Vehicle systems

Lecture notes

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Chassis and production

Historical view

The first motor car bodies and chassis frames, made between 1896 and 1910, were similar in design to horse-drawn carriages and, like the carriages, were made almost entirely of wood.

The frames were generally made from heavy ash, and the joints were reinforced by wrought iron brackets which were individually fitted. The panels were either cedar or Honduras mahogany about 9.5 mm thick, glued, pinned or screwed to the framework.

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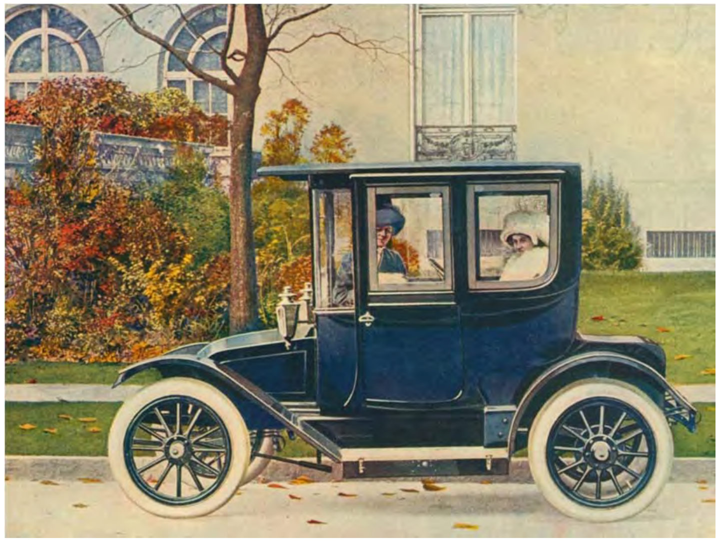
Historical view



- The tops, on cars which had them, were of rubberized canvas or other fabrics. Some bodies were built with closed cabs, and the tops were held in place by strips of wood bent to form a solid frame.

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Historical view

- About 1921 the Weymann construction was introduced, in which the floor structure carried all the weight of the seating, and the body shell, which was of very light construction, was attached to the floor unit. Each joint in the shell and between the shell and the floor was made by a pair of steel plates, one on each side of the joint and bolted through both pieces of timber, leaving a slight gap between the two pieces. The panelling was of fabric, first canvas, then a layer of wadding calico and finally a covering of leather cloth. This form of construction allowed flexibility in the framing and made a very light and quiet body frame, but the outer covering had a very short life.

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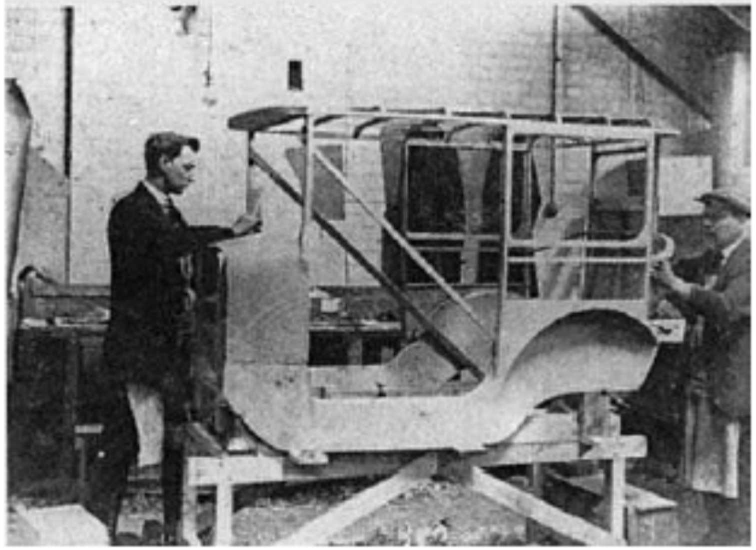
Historical view



As the demand for vehicles increased it became necessary to find a quicker method of production. Up to that time steel had been shaped by hand, but it was known that metal in large sheets could be shaped using simple die tools in presses, and machine presses were introduced to the steel industry to form steel sheets into body panels. Initially the sheets were not formed into complex shapes or contours, and the first bodies were very square and angular with few curves. The frame and inner construction was still for the most part made of wood.

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Historical view

About 1923 the first attempts were made to build all-steel bodies, but these were not satisfactory as the design principles used were similar to those which had been adopted for the timber-framed body. The **real beginning of the all-steel body shell came in 1927**, when presses became capable of producing a greater number of panels and in more complex shapes; this was the dawn of the mass production era. During the 1930s most of the large companies who manufactured motor vehicles adopted the use of metal for the complete construction of the body shell, and motor cars began to be produced in even greater quantities.

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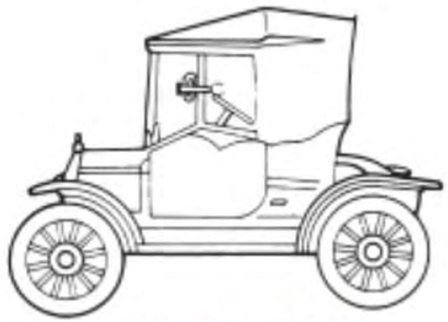
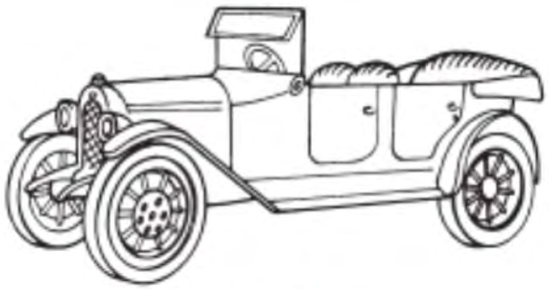
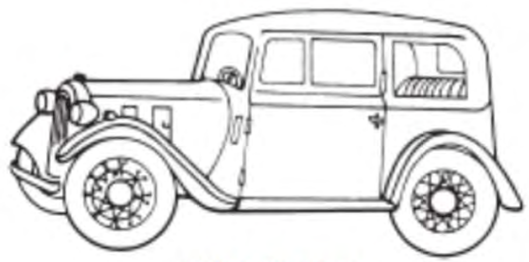
Historical view



1909 The first Baby Austin



1922 Austin Tourer



1932 Austin Saloon

1946 Austin 16

Owing to the ever-increasing demand for private transport, competition increased between rival firms, and in consequence their body engineers began to incorporate features which added to the comfort of the driver and passenger. **This brought about the development of the closed cars or saloons as we know them today.** Then came the general use of **celluloid for windows instead of side curtains**, and next a raising and lowering mechanism for the windows. Nowadays the windscreen and door glasses are made of laminated and/or toughened safety glass. The window mechanism in use today did not begin to develop until well into the 1920s.

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Historical view


1948 Austin A–70


1952 Austin Seven


1959 Austin Princess


1960 Austin Mini

Mudguards, which began as wooden or leather protections against splattered mud, grew into wide splayed deflectors in the early part of the twentieth century and then gradually receded into the body work, becoming gracefully moulded into the streamlining of the modern motor car and taking the name of wings. Carriage steps retained on earlier models gave place to running boards which in their turn disappeared altogether.

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1963 Austin 1100

1964 Austin 1800

1970 Austin Maxi 1800

1973 Austin Allegro

1975 Austin Princess

1976 Austin Rover SDI

1980 Austin Metro

1983 Austin Maestro

1984 Austin Montego

1986 Austin Rover 200

1987 Austin Rover Sterling

1988 Rover 820 Fastback

1989 Mini Flame

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Historical view

Steering between 1890 and 1906 was operated by a tiller. This was followed by the steering wheel which is in current use. The position of the gear lever made an early change from the floor to the steering column, only to return to some convenient place on the floor.

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Historical view

Some of the first vehicles, or horseless carriages as they were known, carried no lights at all; then **carriage candle lamps** made their appearance. Later came **oil lamps, acetylene lamps and finally the electric lighting system,** first fitted as a luxury extra and ultimately becoming standard and finally obligatory equipment which must conform with legislation of the day.

When windscreens were first introduced such accessories as windscreen wipers and washers were unknown. Then came the single hand operated wiper, followed by the suction wiper and finally electrically driven wipers.

Images from, https://www.al-lighting.com/company/history/

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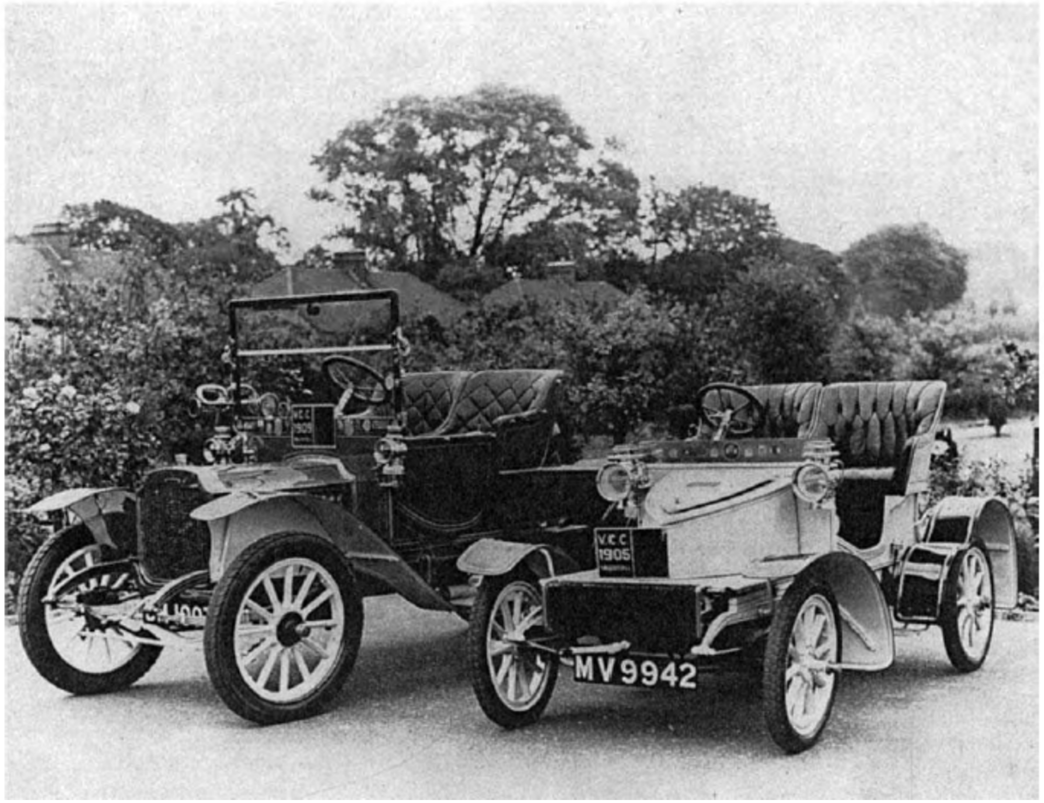
Historical view



The design of the wheels was at first dictated by fashion. It was considered necessary for the rear wheels to be larger than the front, a legacy from the elegant horse-drawn carriages. Wooden spokes and iron tyres were the first wheels to appear, and with both rear and front wheels of the same dimensions. Then came the wooden-spoked artillery wheel with pneumatic tyre.

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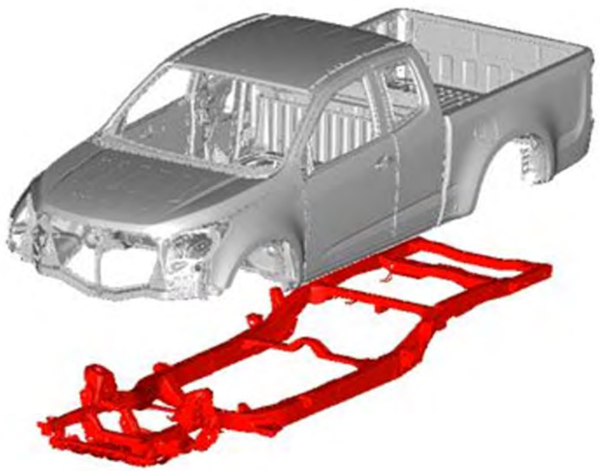
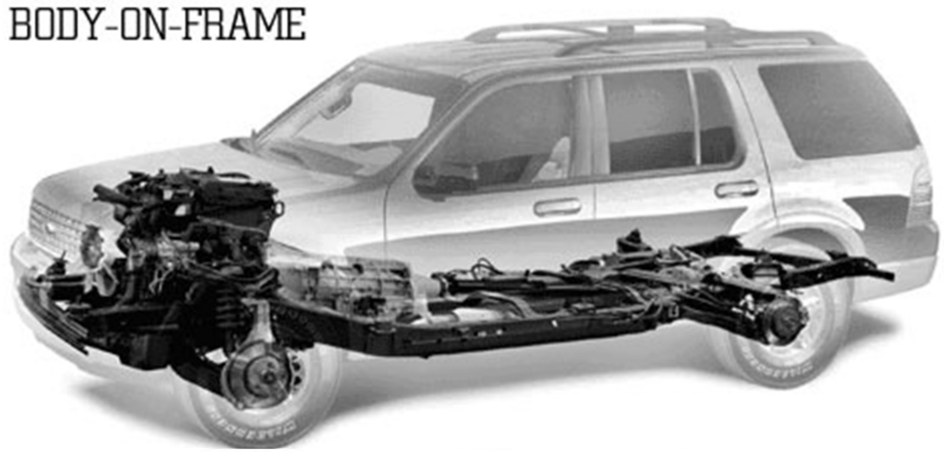
CHASSIS TYPES

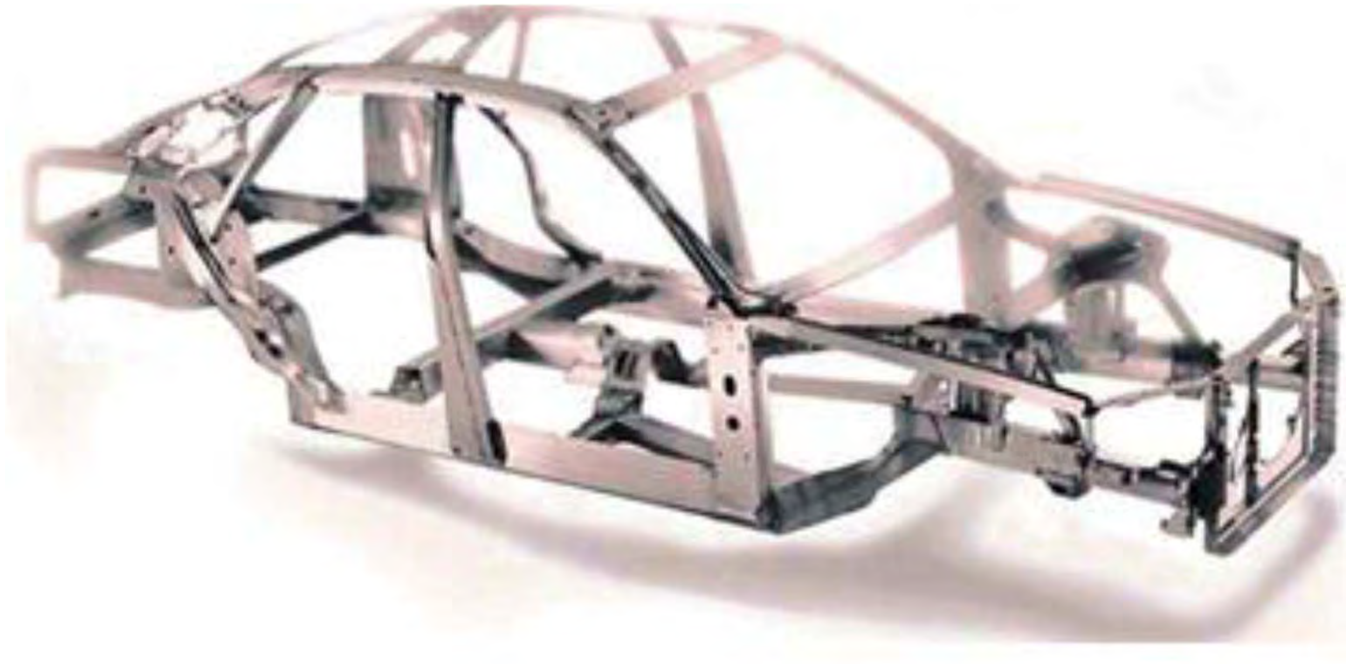
Body-on-frame





Since the 80's it is a common Body Structure type for Medium and Heavy Pickup trucks. The main characteristic is a sub frame attached to Body Structure by flexible Body Mounts.

Unibody structure types- Space Frame



Space Frame: Framework of beams connected at nodes. The framework is responsible to provide the structural integrity and performance. Usually the process used in order to produce this kind of Body Structure is the Roll forming and Hydro form process, that drives to be a low volume product.

*SAE-2013-36-0142

Unibody structure types- Central Close Tunnel

Central Close Tunnel: Large member down the center portion of the vehicle, responsible to bring structural integrity to the vehicle. **This kind of construction limits the quantity of seats on the vehicle.**

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Unibody structure types- **Body Frame Integral**

This is the currently predominant configuration for the passenger's cars.

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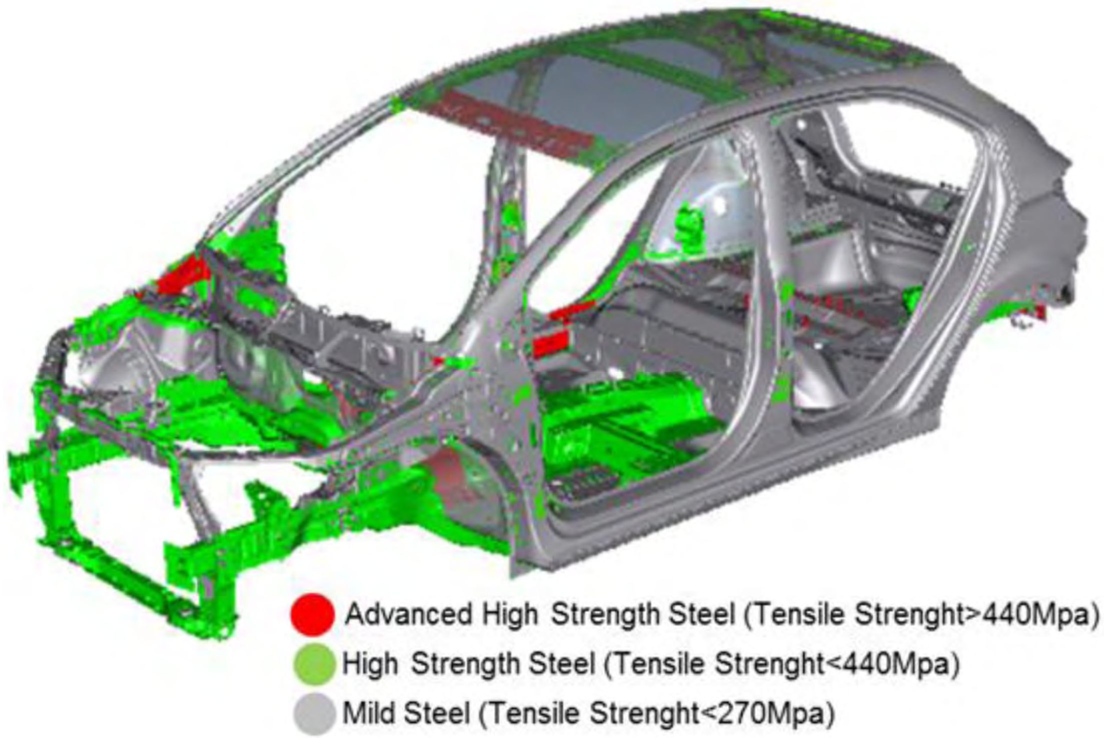
Chassis frame construction-The chassis frame

Most modern cars do in fact combine the frame with the body. This integral or unitary construction produces a stronger, lighter vehicle unit which is cheaper to produce when a large number of similar units are made. However, for heavier vehicle applications (such as trucks) and some vehicles where limited numbers are produced, the chassis frame is a separate structural member to which the main components, such as the engine, transmission and body, are attached, i.e. it forms the 'skeleton' of the vehicle.

*Alma Hillier, Hillier's fundamentals of motor vehicle technology

Body materials

Typical Body structure is assemble with metallic parts, usually steel, but nowadays, in order to meet fuel consumption and performance requirements, new materials like aluminum and Advanced High Strength Steel (AHSS) have become very common on this kind of usage.



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Chassis frame construction-The chassis frame

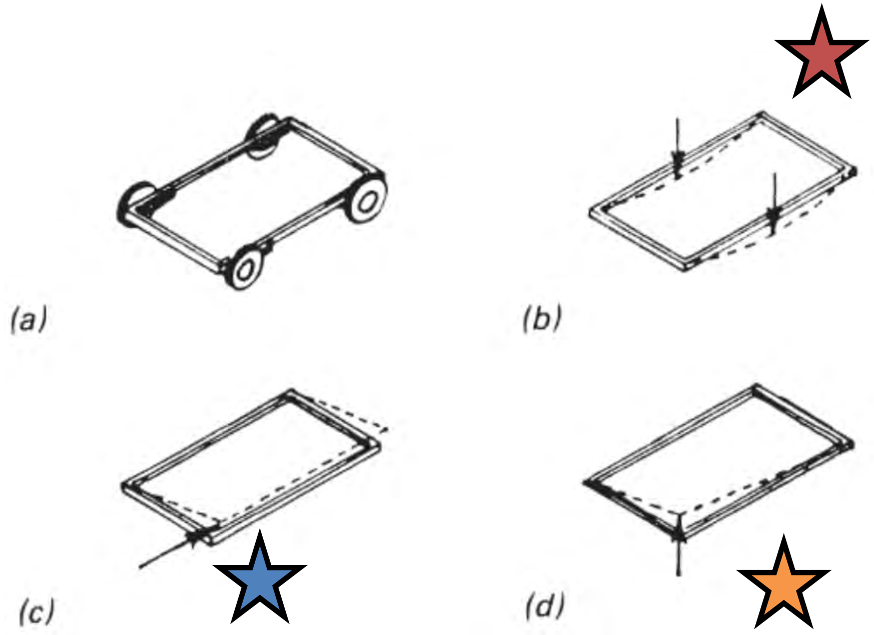
Whether in a car or a truck, a vehicle structure has to withstand various static and dynamic loads. The deflections of a simple rectangular frame, consisting of two side-members connected together with two cross-members. These deflections are caused by the following forces:

A. The weight of the components and passengers gives a *bending* action; this causes the frame to sag,

B. Road shocks, caused by vehicle motion or impact with an obstacle, produce two types of deflection in the frame

C. *Lozenging*, the term used when the rectangular frame is pushed into a parallelogram shape

D. *Twisting* due to a deflection at one corner of the frame



The body and frame must be as light as possible, yet offer maximum resistance to these deflections.

*Alma Hillier, Hillier’s fundamentals of motor vehicle technology

Chassis frame construction-Frame sections

The ideal frame section has a good resistance to **bending and torsional** effects. The three main forms are in general use are:

- Channel
- Tubular
- Box

*Alma Hillier, Hillier's fundamentals of motor vehicle technology

Chassis frame construction-Frame sections

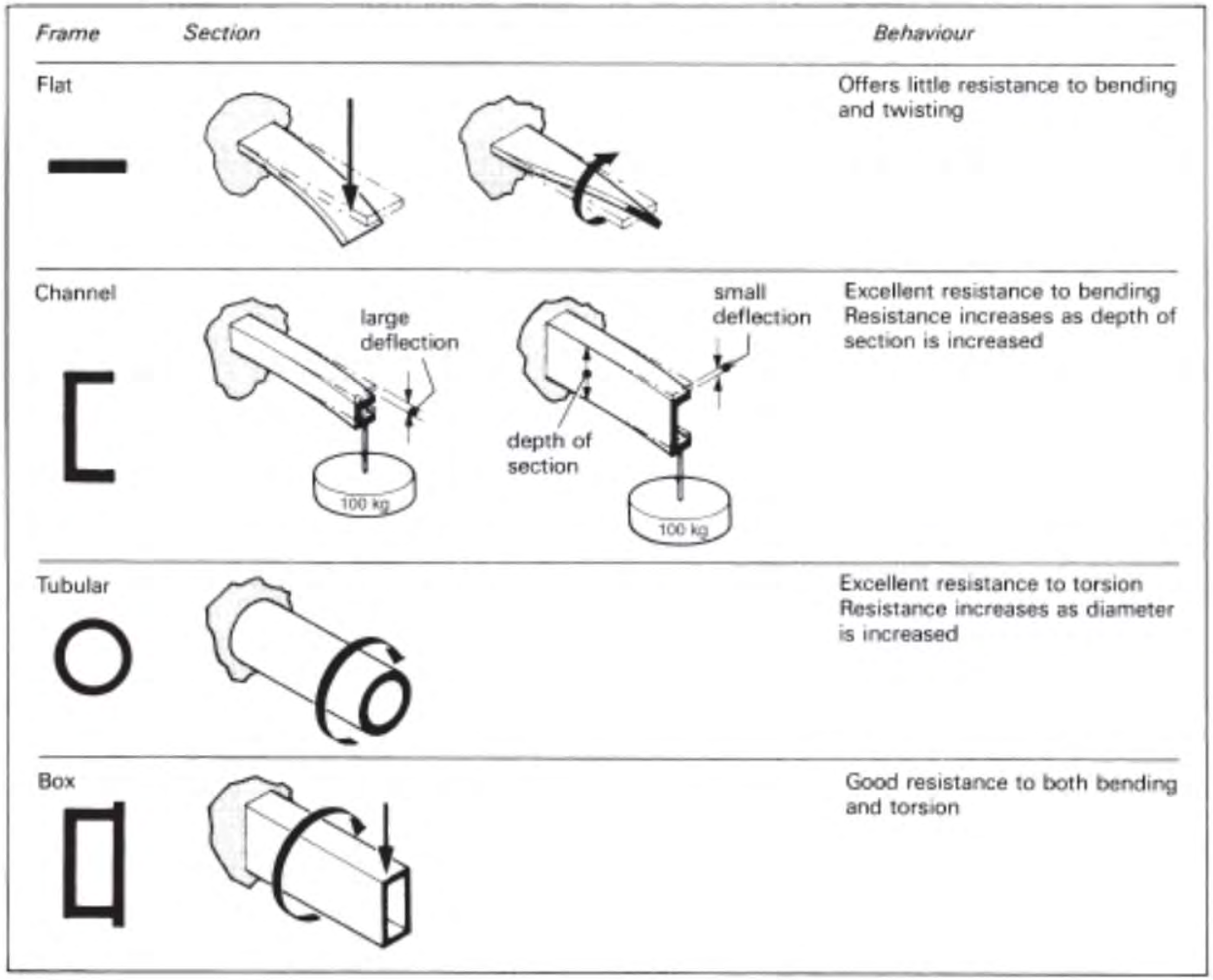


Figure 1.32 Frame sections

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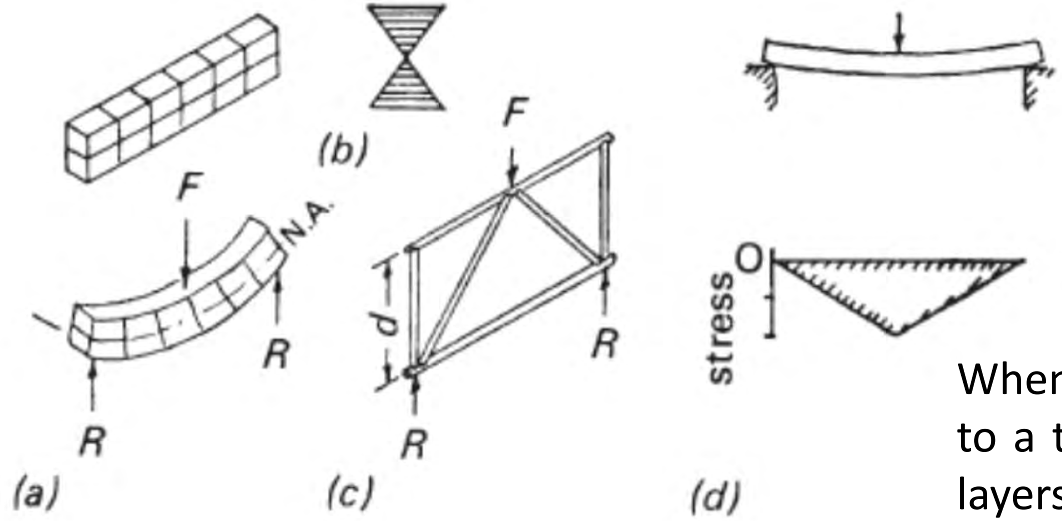
Chassis frame construction-Frame sections



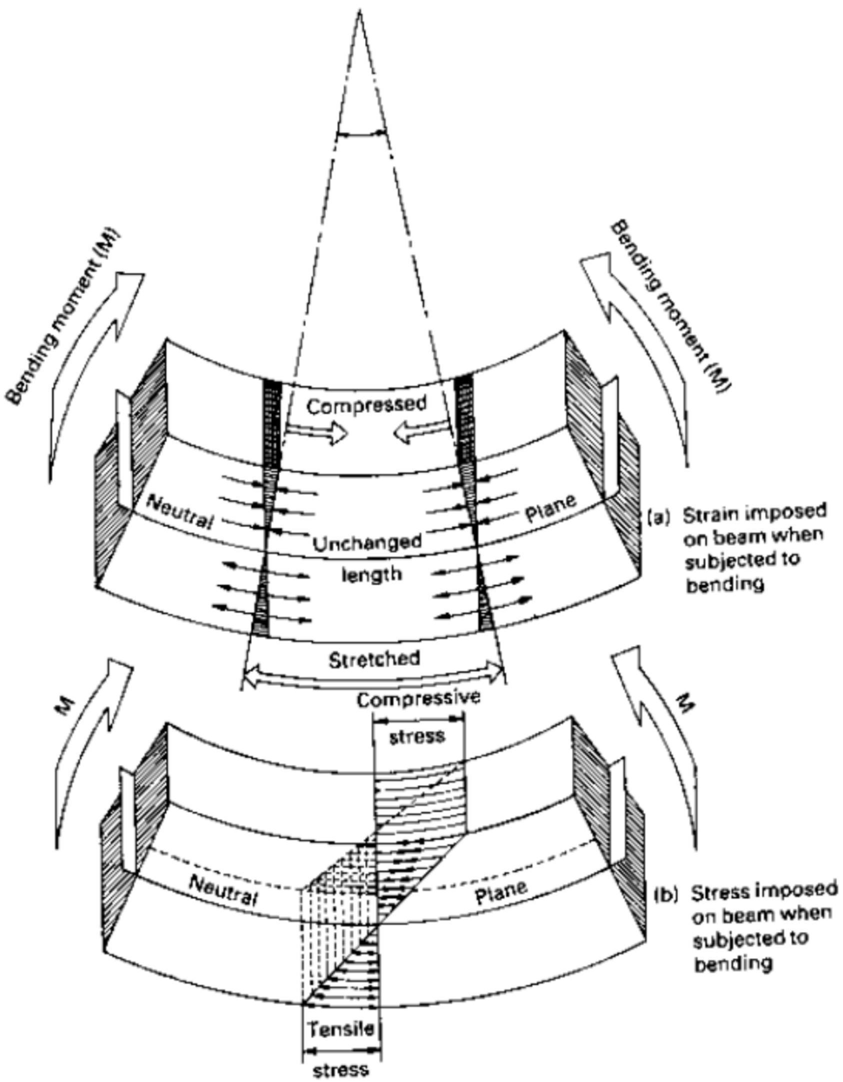
When a beam bends, the material is subjected to a tensile and a compressive stress. The top layers of the material being compressed, while the bottom layers are extended. The mid-layer is not subjected to tension or compression, and is known as the neutral axis.

A slightly deeper channel or box section can give the same resistance to bending as a much heavier solid, rectangular section. In a similar manner, the distance between the top compression member and the lower tension member is the main factor governing the strength of the tubular frame

Whenever a hole has to be drilled in a chassis member, either to reduce weight or to attach something, it should be positioned in a low-stress region, e.g. along the neutral axis.

*Alma Hillier, Hillier's fundamentals of motor vehicle technology

Chassis frame construction-Frame sections



When a force is applied to the centre of a beam there is a tendency for the material to break at its centre. This is because the stress is greatest at this point, as shown in the diagram. In order to resist this stress, either the beam must have the same deep section throughout its length, or a varying section of a depth proportional to the stress suffered. The latter design would be much lighter.

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Chassis frame construction-Frame sections

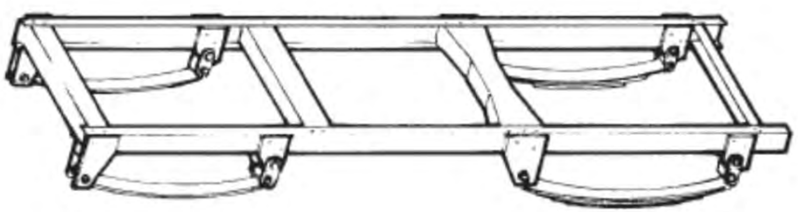


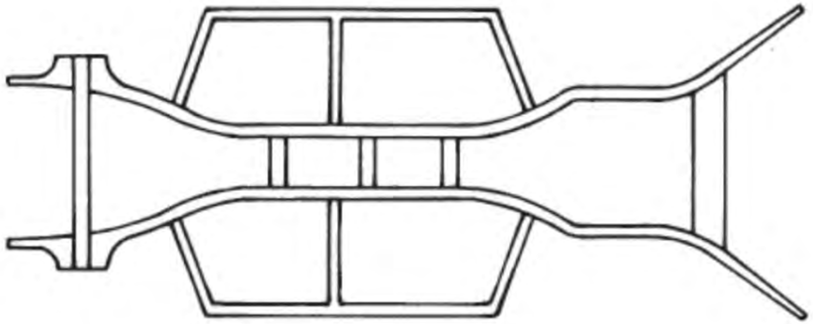
Figure shows a pictorial view of a frame suitable for a light truck or minibus that uses a non-independent suspension system. It consists of two channel-shaped side-members, which are held apart by a series of crossmembers. These are positioned at points of high stress and are cold-riveted to the side-members. The depth of the channel section must be sufficient to minimize deflection.

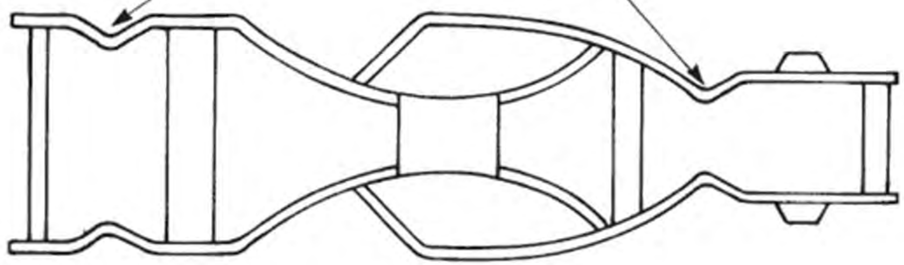
Lozenging of the frame is prevented by fitting gusset plates to reinforce the joins between the side- and crossmembers, or by adding X–type (cruciform) bracing between two or more of the cross members.

*Alma Hillier, Hillier's fundamentals of motor vehicle technology

Chassis frame construction-Frame sections

A backbone frame

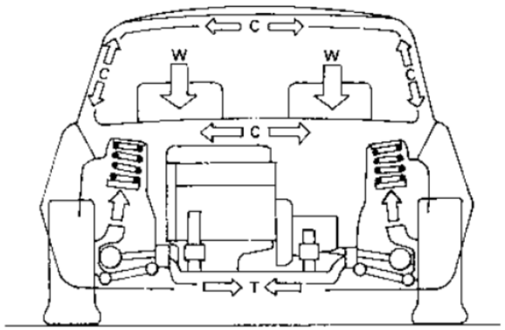




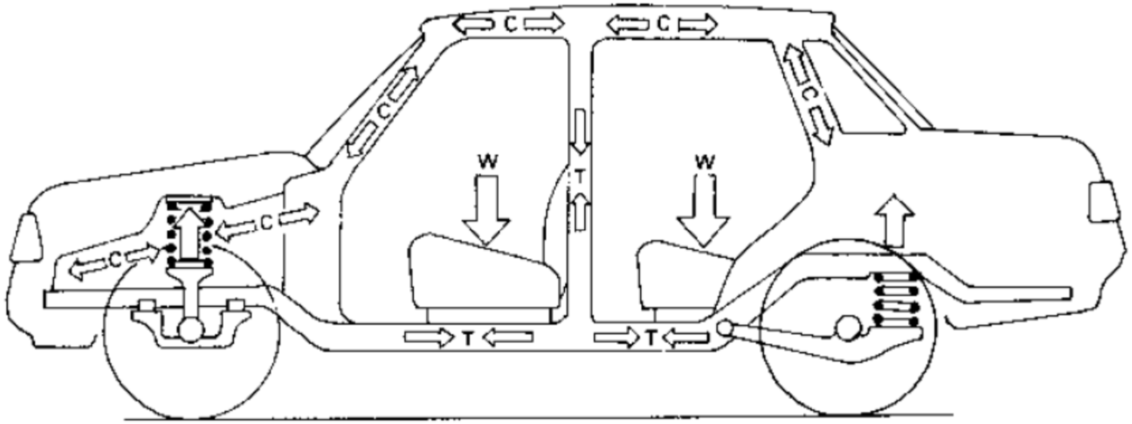
A backbone frame, as shown in Figure is an alternative construction to the conventional rectangular frame. This consists of two longitudinal, box-section members welded together at the centre and separated at the front and rear so as to accommodate the main components. A series of outrigger frame members are welded to the spine to support the floor of the body.

In the past it was considered that safety for the occupants of a car involved in a collision could be improved by making the chassis frame very stiff. This is untrue because on impact a 'tank-like' structure subjects the occupants to an extremely high deceleration. As a result the forces acting on the human body as it smashes into a hard surface are likely to cause death or serious injury. Most modern frames overcome this problem by constructing the front and rear ends of the frame in a manner that allows them to absorb the main shock of the impact. Body panels in the vicinity of these crumple zones are generally damaged beyond repair when they suffer a substantial impact, but this is a small price to pay for occupant safety.

*Alma Hillier, Hillier's fundamentals of motor vehicle technology



(b) Transverse body loading



(a) Lengthwise body loading

The integral or unitary body structure of a car can be considered to be made in the form of three box compartments; the middle and largest compartment stretching between the front and rear road wheel axles provides the passenger space, the extended front box built over and ahead of the front road wheels enclosing the engine and transmission units and the rear box behind the back axle providing boot space for luggage. These box compartments are constructed in the form of a framework of **ties (tensile) and struts (compressive), pieces made from rolled sheet steel pressed into various shapes such as rectangular**, **triangular, trapezium, top-hat or a combination of these to form closed box** thin gauge sections. These sections are designed to resist direct tensile and compressive or bending and torsional loads, depending upon the positioning of the members within the structure.

