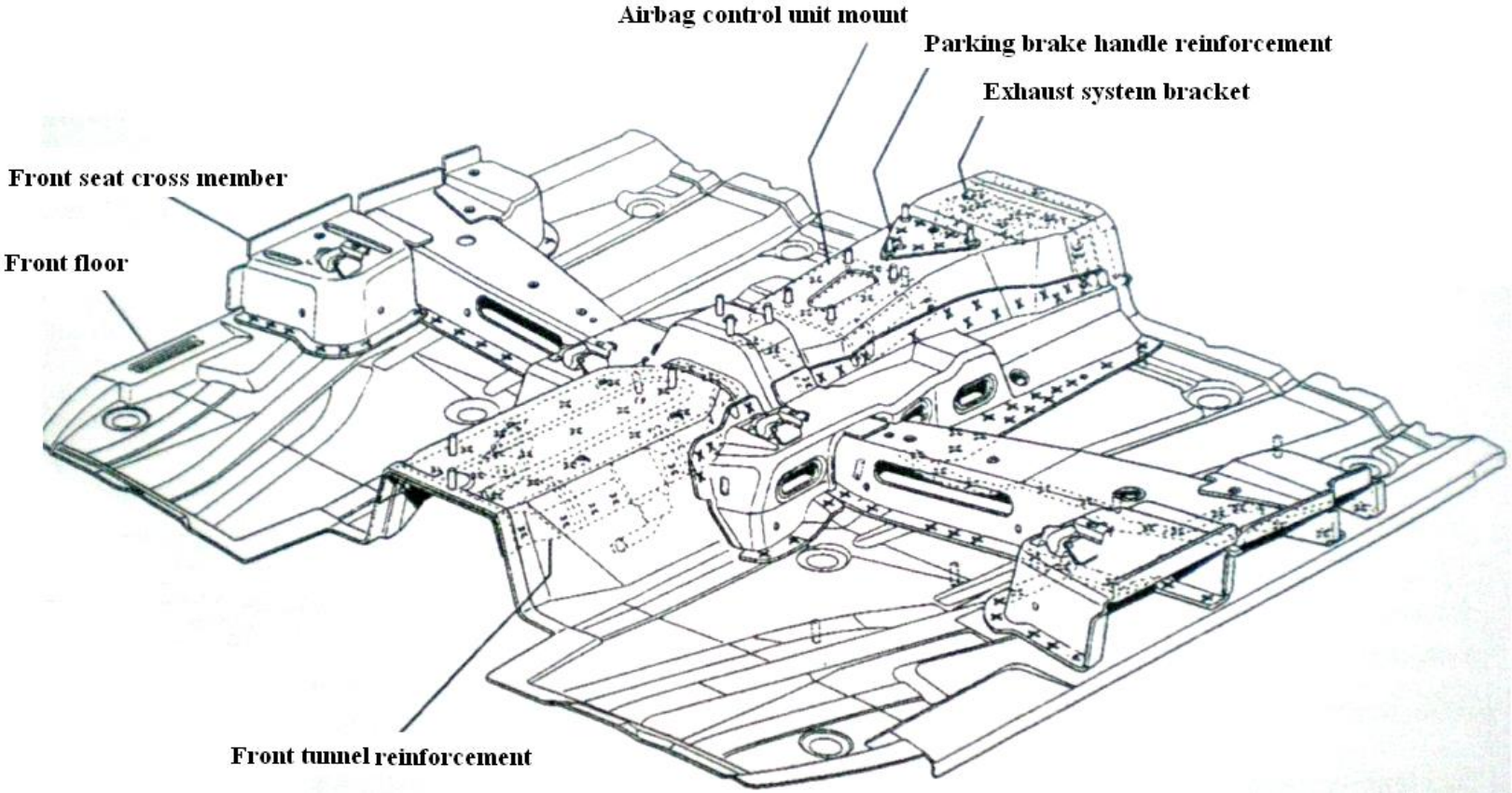
Basic Automotive Construction



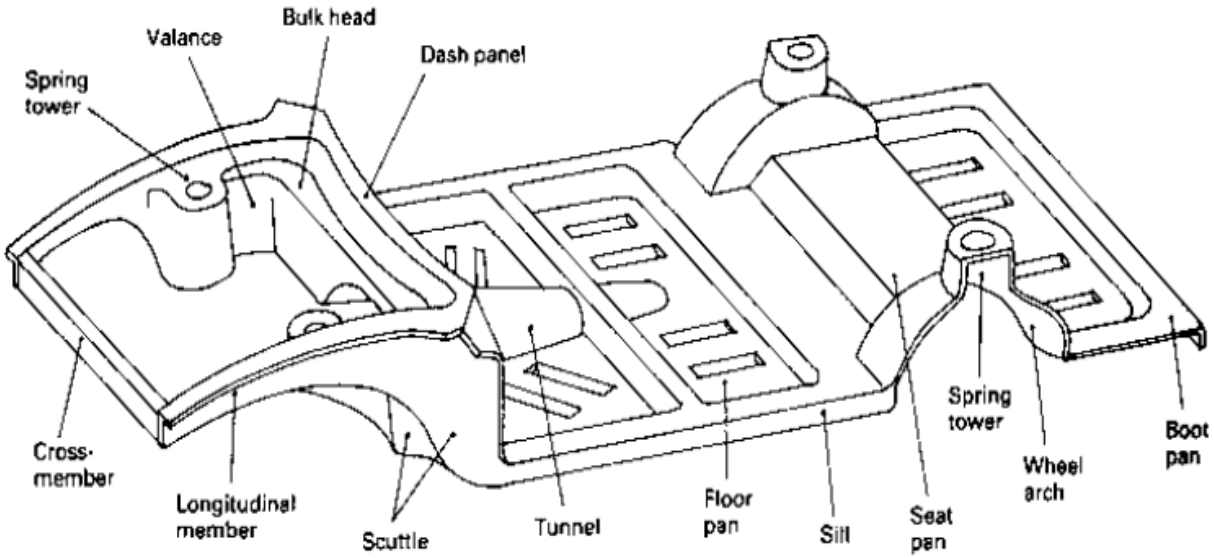


- Main Central Pannel
  - Carry the weight of front seat and passengers
- Main floor pan
  - Comprises a toe board or pedal panel, provide rest for passengers feet
  - Seals off the engine and gear box from the body and connect scuttle to the main floor