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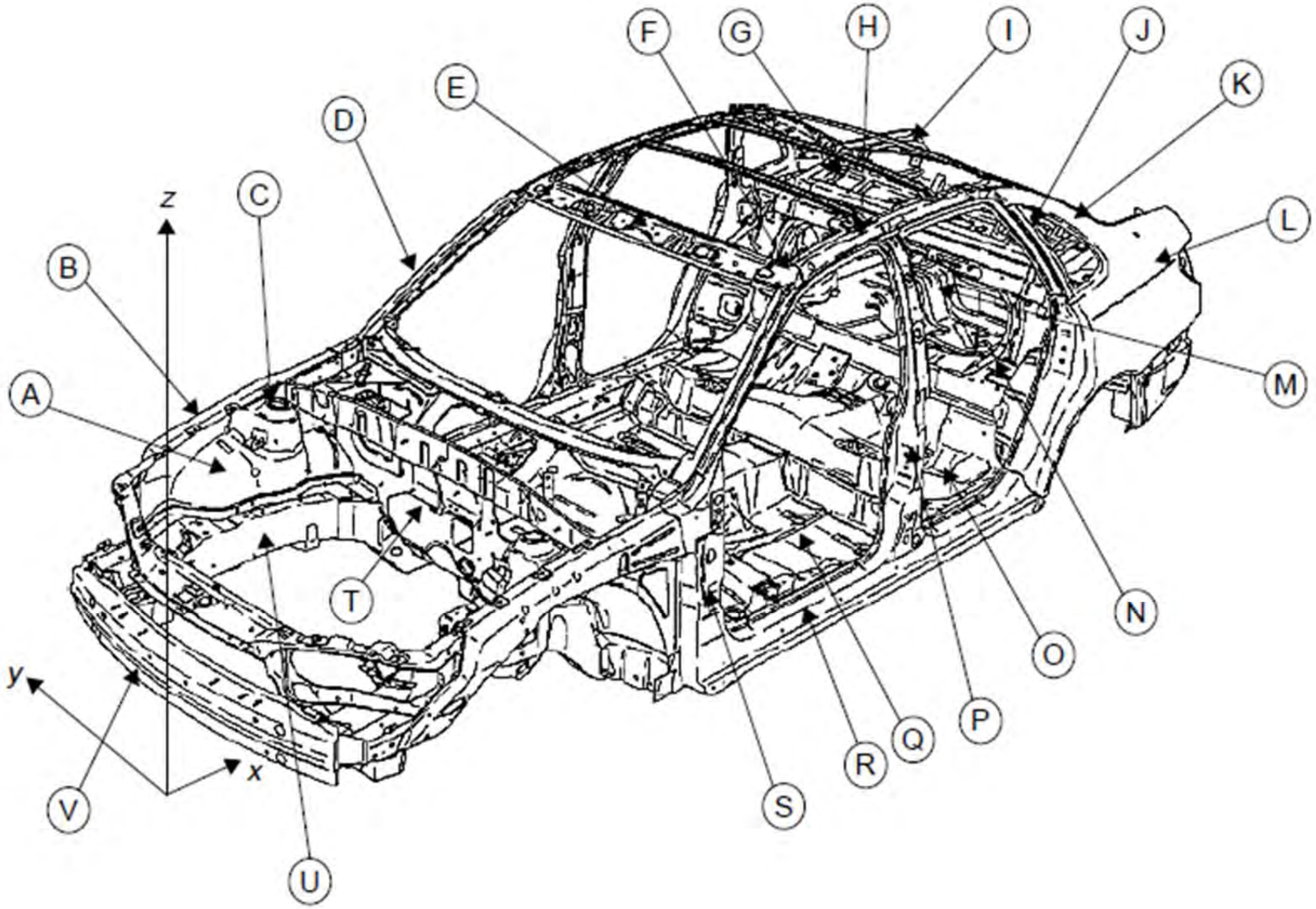
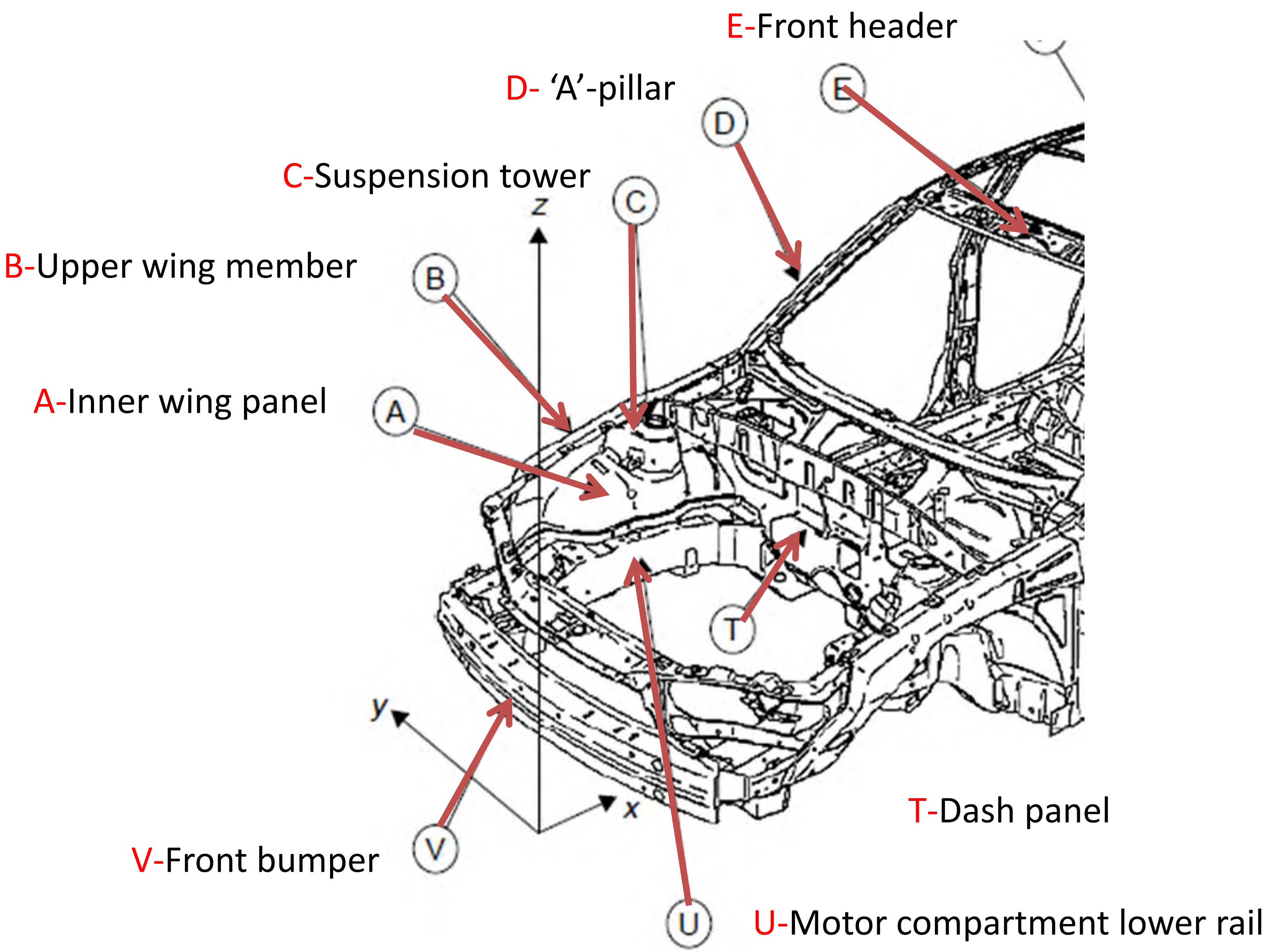
Unibody/Monocoque Chassis Members



Unibody/Monocoque Chassis Members



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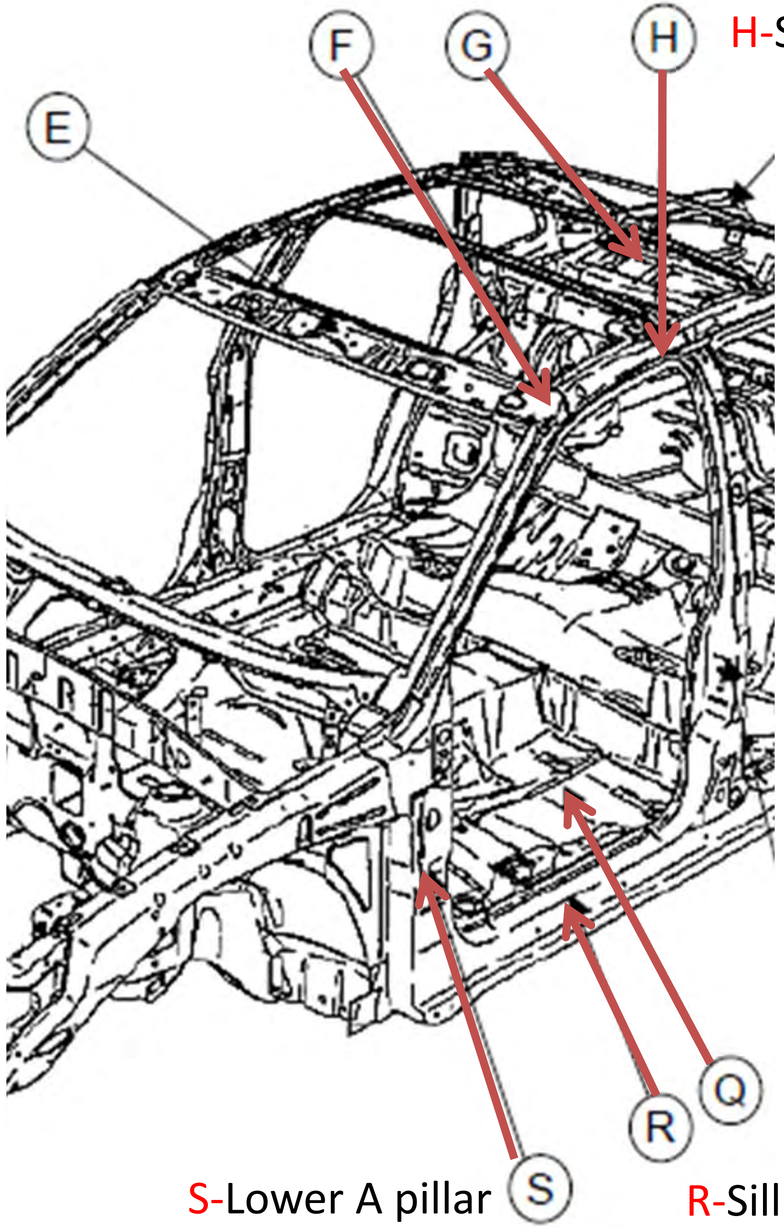
Unibody/Monocoque Chassis Members



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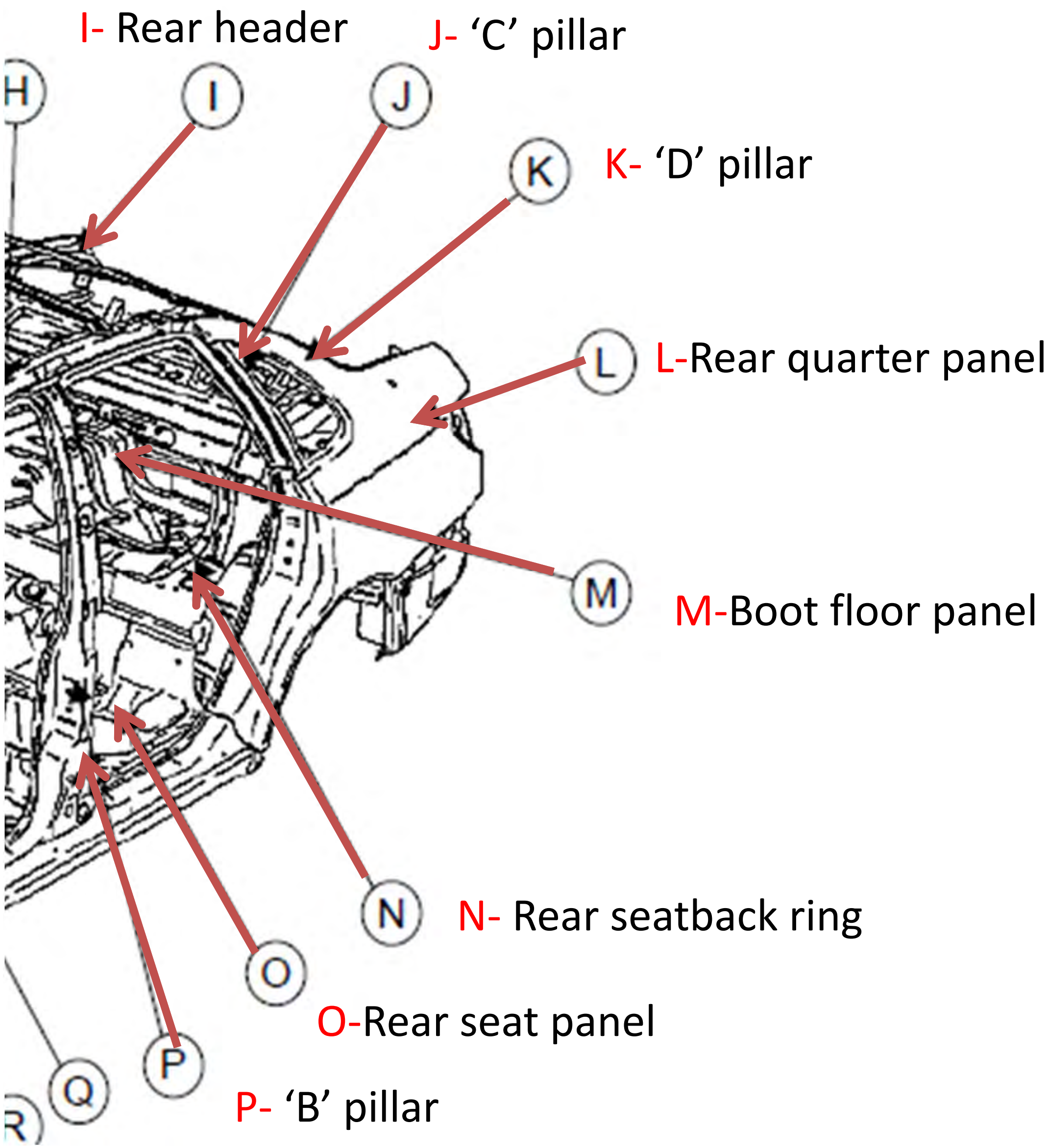

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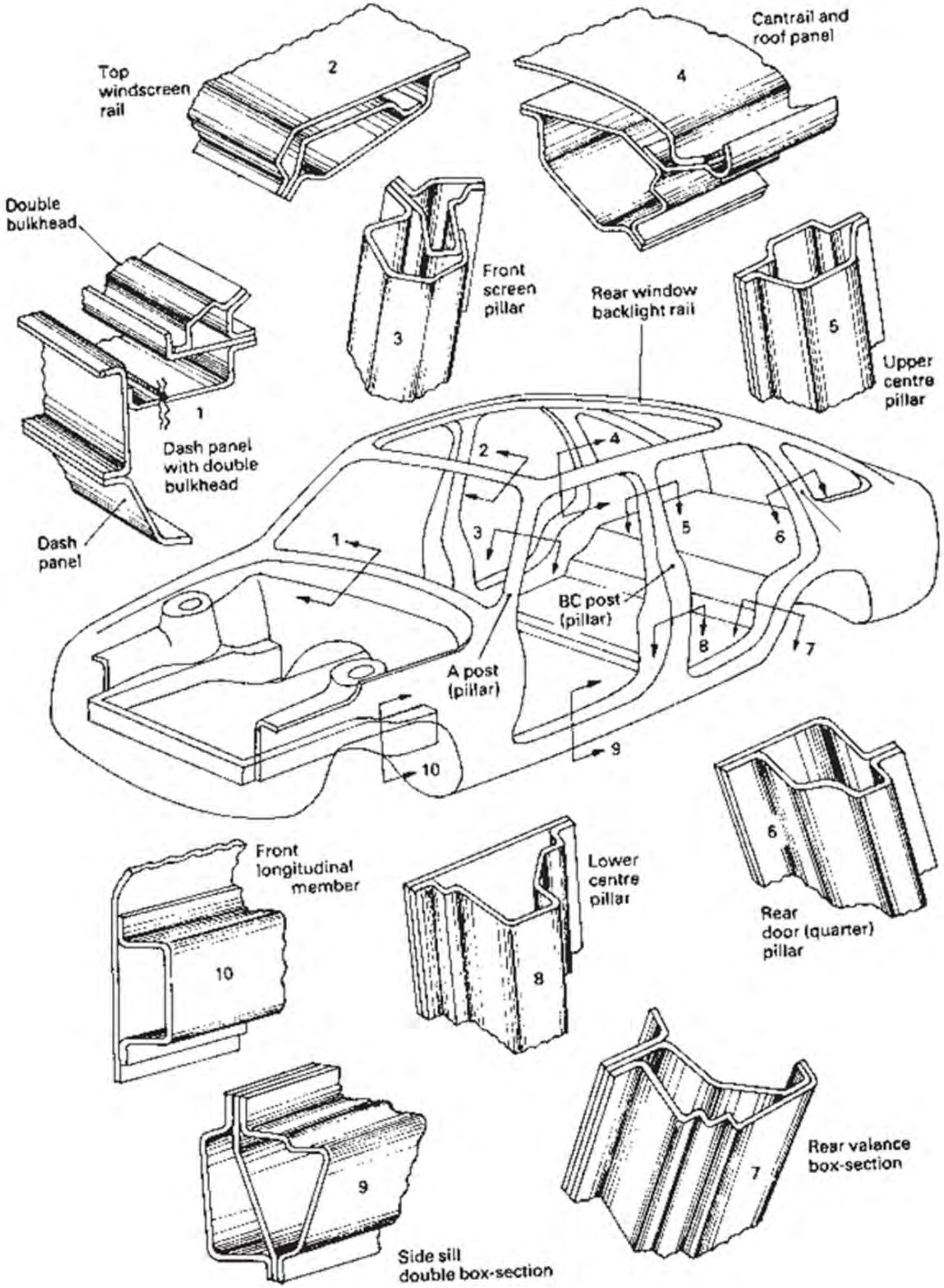

Description and function of body components

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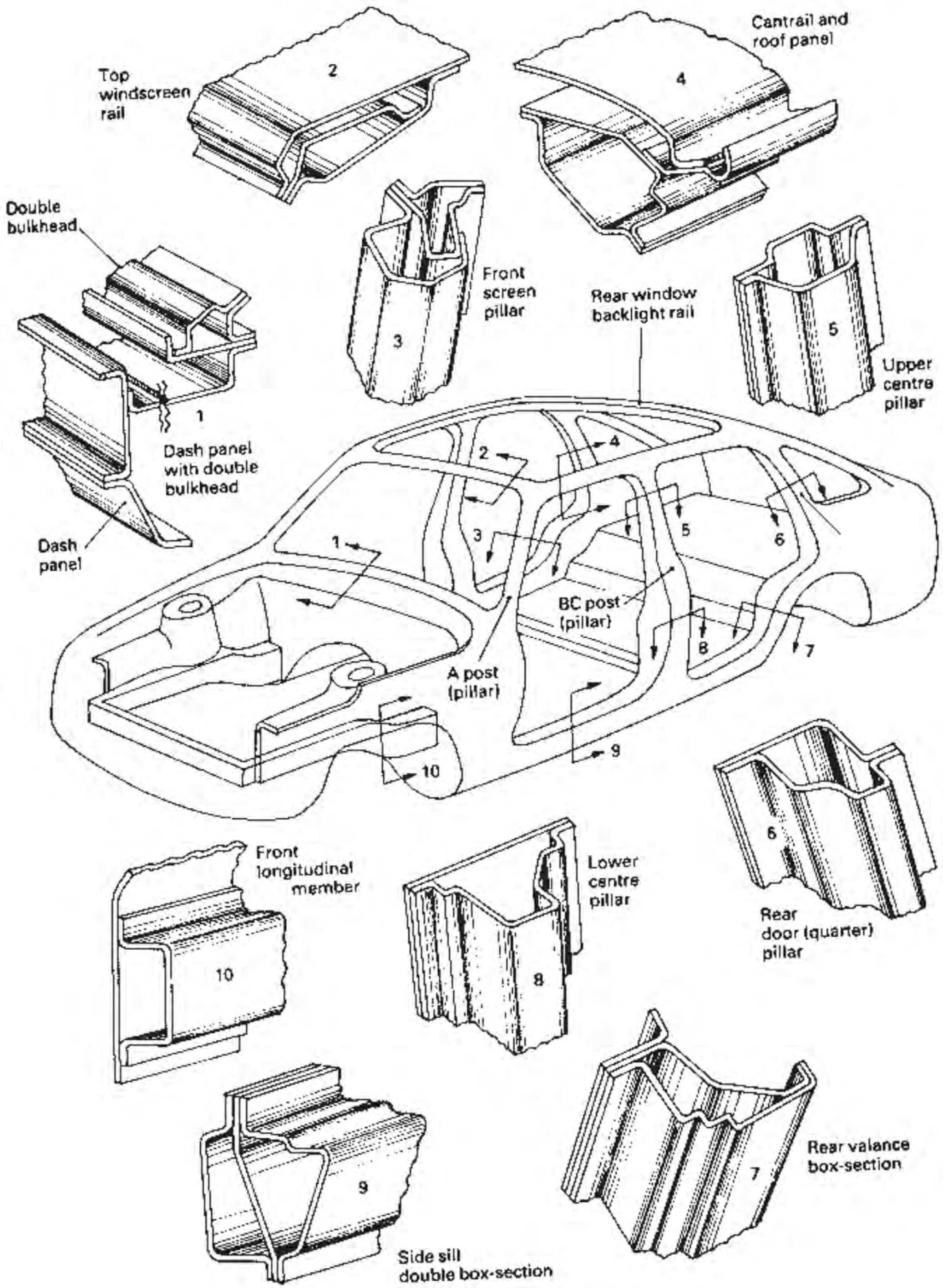

Window and door pillars (3, 5, 6, and 8)

Windowscreen and door pillars are identified by a letter coding; the front windscreen to door pillars are referred to as A post, the centre side door pillars as B post and the rear door to quarter panel as D post.

These pillars form the part of the body structure which supports the roof. The short form A pillar and rear D pillar enclose the windscreen and quarter windows and provide the glazing side channels, whilst the centre B pillar extends the full height of the passenger compartment from roof to floor and supports the rear side door hinges. The front and rear pillars act as struts (compressive members) which transfer a proportion of the bending effect, due to underbody sag of the wheelbase, to each end of the cantrails which thereby become reactive struts, opposing horizontal bending of the passenger compartment at floor level. The central B pillar however acts as ties (tensile members), transferring some degree of support from the mid-span of the cantrails to the floor structure.

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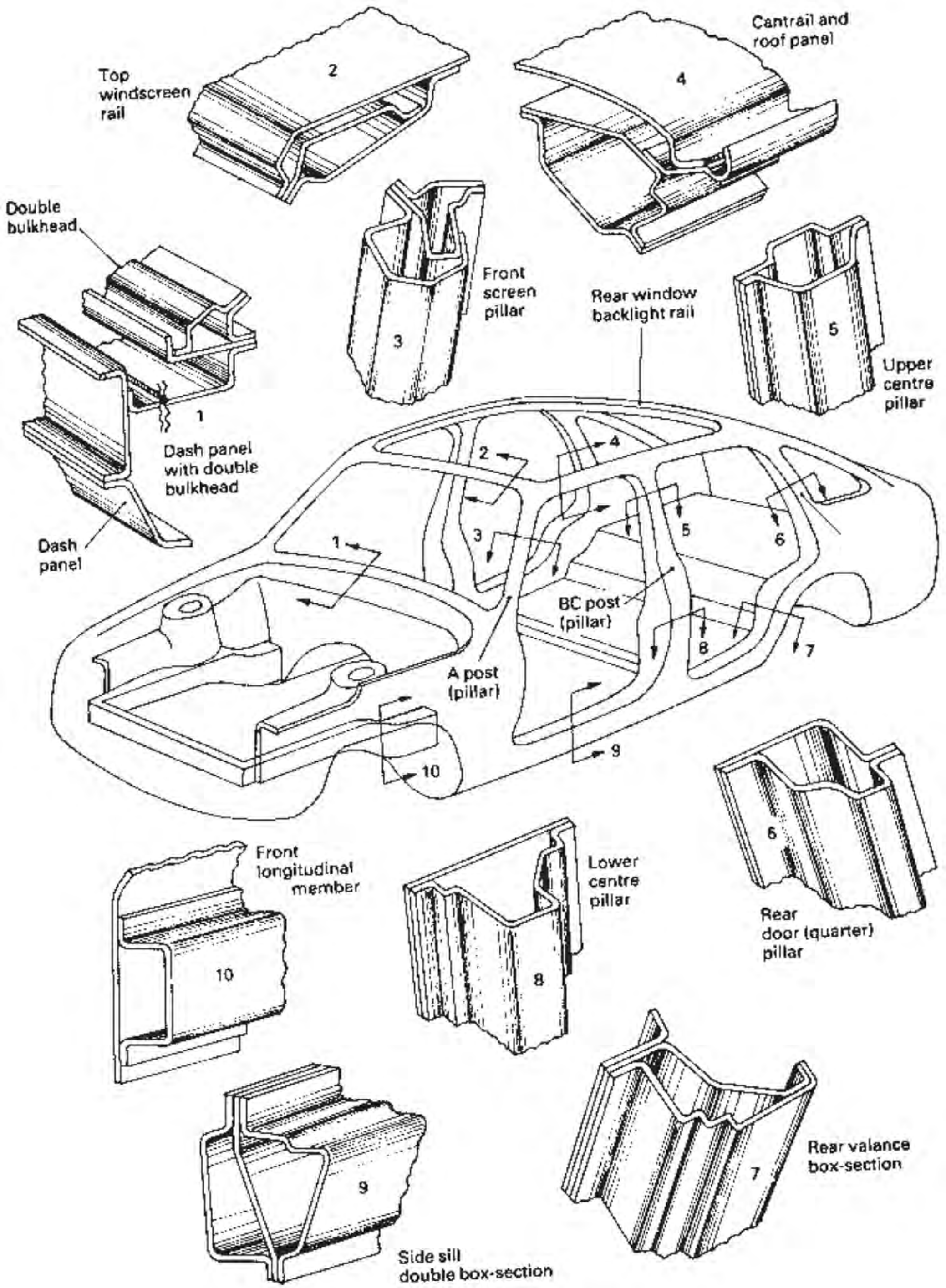

Windscreen and rear window rails (2)

These box-section rails span the front window pillars and rear pillars or quarter panels depending upon design, so that they contribute to the resistance opposing transverse sag between the wheel track by acting as compressive members. The other function is to support the front and rear ends of the roof panel. The undersides of the rails also include the glazing channels.

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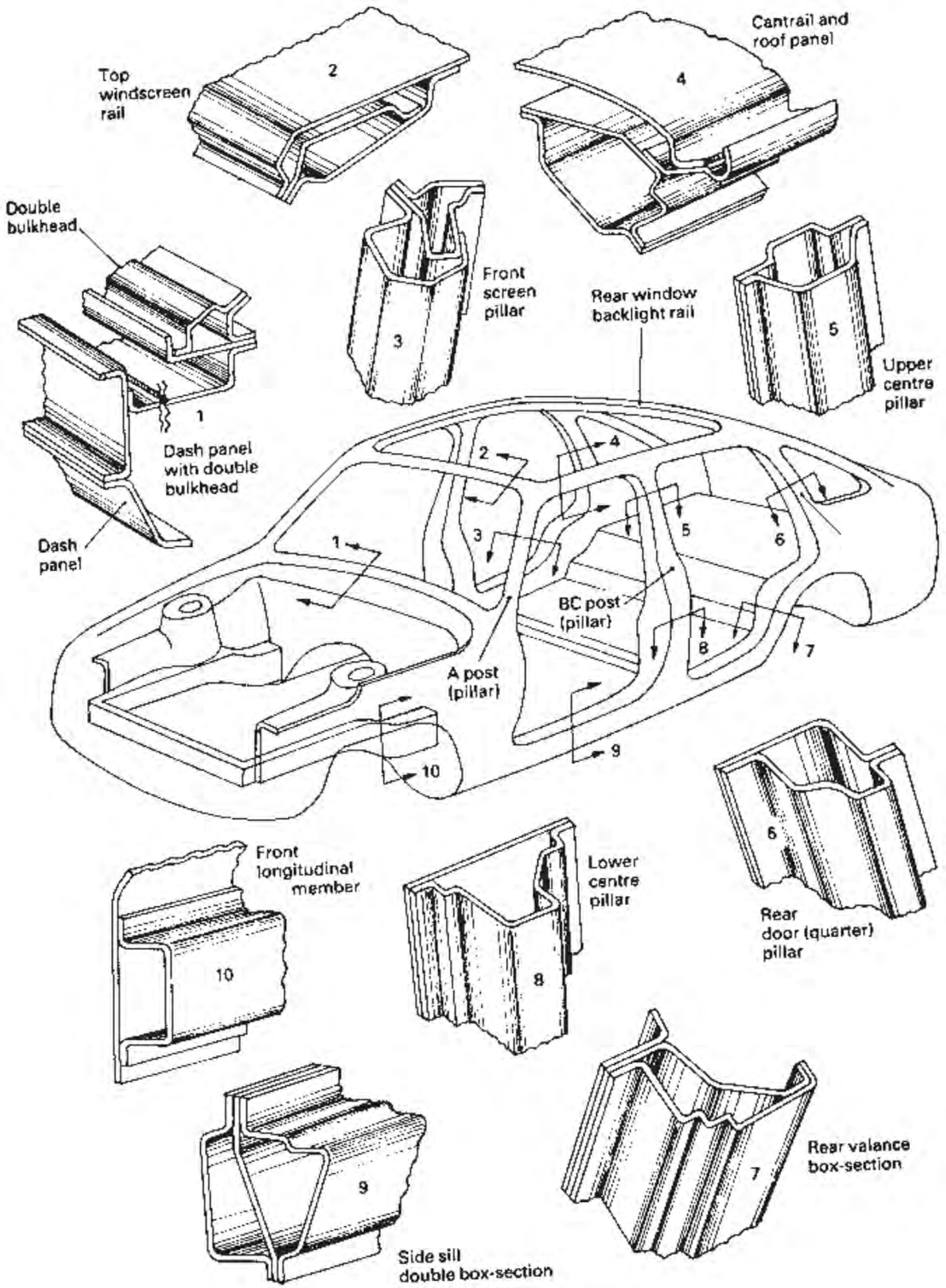

Cantrails (4)

Cantrails are the horizontal members which interconnect the top ends of the vertical A, B and C and D door pillars (posts). These rails form the side members which make up the rectangular roof framework and as such are subjected to compressive loads. Therefore, they are formed in various box-sections which offer the greatest compressive resistance with the minimum of weight and blend in with the roofing. A drip rail (4) is positioned in between the overlapping roof panel and the cantrails, the joins being secured by spot welds.

Roof structure

The roof is constructed basically from four channel sections which form the outer rim of the slightly dished roof panel. The rectangular outer roof frame acts as the compressive load bearing members. Torsional rigidity to resist twist is maximized by welding the four corners of the channel-sections together. The slight curvature of the roof panel stiffens it, thus preventing winkling and the collapse of the unsupported centre region of the roof panel. With large cars, additional cross-rail members may be used to provide more roof support and to prevent the roof crushing in should the car roll over.

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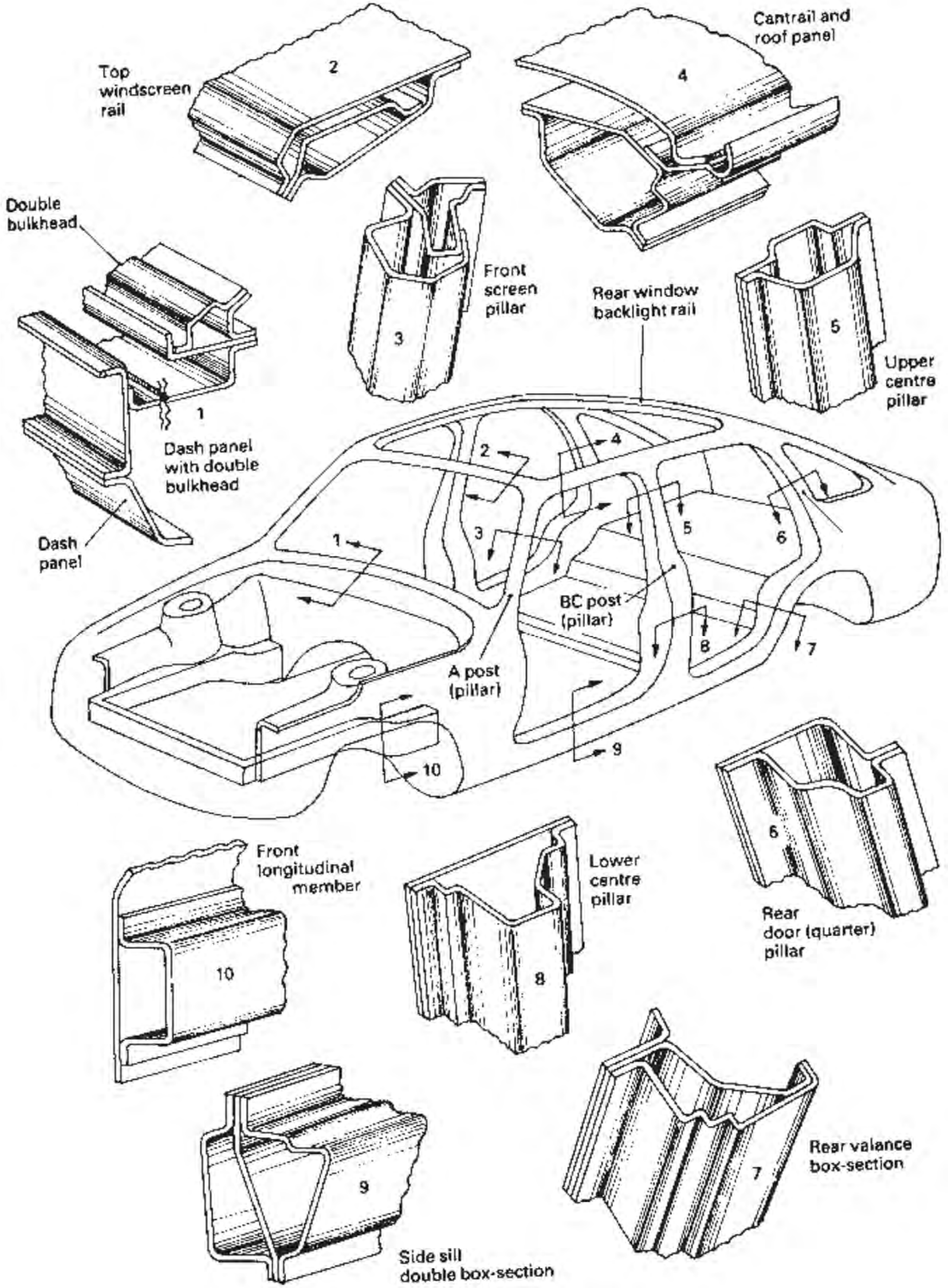
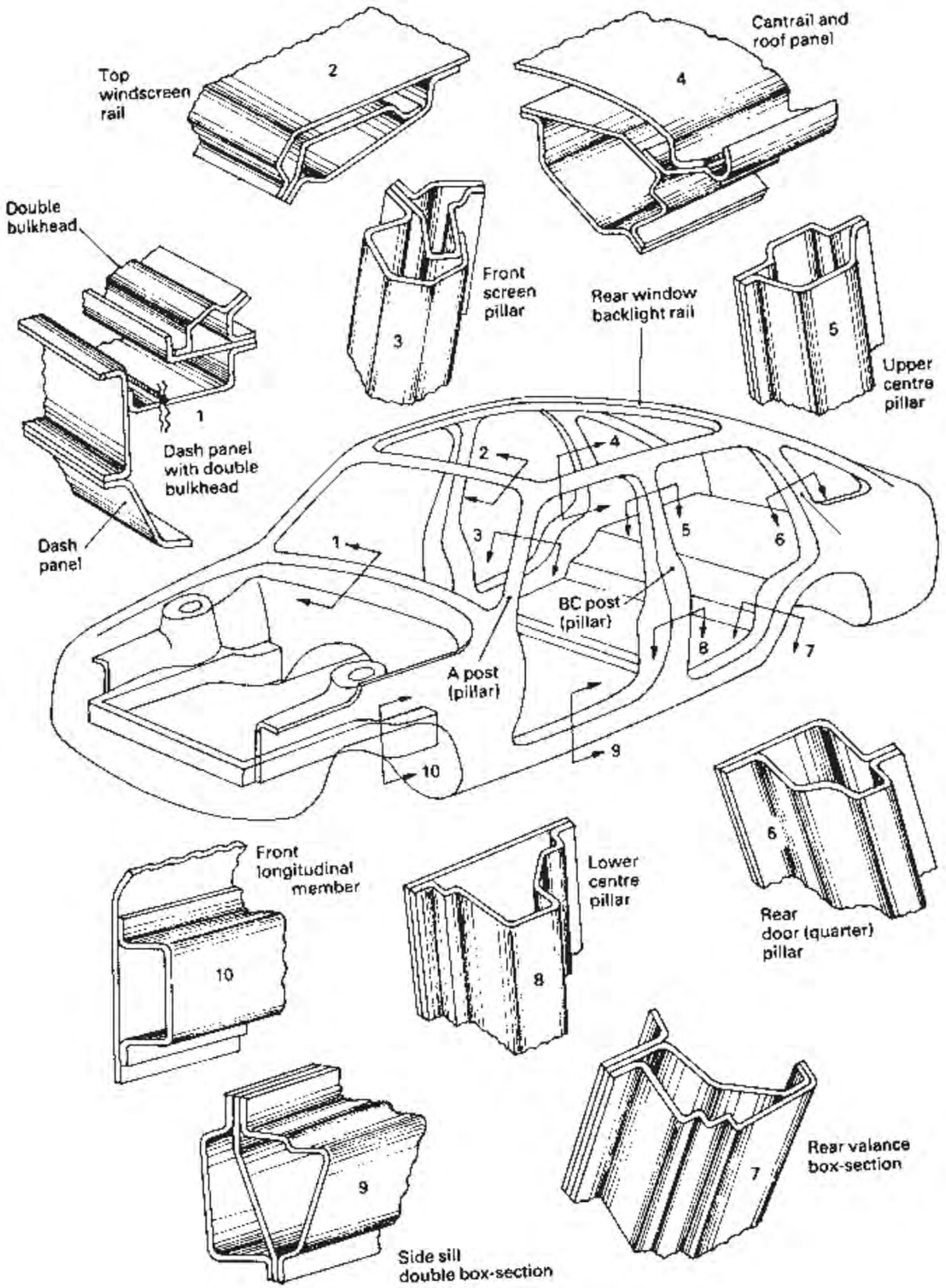


Upper quarter panel or window (6)

This is the vertical side panel or window which occupies the space between the rear side door and the rear window. Originally the quarter panel formed an important part of the roof support, but improved pillar design and the desire to maximize visibility has either replaced them with quarter windows or reduced their width, and in some car models they have been completely eliminated.

*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann



Sills (9)

These members form the lower horizontal sides of the car body which spans between the front and rear road-wheel wings or arches. To prevent body sag between the wheelbase of the car and lateral bending of the structure, the outer edges of the floor pan are given support by the side sills. These sills are made in the
form of either single or double box-sections . To resist the heavier vertical bending loads they are of relatively deep section. Open-top cars, such as convertibles, which do not receive structural support from the roof members,
usually have extra deep sills to compensate for the increased burden imposed on the underframe.

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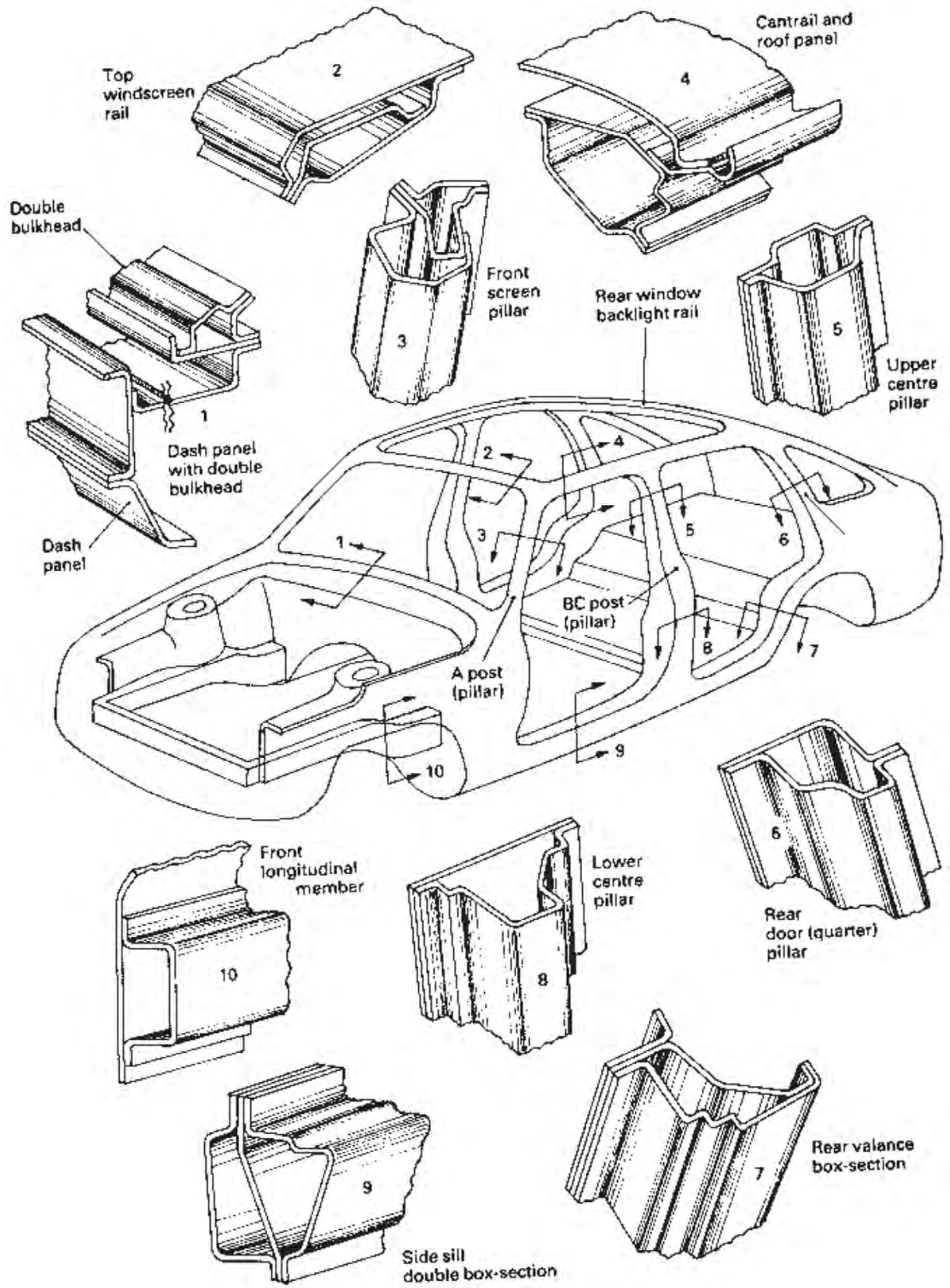
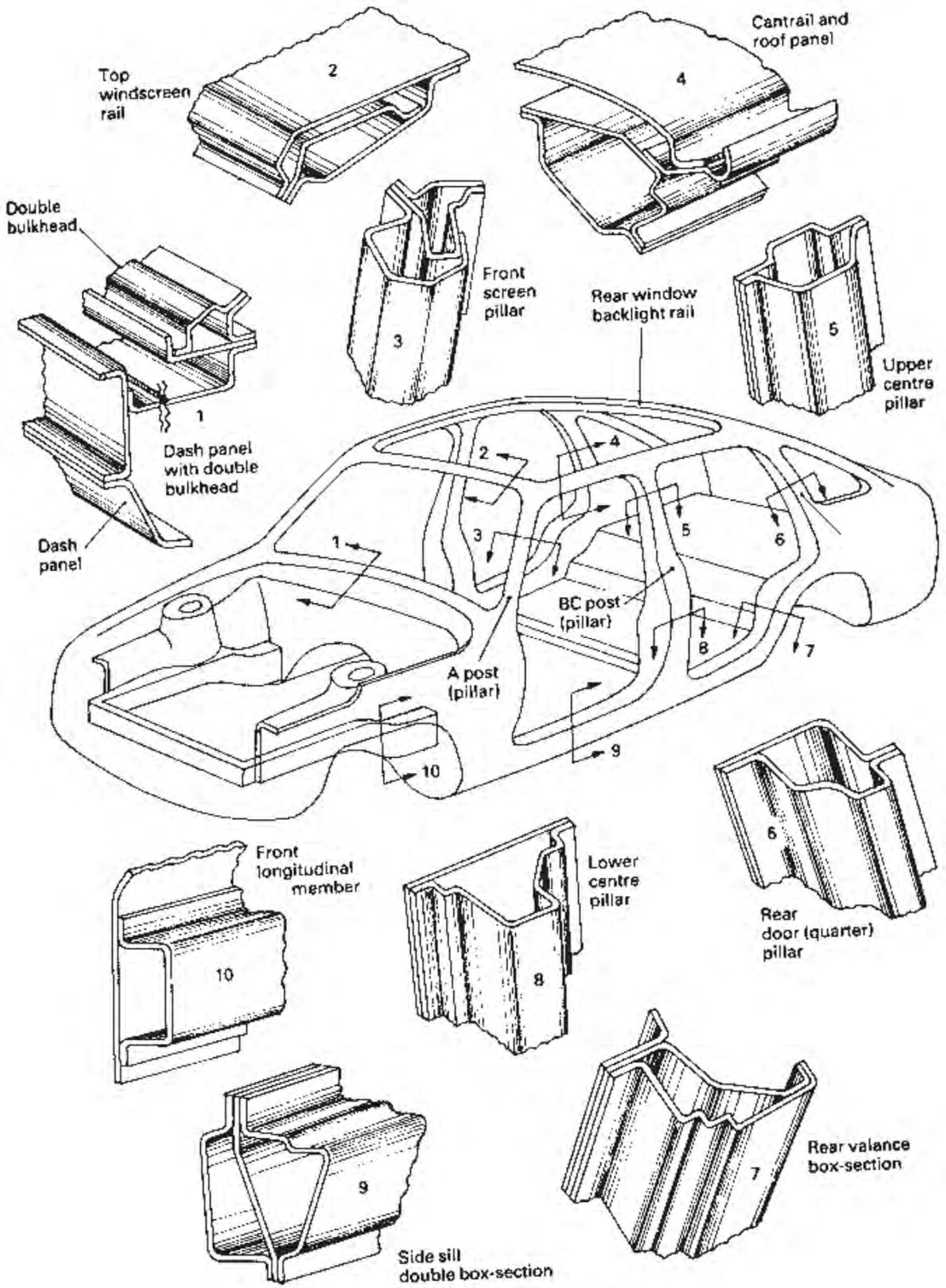


Bulkhead (1)

This is the upright partition separating the passenger and engine compartments. Its upper half may form part of the dash panel which was originally used to display the driver's instruments. Some body manufacturers refer to the whole partition between engine and passenger compartments as the dash panel. If there is a double partition, the panel next to the engine is generally known as the bulkhead and that on the passenger side the dash board or panel. The scuttle and valance on each side are usually joined onto the box-section of the bulkhead. This braces the vertical structure to withstand torsional distortion and to provide platform bending resistance support. Sometimes a bulkhead is constructed between the rear wheel arches or towers to reinforce the seat pan over the rear axle

*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann



Front longitudinals (10)

These members are usually upswept box-section members, extending parallel and forward from the bulkhead at floor level. Their purpose is to withstand the engine mount reaction and to support the front suspension or subframe. A common feature of these members is their ability to support vertical loads in conjunction with the valances. However, in the event of a head-on collision, they are designed to collapse and crumble within the engine compartment so that the passenger shell is safeguarded and is not pushed rearwards by any great extent.

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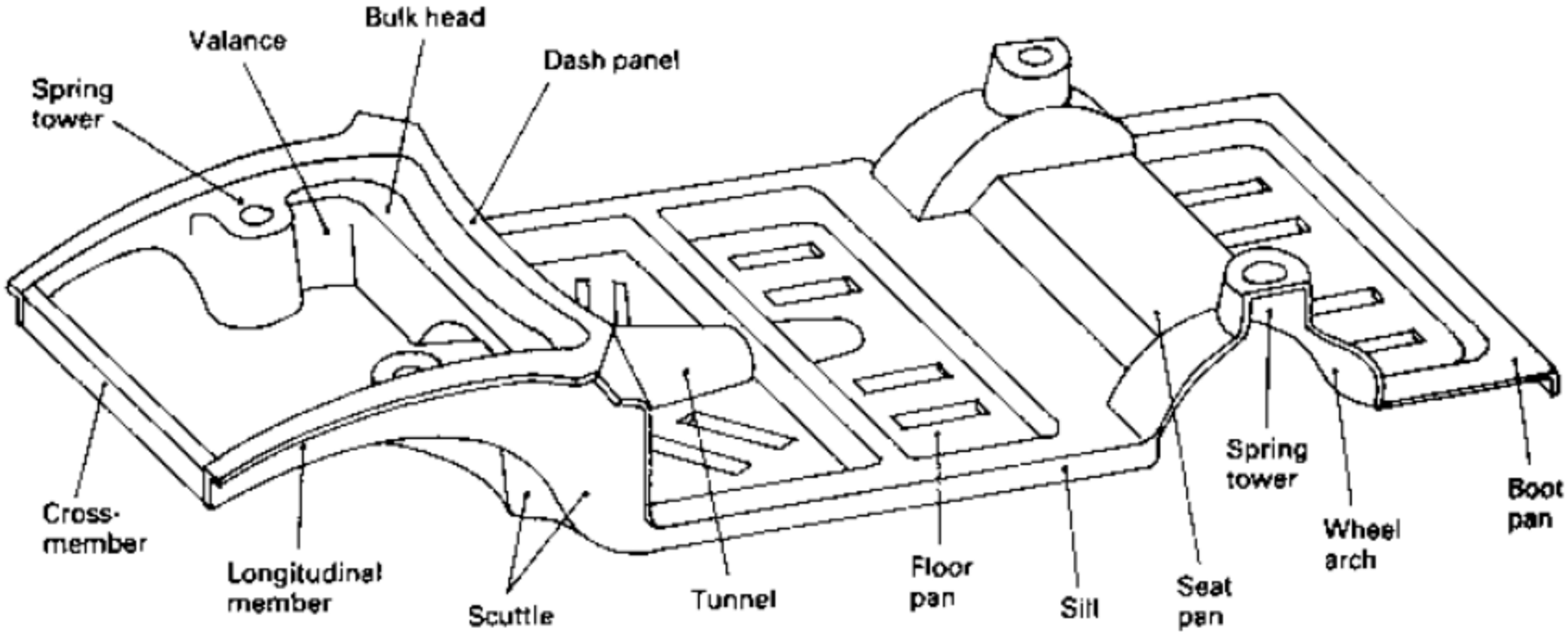
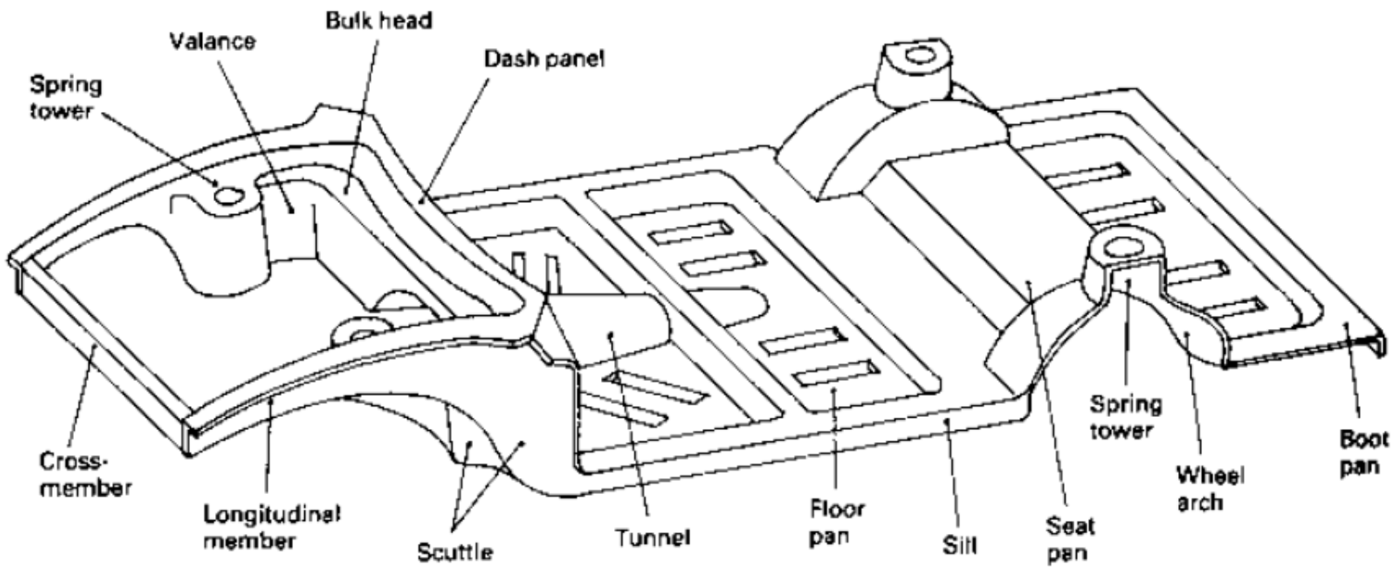
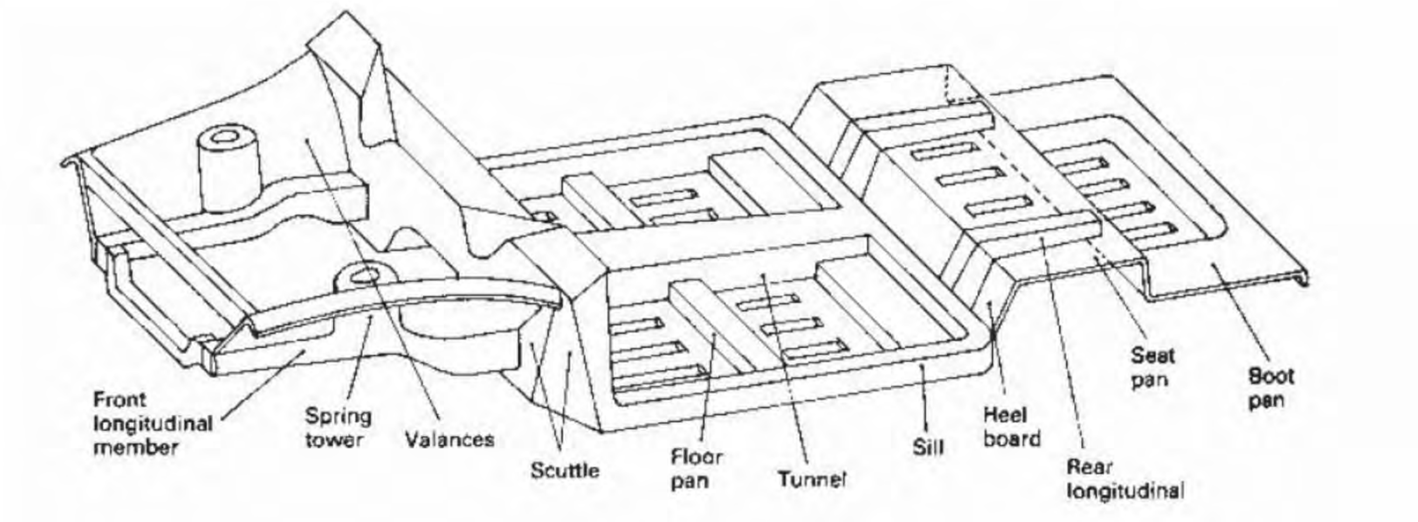


Floor seat and boot pans

The horizontal spread-out pressing between the bulkhead and the heel board is called the floor pan, whilst the raised platform over the rear suspension and wheel arches is known as the seat or arch pan. This in turn joins onto a lower steel pressing which supports luggage and is referred to as the boot pan. To increase the local stiffness of these platform panels or pans and their resistance to transmitted vibrations such as drumming and droning, many narrow channels are swaged (pressed) into the steel sheet, because a sectional end-view would show a semi-corrugated profile (or ribs). These channels provide rows of shallow walls which are both bent and stretched perpendicular to the original flat sheet. In turn they are spaced and held together by the semicircular drawn out channel bottoms. Provided these swages are designed to lay the correct way and are not too long, and the metal is not excessively stretched, they will raise the rigidity of these panels so that they are equivalent to a sheet which may be several times thicker.

*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann

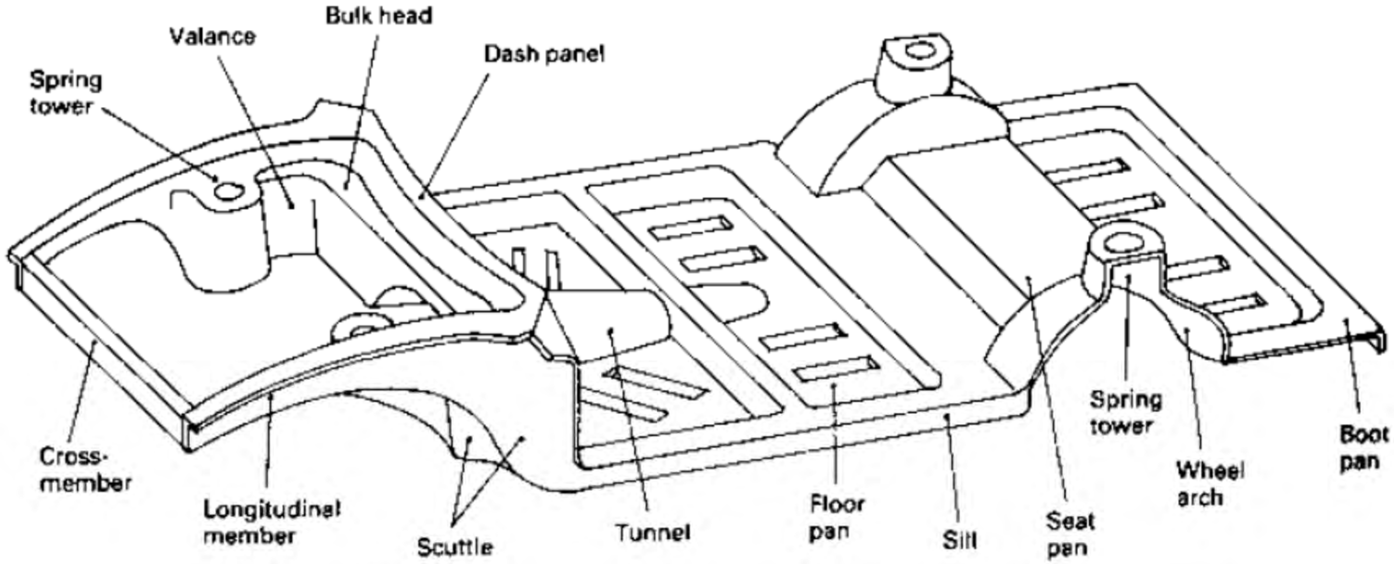


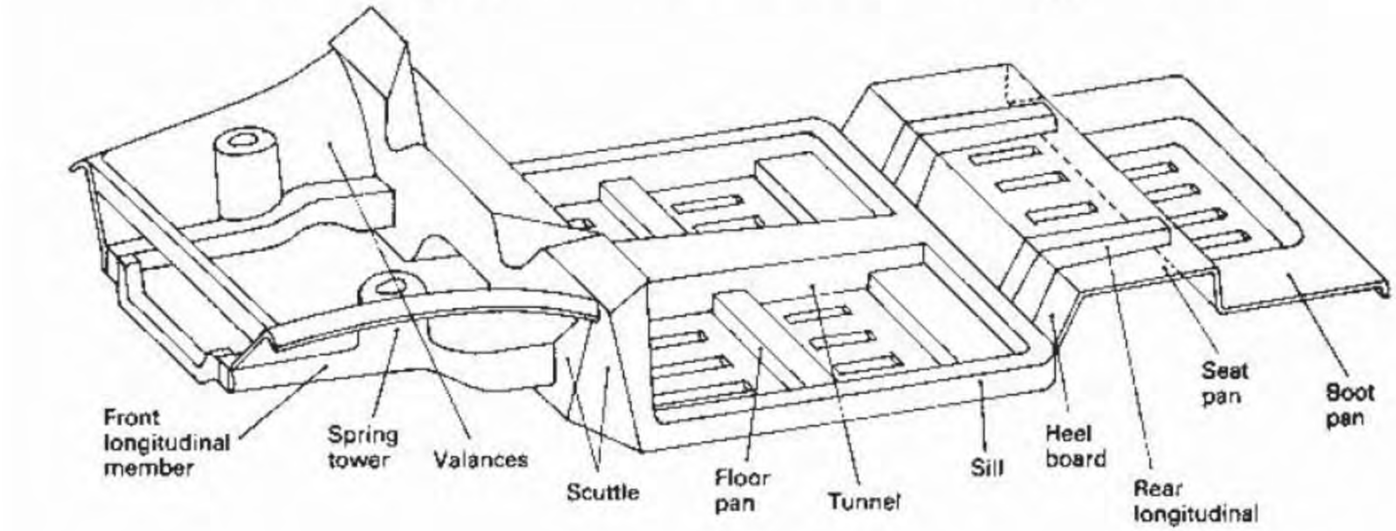


Central tunnel

This is the curved or rectangular hump positioned longitudinally along the middle of the floor pan. Originally it was a necessary shape to provide transmission space for the gearbox and propeller shaft for rear wheel drive, front-mounted engine cars, but since the chassis has been replaced by the integral box- section shell, it has been retained with front wheel drive, front-mounted engines as it contributes considerably to the bending rigidity of the floor structure. Its secondary function is now to house the exhaust pipe system and the hand brake cable assembly.

*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann



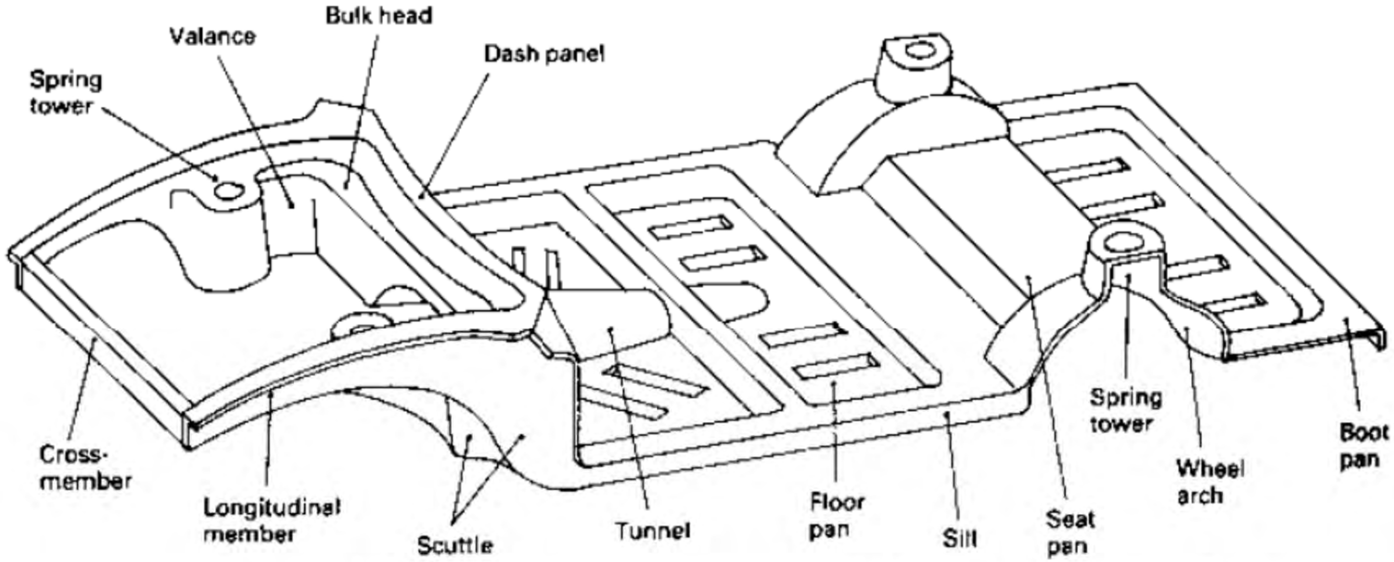


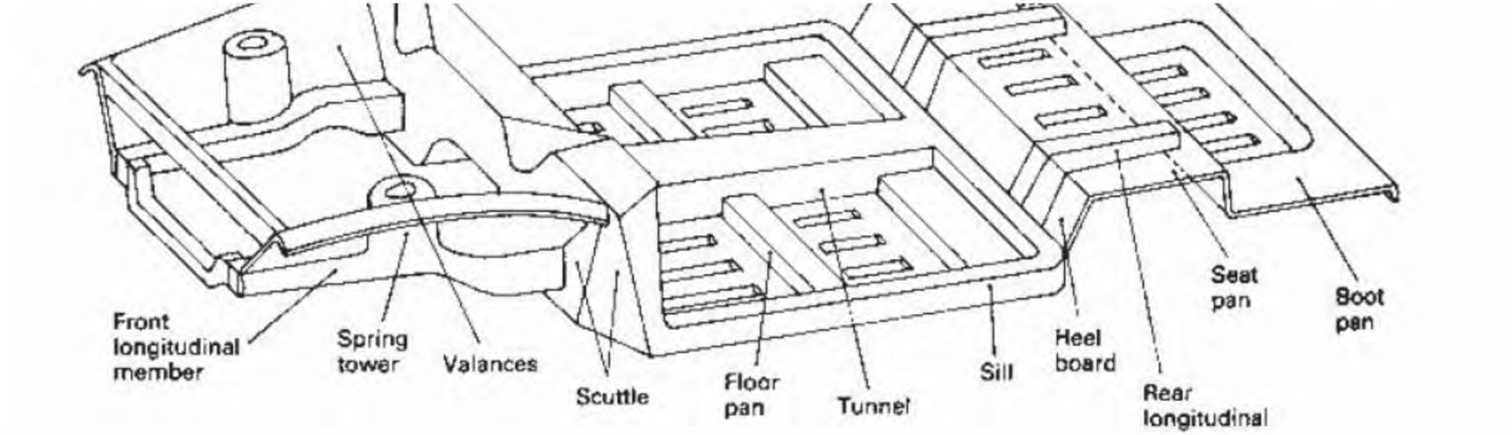
Scuttle

This can be considered as the panel formed under the front wings which spans between the rear end of the valance, where it meets the bulkhead, and the door pillar and wing. The lower edge of the scuttle will merge with the floor pan so that in some cases it may form part of the toe board on the passenger compartment side. Usually these panels form inclined sides to the bulkhead, and with the horizontal ledge which spans the full width of the bulkhead, brace the bulkhead wall so that it offers increased rigidity to the structure. The combined bulkhead dash panel and scuttle will thereby have both upright and torsional rigidity.

*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann

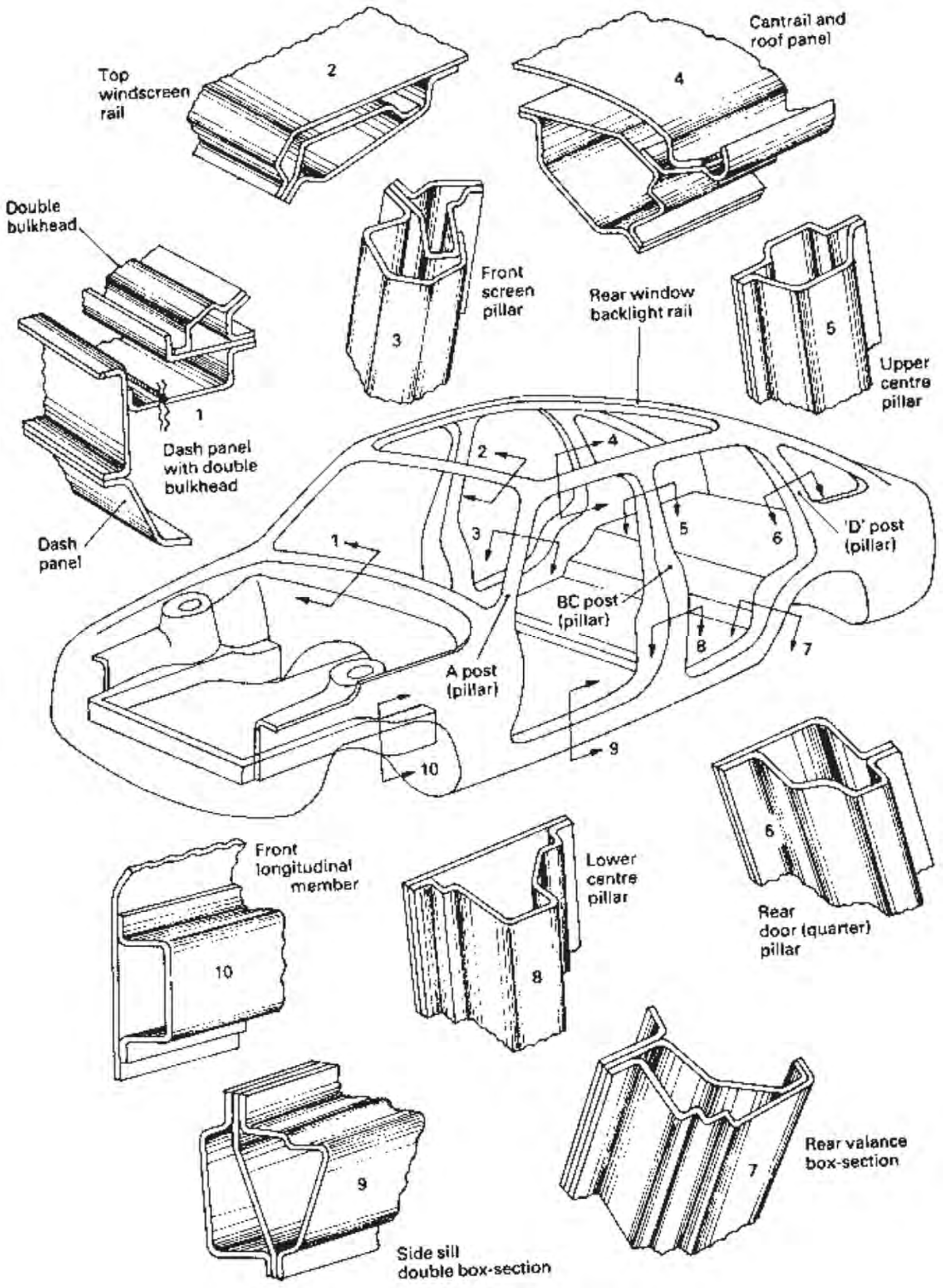
Front valance





These panels project upwards from the front longitudinal members and at the rear join onto the wall of the bulkhead. The purpose of these panels is to transfer the upward reaction of the longitudinal members which support the front suspension to the bulkhead. Simultaneously, the longitudinals are prevented from bending sideways because the valance panels are shaped to slope up and outwards towards the top. The panelling is usually bent over near the edges to form a horizontal flanged upper, thus presenting considerable lateral resistance. Furthermore, the valances are sometimes stepped and wrapped around towards the rear where they meet and are joined to the bulkhead so that additional lengthwise and transverse stiffness is obtained. If coil spring suspension is incorporated, the valance forms part of a semi-circular tower which houses and provides the load reaction of the spring so that the merging of these shapes compounds the rigidity for both horizontal lengthwise and lateral bending of the forward engine and transmission compartment body structure. Where necessary, double layers of sheet are used in parts of the spring housing and at the rear of the valance where they are attached to the bulkhead to relieve some of the concentrated loads.

*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann



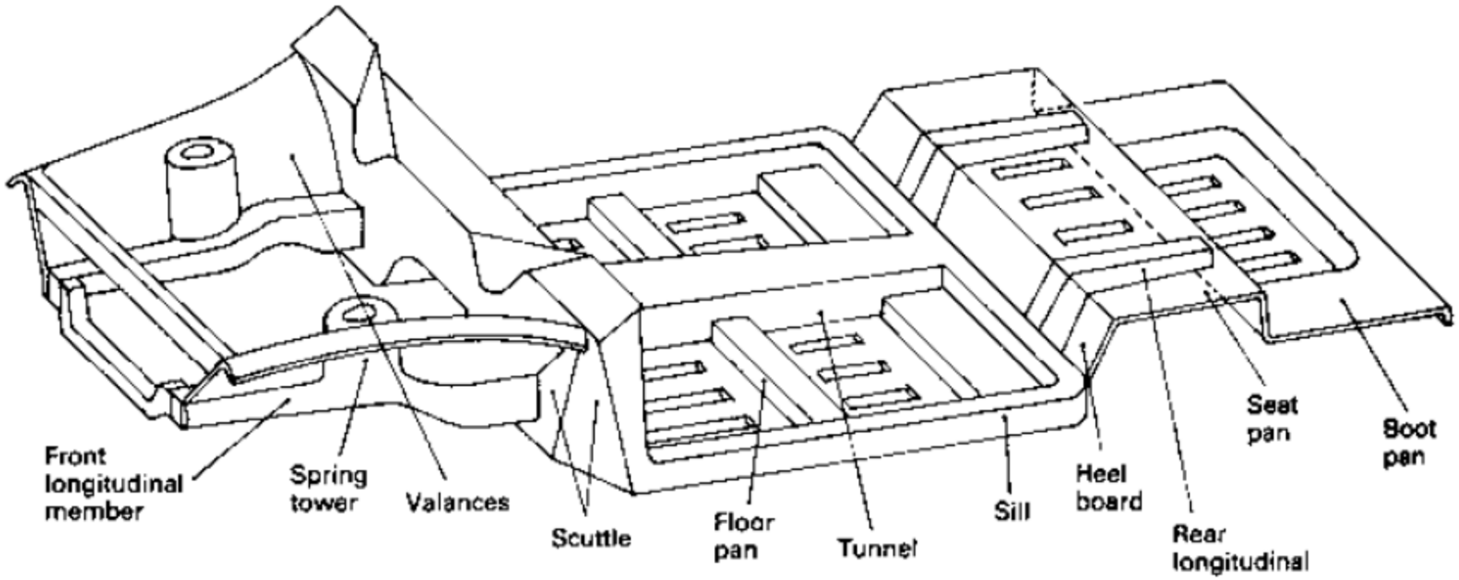
Rear valance (7)

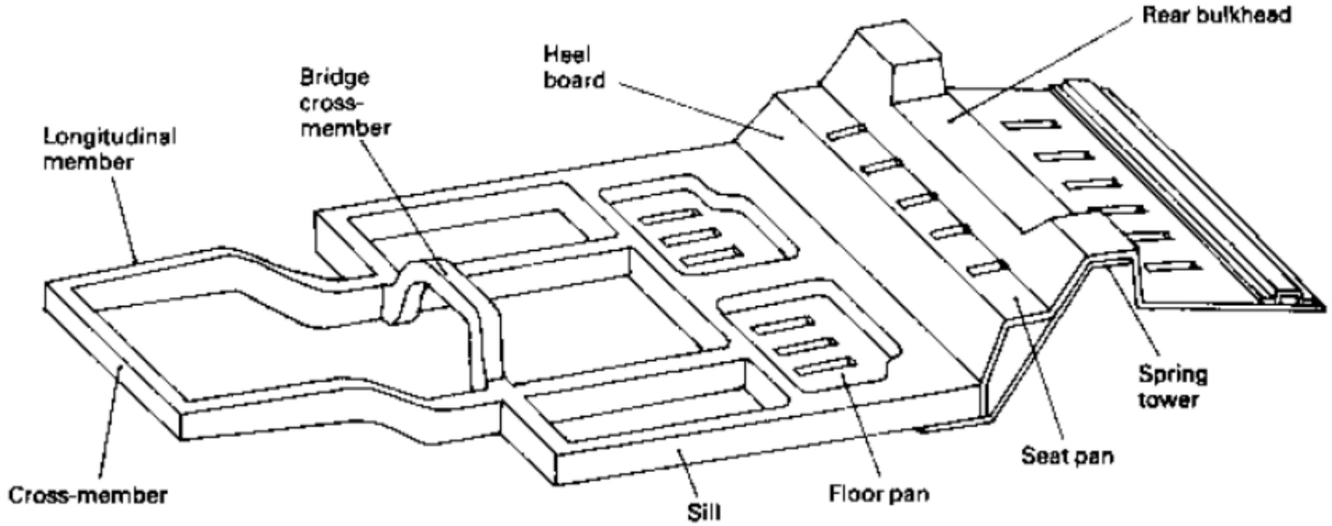
This is generally considered as part of the box section, forming the front half of the rear wheel arch frame and the panel immediately behind which merges with the heel board and seatpan panels. These side inner-side panels position the edges of the seat pan to its designed side profile and thus stiffen the underfloor structure above the rear axle and suspension. When rear independent coil spring suspension is adopted, the valance or wheel arch extends upwards to form a spring tower housing and, because it forms a semi-vertical structure, greatly contributes to the stiffness of the underbody shell between the floor and boot pans.

Toe board

The toe board is considered to form the lower regions of the scuttle and dash panel near where they merge with the floor pan. It is this panelling on the passenger compartment side where occupants can place their feet when the car is rapidly retarded.

*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann

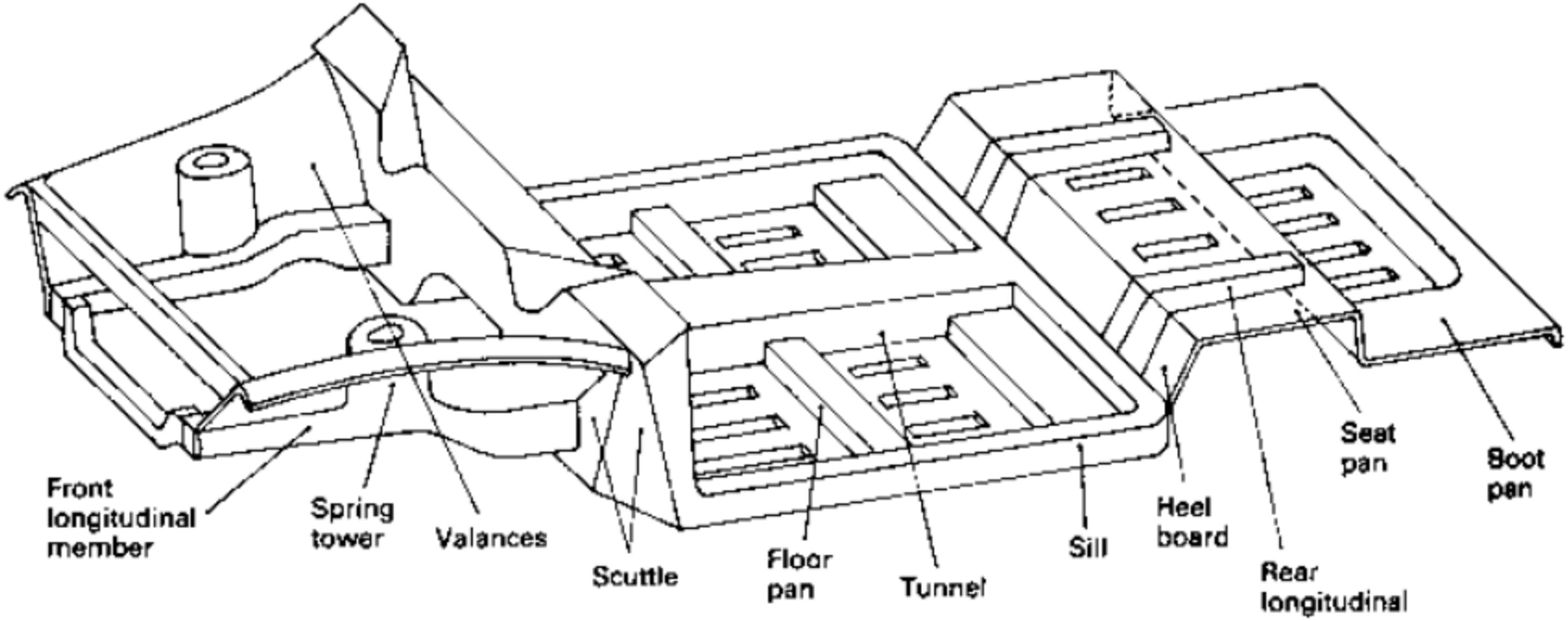




Heel board

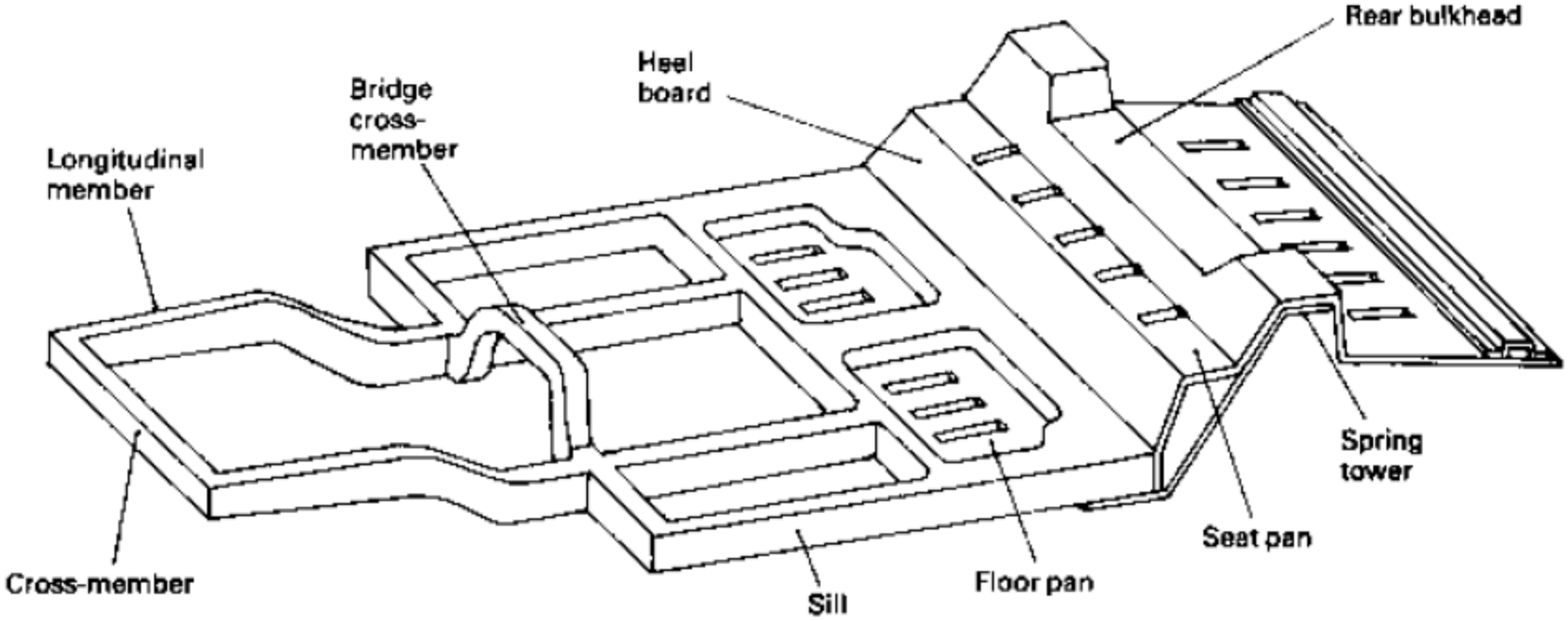
The heel board is the upright, but normally shallow, panel spanning beneath and across the front of the rear seats. Its purpose is to provide leg height for the passengers and to form a raised step for the seat pan so that the rear axle has sufficient relative movement clearance.