  - Access holes were provided for to access to the gear box, oil filler and dipstick.

Basic Automotive Construction

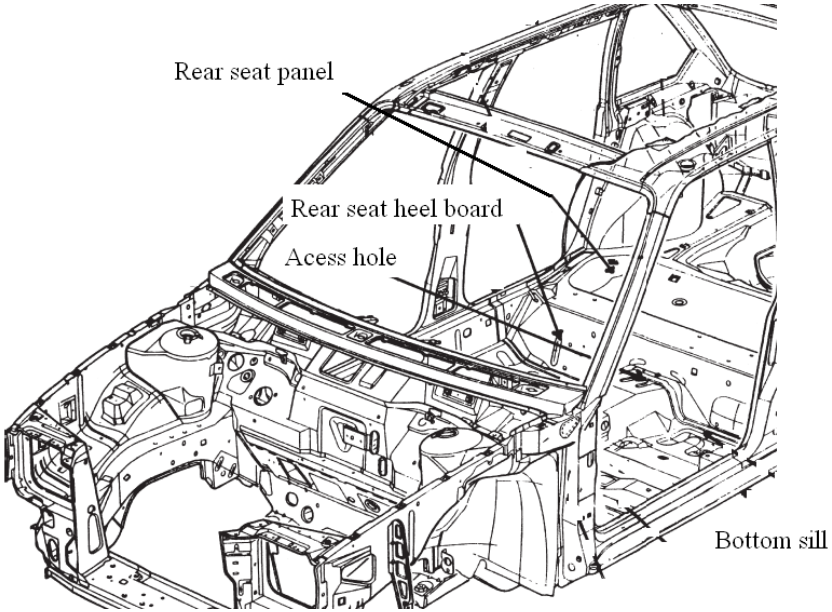


Basic Automotive Construction



- The front end of the main floor is fixed to the toeboard panel and the sides of the main centre floor are strengthened by the bottom sills (lower horizontal sides of the car body which span between front and rear wheel arches)