Description and function of body components



*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann

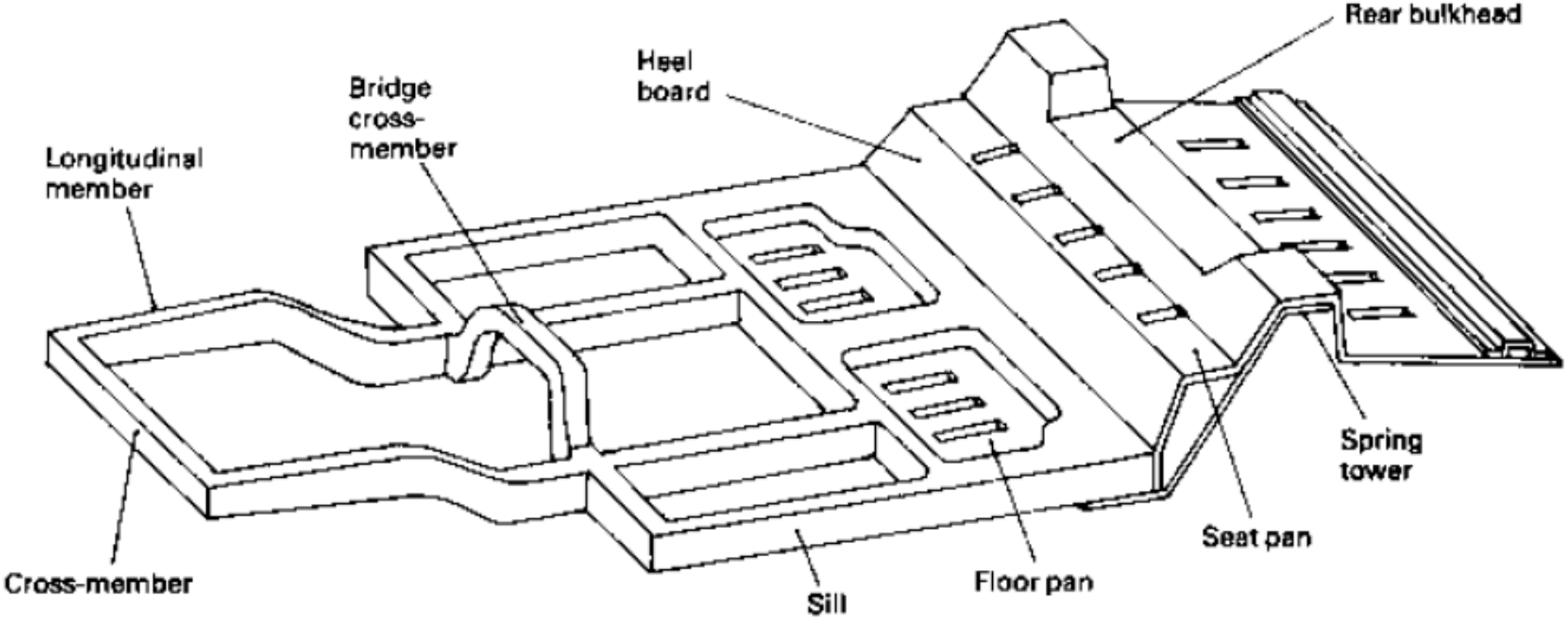
Description and function of body components



*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann

Description and function of body components

- The majority of the lengthwise (wheelbase) bending stiffness to resist sagging is derived from both the central tunnel and the side sill box-sections. If further strengthening is necessary, longitudinal box-section members may be positioned parallel to, but slightly inwards from the sills.

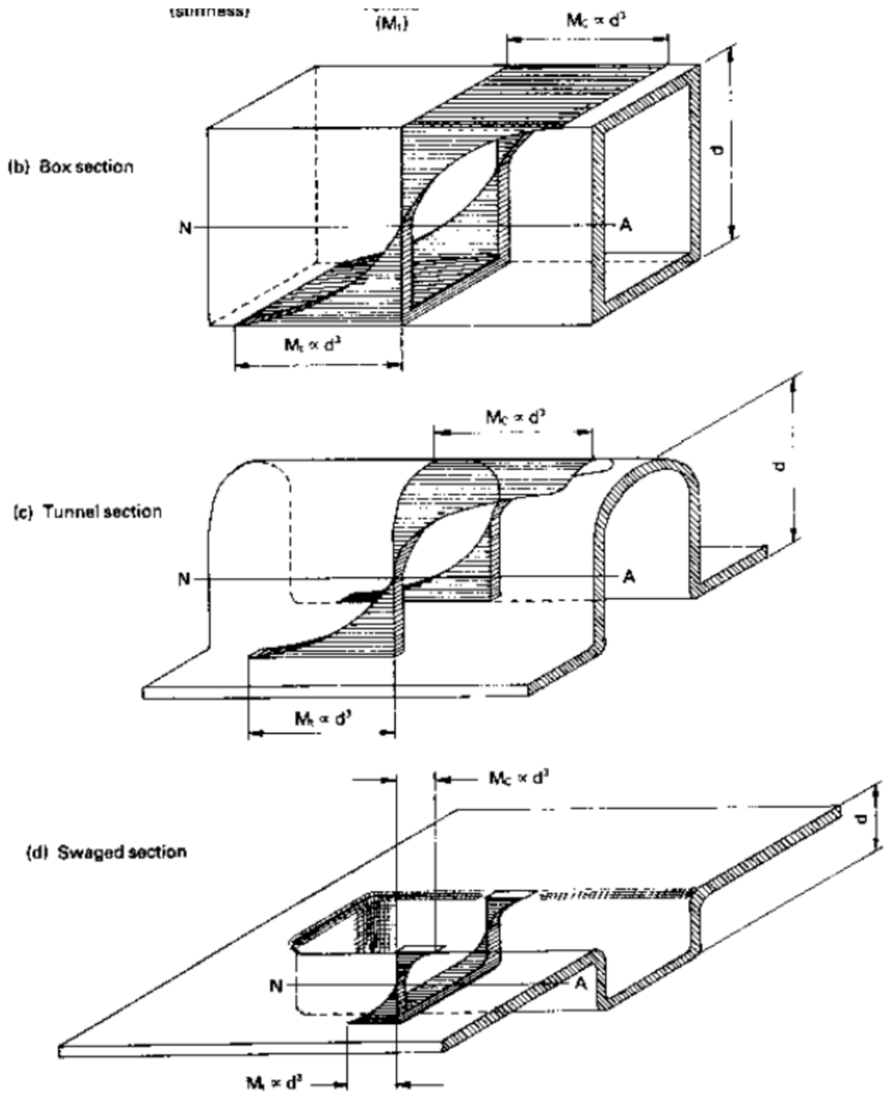


*H. Heisler, Advanced Vehicle Technology, Butterworth-Heinemann

Description and function of body components

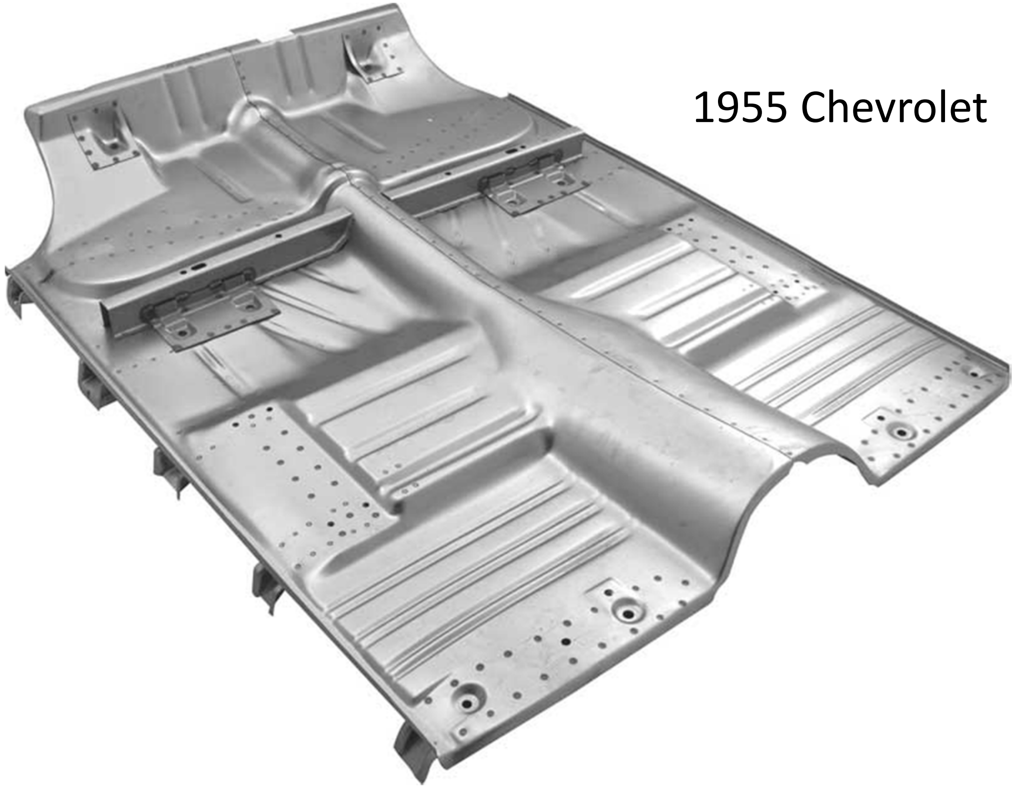
Torsional rigidity of the platform is usually derived at the front by the bulkhead, dash pan and scuttle at the rear by the heel board, seat pan, wheel arches and if independent rear suspension is adopted, by the coil spring towers.

Description and function of body components



Bending resistance may be improved by using longitudinal or cross-member deep box-sections and tunnel sections to restrain the platform chassis from buckling and to stiffen the flat horizontal floor seat and boot pans. So that vibration and drumming may be reduced, many swaged ribs are pressed into these sheets.

Beams and tunnels for Stiffnes



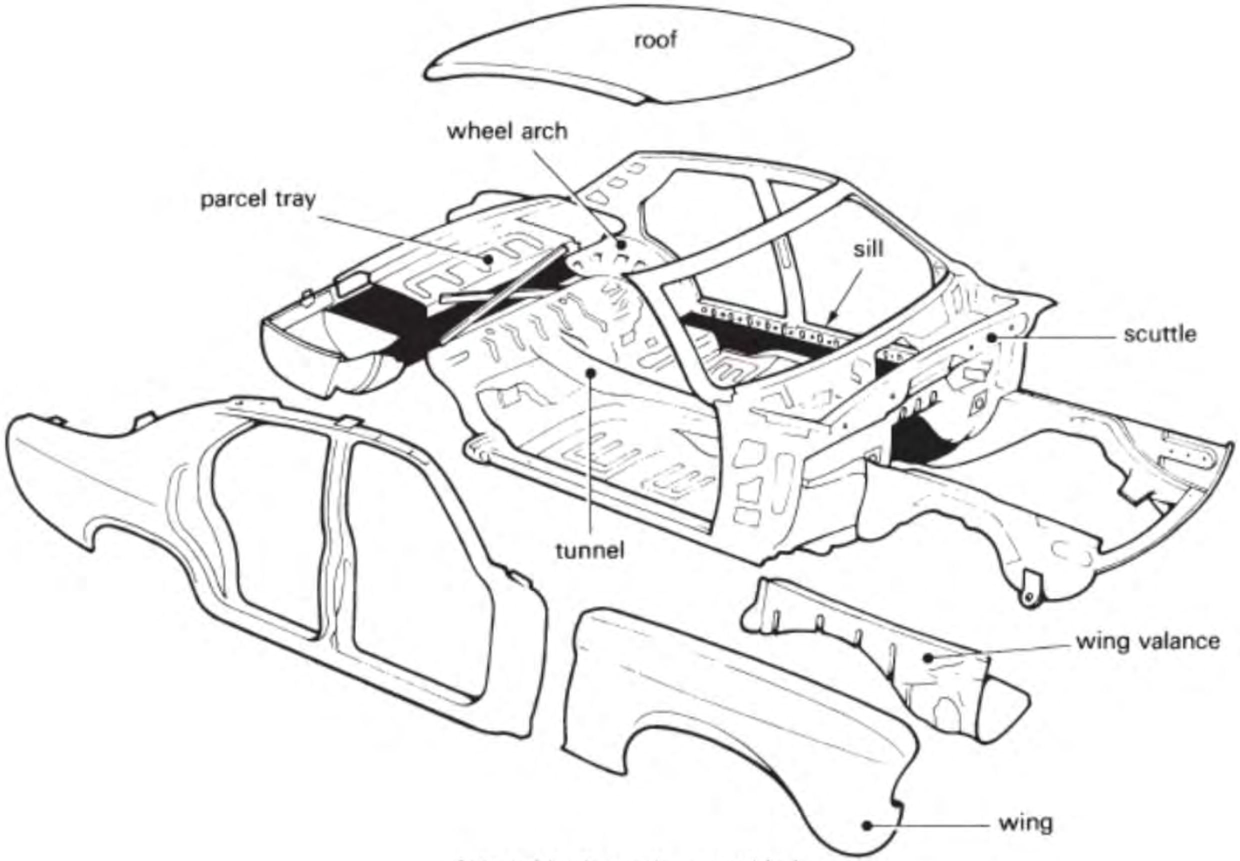
1955 Chevrolet

1960 Ford

Beams and tunnels for Stiffnes

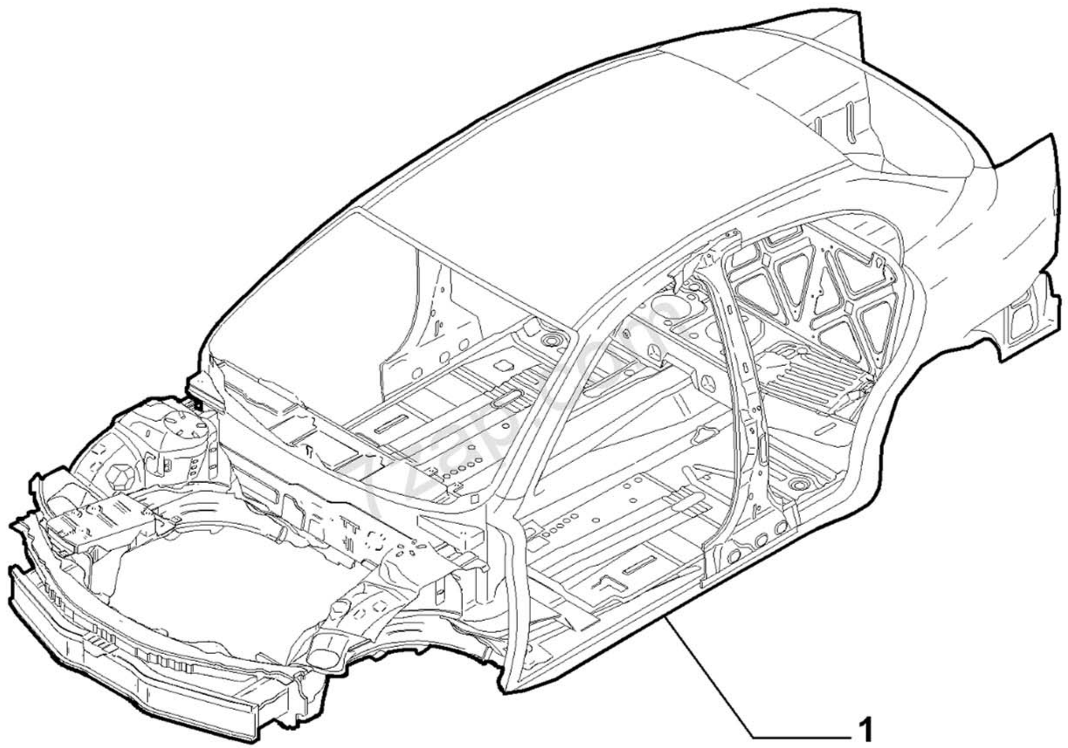
1962 Chevy II

1969 Pontiac

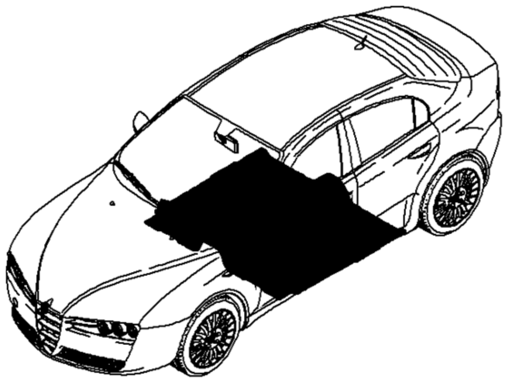


integral body partly assembled

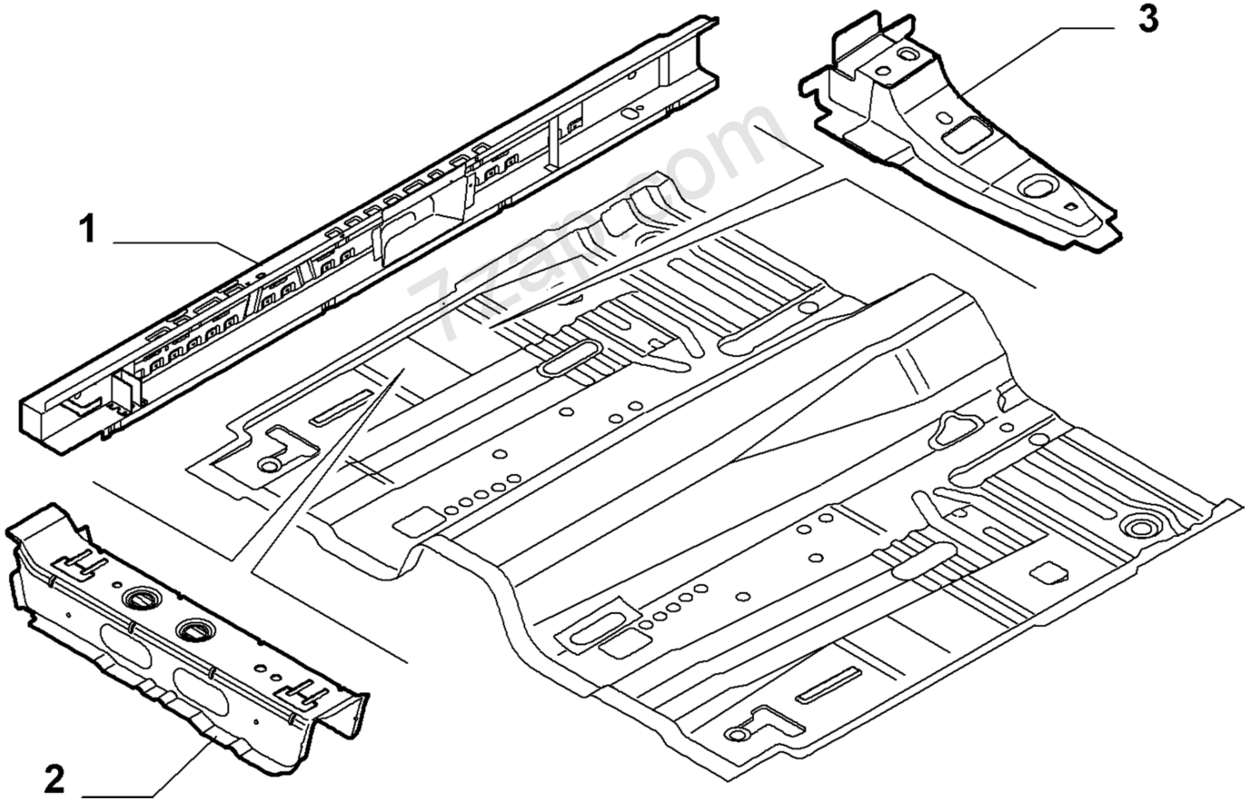
Modern design of the chassis



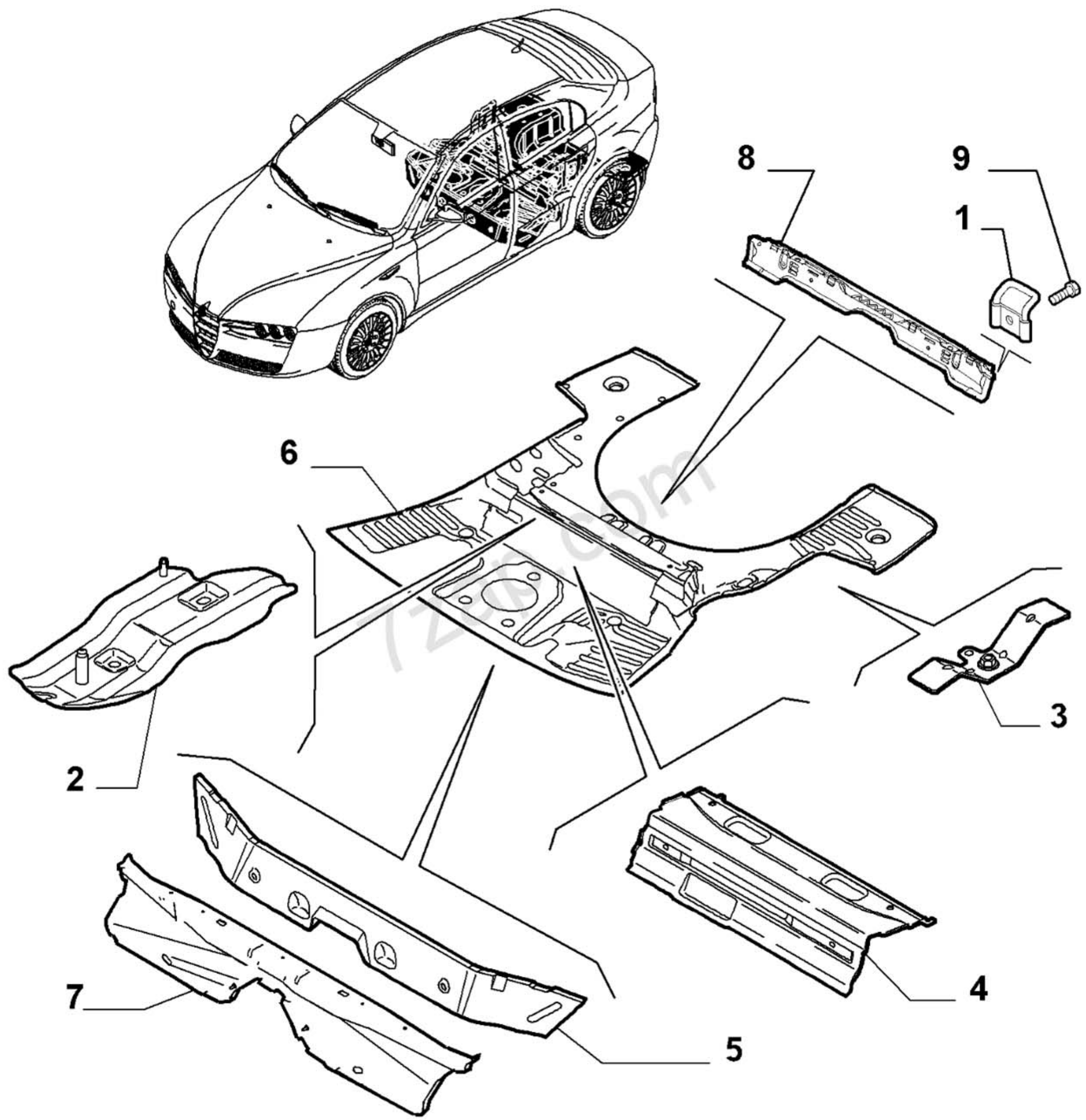
Side member floor pan



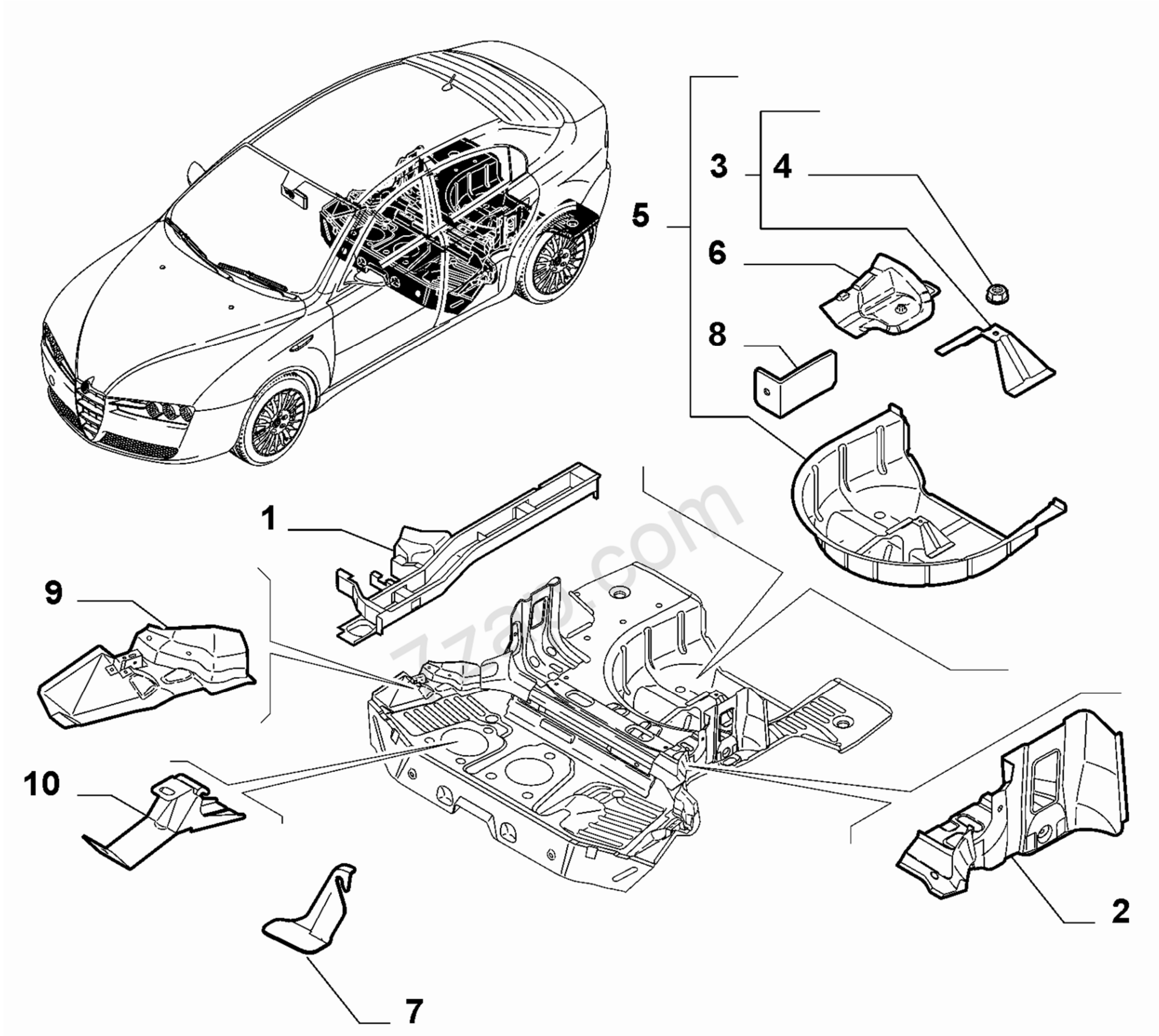
1-Side member
2-Crossrail
3-Support member



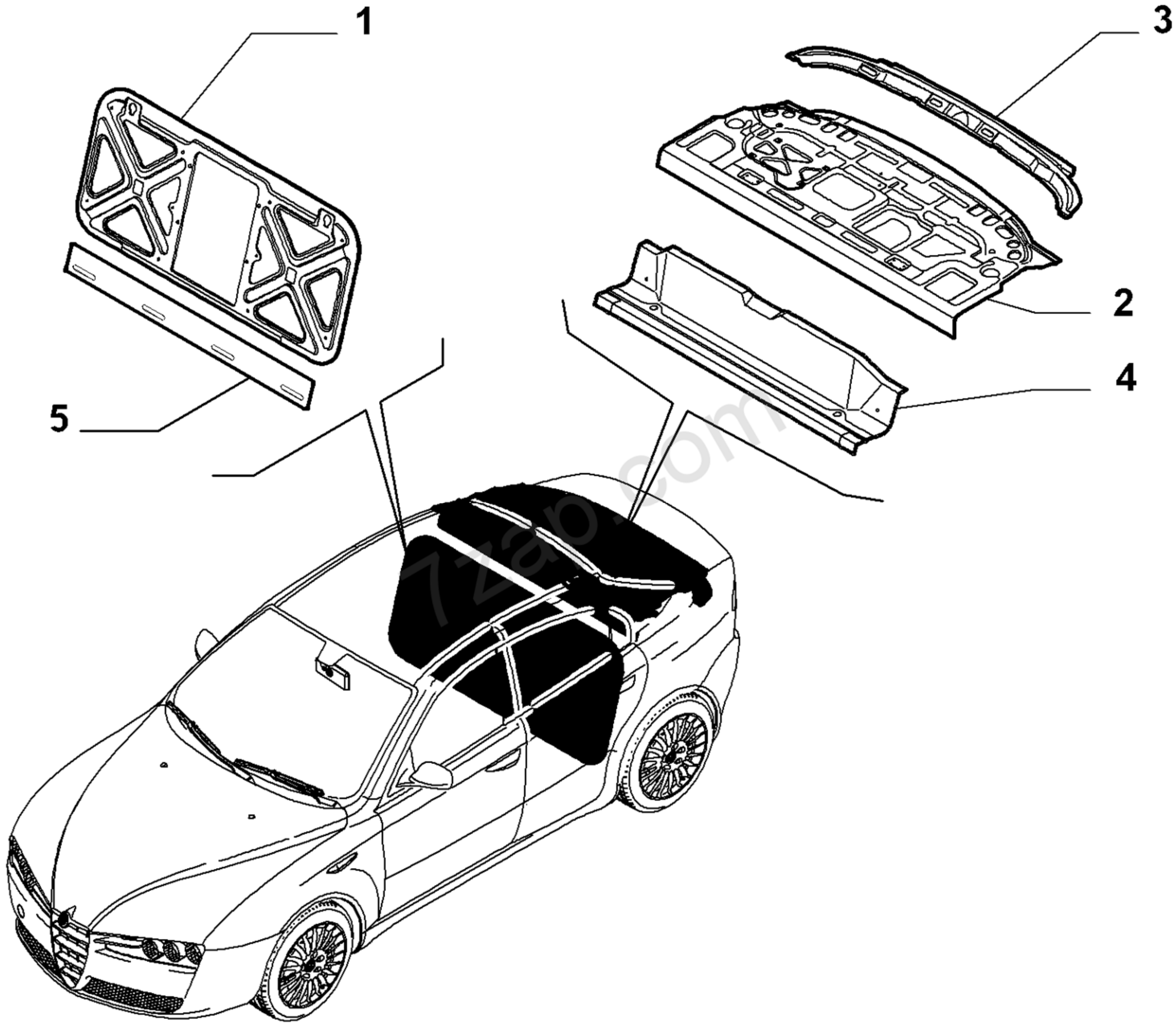
Rear floor panel



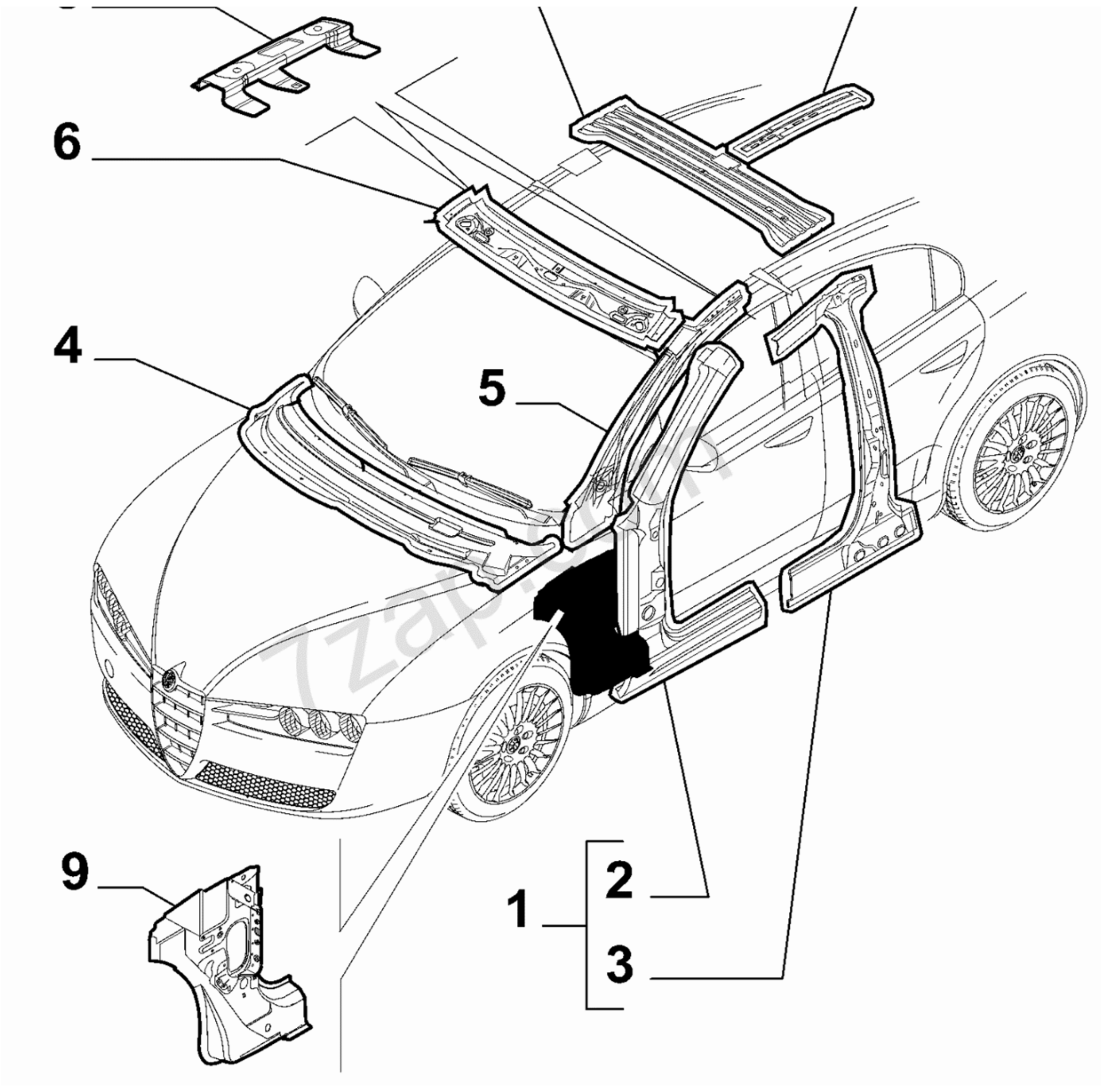
Spare tyre housing



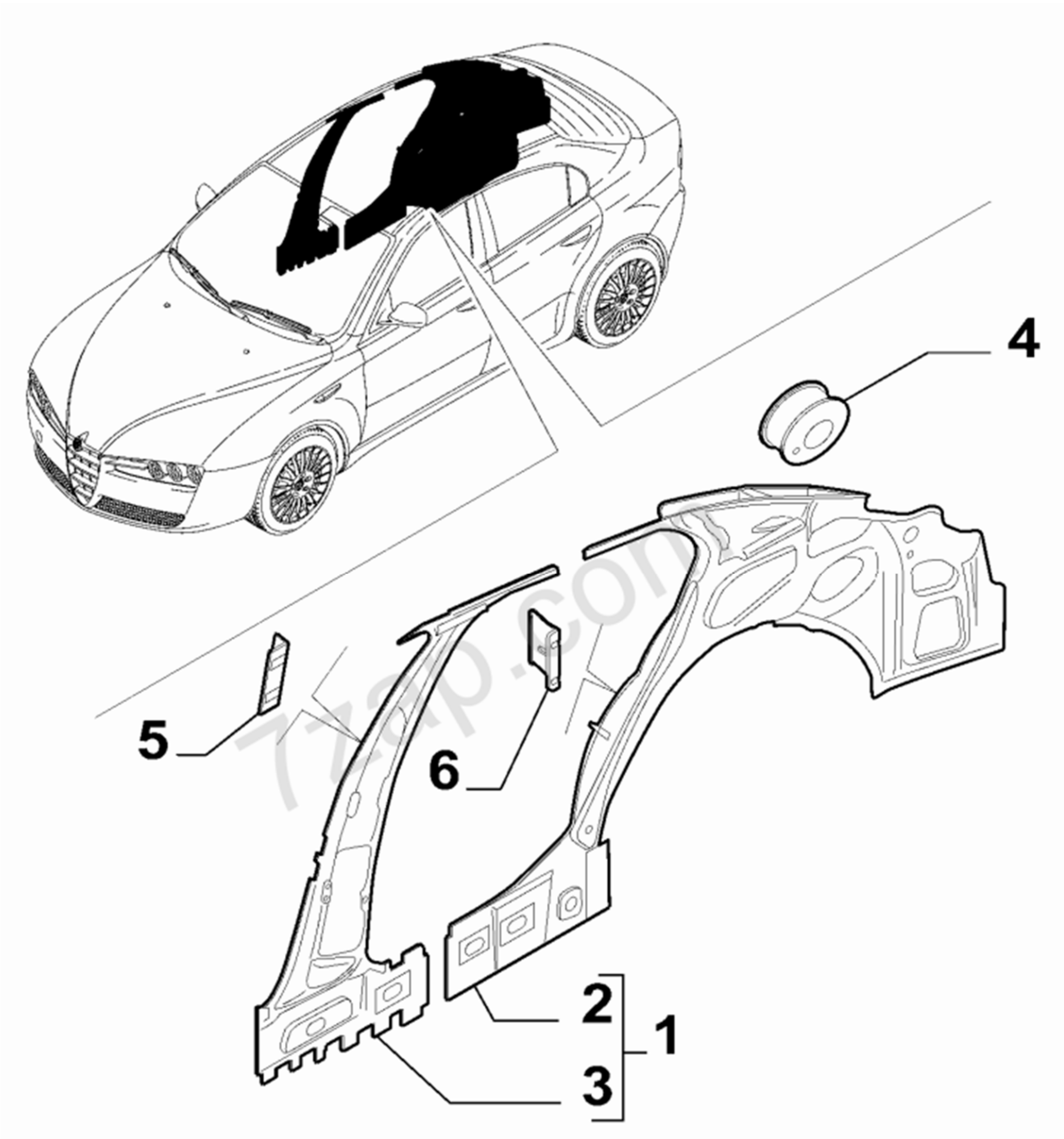
Wall Behind The Seatback And Under The Rear Window