Basic Automotive Construction

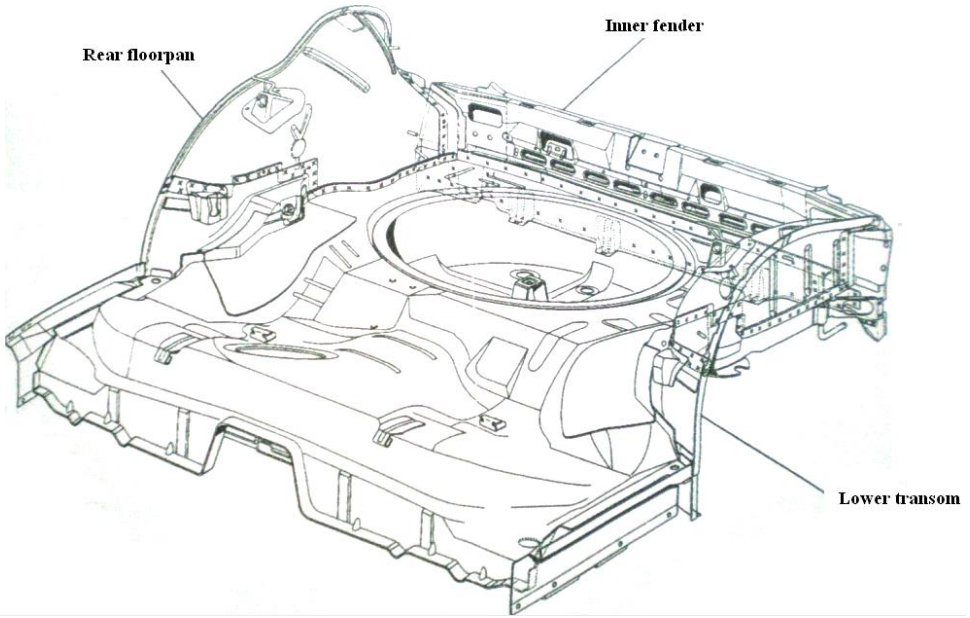


- The rear end of the floor is stiffened transversely by the rear seat heelboard(It is an upright, shallow panel spanning beneath front of rear seats)
- Main purpose is to provide leg height for the passengers and to form a raised step for the seat pan so that the rear axle has sufficient relative movement clearance

Basic Automotive Construction

- Rear seat panel is reinforced to gain enough strength to support the rear passengers
- The front edge of the rear seat panel is stiffened by the rear seat heelboard, and the rear edge of the seat panel is stiffened by the rear squab panel.

Basic Automotive Construction



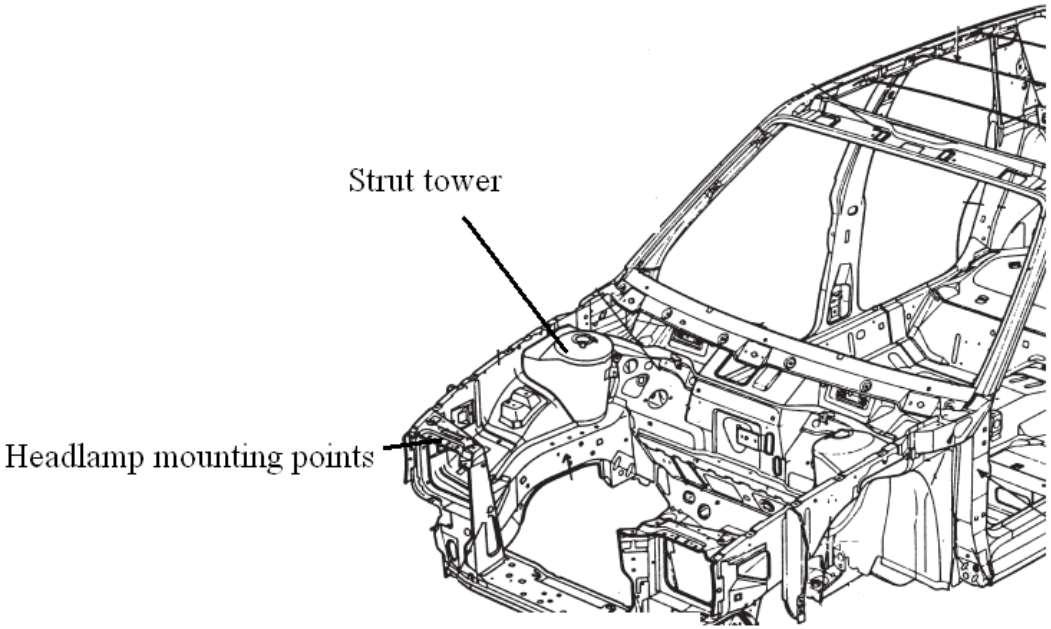
- Boot floor which extends from the back of the rear squab panel to the extreme back of the body, completes the floor unit.
- The lower steel pressing which supports luggage and accommodate the spare wheel
- The wheel arch panels seal the rear road wheels from the body