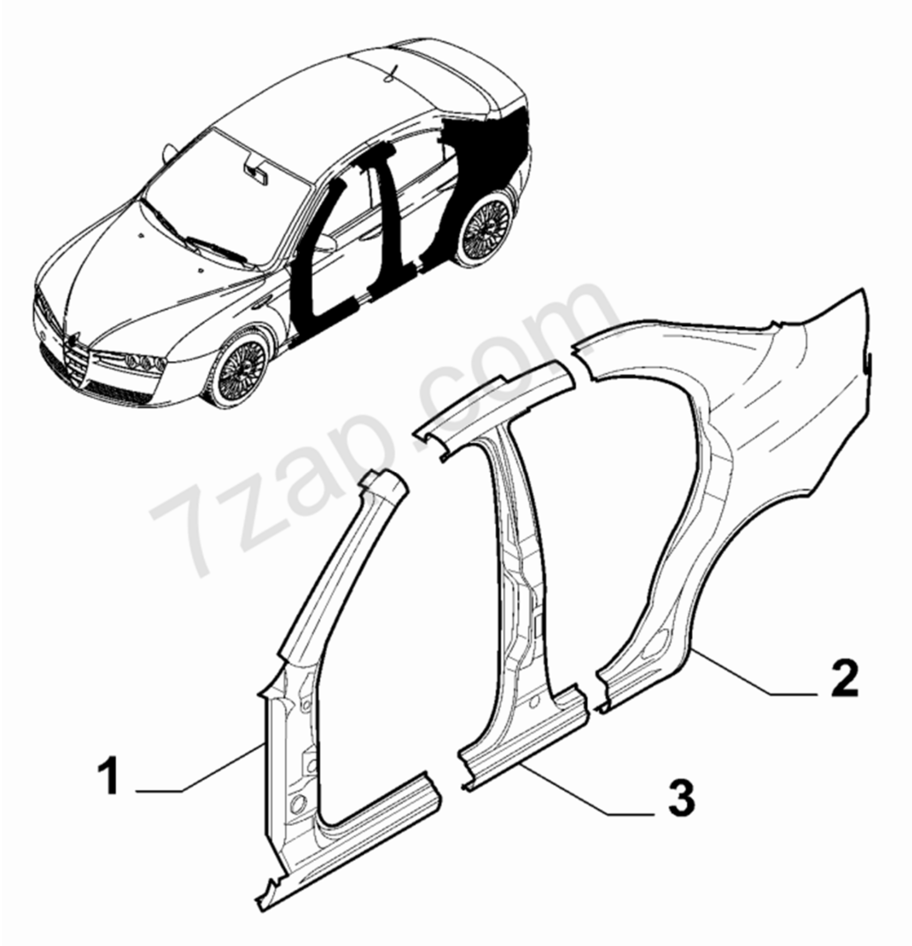
Central body structure

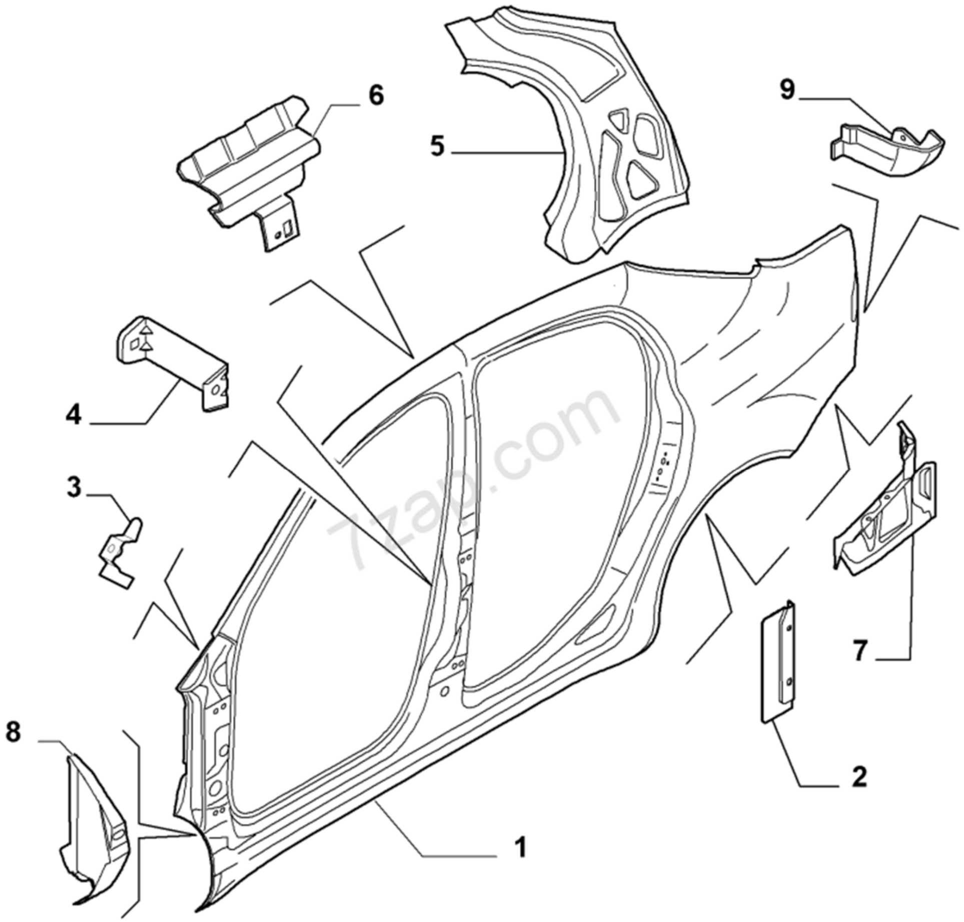


Rear side frame structure

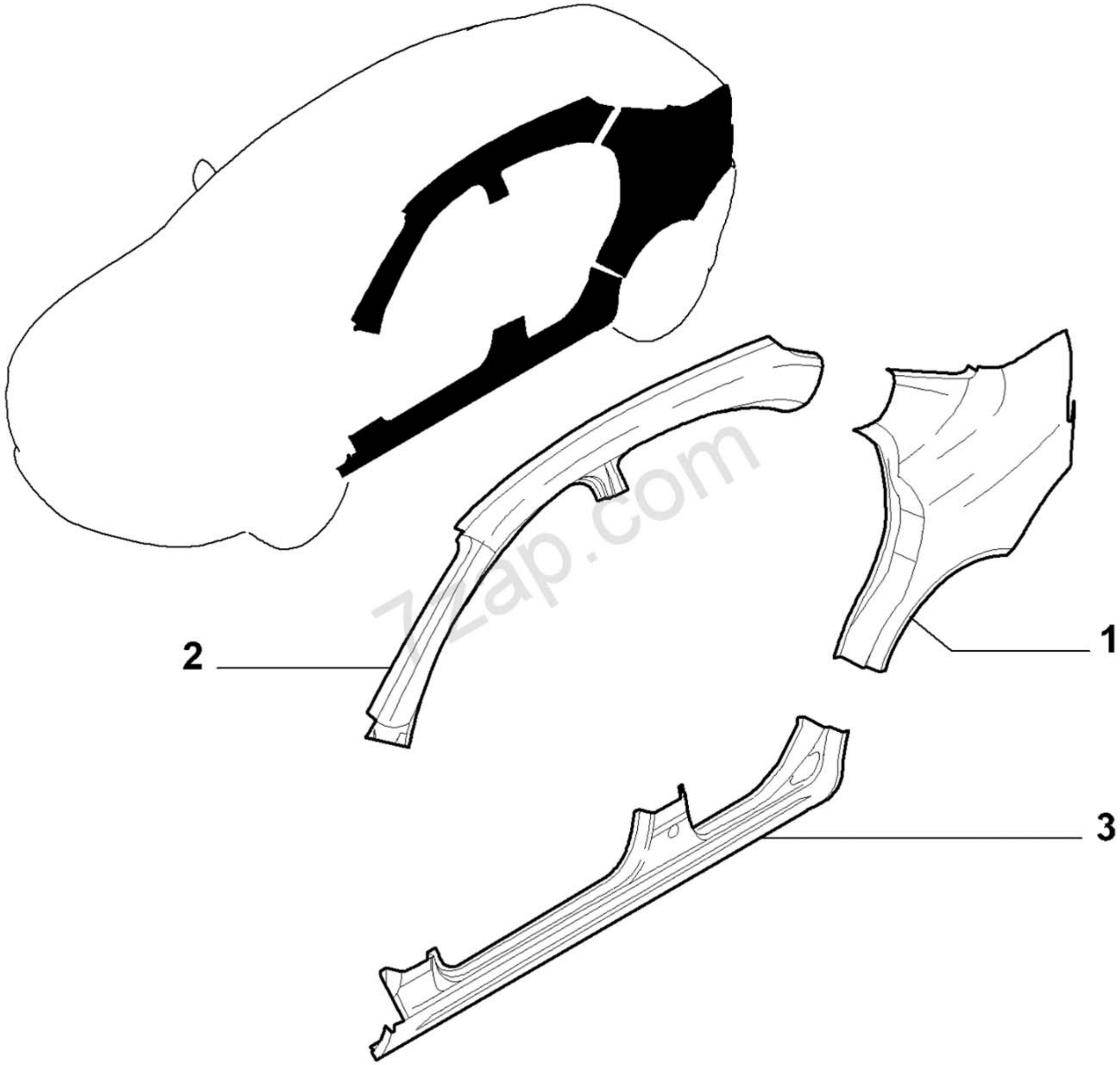


Side panels/plates



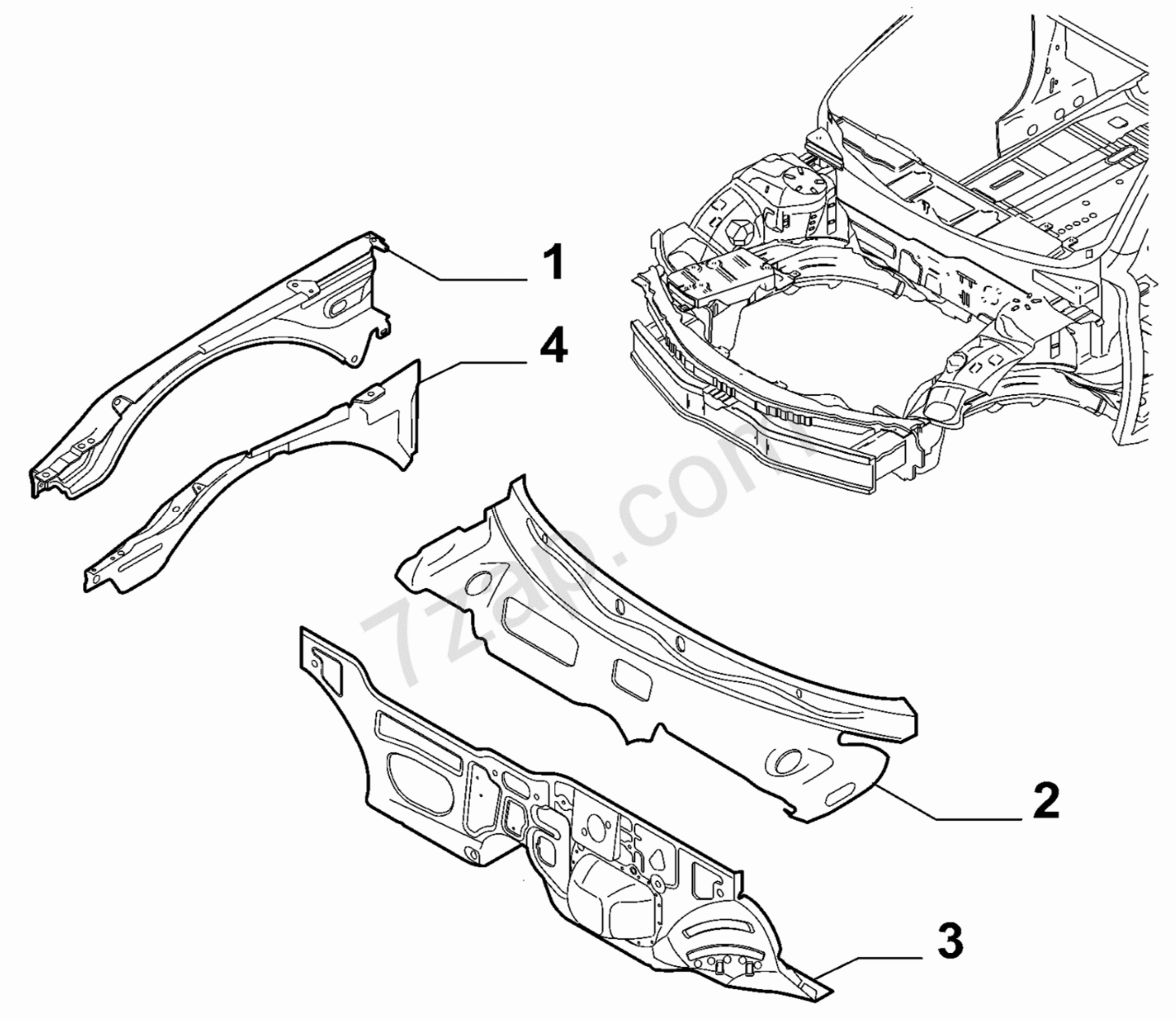


Side panels/plates



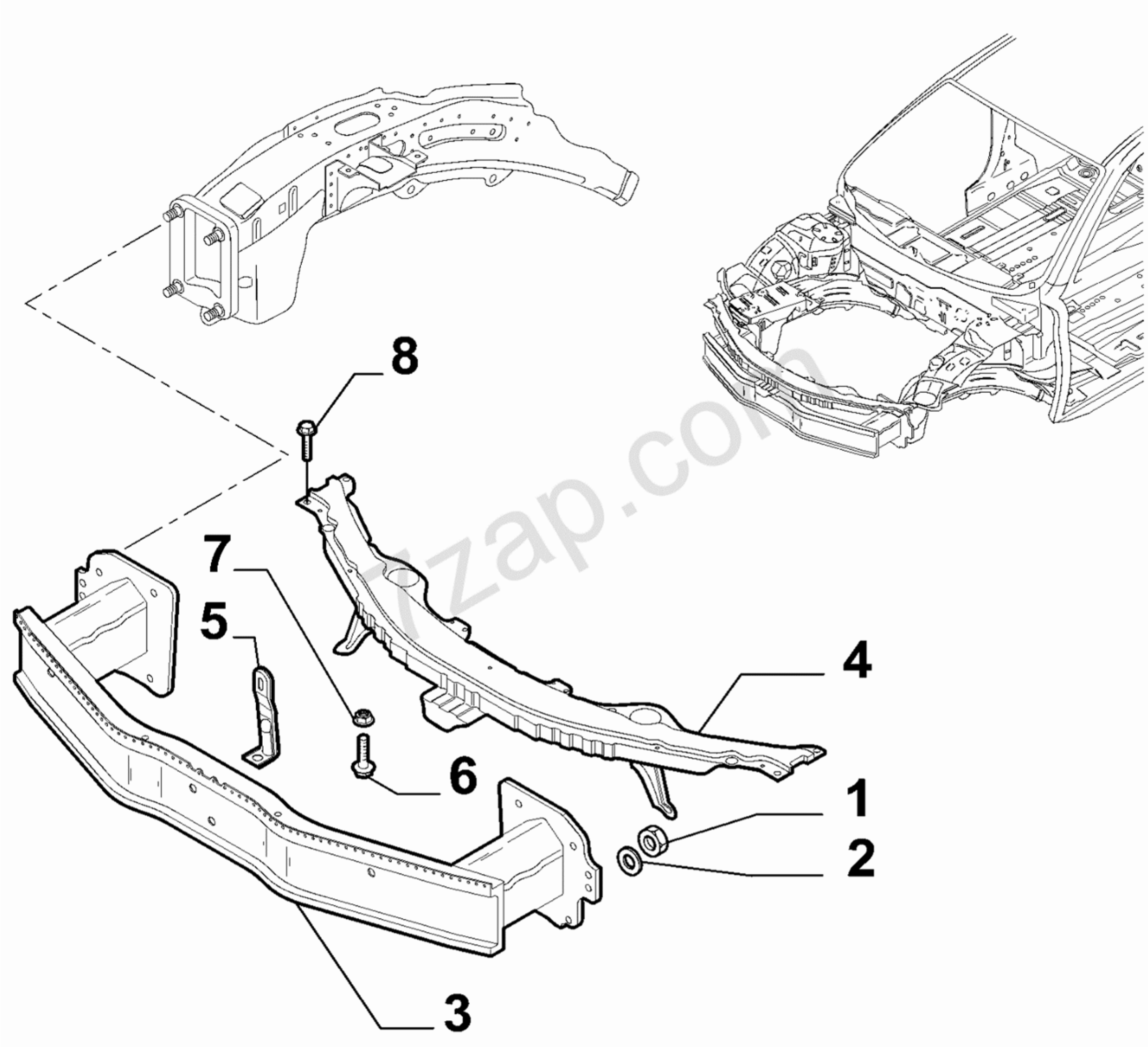
1-Rear fender
2-Cantrail
3-Sill

Instrument panel wall

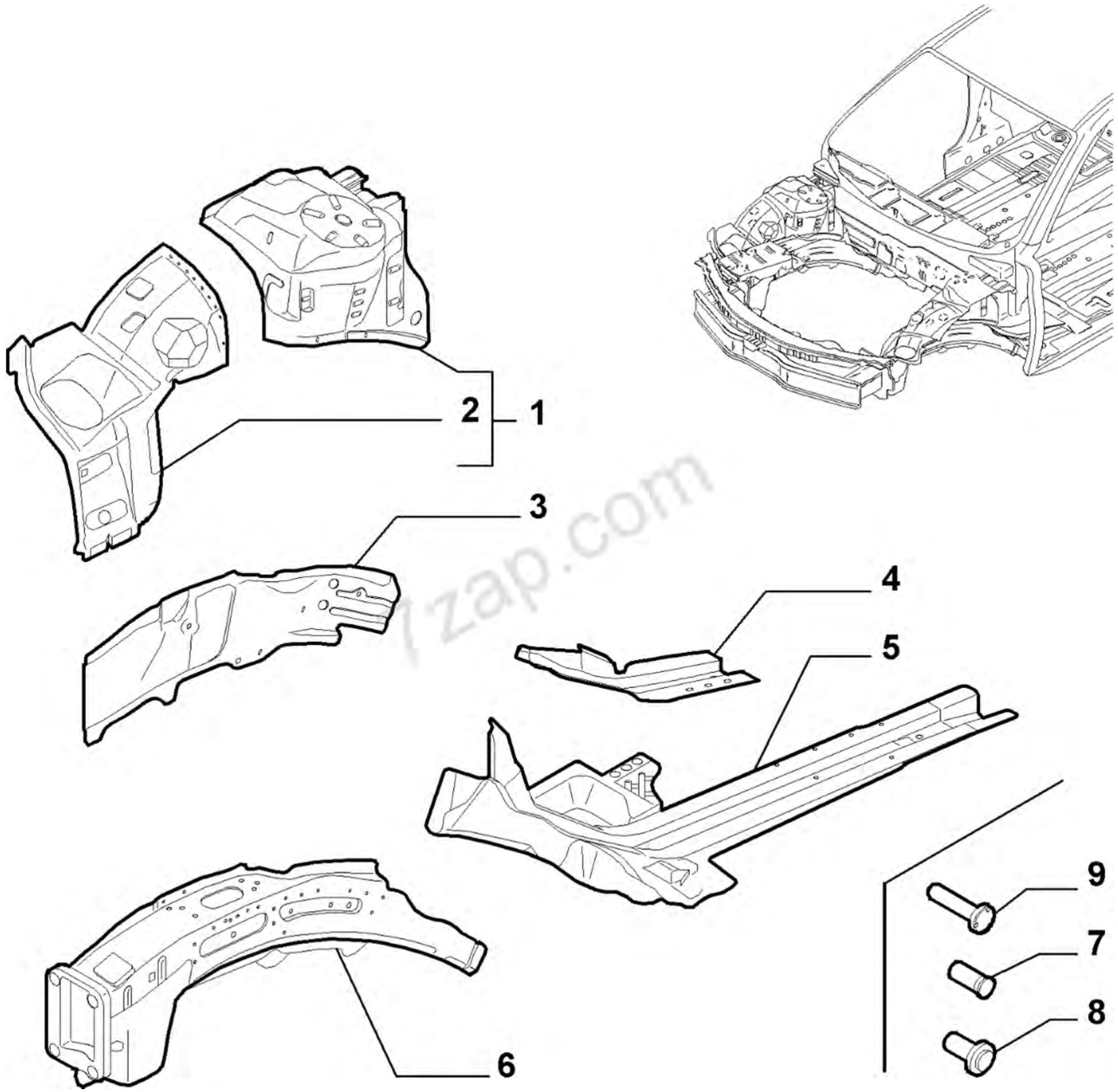


1-Cover
2-Dash panel sheet
3-Dash panel sheet
4-Boxed panel

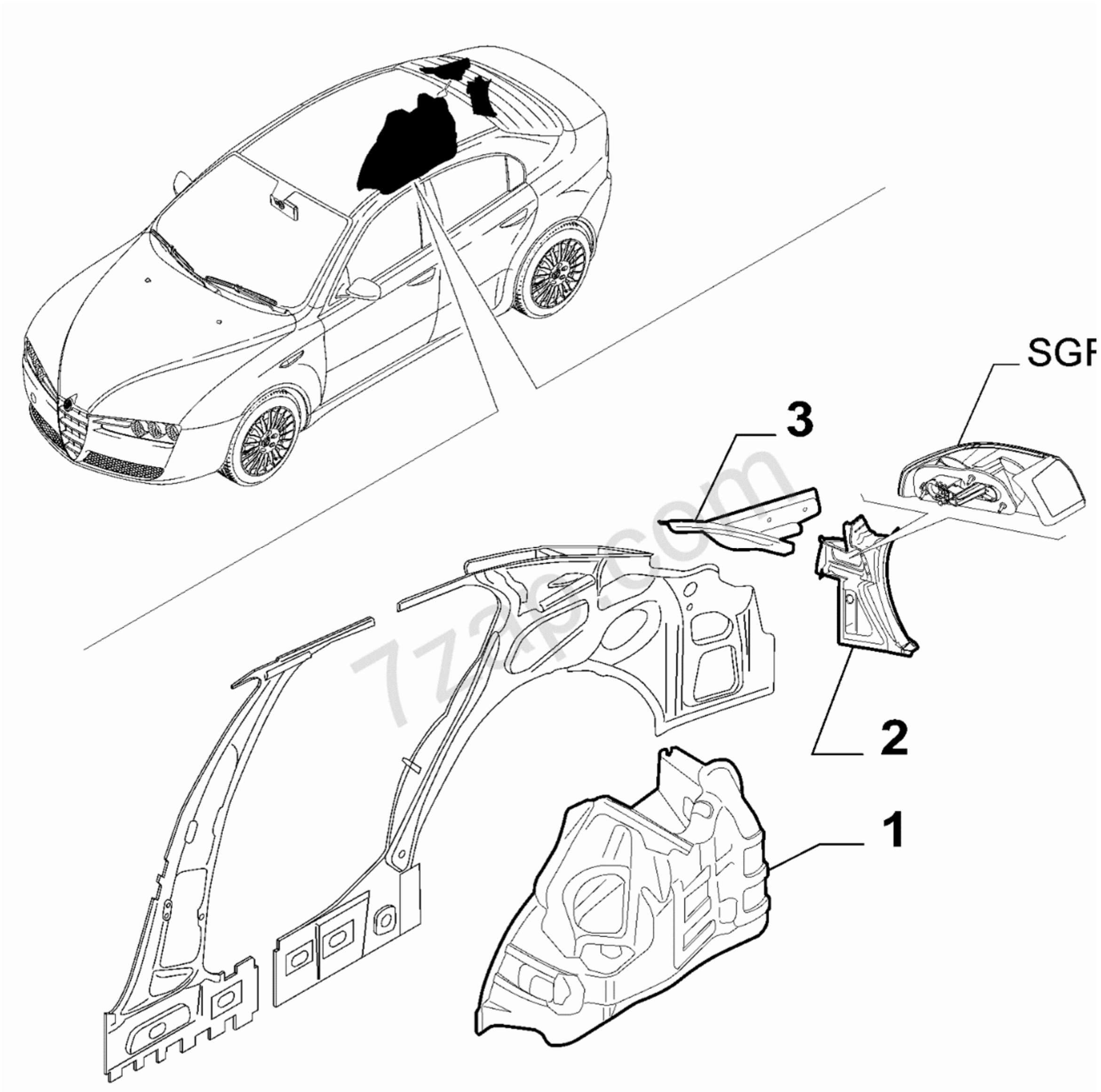
Front end



Front end

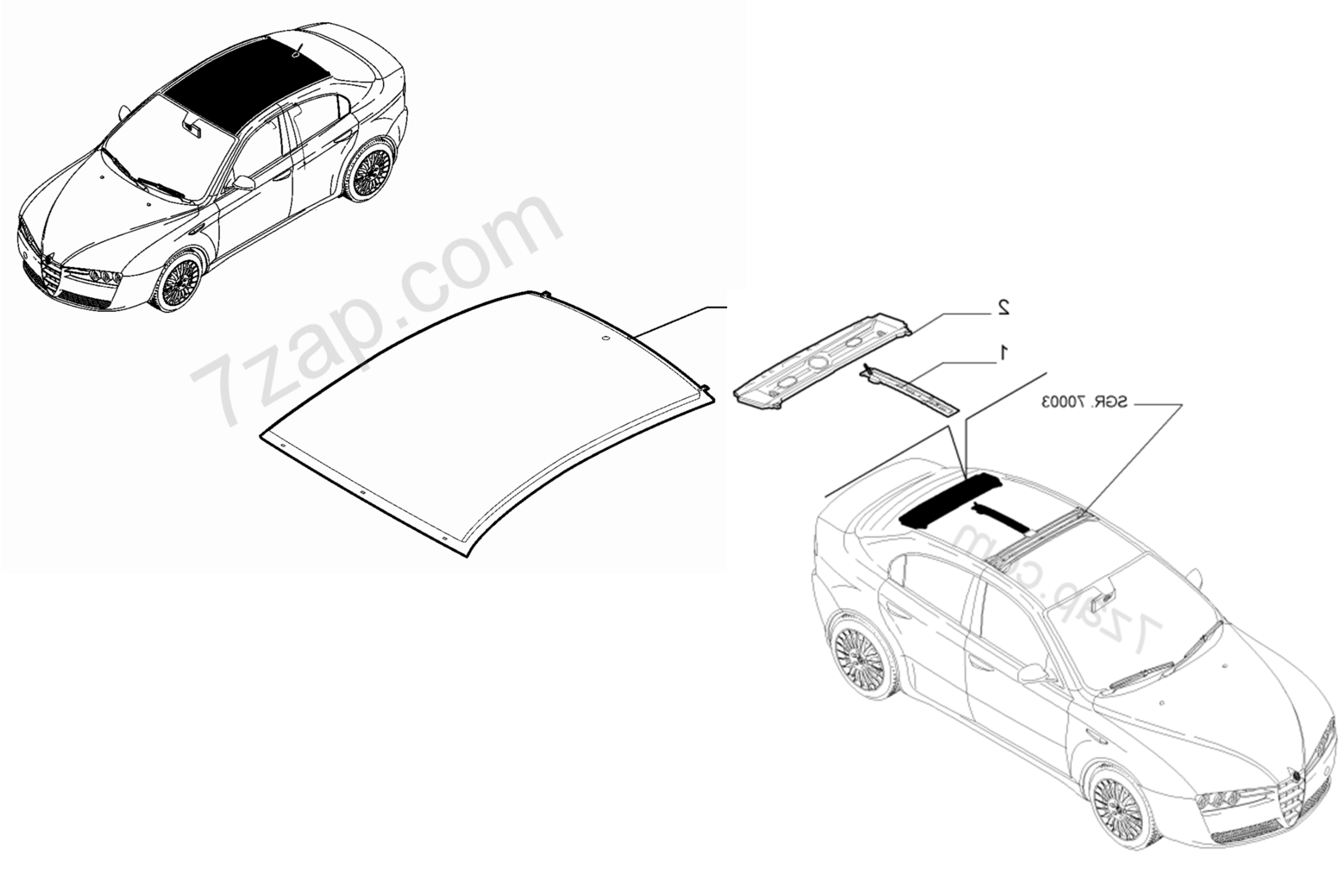


Rear wheel house

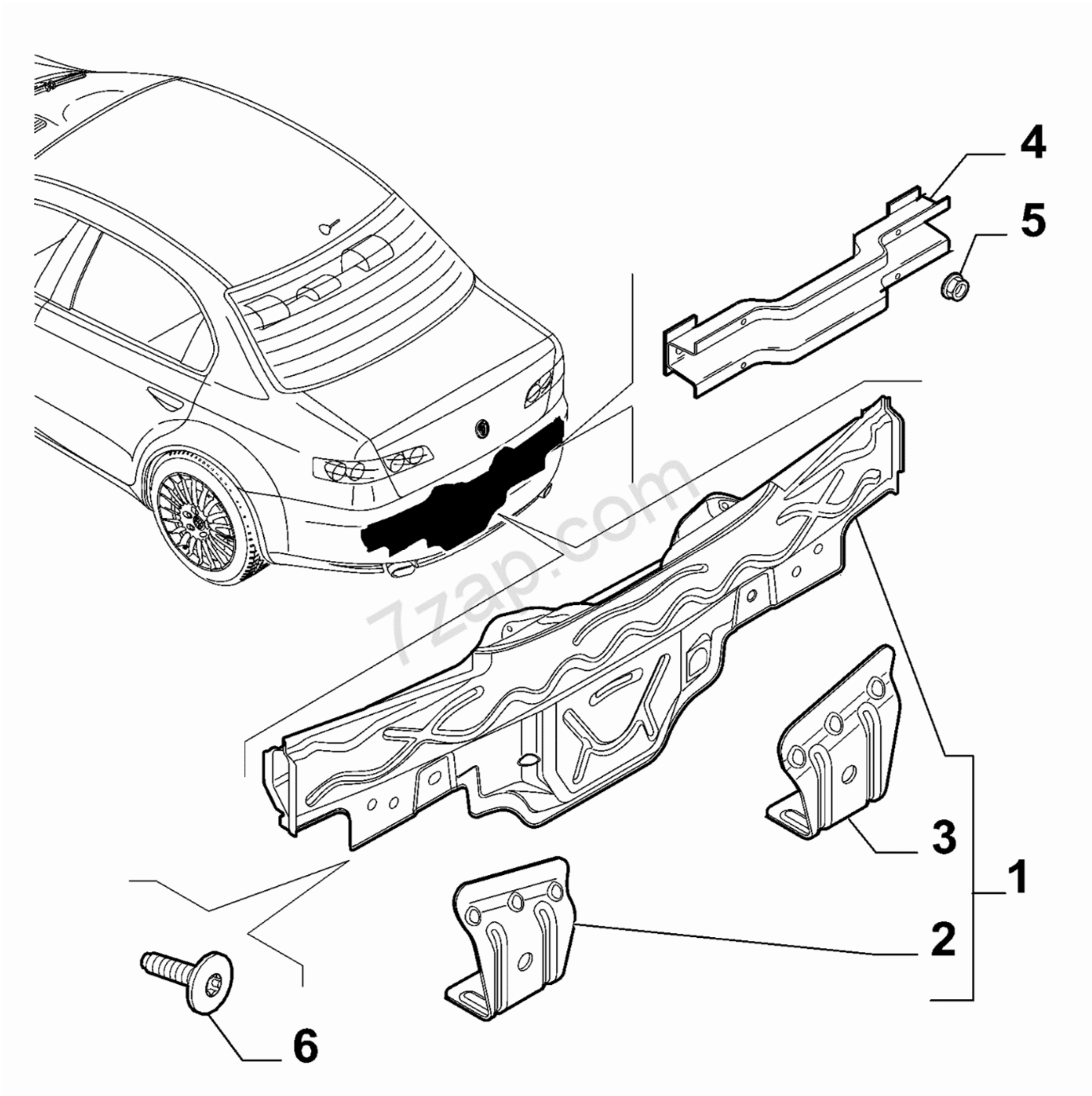


1-Wheel house
2&3 Glass Run

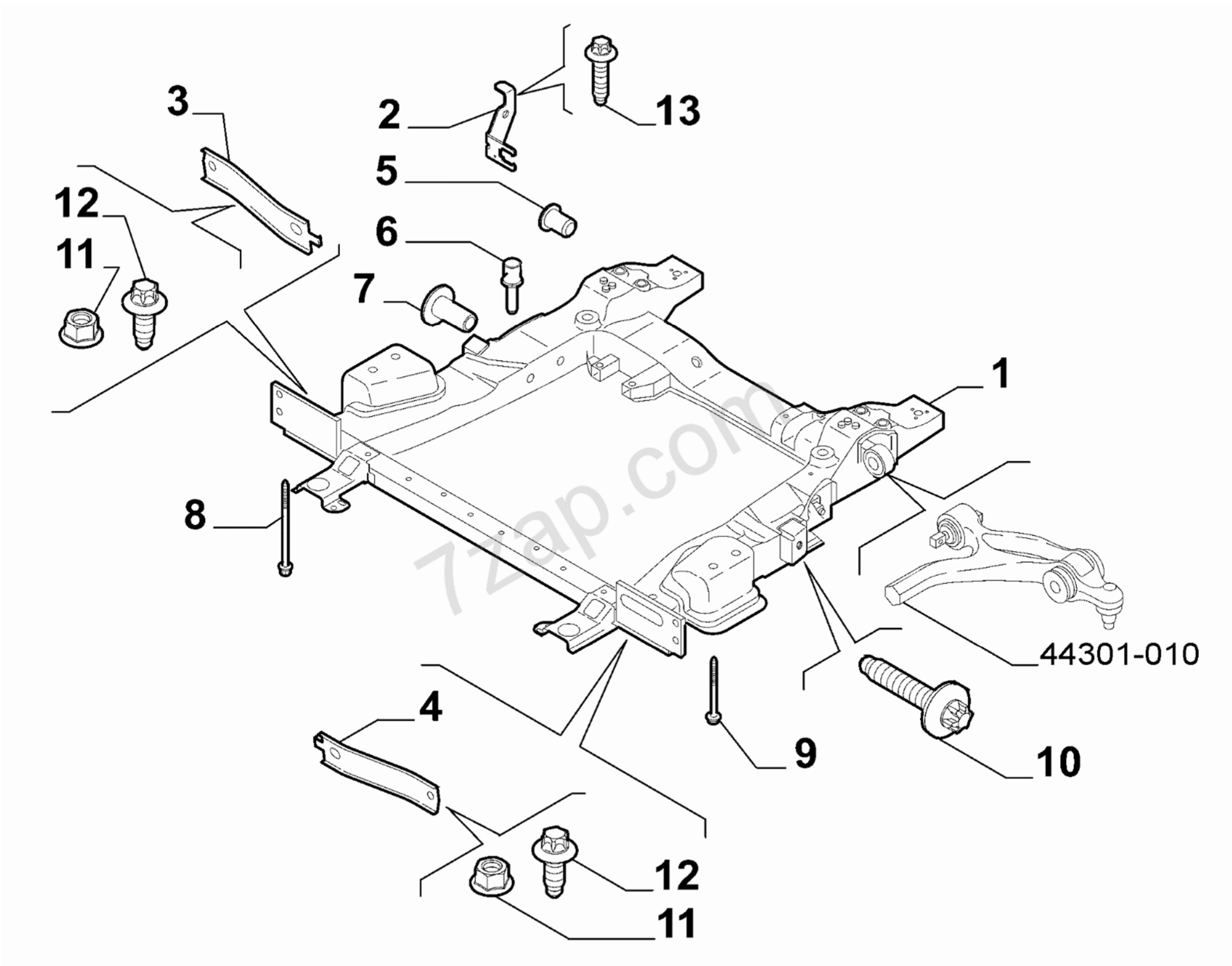
Roof



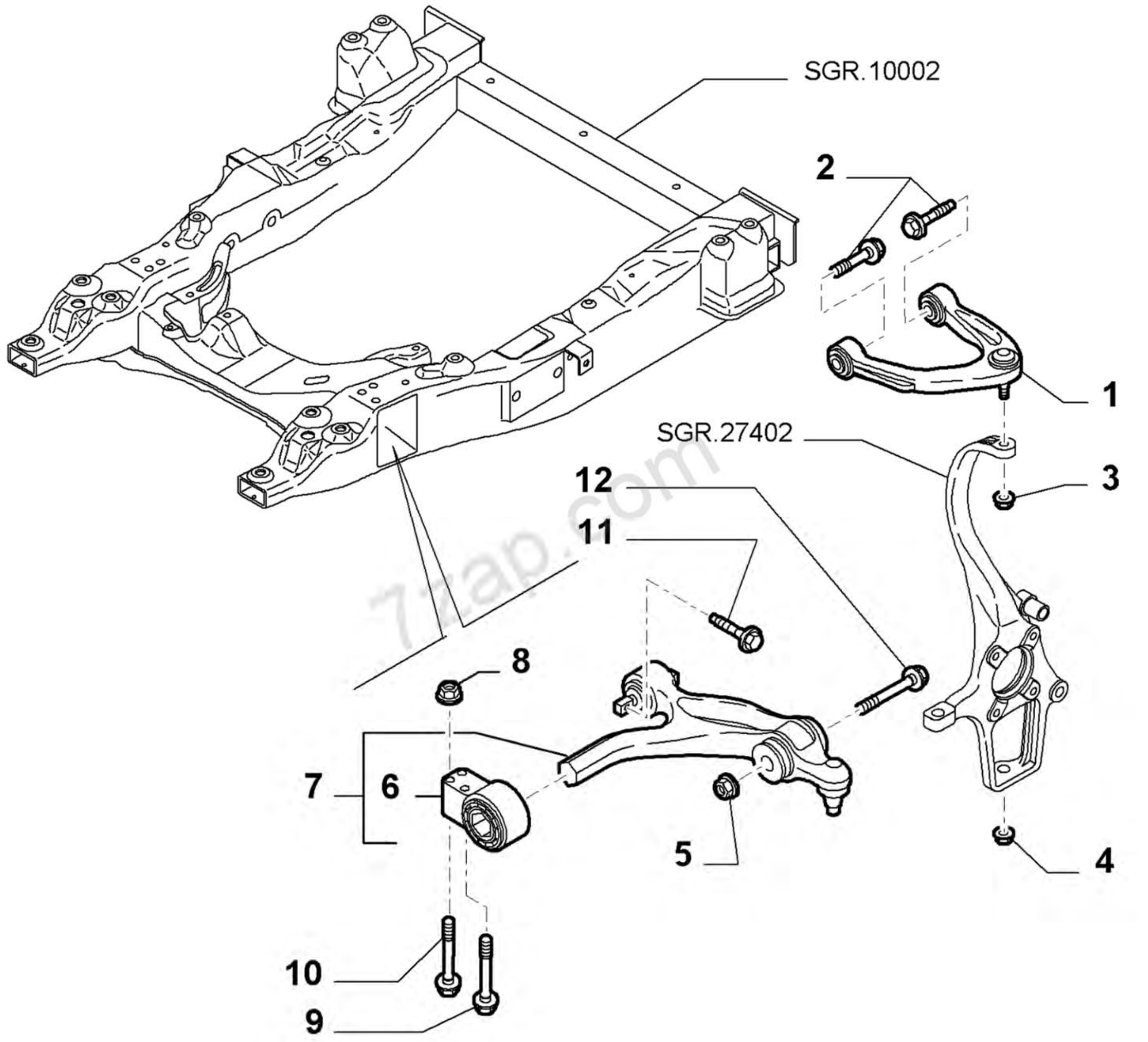
Rear covering



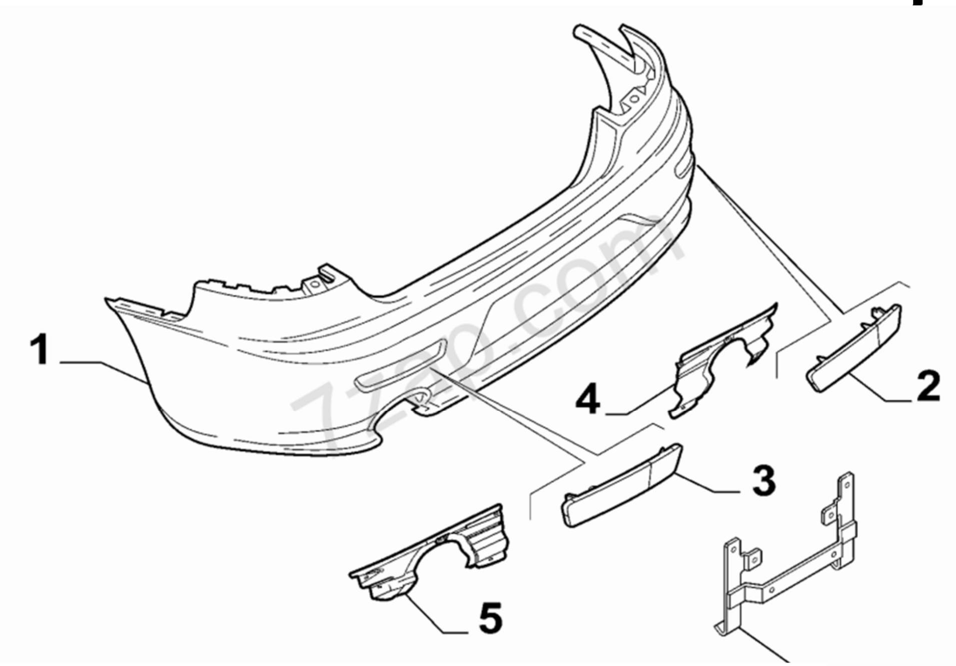
Rear suspension frame

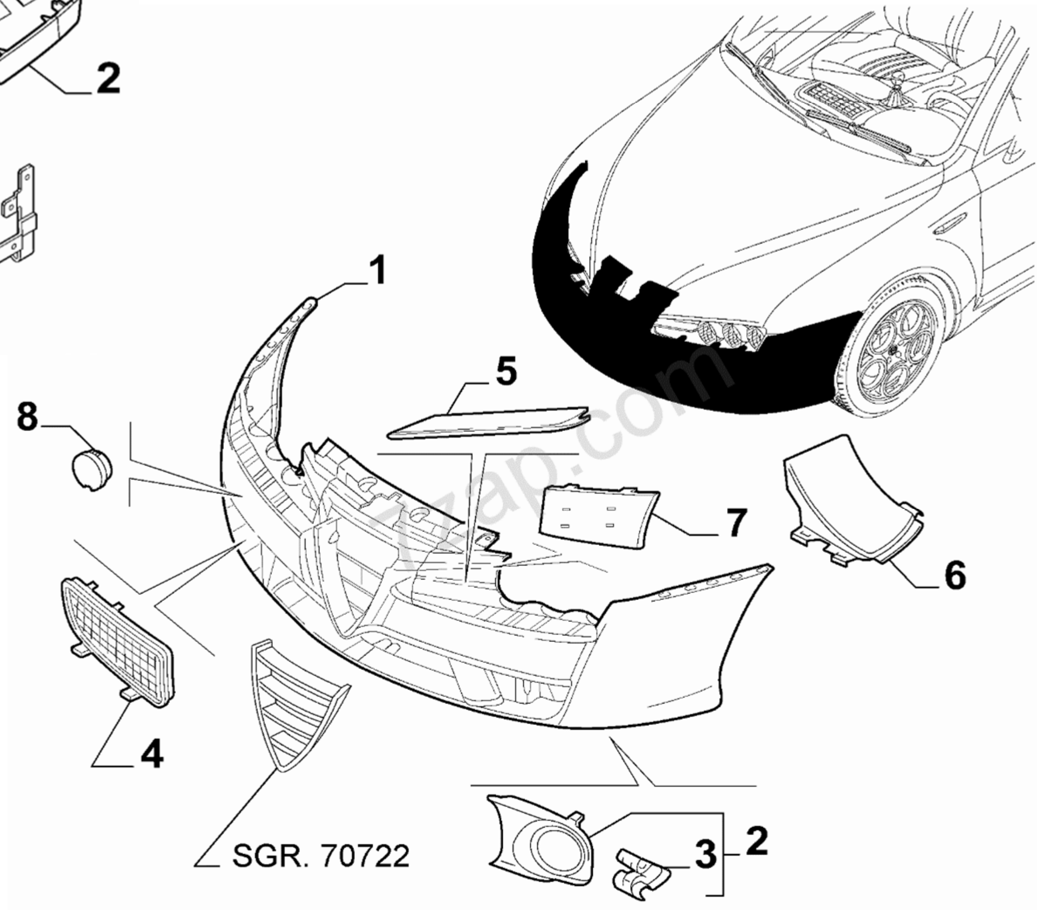


Front suspension frame/Cradle

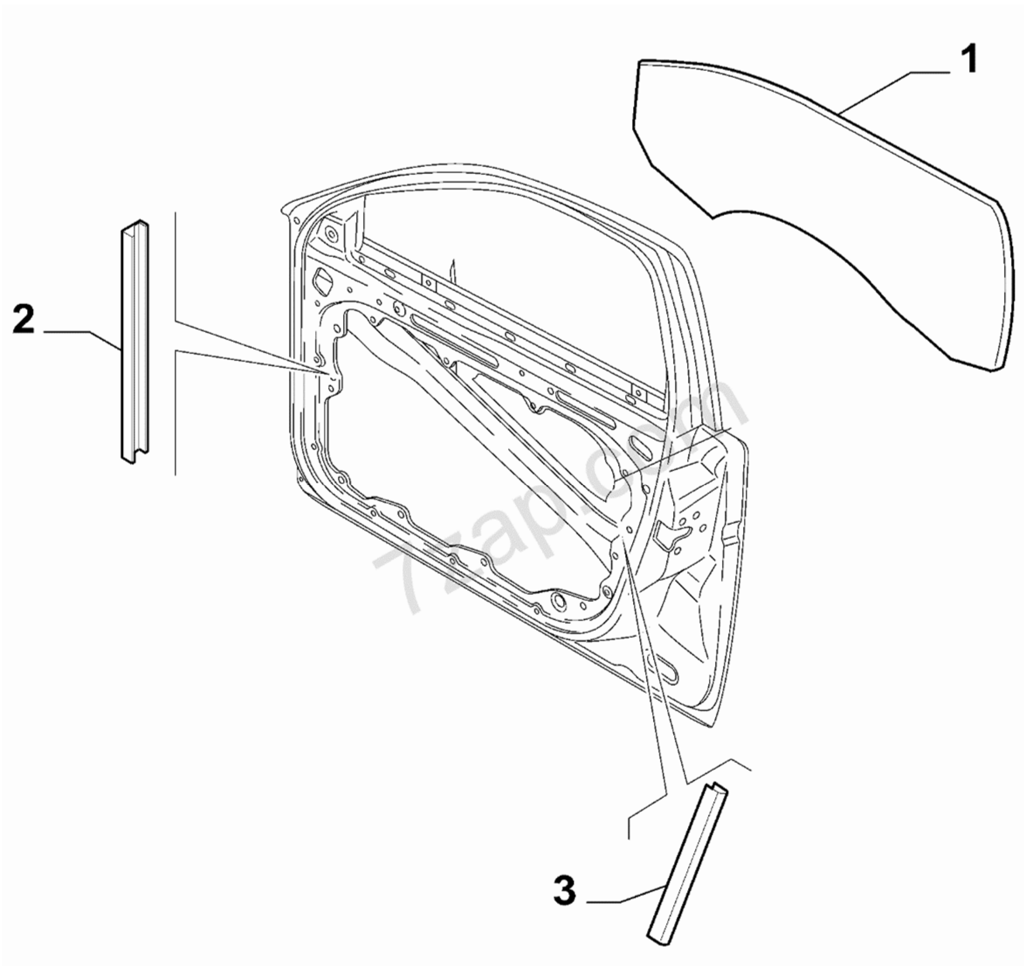


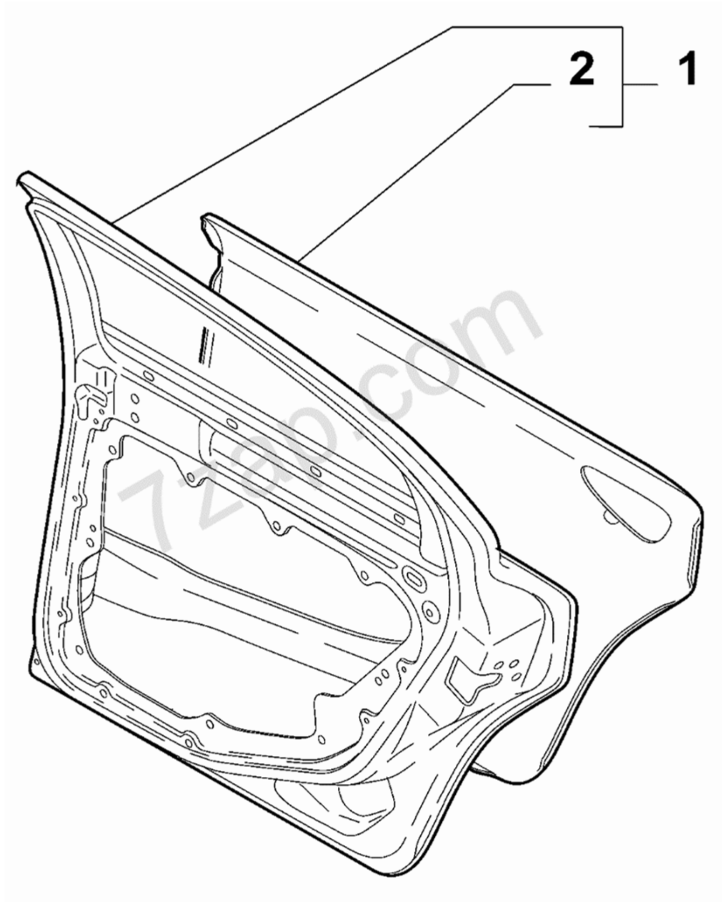
Bumpers



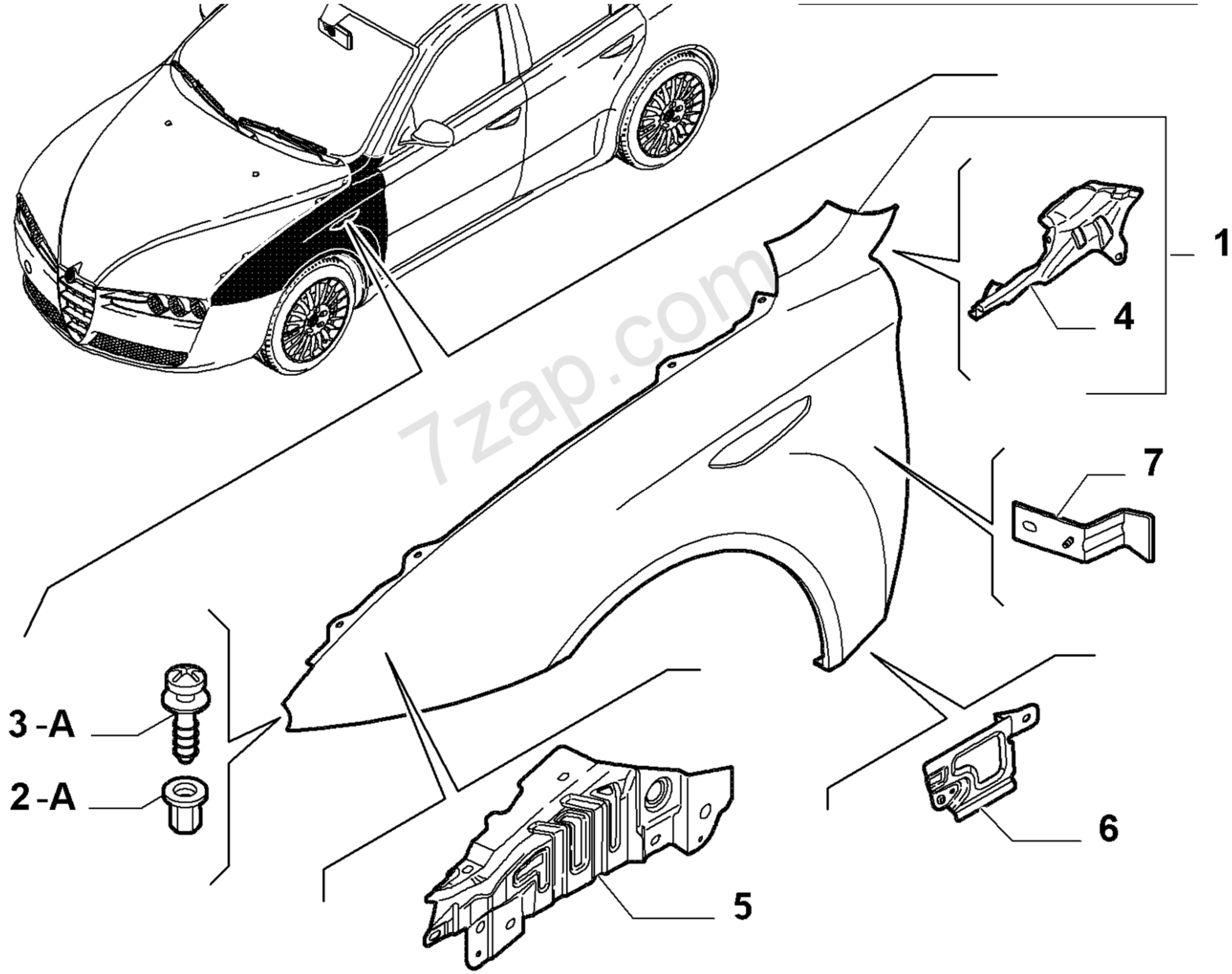


Doors

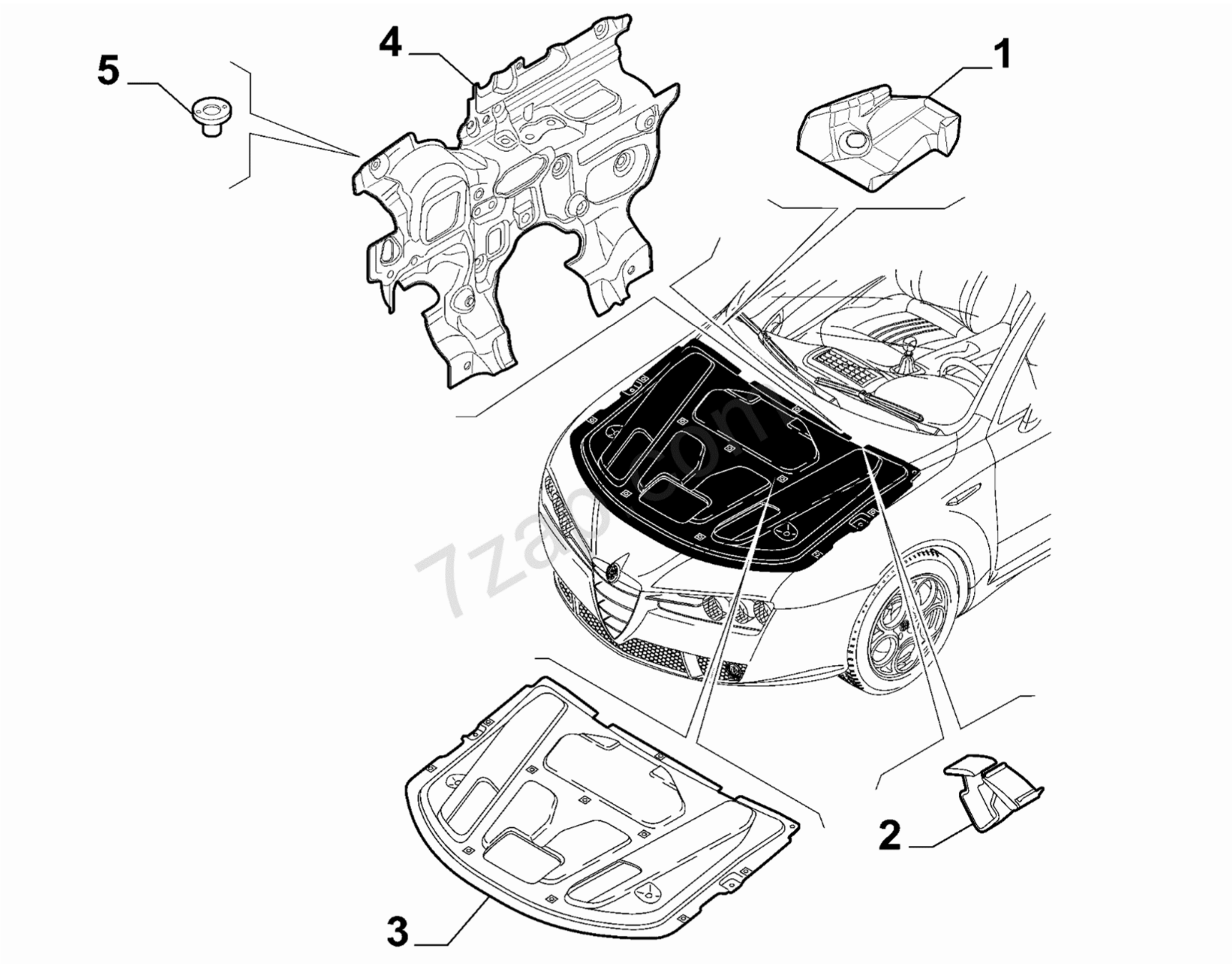




Mudgards



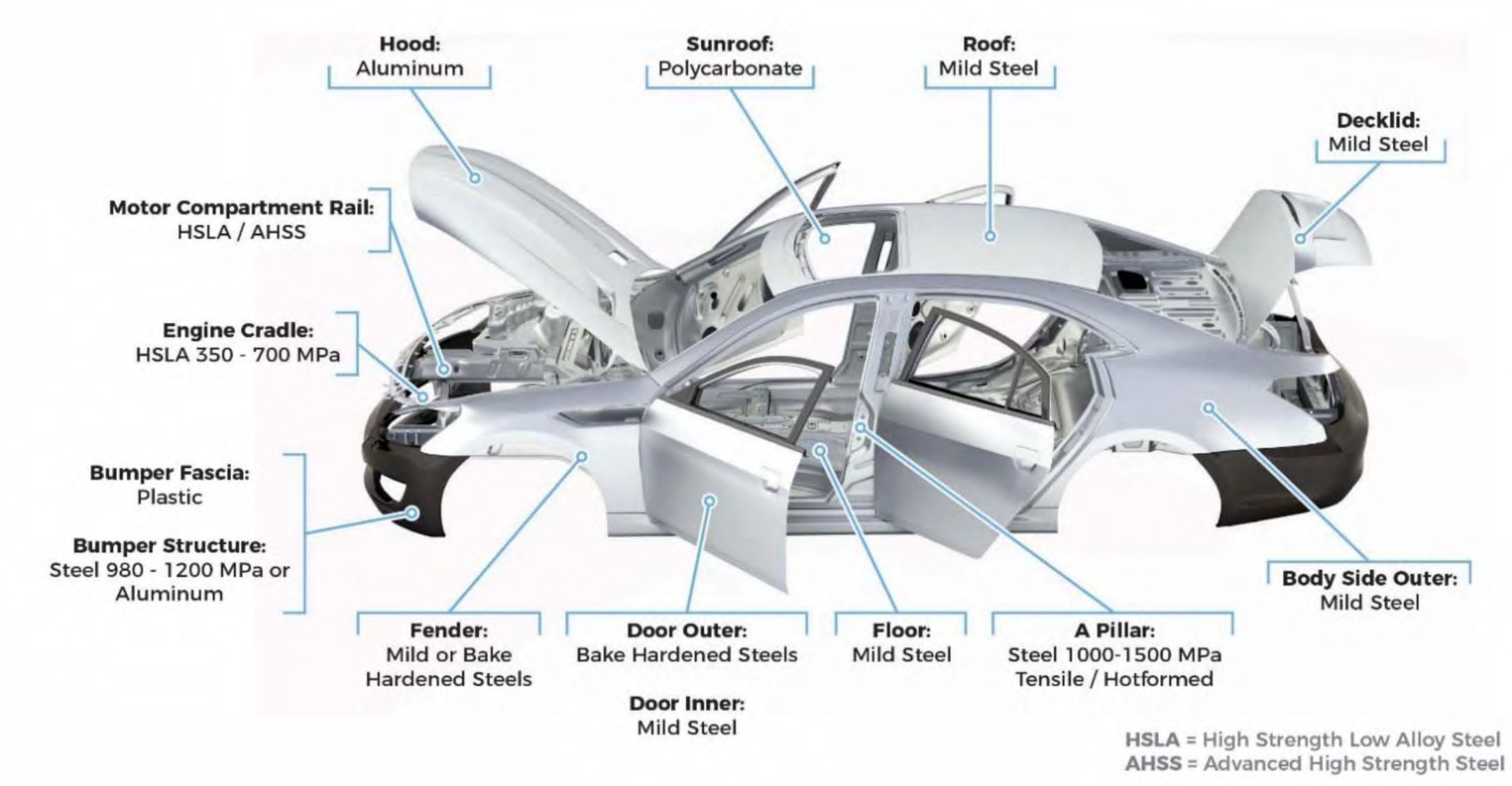
Bonnet



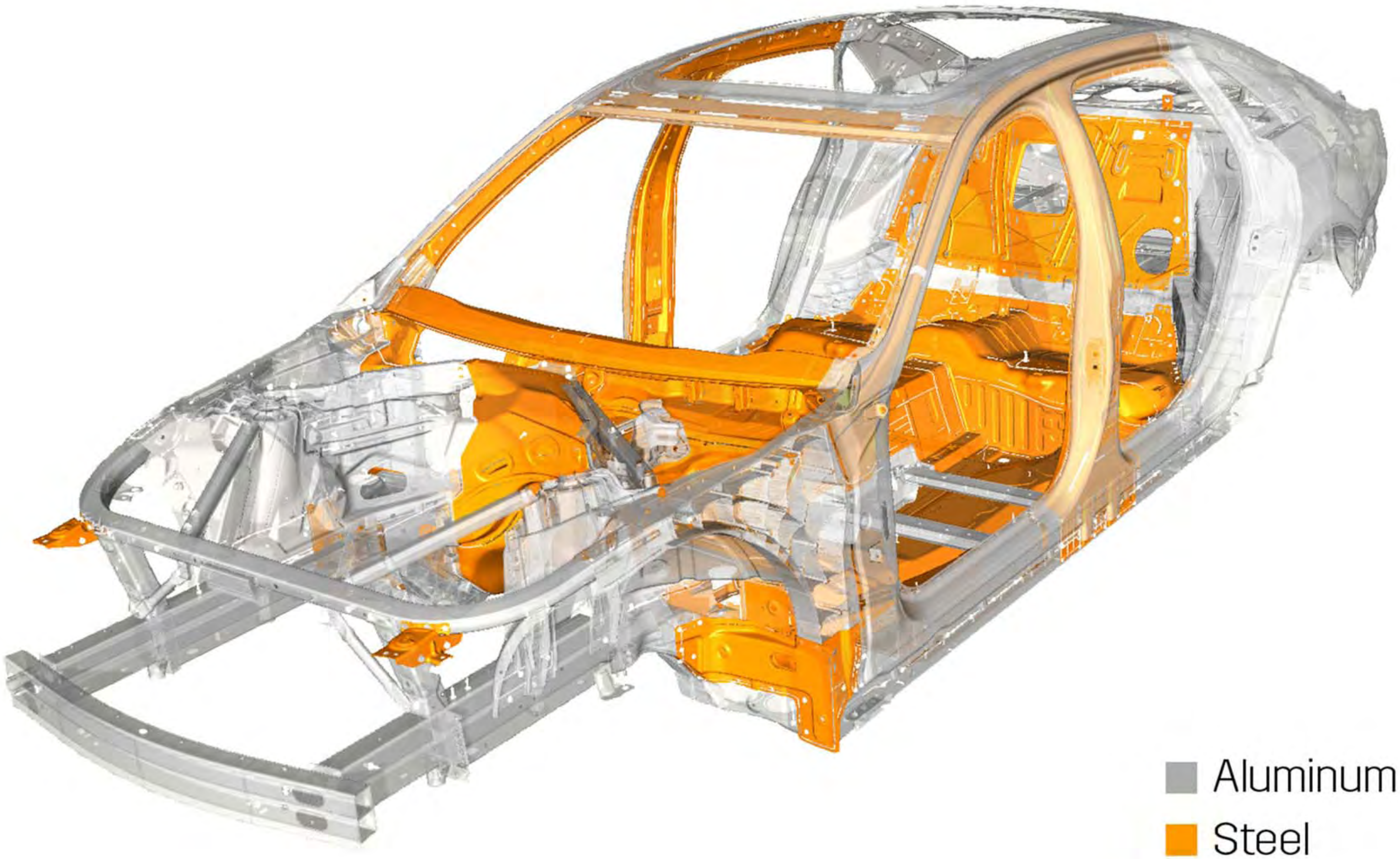
Materials

- New automotive materials are constantly being introduced to improve a vehicle’s crash safety, noise and vibration, fuel economy, and overall cost.
- Theoretically, a material can be used to make vehicle parts if it is commercially available, can be manufactured with an available technology, and meets the performance requirements.

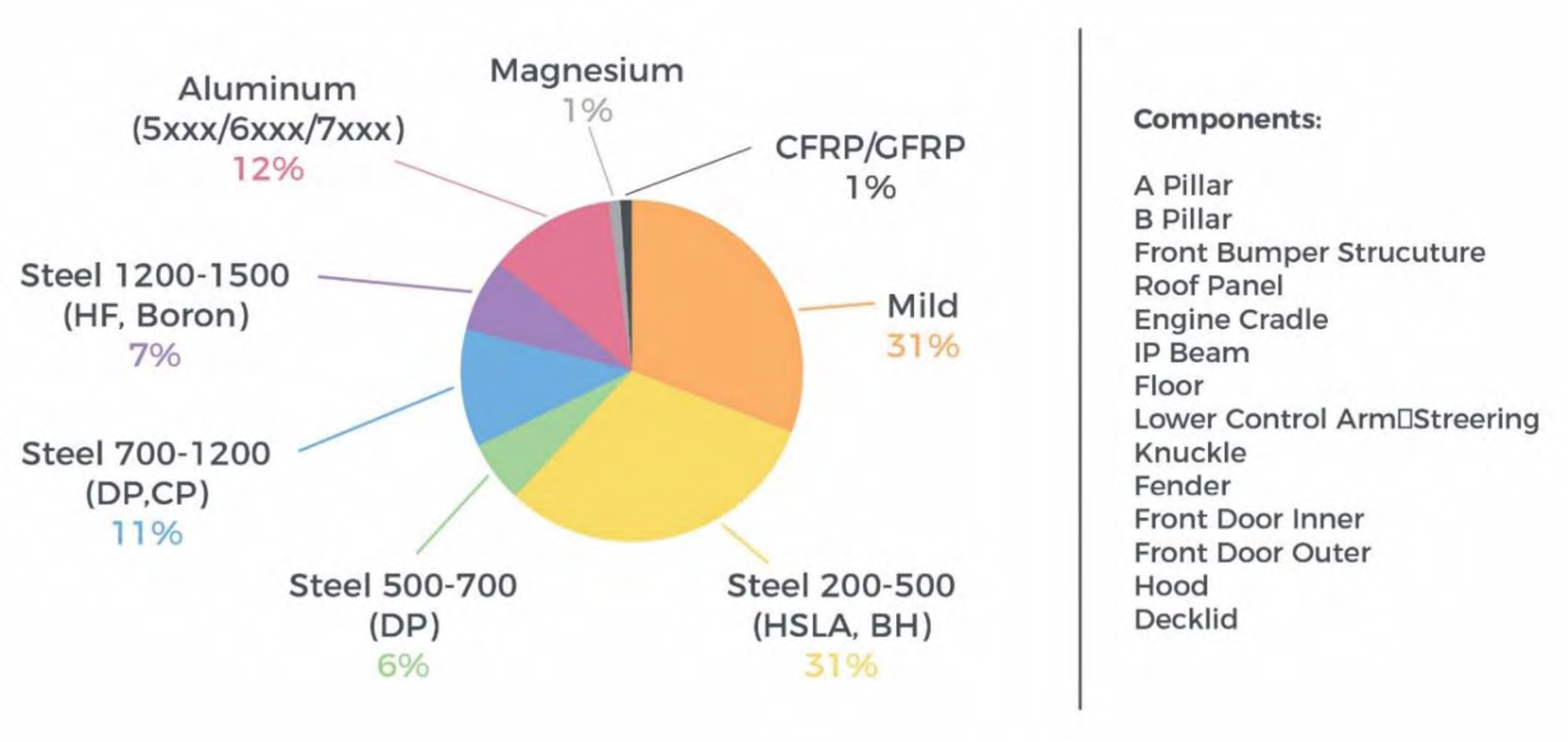
Materials


Hood:
Aluminum
Sunroof:
Polycarbonate
Roof:
Mild Steel
Decklid:
Mild Steel
Motor Compartment Rail:
HSLA / AHSS
Engine Cradle:
HSLA 350 - 700 MPa
Bumper Fascia:
Plastic
Bumper Structure:
Steel 980 - 1200 MPa or Aluminum
Body Side Outer:
Mild Steel
Fender:
Mild or Bake Hardened Steels
Door Outer:
Bake Hardened Steels
Door Inner:
Mild Steel
Floor:
Mild Steel
A Pillar:
Steel 1000-1500 MPa Tensile / Hotformed
HSLA = High Strength Low Alloy Steel
AHSS = Advanced High Strength Steel

Cadillac CT6



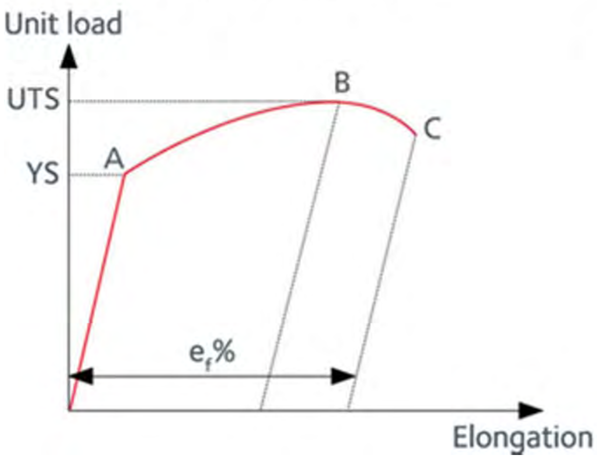
Materials

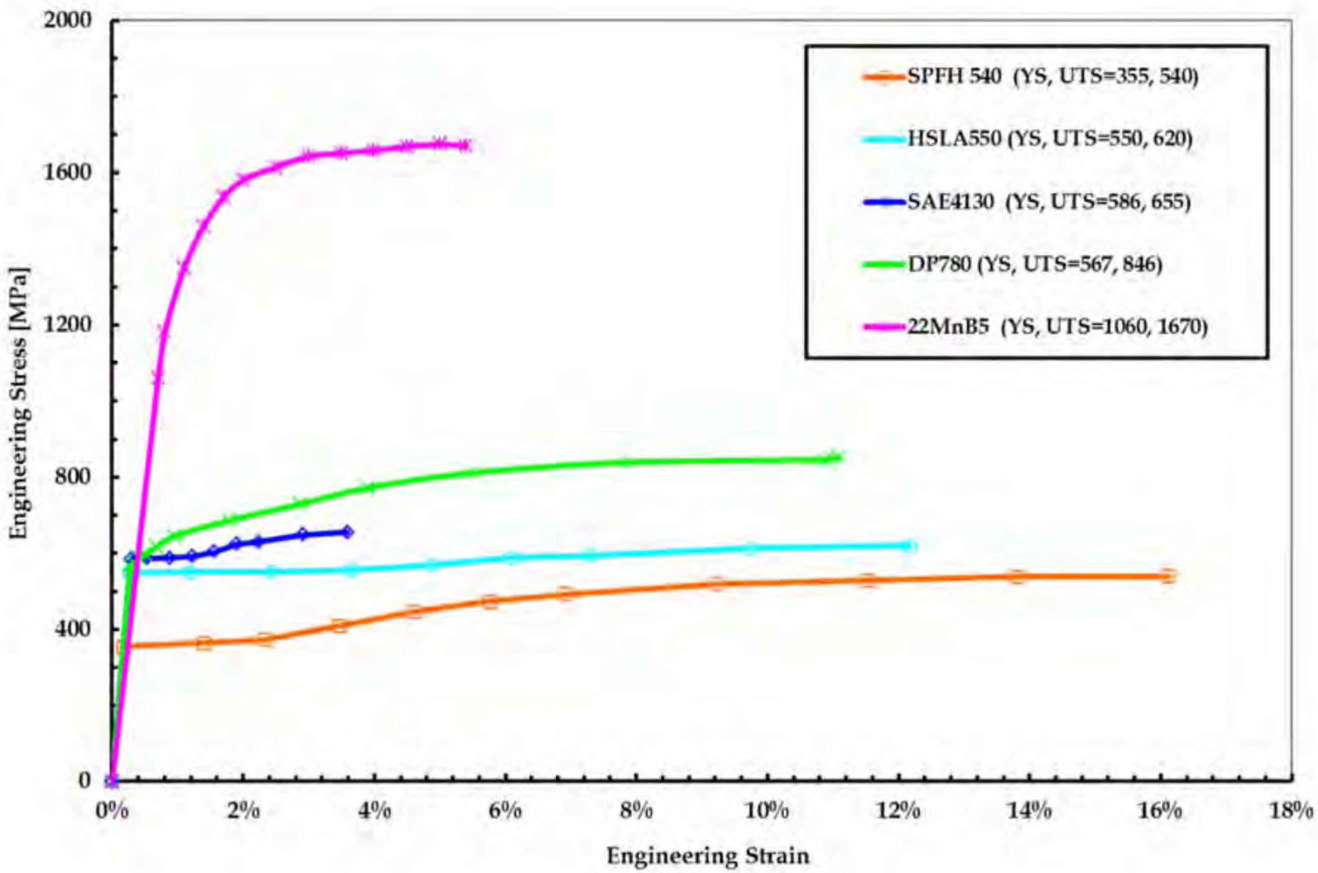


Current Vehicle Material Mix Based Upon 14 Major Components from 42 Mass Produced Vehicles

Chassis materials

For the U-Beam and S-Beam designs, the material grade selection was primarily influenced by the durability and extreme load cases. Additional material selection criteria included formability, weldability, availability and cost.





*Stell market development institute, Lightweight Twist Beam Final Report

Steel Grade	YS (MPa)	UTS (MPa)	Total EL (%)	n-value[1] (5-15%)	r-bar	K-value[2] (MPa)
	(flat sheet, as shipped properties)					
BH 210/340	210	340	34-39	0.18	1.8	582
BH 260/370	260	370	29-34	0.13	1.6	550
DP 280/600	280	600	30-34	0.21	1.0	1082
IF 300/420	300	420	29-36	0.20	1.6	759
DP 300/500	300	500	30-34	0.16	1.0	762
HSLA 350/450	350	450	23-27	0.14	1.1	807
DP 350/600	350	600	24-30	0.14	1.0	976
DP 400/700	400	700	19-25	0.14	1.0	1028
TRIP 450/800	450	800	26-32	0.24	0.9	1690
DP 500/800	500	800	14-20	0.14	1.0	1303
CP 700/800	700	800	10-15	0.13	1.0	1380
DP 700/1000	700	1000	12-17	0.09	0.9	1521
Mart 950/1200	950	1200	5-7	0.07	0.9	1678
Mart 1250/1520	1250	1520	4-6	0.065	0.9	2021
	(straight tubes, as shipped properties)					
DP 280/600	450	600	27-30	0.15	1.0	1100
DP 500/800	600	800	16-22	0.10	1.0	1250
Mart 950/1200	1150	1200	5-7	0.02	0.9	1550

YS and UTS are minimum values, others are typical values

Total EL % - Flat Sheet (A50 or A80), Tubes (A5)

[1]n-value is calculated in the range of 5 to 15% true strain.

[2]K-value is the magnitude of true stress extrapolated to a true strain of 1.0. It is a material property parameter frequently used by one-step forming simulation codes.

*Future Generation Passenger Compartment Phase1 report, Auto steel partnership

Chassis materials-Steels

- Steel accounts for roughly 60% of the metal used in an average vehicle. Modern vehicle structures contains different grades of steels.
  - Mild steels
  - HSS-High-strength steels
  - AHSS-Advanced high-strength steels
  - UHSS-Ultra high-strength steels

Chassis materials-Steels

- Mild Steel: Mild steels are easy to form, which makes them a top choice for automotive parts manufacturers using cold stamping and other dated manufacturing processes. They have a maximum tensile strength of **270** MPa.
- High Strength Steel (HSS): High strength steels use traditional steels and remove carbon during the baking cycle. This means softer steels can be formed, then baked into harder metals. Typical tensile strength grades range from **250 to 550 MPa.**
- High Strength Low Alloy (HSLA): HLSAs are carbon manganese steels strengthened with the addition of a micro alloying element such as titanium, vanadium, or niobium. These have a tensile strength up to 800 MPa, and can still be press formed.
- Advanced High Strength Steel (AHSS): Advanced high strength steels generally yield strength levels in excess of 550 MPa. They are composites made of multiple metals, then heated and cooled throughout the manufacturing process to meet a part's specifications.
- Ultra High Strength Steel (UHSS): These follow similar properties as AHSS, but maintain strength levels of at least 780MPa.

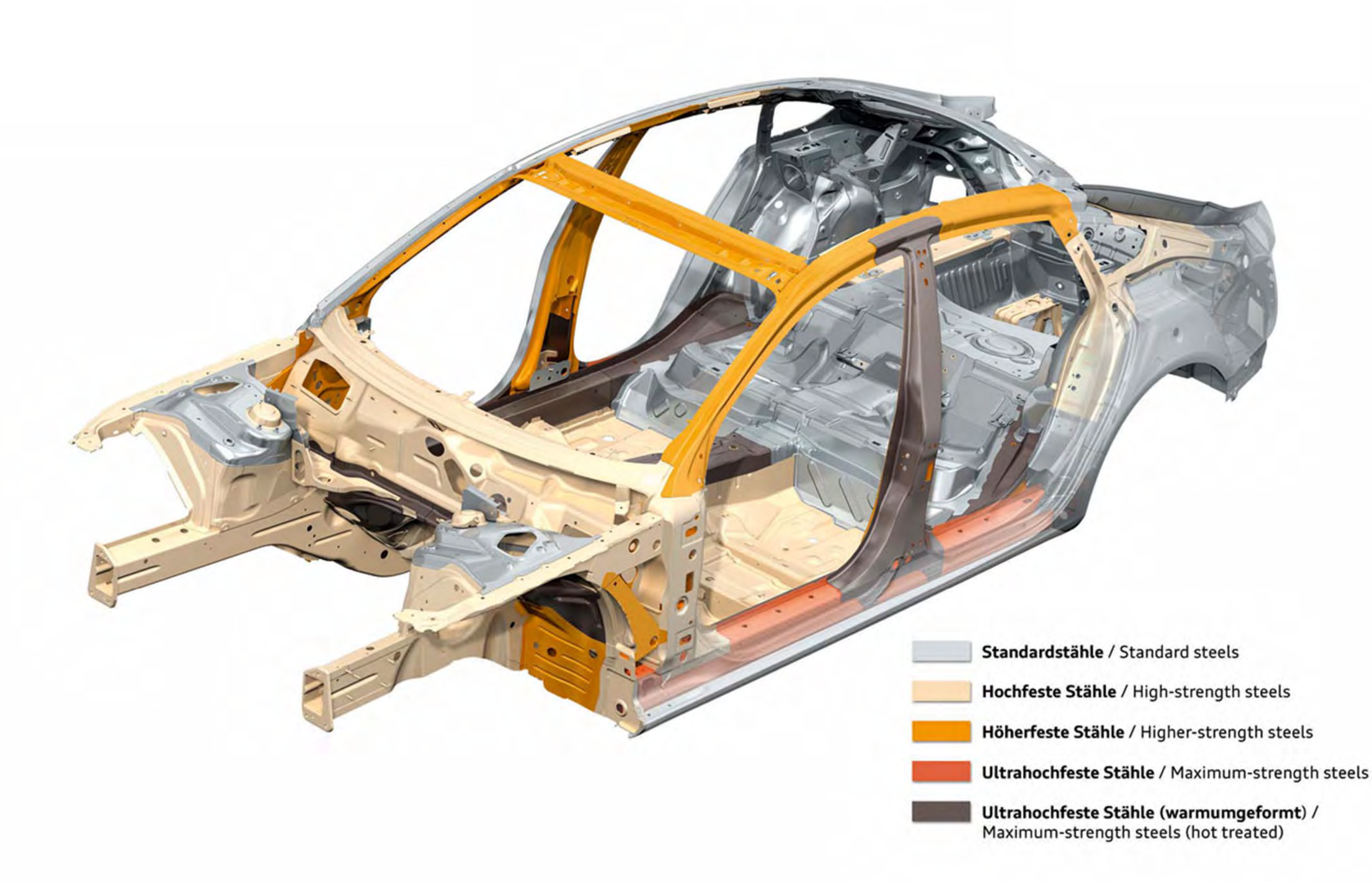
*Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light Duty Vehicle Propulsion

- Boron/Martensite: Martensite is the hardest and strongest form of steel, but it’s also the least formable. It shares properties with boron, which has a tensile strength of around 1,200 to 1,800 MPa. These are usually combined with softer steels to form composites.
- Aluminum 5000/6000 (AL 5000/6000): 5000-series aluminum is alloyed with magnesium. 6000-series aluminum contains both silicon and magnesium which forms magnesium silicide and makes the aluminum alloy heat-treatable.
- Magnesium: Magnesium is an attractive material for automotive use because of its light weight. When alloyed, magnesium has the highest strength-to-weight ratio of all structural metals.
- Carbon Fiber Reinforced Plastic (CFRP): CFRPs are extremely strong, light plastics which contain carbon fibers to increase strength. They are expensive to produce but will have a growing demand in the future automotive industry as costs are reduced.