Basic Automotive Construction

Bodywork

- Front components are first attached to the floor pan
- Upper front section provides lock and latch for engine compartment hood
- Also mounting point for bumpers and have mounting point for radiators

Basic Automotive Construction

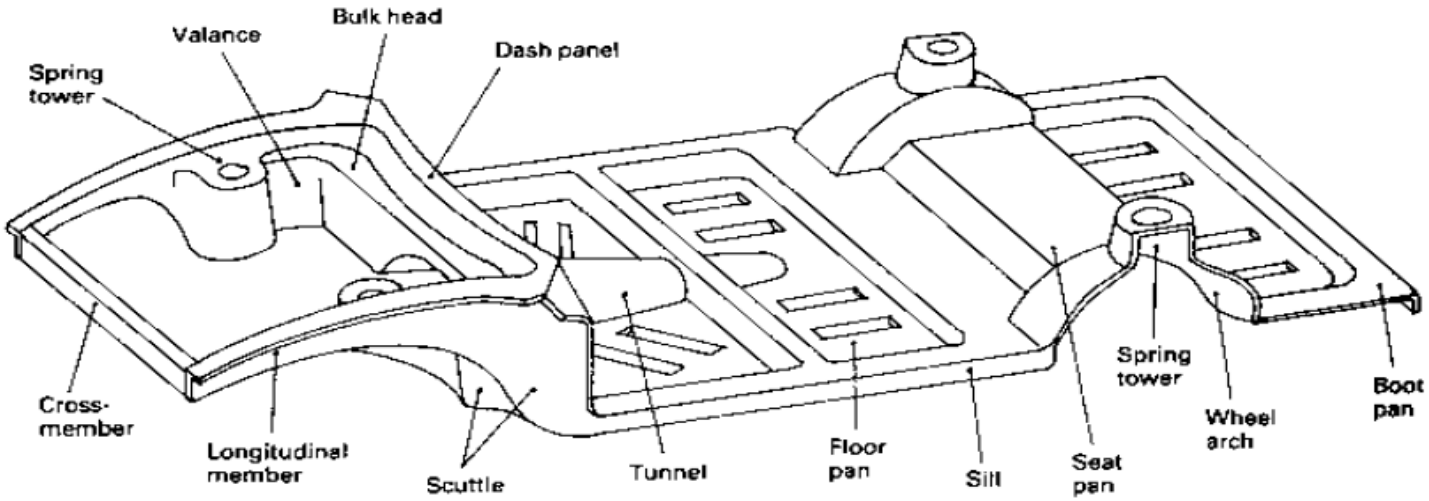


- Front side provides the headlamp mounting points
- Suspension strut mounting (strut towers) are located at the top of inner fenders, which absorbers all suspension strut reaction force