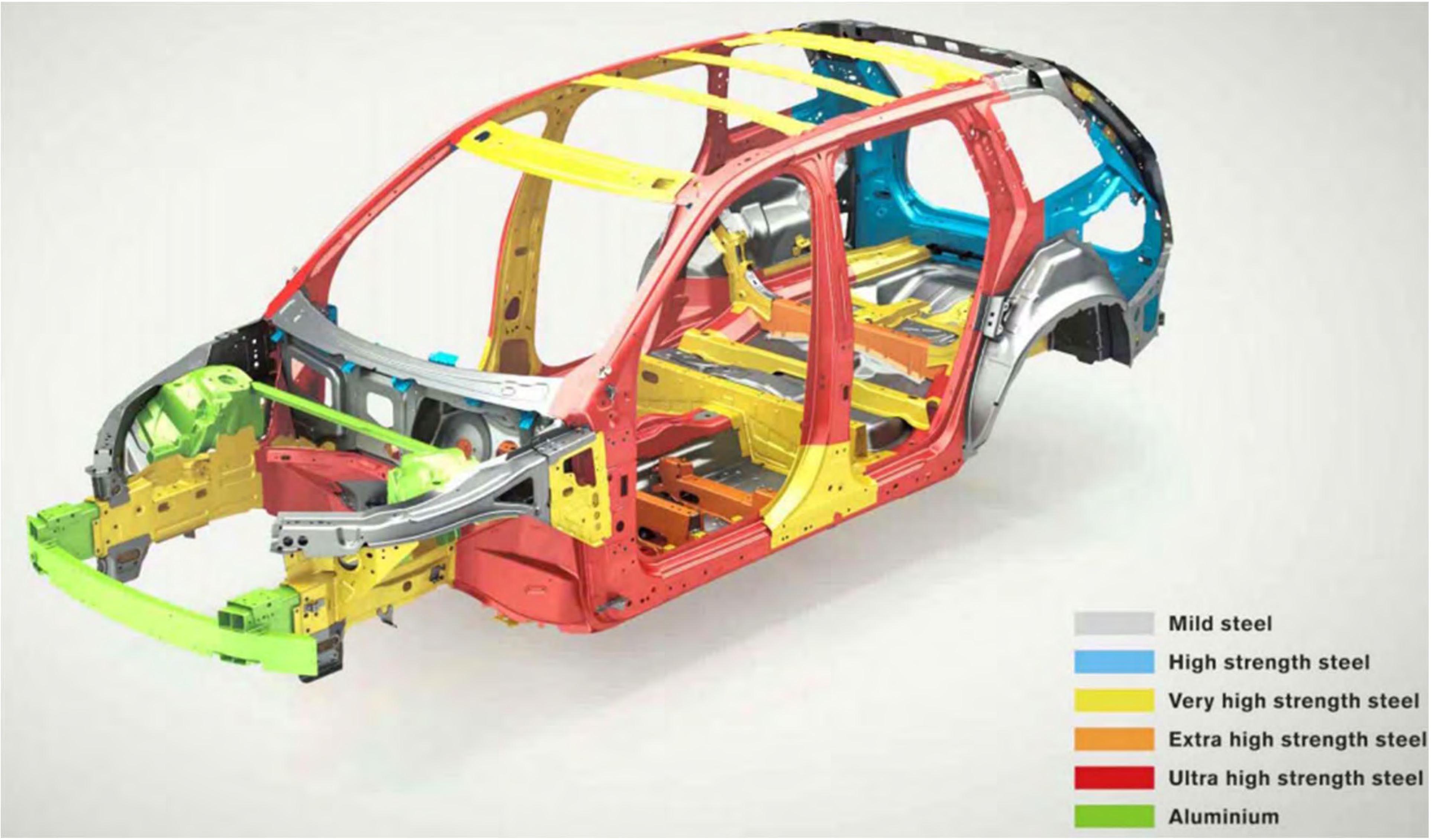
AHSS-UHSS

- Development of AHSS, and more recently dual-phase and ultra-high-strength steels (UHSS), has resulted in steels with very high tensile strengths, rated between 600 and 1100 MPa, due to higher percentages of martensite.
- Compared to conventional steels, AHSS are said to enable lowering a vehicle’s body-in-white structural mass by up to 25%

Audi A5 sportback

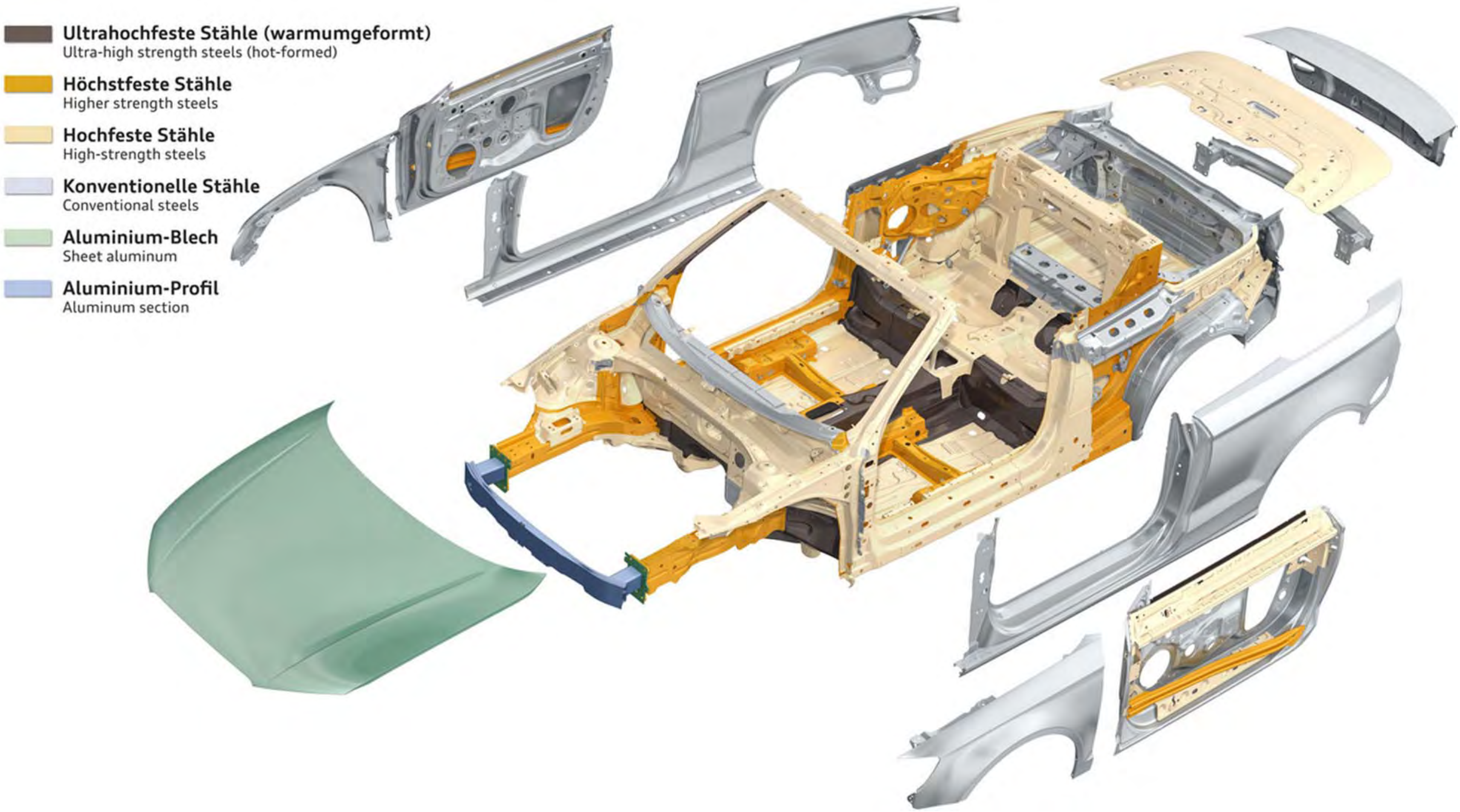


Volvo XC90



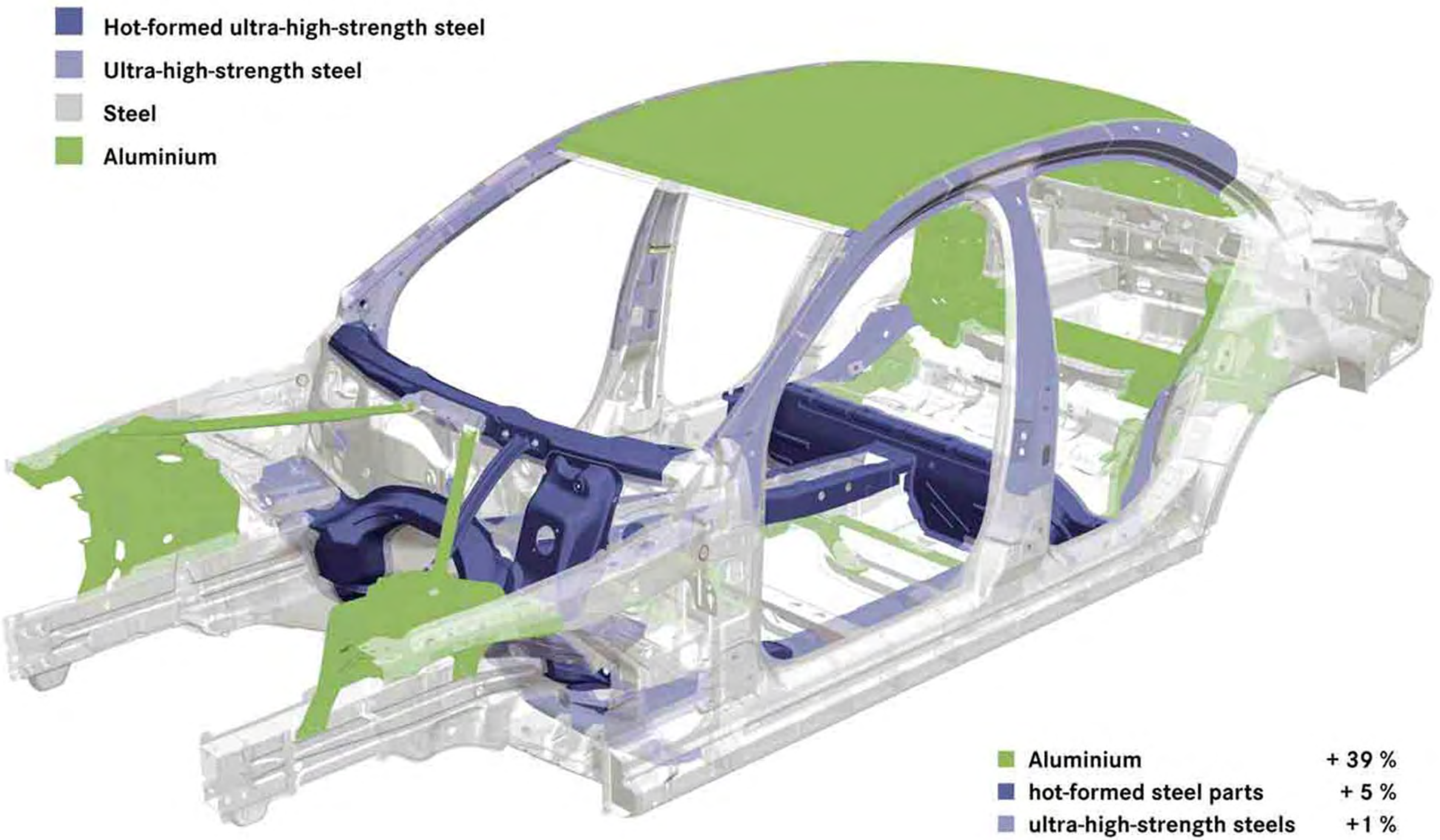
Mild steel
High strength steel
Very high strength steel
Extra high strength steel
Ultra high strength steel
Aluminium

Audi A3



Ultrahochfeste Stähle (warmumgeformt)
Ultra-high strength steels (hot-formed)
Höchstfeste Stähle
Higher strength steels
Hochfeste Stähle
High-strength steels
Konventionelle Stähle
Conventional steels
Aluminium-Blech
Sheet aluminum
Aluminium-Profil
Aluminum section

Mercedes W205



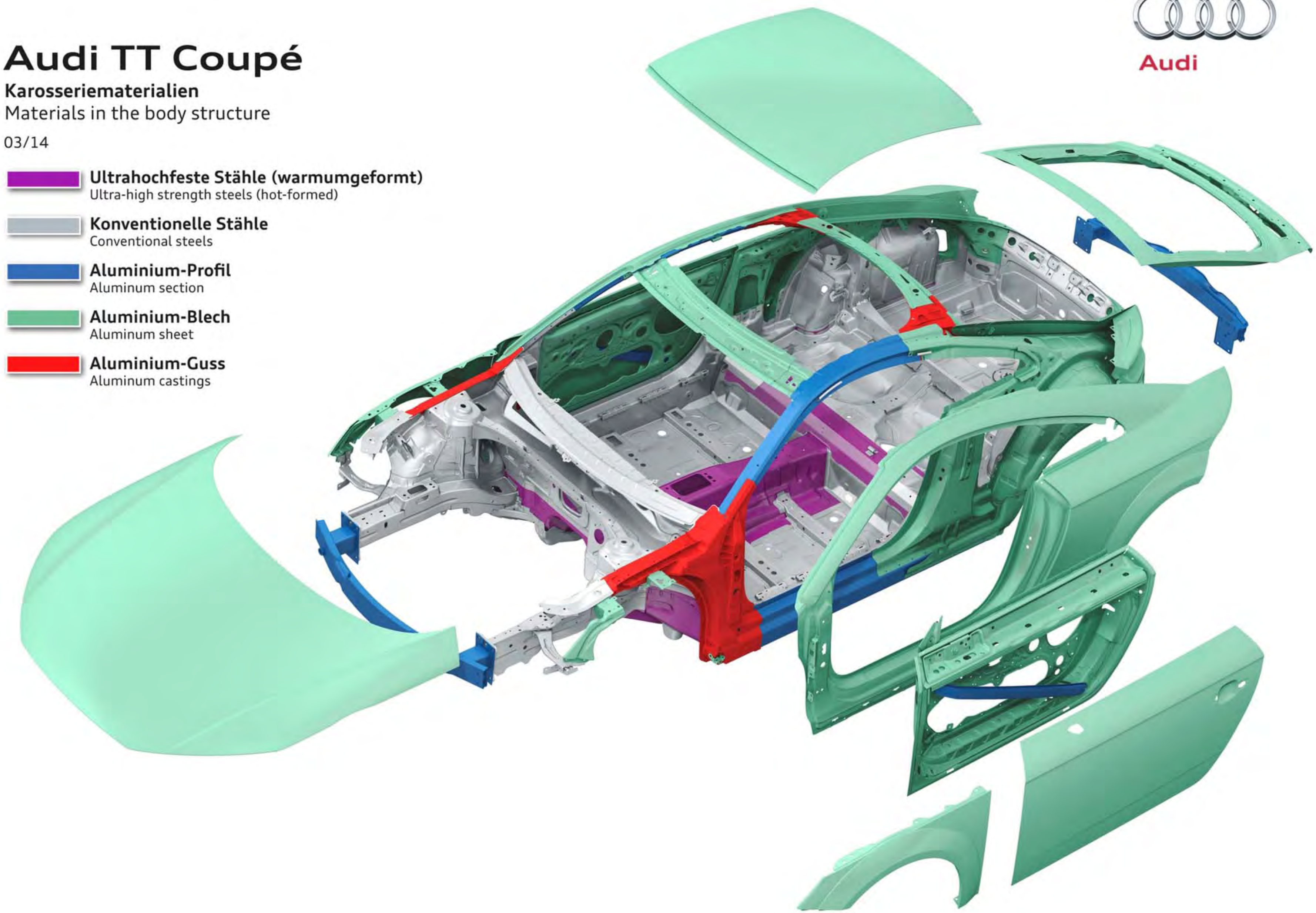
Audi TT Coupé

Karosseriematerialien

Materials in the body structure

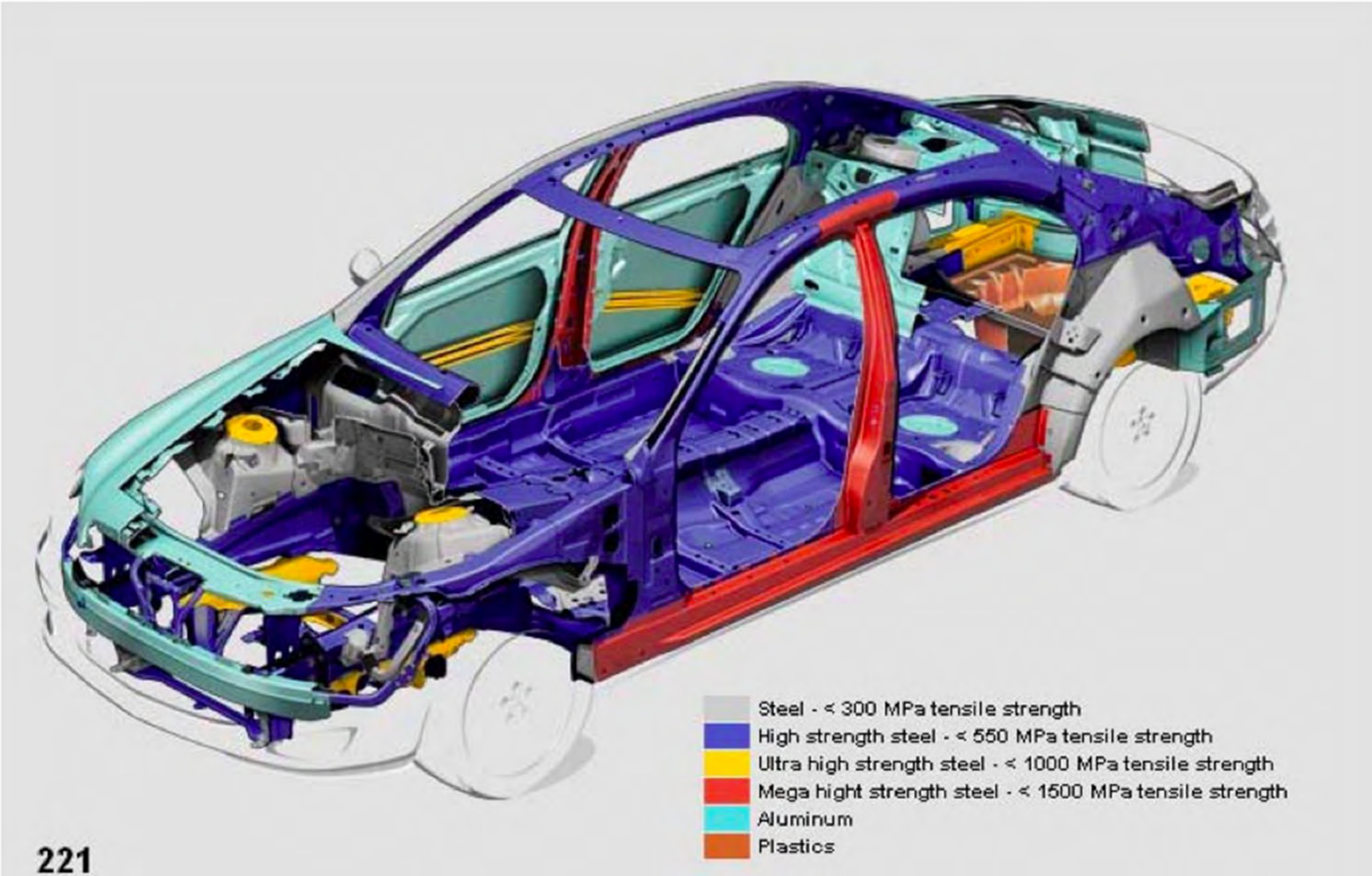
03/14

- **Ultrahochfeste Stähle (warmumgeformt)** Ultra-high strength steels (hot-formed)
- **Konventionelle Stähle** Conventional steels
- **Aluminium-Profil** Aluminum section
- **Aluminium-Blech** Aluminum sheet
- **Aluminium-Guss** Aluminum castings

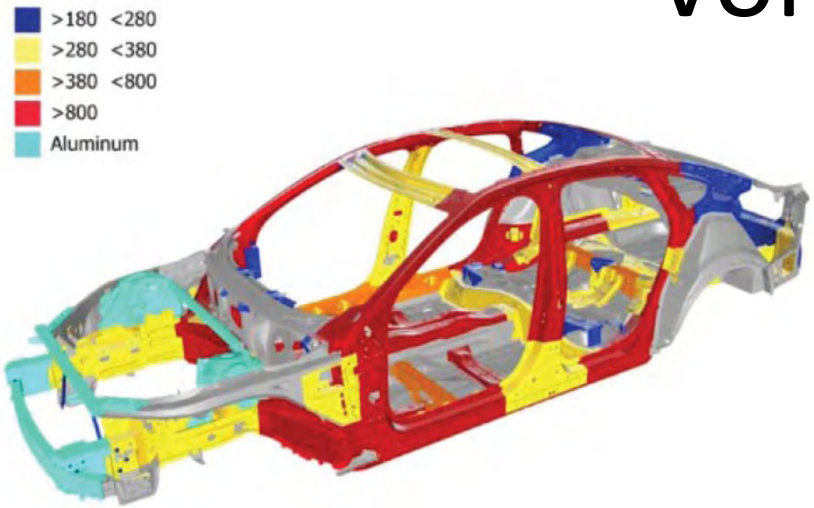


S-Class Sedan (Model 221) – continued

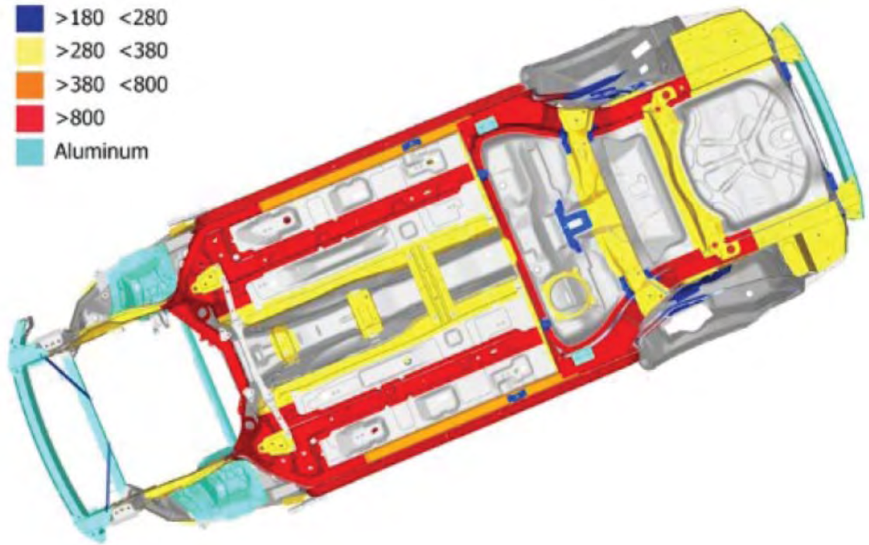
Materials Mix



Volvo S90



>180 <280
>280 <380
>380 <800
>800
Aluminum



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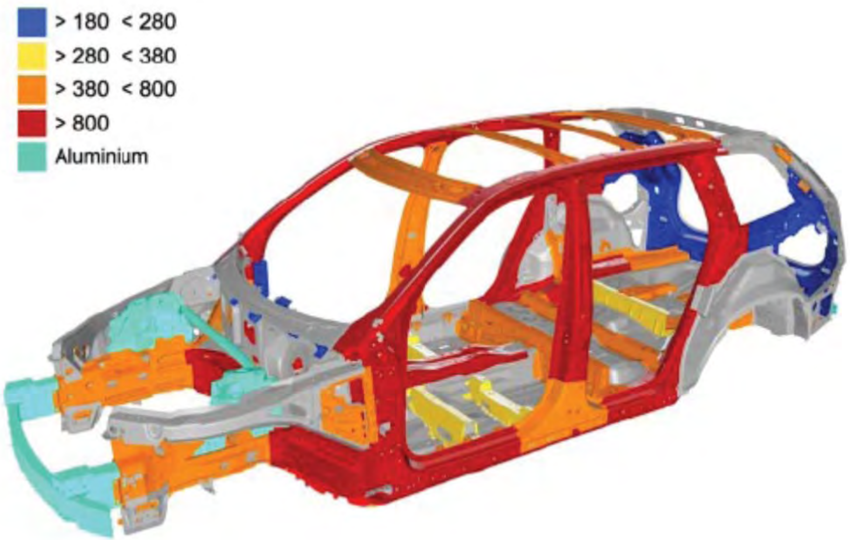
Aluminum



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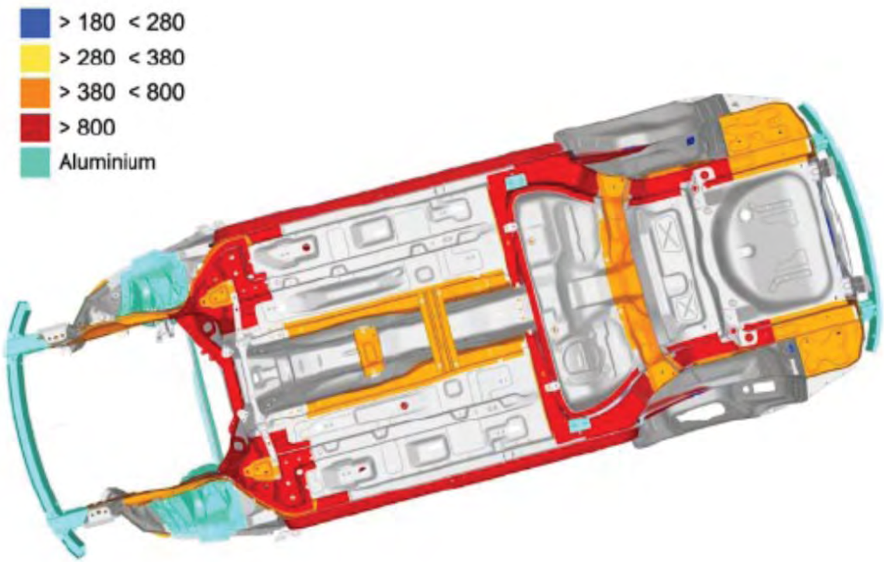
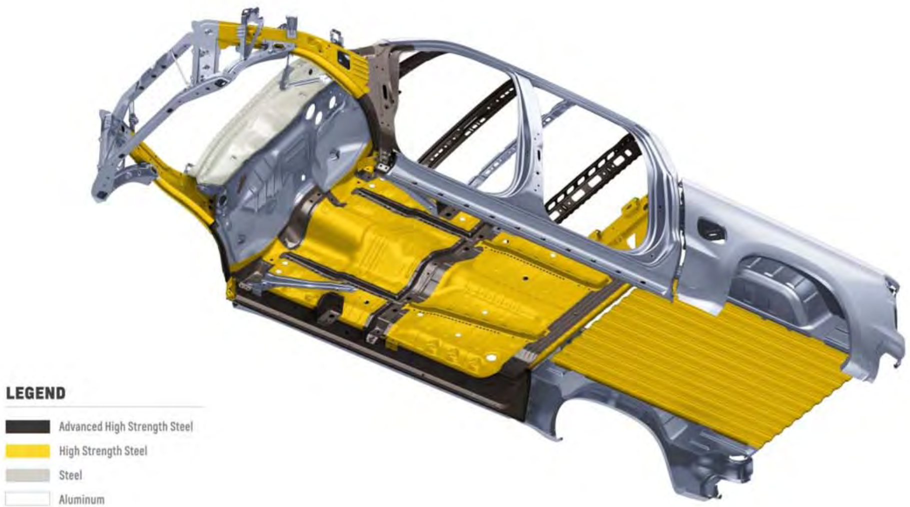
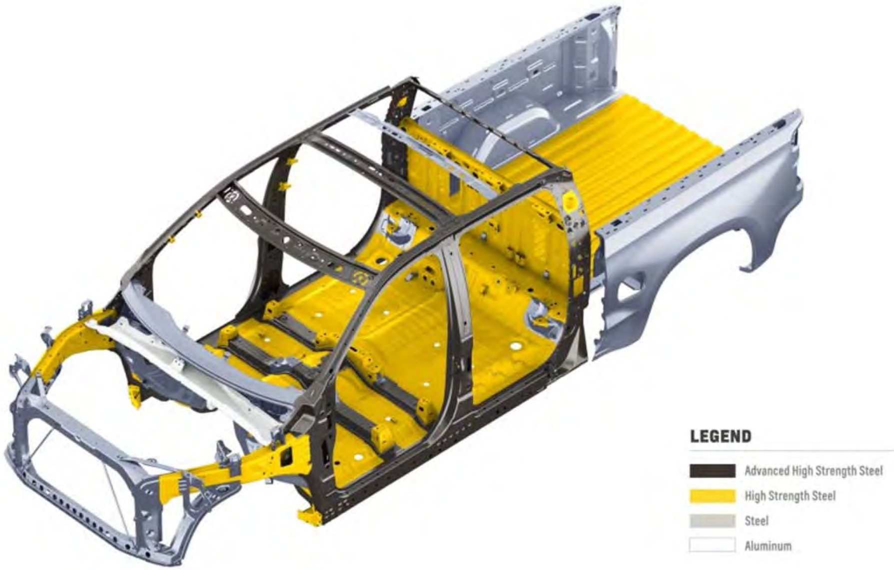
Aluminium

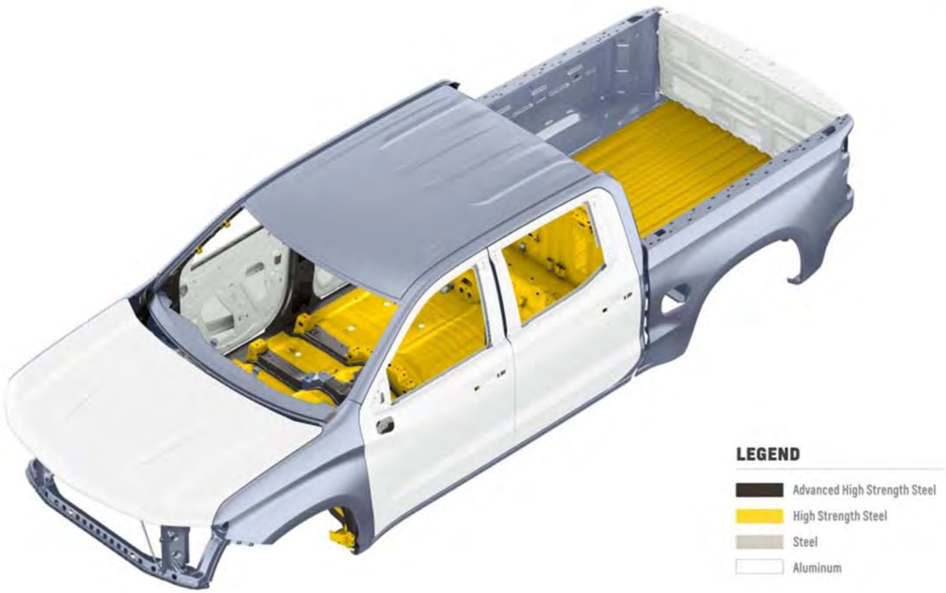


> 180 < 280
> 280 < 380
> 380 < 800
> 800
Aluminium

Chevrolet silverado







LEGEND

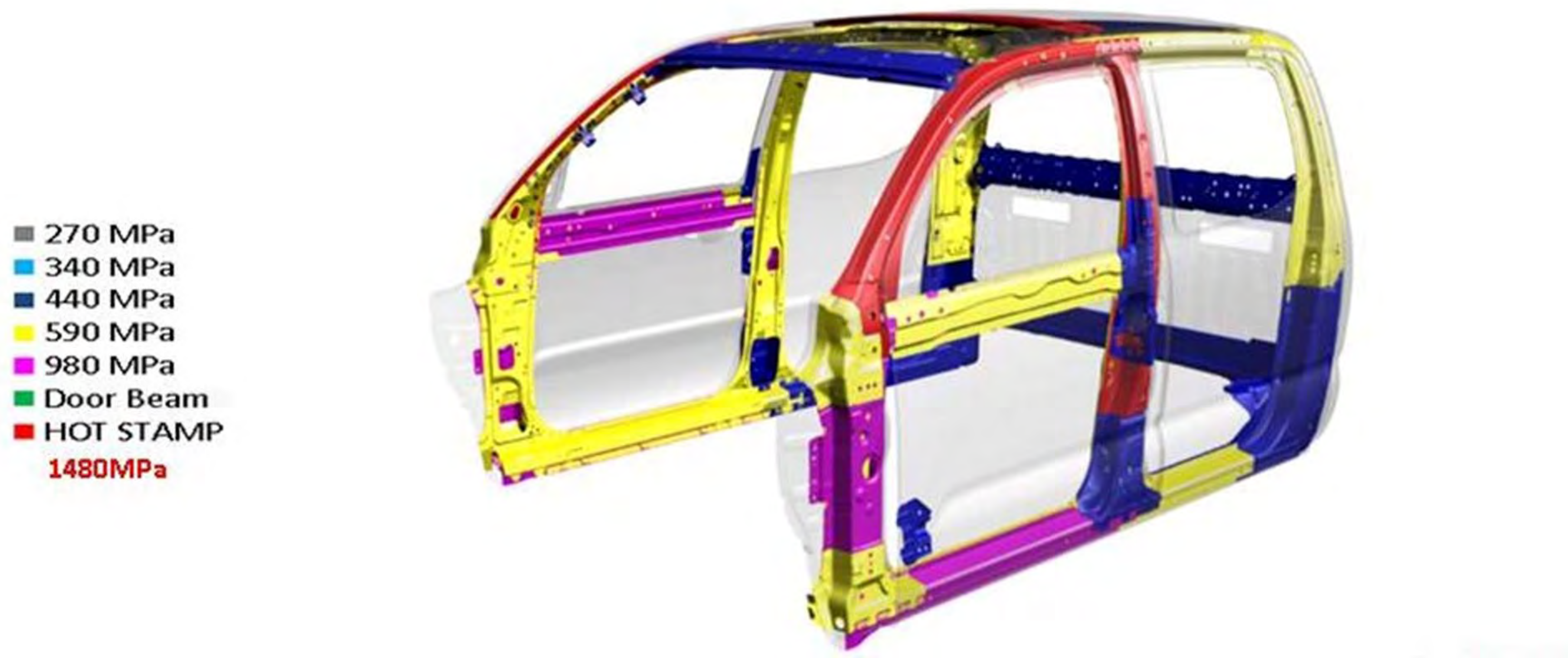
- Advanced High Strength Steel
- High Strength Steel
- Steel
- Aluminum

2015 CHEVROLET COLORADO

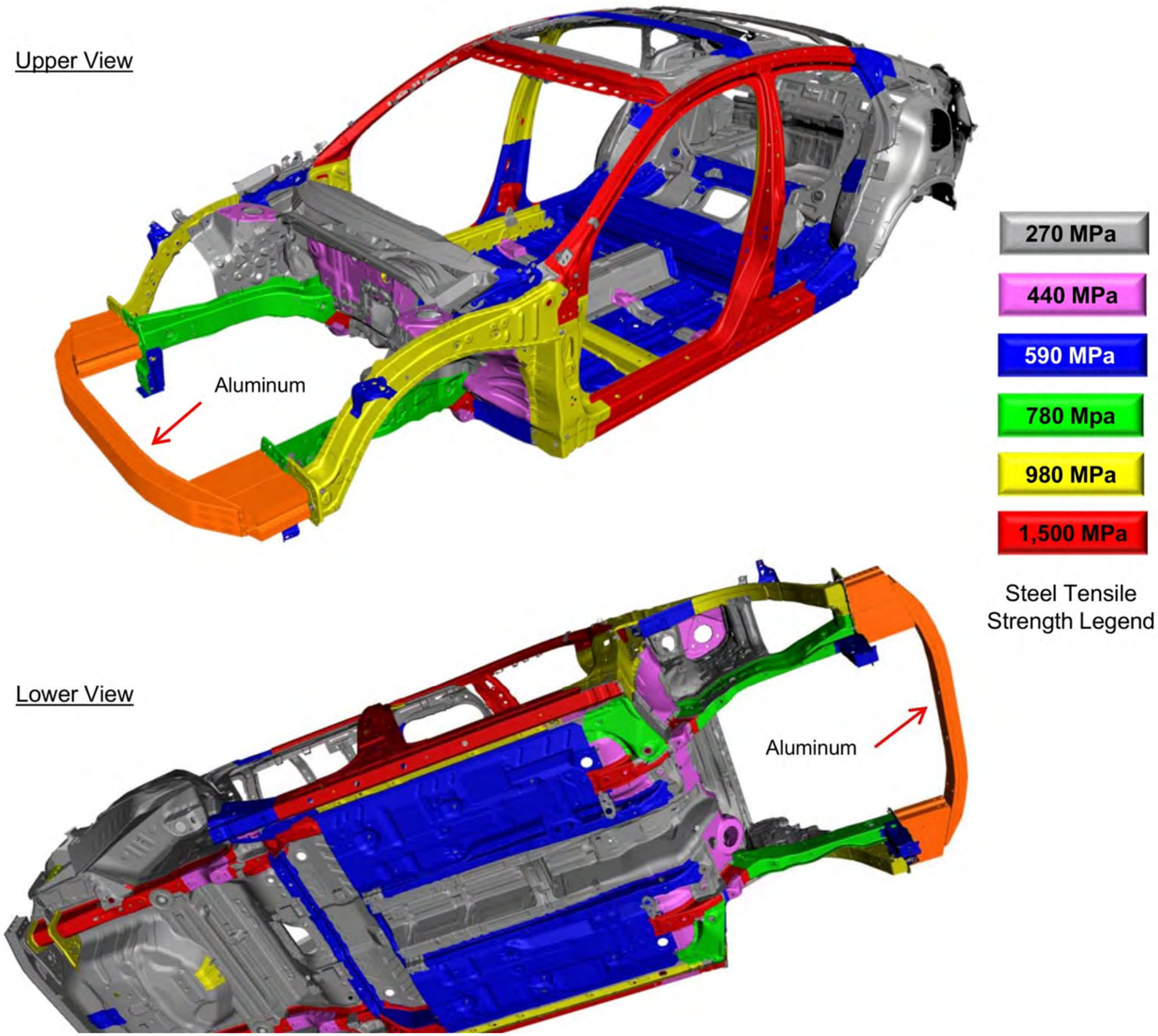
STEEL STRUCTURE

FIND NEW ROADS™

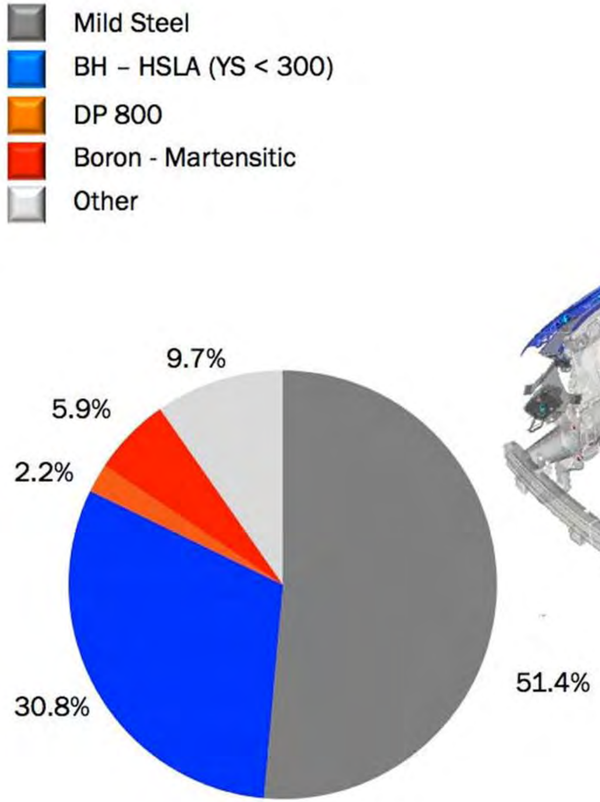
Optimisation



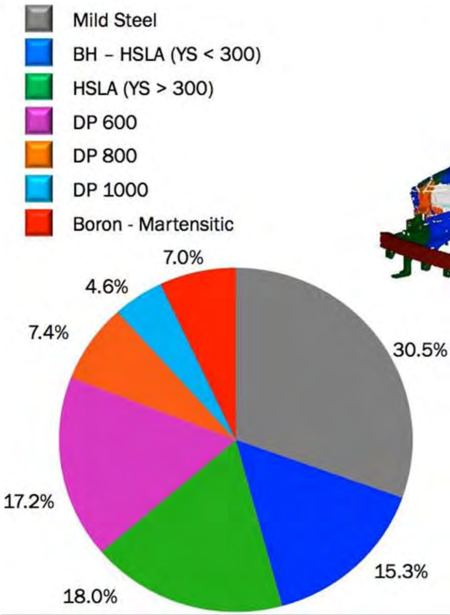
Optimisation

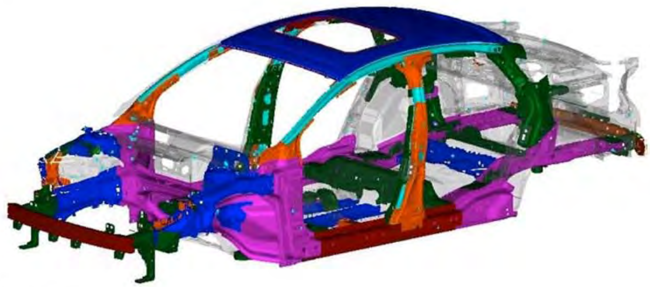


Material - Closures



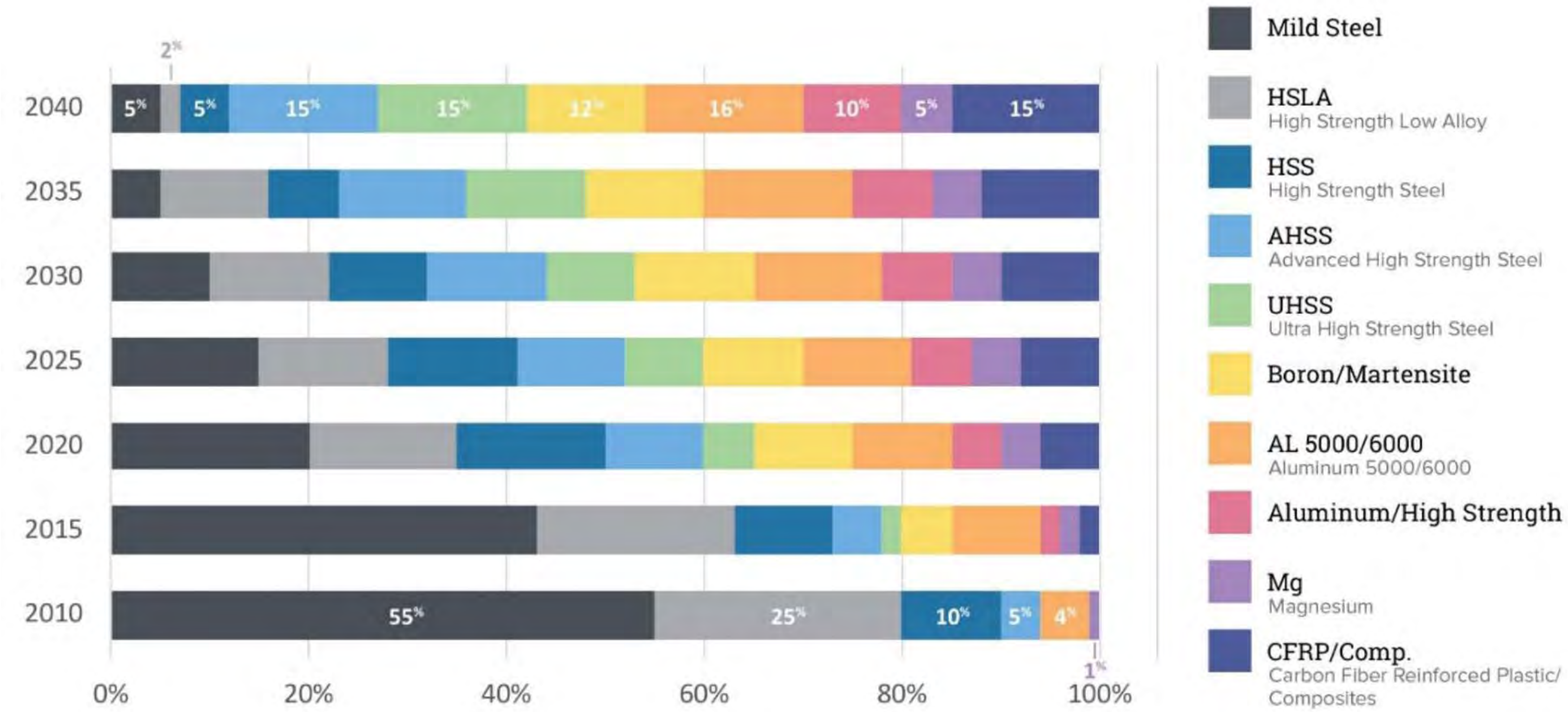
Material - BIW





Average Yield Strength = 348 MPa

Optimisation



The regulatory pressure to reduce carbon emissions and the race to improve performance are drivers for change to the material mix in the vehicles. Automakers are looking for materials with higher strength-to-weight ratio which reduces weight, while improving performance. CAR research indicates the U.S. fleet will achieve a five percent curb weight reduction by 2025 through greater use of aluminum predominantly in the closures and body-structure. Interiors are also a recent focus for lightweighting as it is considered dead weight. Figure shows the change in material mix in the U.S. fleet between 2010-2040. Experts agree that no single material wins in the race to lightweighting. A weight and performance optimized vehicle will have a mixed-material body structure. The industry is already experiencing this shift in recently introduced vehicles which use materials customized for each area of the car to simultaneously advance driving dynamics, fuel economy, and cabin quietness.