Basic Automotive Construction

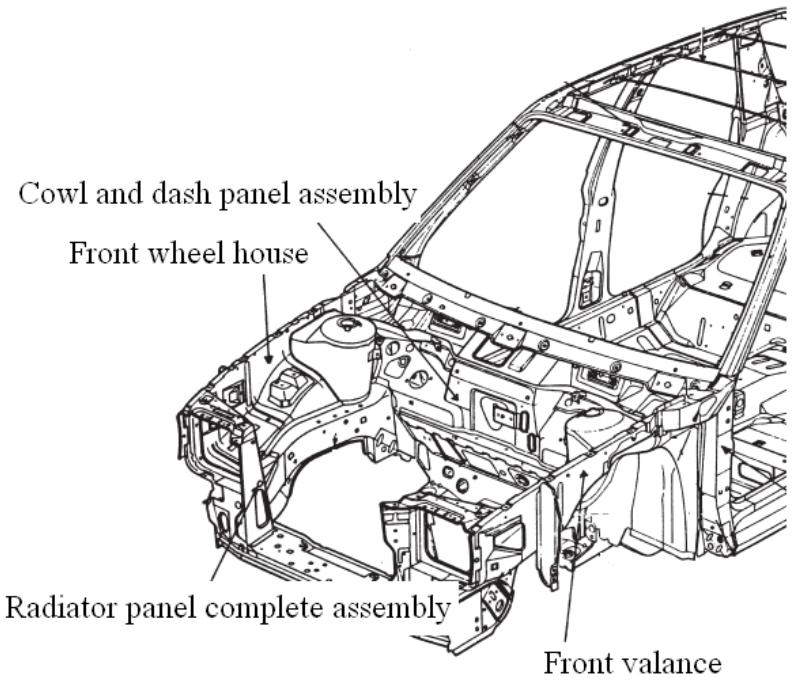
- Frame horn located above inner fender direct the forces to the A-pillar and doors post in the event of frontal collision
- Each inner fender is joined to the side panel bulkhead

Bulk Head



- Is the upright partition separating the passenger and engine compartment
- Its upper part forms a part of the dash board
- The scuttle and valance on each side are usually joined onto the box-section of the bulkhead

Basic Automotive Construction



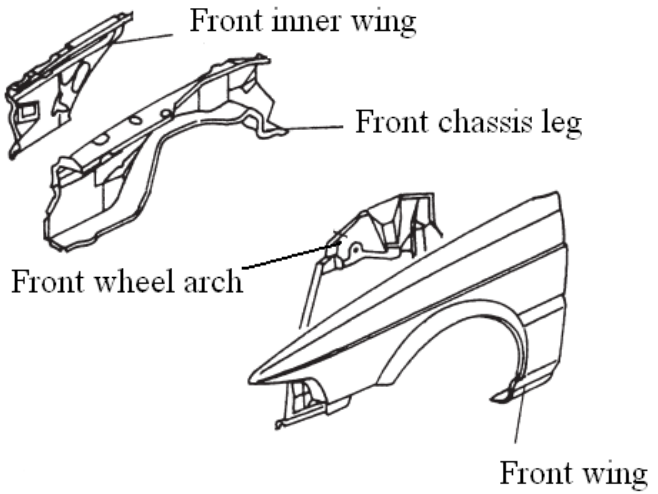
- The cowl or dash panel or fire wall forms the front bulkhead of the body
- The cowl is the partition between the passenger and engine compartments, and it accommodate the necessary mounting points for various components and controls

Basic Automotive Construction

- Firewall deformation after a frontal collision a measure of a body design's structural quality

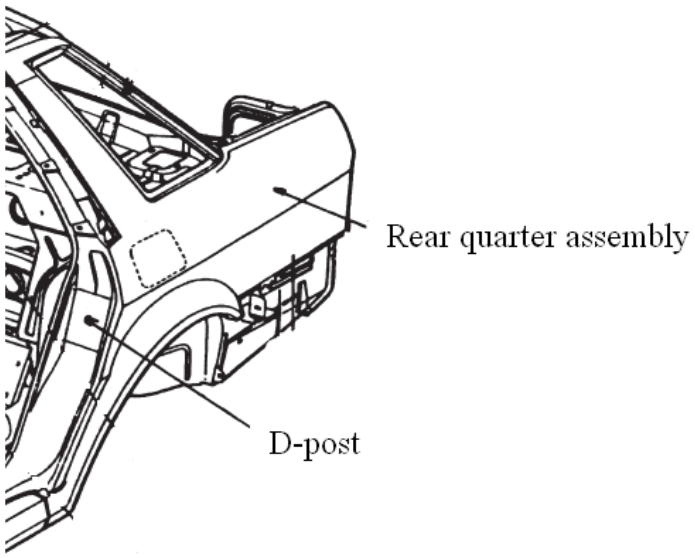
Basic Automotive Construction

- Wings (fender assembly):covers the wheels and suspension construction
- Wings are attached to the wing valance by means of flanges
- Headlights and side lights are recessed into the front wing
- Bead is a flange which turn inwards to form a U section with rounded bottom
- It provide strength and prevent cracks developing in the edges of wing due to vibration



Basic Automotive Construction

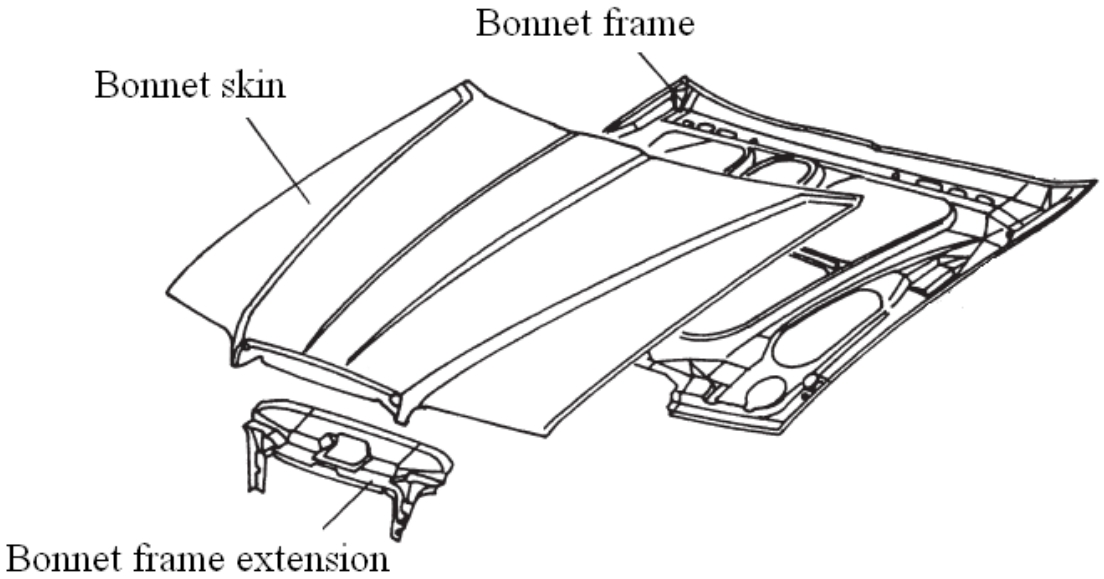
- Rear Wing forms the integral part of quarter panel
- Inner construction is used to from part of the housing around wheel arch
- Wheel arch is welded to the rear floor section and is concealed by rear quarter panel



Basic Automotive Construction

- Boot lid
- Door which allow access to the luggage compartment
- Composed of outer and inner panel, which are spot welded along their flanged edges to form a single unit
- Hatch back and estate cars have rear window built into the bootlid (tail gate)
- External handle and locking mechanism
- Surrounding the boot lid opening gutter are provided to carry away rain and water to prevent it entering the boot

Basic Automotive Construction



- Engine Hood
- Covers the engine compartment front engine vehicle (boot compartment of rear engine vehicle)
- Bonnet has inner and outer panels reinforced in the H pattern
- In some cars the outer panel is bonded to the inner panel using epoxy resin

Basic Automotive Construction

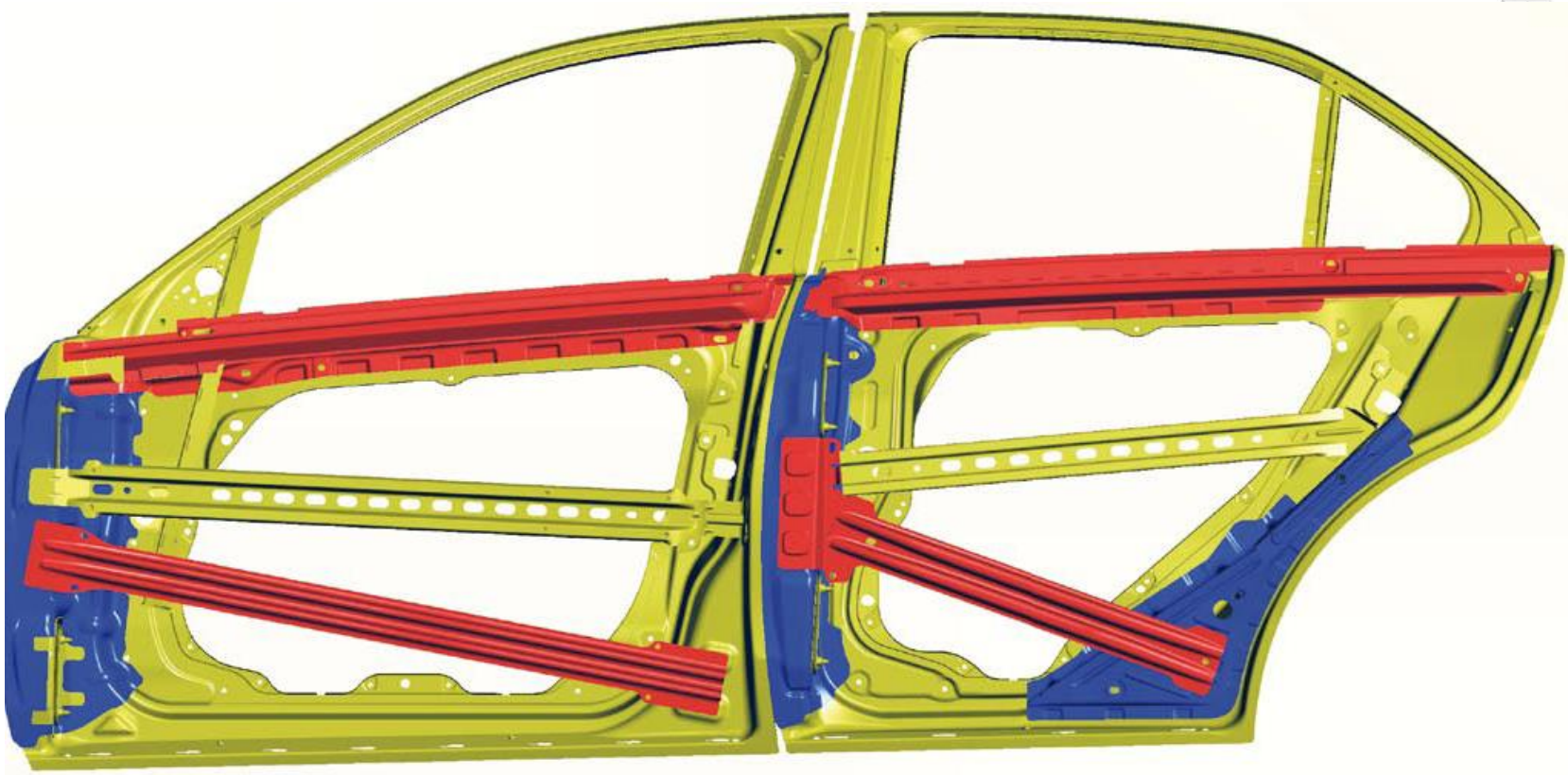
- Engine Hood
- Legal requirements for pedestrian protection
- Design of inner section of the hood
- Use of actuator to raise the hood in milliseconds during pedestrian impact

Basic Automotive Construction

- Early models used a pianotype hinge was used where the bonnet hinged both at the centre and at the side
- Mono or one-piece type are common in later designs, and can be opened by a variety of methods
- On some types it is hinged at the front so that the rear end swings up when the bonnet is open
- Others are designed so that they can be opened from either side, or unlatched from both sides and removed altogether
- Most bonnets, however are of the alligator pattern, which is hinged at the rear so that the front end swings up when opened

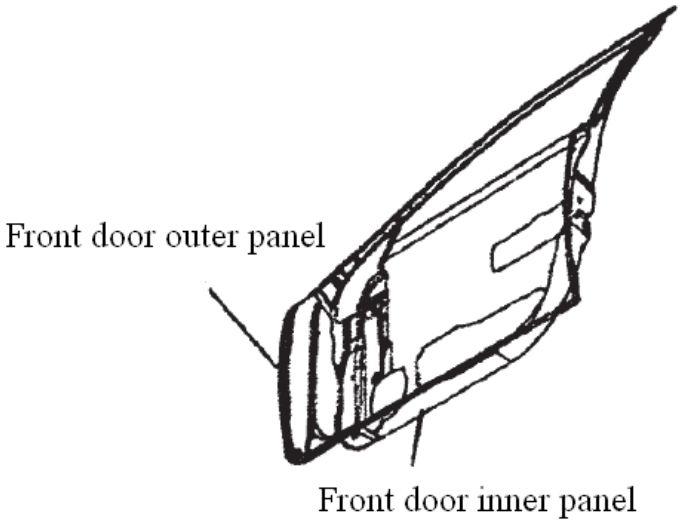
Basic Automotive Construction

Door



Basic Automotive Construction

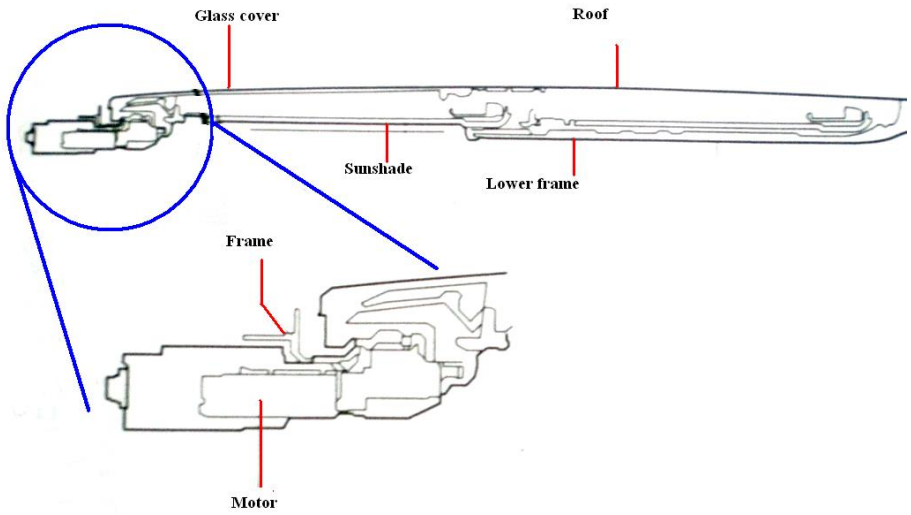
- Door composed of ouert and inner panels:
- Inner panel act a frame for better strength
- Outer panel flanges over the inner panel to form a single unit which is then spot welded or adhesive bonded to the frame
- Inner panel has holes for door trim attachments
- Inner panel form the lock and hinge pillar section for doors
- The trim consists of window regulator assembly and door locking mechanism



Basic Automotive Construction

- Largest and simplest in construction
- Area which roof covers varies between different model
- Optionally the roof may include a sliding or tilting sunroof

Basic Automotive Construction



- Factor has to consider in sunroof design:
- Integration of entire sunroof mechanism including electronic drive in the available space (not more that 6 cm)
- Based on aerodynamics
- Occupant space requirement
- Sunroof water drainage .Rainwater from the sunroof is carried by a hose within the roof leading to the wheel well by way of A pillar

Summary/Conclusion

- History behind automotive chassis evolution have been introduced
- Basic automotive construction and different types of automotive structures has been discussed