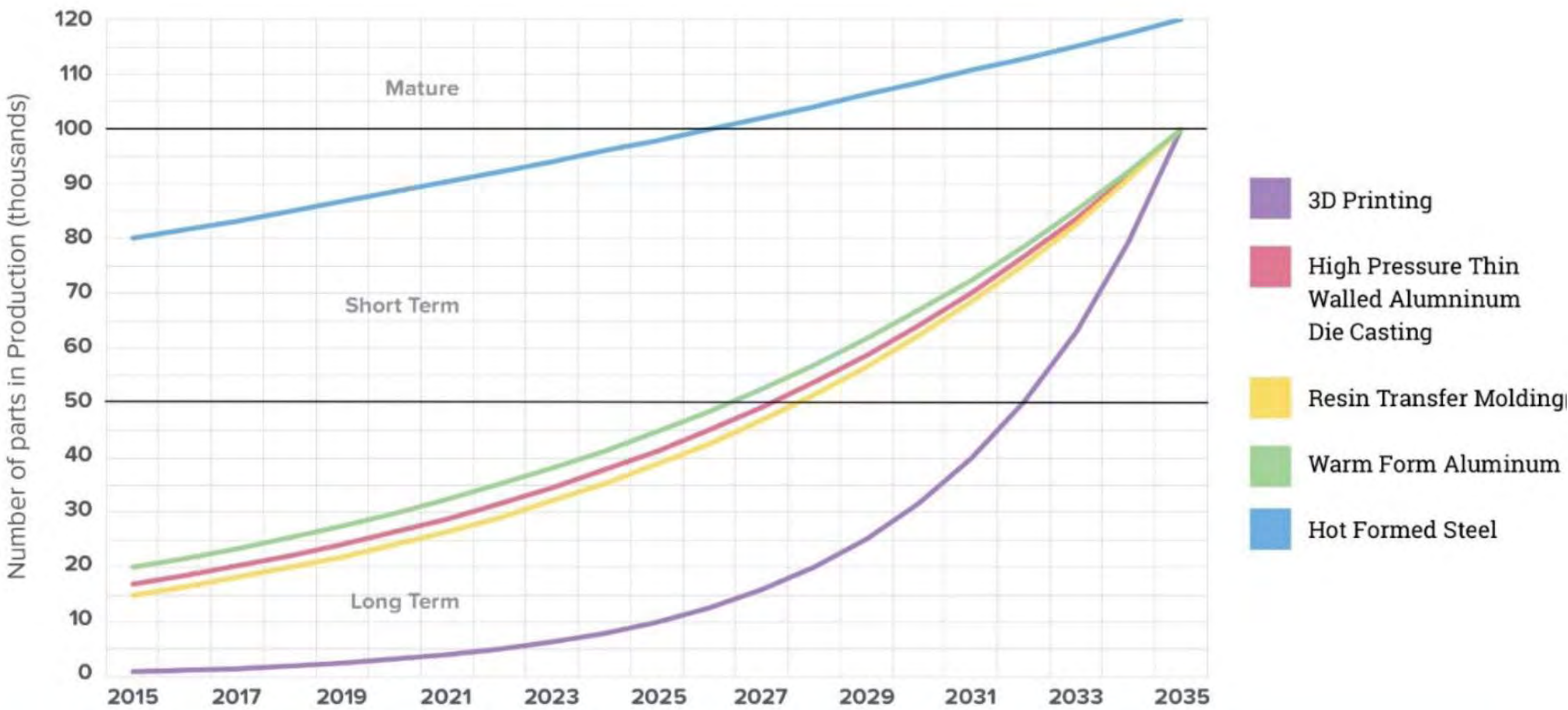
*Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light Duty Vehicle Propulsion

Chassis materials-Production methods

- The predominant manufacturing technology today is cold stamping, but higher strength steels are difficult to cold form. The use of hot stamping is increasing as the heat increases the ductility of the material which helps in forming complex shapes without cracking.

Chassis materials-Production methods

- Hot-shaped steel sheets: tailored blanks of boron alloy steel are heated to 950 degrees Celsius in a continuous furnace and immediately quenched and shaped in a water-cooled die. Hot-shaped steels are used in the side sills, the longitudinal members, the center console, the B-pillars and the front cross members.
- Hot forming has become very important to the automotive industry as a way of meeting specific crash-performance criteria and ensuring low overall weight at an affordable cost. Global automakers use the process to produce structural automotive parts such as: B-pillars; roof frames and bows; bumpers; stiffeners; sills; and cross members.



	3D Printing	High Pressure Thin Walled Aluminum Die Casting	Resin Transfer Molding	Warm Form Aluminum	Hot Formed Steel
Enablers for Growth	Reduce Cycle Time	More R&D Needed	Reduce Cycle Time	More R&D Needed	Increase Equipment Capacity
	Reduce Equipment Cost	Increase Equipment Capacity	Standardization of Operating Barometers	Increase Equipment Capacity	Reduce Cycle Time
			Develop Supply Chain for CFRP		

New manufacturing technologies are also advancing to achieve the speed and cost effectiveness required for mass production. Hot forming of steels is already used in high production parts and will reach maturity by 2025 as the need for ultra-high strength steels increases. Maturity of a technology is a subjective term which depends on the vehicle program. In broad terms, a mature technology can be used in mass-produced vehicles (volume over 100,000 units a year), has multiple product applications, and is available from multiple suppliers with a global supply capability. Additive manufacturing, also called 3D printing, is a revolutionary technology with the potential to change the tool and die business but is not yet suited for mass production in terms of cost or cycle time.

*Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light Duty Vehicle Propulsion

Chassis materials-Production methods

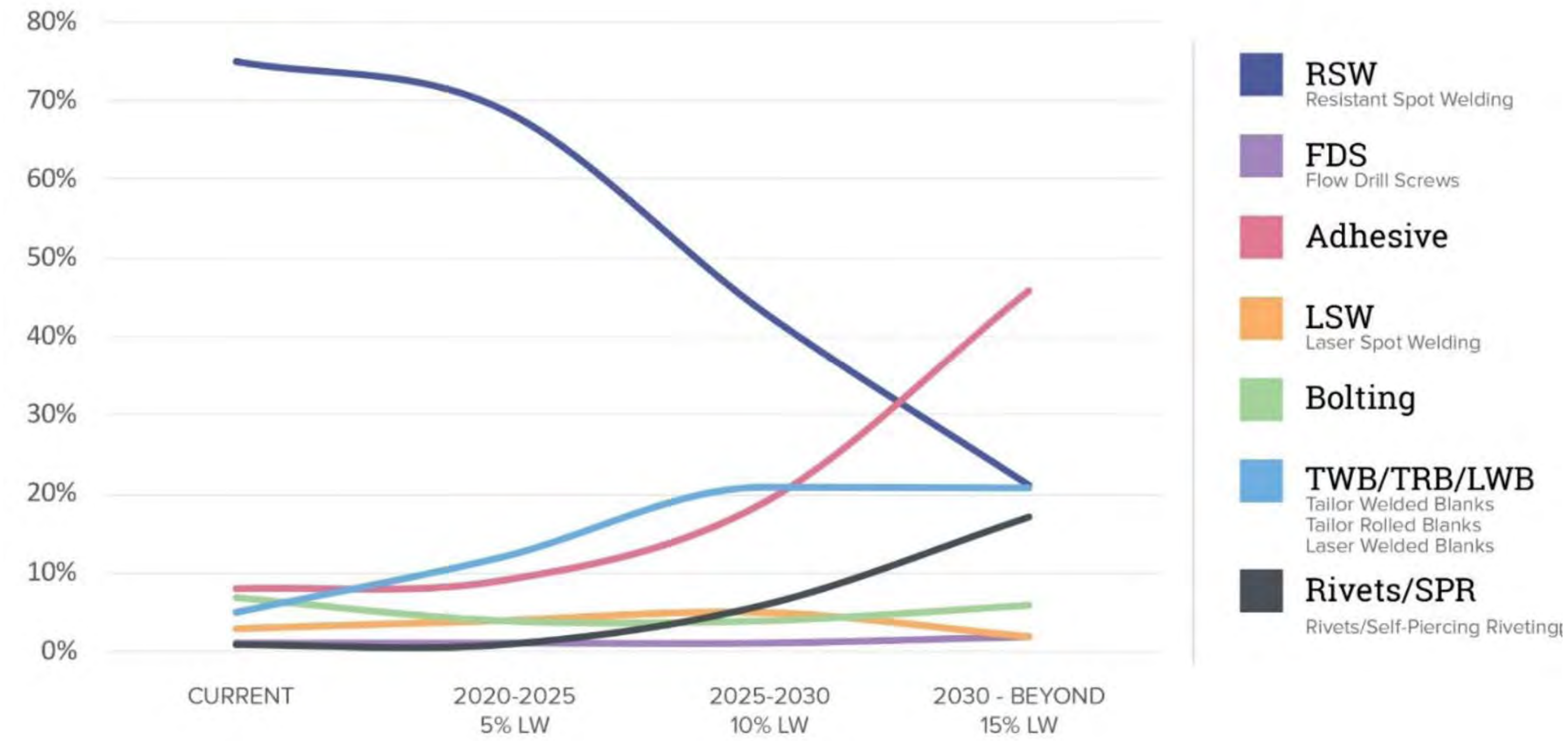
- **Adhesives**: Contains a wide range of glue-type substances that can currently join carpet, windshields, etc. but will soon have additional applications as an increase in plastic parts is expected.
- **Tailor Welded/Rolled Blanks and Laser Welded Blanks (TWB/TRB/LWB)**: Combines several grades, thicknesses, and coatings of steel to place the best material in the best places.
- **Rivets/Self-Piercing Riveting (SPR)**: Uses a high-speed mechanical fastening process for point joining sheet material, typically steels and aluminum alloys.
- **Bolting**: Uses pre-drilled holes to insert a bolt and nut which can be tightened and locked to bring two similar or dissimilar materials together.
- **Laser Spot Welding (LSW)**: Uses advanced laser systems to create a weld spot which fuses metals to a rigid connection.
- **Flow Drill Screws (FDS)**: Uses self-piercing and extruding fastener for joining layers of sheet metal. This combines the properties of friction drilling and thread forming, as the screw acts as both a fastener and a drilling-and-tapping tool.

Cost

MATERIAL NAME	Relative Cost
IF 140/270	1.0
DQSK 210/340	1.104
BH 250/550	1.13
DP 300/500	1.169
HSLA 350/450	1.1948
DP 350/600	1.39
DP 500/800	1.506
Boron 1550	1.805
DP 700/1000	1.584
Mart 1300	1.688

The cost of each part was calculated by multiplying the mass of the part with the normalized cost factor for the material considered.

Chassis materials-Production methods



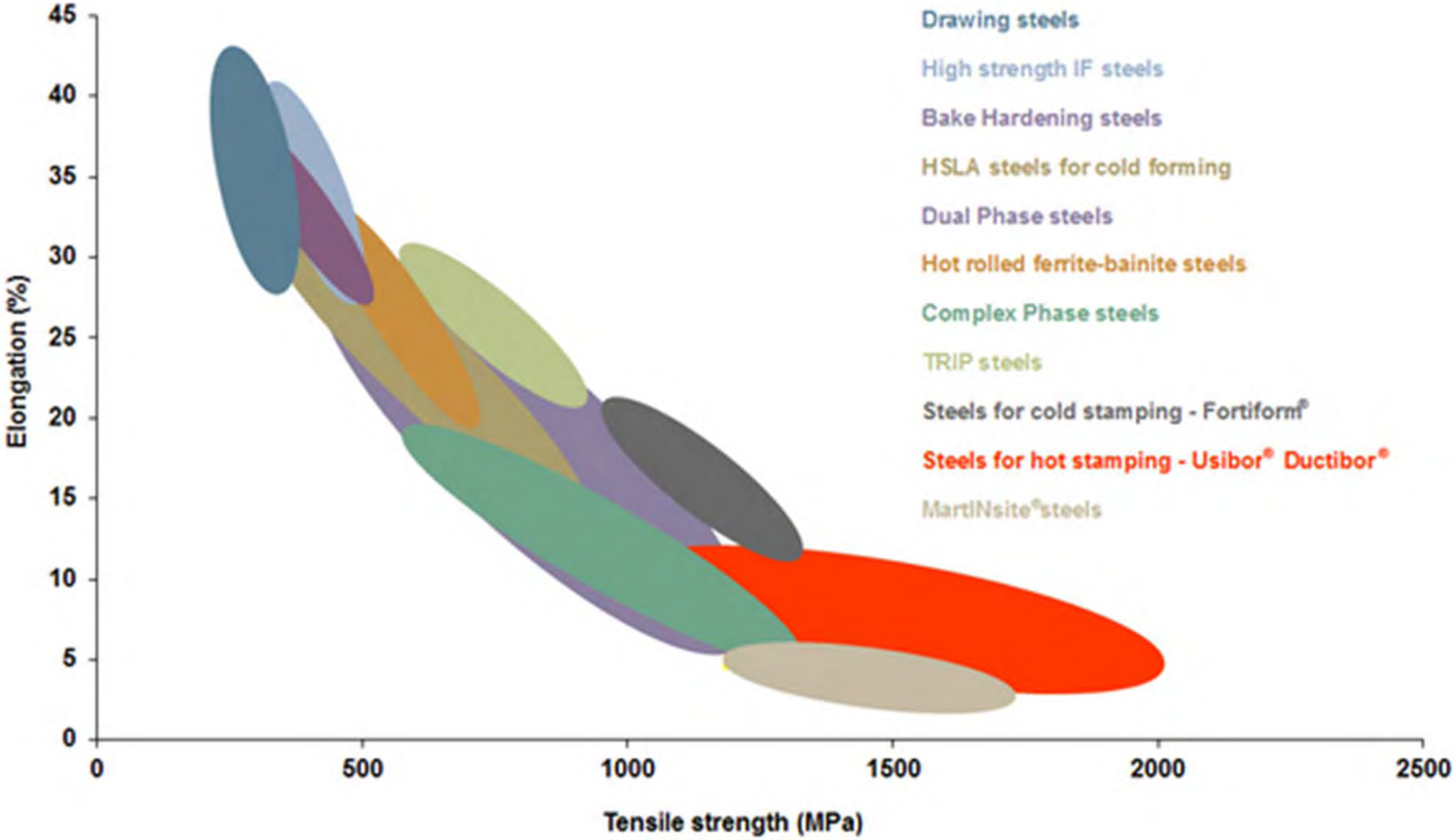
With new materials come new challenges. Joining dissimilar materials is not easy, and is sometimes impossible to do using traditional resistance spot welding due to differences in melting point. Joining technologies–such as adhesives and advanced fasteners–will play an important role in achieving the optimized mixed-material architecture, since they have the ability to join any combination of dissimilar materials

*Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light Duty Vehicle Propulsion

Mixed-Material Joining	Difference in melting point between materials
Corrosion	Relative placement in the galvanic series and exposure to moisture
Thermal Expansion	Differences in coefficient of linear expansion (CLTE) cause materials to expand differently in the paint oven
Cycle Time	Automotive industry needs process cycle times to match line speed which is approximately one unit a minute for mass production
Cost	Cost of newer materials like carbon fiber is very high compared to steels. Carbon fiber for automotive costs $10 to $12 a pound, compared to less than a dollar for steel.
Supply Chain	Automakers are shifting towards global platforms. The availability of material across the world from multiple suppliers is critical.
End-of-life Recycling	Most materials used in automobiles should be easily recyclable for environmental reasons and to meet regulatory requirements
Repair	A hard to repair vehicle will have increased insurance cost and in turn will affect sales
Talent Gap	Engineers and plant workers need to be retrained to work with new materials and processes

Working with multiple materials in a manufacturing environment is not an easy task. Apart from joining, galvanic corrosion and thermal management are two major issues engineers face while designing vehicles with mixed-material body structures. While engineers worry more about the technical challenges, purchasing and manufacturing executives are more concerned about the cost of new materials and potential supply-chain risks. Newer manufacturing technologies such as additive manufacturing, resin transfer molding, thin walled die casting, etc. are not yet mature processes. These technologies have longer cycle times, as well as quality issues that need to be resolved for use in mass production across-the-board. Upper scheme lists major challenges the auto-industry is facing with new materials and mixed-material assemblies.

*Technology Roadmaps: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light Duty Vehicle Propulsion



Drawing steels
High strength IF steels
Bake Hardening steels
HSLA steels for cold forming
Dual Phase steels
Hot rolled ferrite-bainite steels
Complex Phase steels
TRIP steels
Steels for cold stamping - Fortiform®
Steels for hot stamping - Usibor® Ductibor®
MartINsite® steels
Elongation (%)
Tensile strength (MPa)
0
5
10
15
20
25
30
35
40
45
500
1000
1500
2000
2500

Family	Offering	Metallurgy	Strength/ductility combination (Indicative, all grades)
Steels for drawing	Cold rolled, Hot rolled	Aluminum killed ferritic steels Interstitial free ferritic steels	UTS ~270-340 MPa e_f% ~28-42%
Isotropic steels	Cold rolled	Aluminum killed ferritic steels with controlled equiaxed structure	UTS ~300-400 MPa e_f% ~32-35%
Re-phosphorized high-strength steels	Cold rolled	Aluminum killed ferritic steels with hardening by substitution elements: Mn, Si, P	UTS ~340-460 MPa e_f% ~26-40%
High-Strength IF steels	Cold rolled	IF ferritic steels with hardening by substitution elements: Mn, Si, P	UTS ~340-460 MPa e_f% ~28-40%
Bake hardening steels	Cold rolled	Aluminum killed ferritic steels or Ultra Low C steels with controlled interstitial C and N after annealing	UTS ~300-480 MPa e_f% ~28-38%
High strength low alloy (HSLA) steels	Cold rolled, Hot rolled	Ferritic steels with hardening by fine distributed Ti or Nb carbonitride precipitation	UTS ~330-590 (cold rolled) e_f% ~21-33% (cold rolled) UTS ~370-900 (hot rolled) e_f% ~14-30% (hot rolled)
Dual Phase Steels	Cold rolled, Hot rolled	Ferrite + martensite steels	UTS-450-1200 MPa e_f% ~6-30%
Ferrite-bainite steels	Hot rolled	Ferrite + bainite steels	UTS-450-670 MPa e_f% ~20-33%
Complex Phase steels	Hot rolled	Ferrite (or hardened ferrite), bainite, martensite steels	UTS-600-1300 MPa e_f% ~5-19%
TRIP steels	Cold rolled, Hot rolled	Ferrite, bainite, residual austenite (progressive transformation of austenite to martensite during cold forming) steels	UTS-590-900 MPa e_f% ~21-30%
Steels for hot stamping	Cold rolled, Hot rolled	Boron steels for hardening, martensite after quenching	UTS > 1500 MPa e_f% > 5% (after drawing and quenching)

Cold rolled   Hot rolled

Chassis materials-Aluminum

Aluminum automotive components can be found nearly everywhere in cars and trucks today. Lighter than steel, aluminum is very ductile, highly recyclable, and can easily be formed into parts, including those used for powertrain applications such as engine blocks and heads. The material makes dramatic reductions in motor-vehicle weight possible.

A growth market today, aluminum has been a key material for automakers since the beginning. The first sports car featuring an aluminum body was unveiled at the Berlin International Motor Show in 1899. Two years later, the first engine with aluminum parts was developed by Carl Benz. Following World War II, aluminum had become inexpensive enough to be considered for use in mass-produced vehicles. A breakthrough occurred in 1961, when the British Land Rover company produced V-8 engine blocks made with aluminum cylinders. From there, aluminum automobile parts gained a foothold in wheels and transmission casings and then moved into cylinder heads and suspension joints. This infinitely recyclable metal is now the leading material for use in powertrain and wheel applications and continues to gain market share in hoods, trunks, doors and bumpers—and complete vehicle structures.

One of the main advantages of aluminum is its availability in a large variety of semi-finished forms, such as shape castings, extrusions and sheet, all suitable for mass production and innovative solutions.

Aluminium is in fierce competitive with other materials, like novel steels recently developed, claiming back the light weight potential by higher strength alloys suitable for reducing wall thickness. Other competitor materials are magnesium, titanium and glass or carbon fibre reinforced plastics. The latter has developed further in the aerospace industries, now heavy R&D efforts are made suitable for mass production also for cars, especially innovative electro cars. Innovative car concepts have adopted the multi-material design idea to use for each function the “best” material available.

Jürgen HIRSCH, Recent development in aluminium for automotive applications, Trans. Nonferrous Met. Soc. China 24(2014)

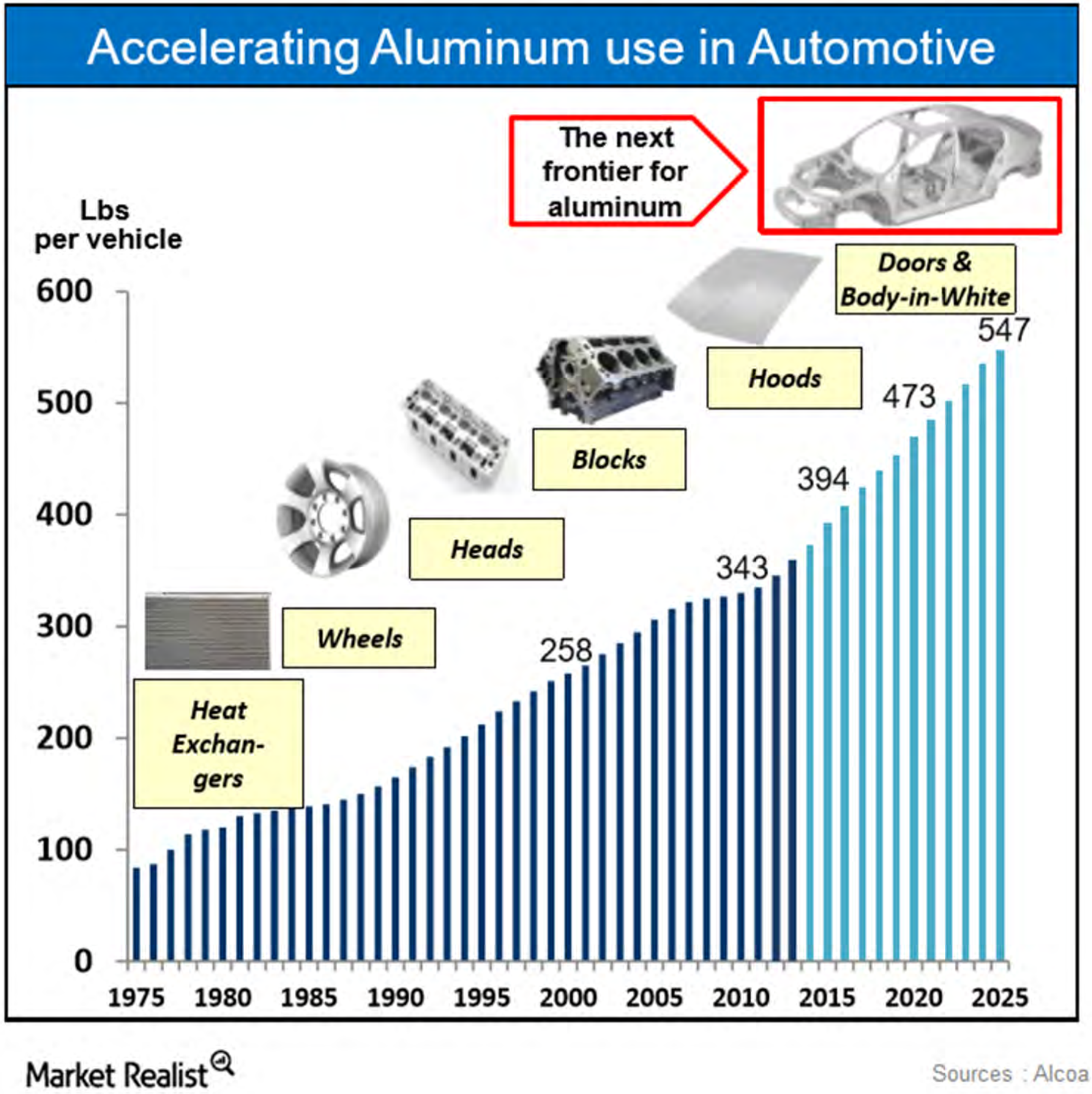
Al Alloys

	Formability or Workability	Weldability	Machining	Corrosion Resistance	Heat Treating	Strength	Typical Applications
Alloy 1100	Excellent	Excellent	Good	Excellent	No	Low	Metal Spinning
Alloy 2011	Good	Poor	Excellent	Poor	Yes	High	General Machining
Alloy 2024	Good	Poor	Fair	Poor	Yes	High	Aerospace Application
Alloy 3003	Excellent	Excellent	Good	Good	No	Medium	Chemical Equipment
Alloy 5052	Good	Good	Fair	Excellent	No	Medium	Marine Applications
Alloy 6061	Good	Good	Good	Excellent	Yes	Medium	Structural Applications
Alloy 6063	Good	Good	Fair	Good	Yes	Medium	Architectural Applications
Alloy 7075	Poor	Poor	Fair	Average	Yes	High	Aerospace Applications

Al Alloys

Aluminum Association series	Type of alloy composition	Strengthening method	Tensile strength range MPa	ksi
1*xxx*	Al	Cold work	70–175	10–25
2*xxx*	Al-Cu-Mg (1–2.5% Cu)	Heat treat	170–310	25–45
2*xxx*	Al-Cu-Mg-Si (3–6% Cu)	Heat treat	380–520	55–75
3*xxx*	Al-Mn-Mg	Cold work	140–280	20–40
4*xxx*	Al-Si	Cold work (some heat treat)	105–350	15–50
5*xxx*	Al-Mg (1–2.5% Mg)	Cold work	140–280	20–40
5*xxx*	Al-Mg-Mn (3–6% Mg)	Cold work	280–380	40–55
6*xxx*	Al-Mg-Si	Heat treat	150–380	22–55
7*xxx*	Al-Zn-Mg	Heat treat	380–520	55–75
7*xxx*	Al-Zn-Mg-Cu	Heat treat	520–620	75–90
8*xxx*	Al-Li-Cu-Mg	Heat treat	280–560	40–80

Alloying: Understanding the Basics J.R. Davis, p351-416 Aluminum and Aluminum Alloys

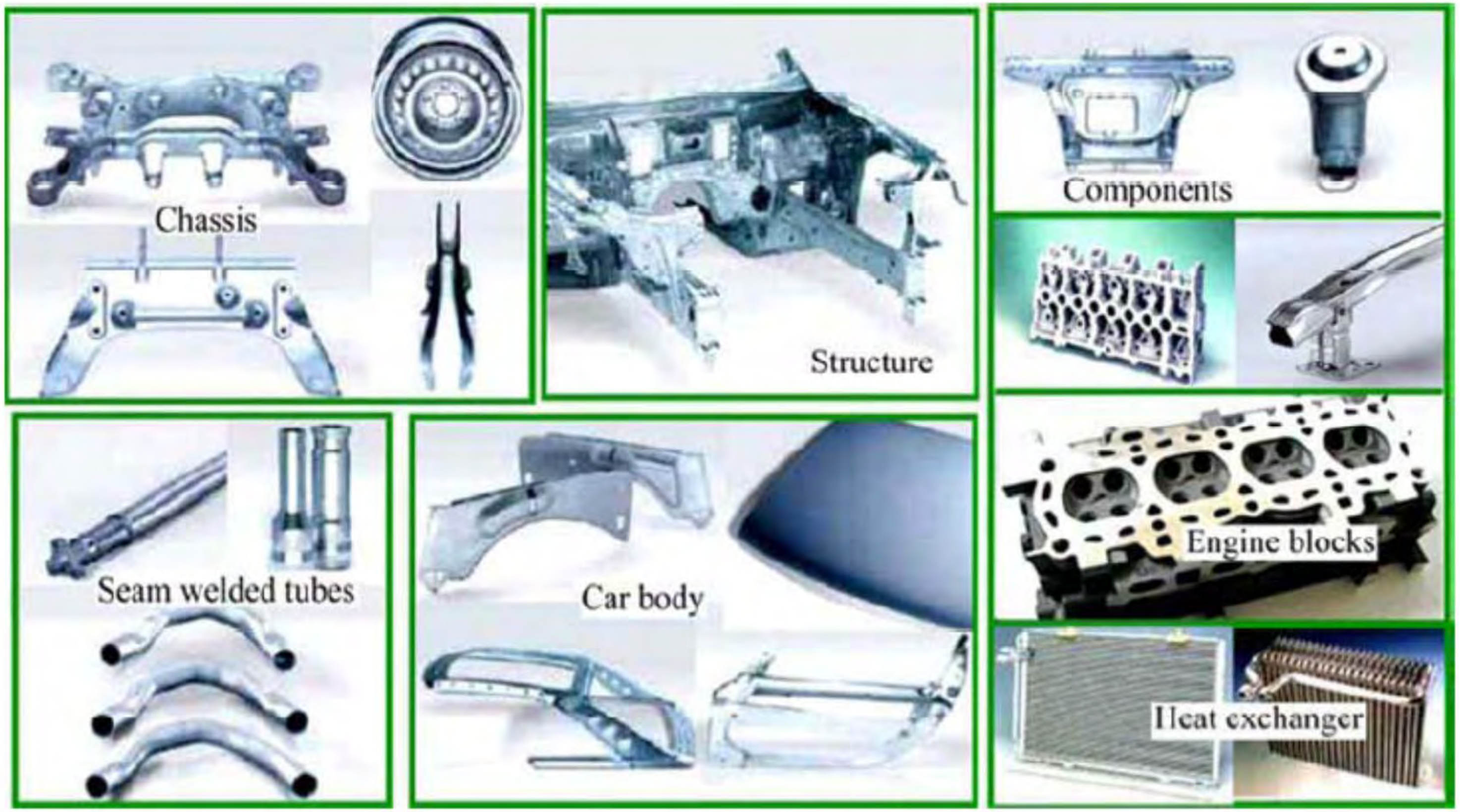


Producing lighter automobiles, improving fuel efficiency, and improving vehicle performance have been some of the automobile industry's top challenges. The industry has done its research on material alternatives to steel such as carbon fiber and aluminum alloys.

Aluminum alloys designed for automobiles weigh half as much as traditional mild steel and absorb twice as much energy during accidents. This makes automobiles stronger, lighter, safer, and more fuel efficient.

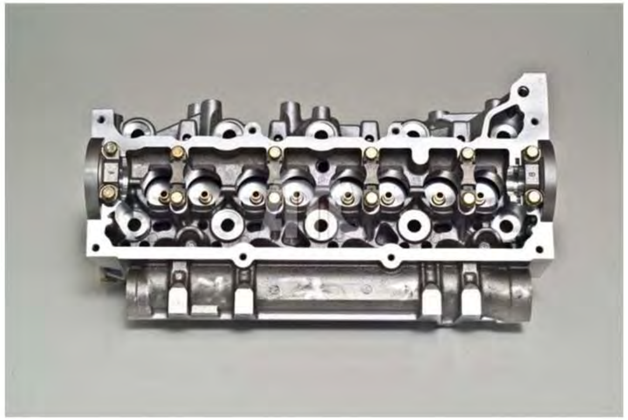
Video

Al Alloys

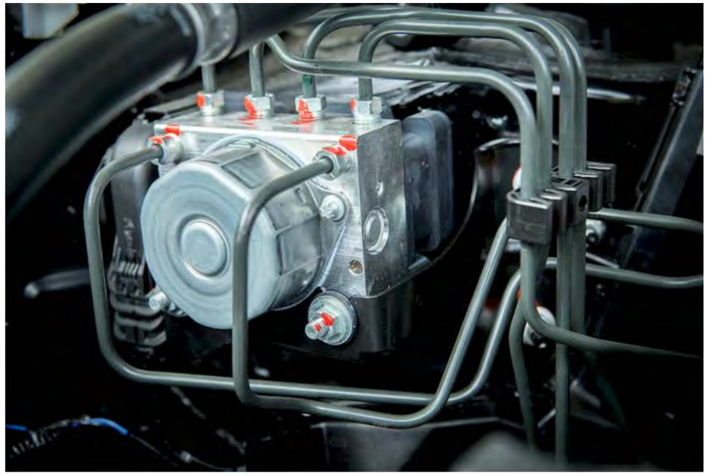


ninium products for advanced automotive applications (Hydro)

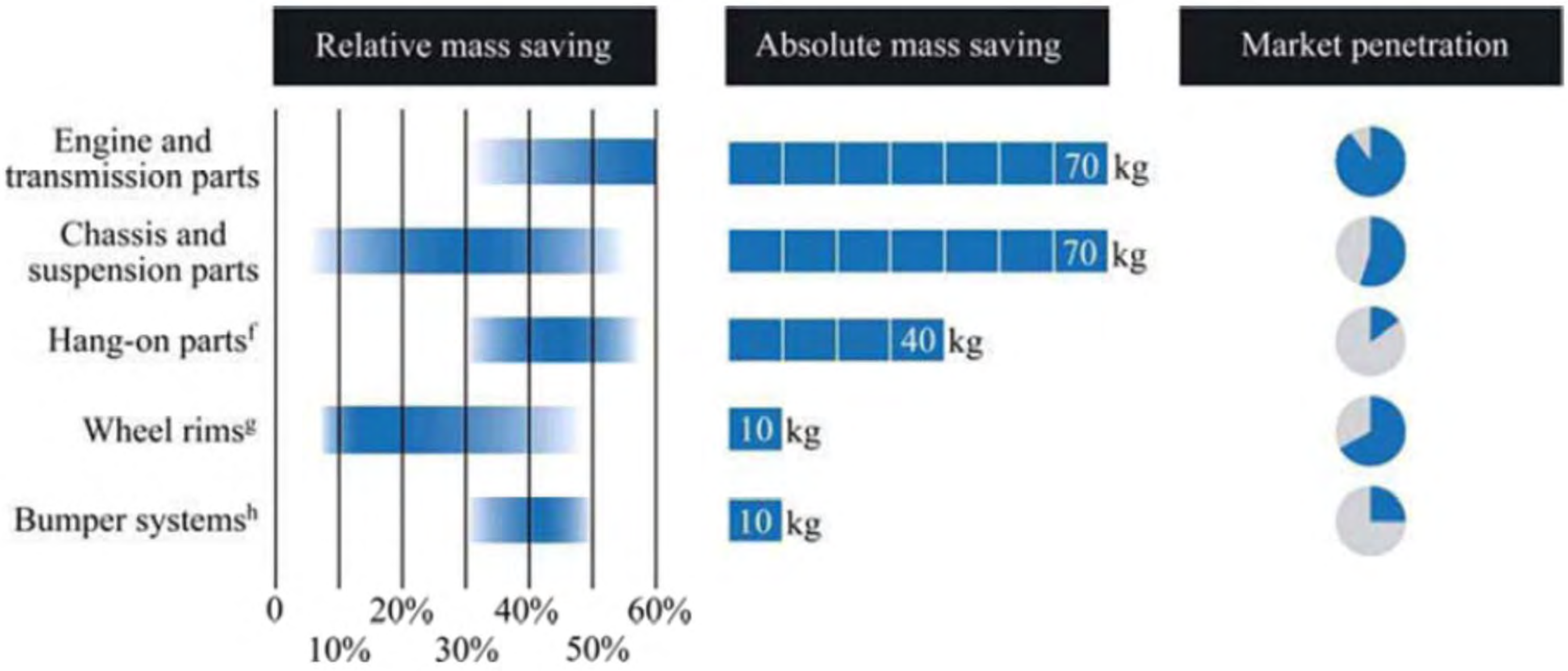
Al Alloys



Al Alloys



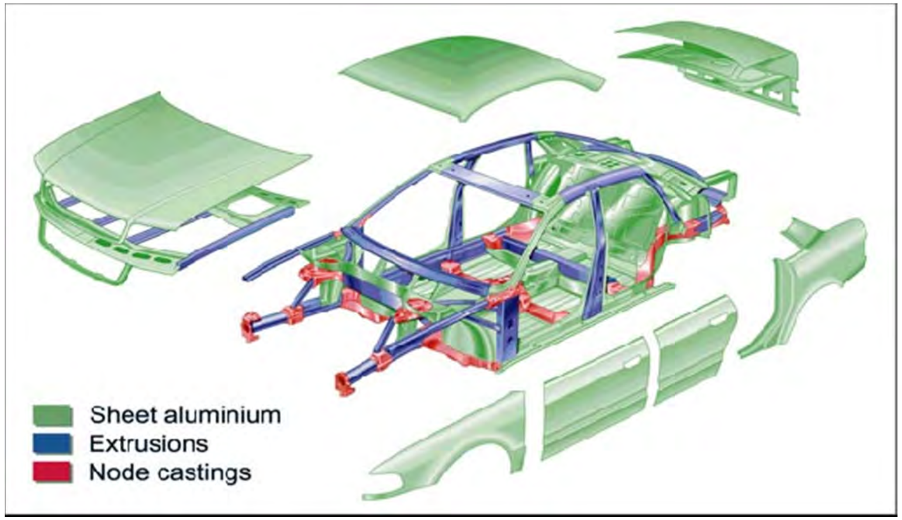
Al Alloys

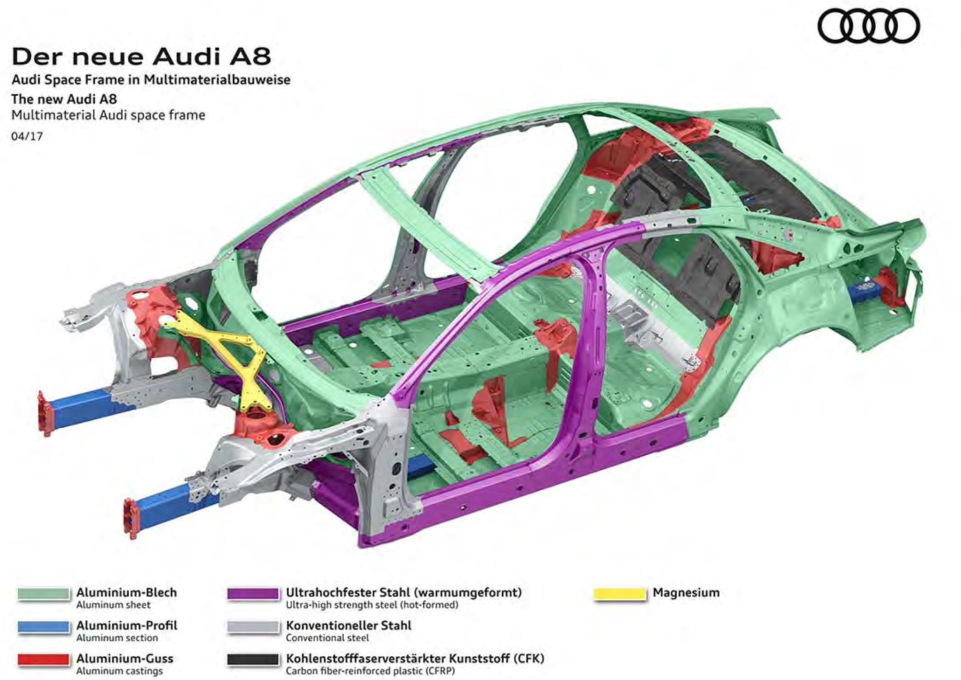


Relative mass saving
Absolute mass saving
Market penetration
Engine and transmission parts
Chassis and suspension parts
Hang-on parts[f]
Wheel rims[g]
Bumper systems[h]
70 kg
70 kg
40 kg
10 kg
10 kg
0
10%
20%
30%
40%
50%
60%

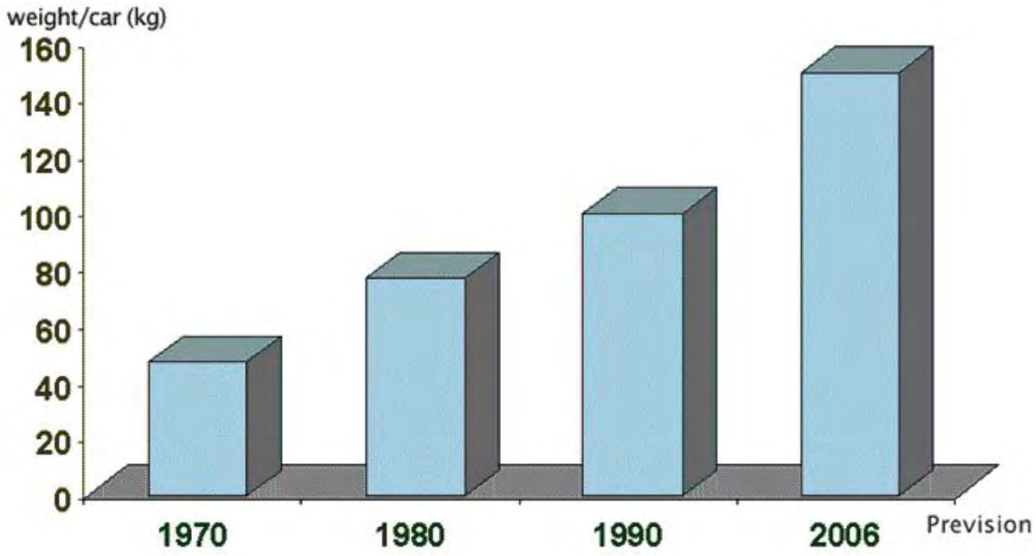
Aluminum BIW

The AUDI A8 is a classical example with a scheduled volume of 25000 cars/year, a BIW mass of 277 kg; consisting of 59 extrusions (61 kg), 31 castings (39 kg) and 170 sheet parts (177 kg). Riveting, MIG-, laser-, and hybrid welds, roll-folding and adhesive bonding are the main joining methods applied here.





Plastics



Originally plastics were specified because they offered good mechanical properties combined with excellent appearance. The application of plastic components in the automotive industry has been increasing over the last decades. Nowadays, the **plastics are used mainly to make cars more energy efficient by reducing weight, together with providing durability, corrosion resistance, toughness, design flexibility, resiliency and high performance at low cost**. The average vehicle uses about **150 kg of plastics** and plastic composites versus 1163 kg of iron and steel currently it is moving around 10-15 % of total weight of the car. The plastics contents of commercial vehicles comprise about 50 % of all interior components, including safety subsystems, door and seat assemblies. A quick look inside any model of the car shows that plastics are now used in exterior and interior components such as **bumpers, doors, safety and windows, headlight and side view mirror housing, trunk lids, hoods, grilles and wheel covers**. Although up to 13 different polymers may be used in a single car model, just three types of plastics make up some 66 % of the total plastics used in a car **polypropylene 32 %, polyurethane 17 % and PVC 16 %.**

Katarína Szeteiová, AUTOMOTIVE MATERIALS PLASTICS IN AUTOMOTIVE MARKETS TODAY,

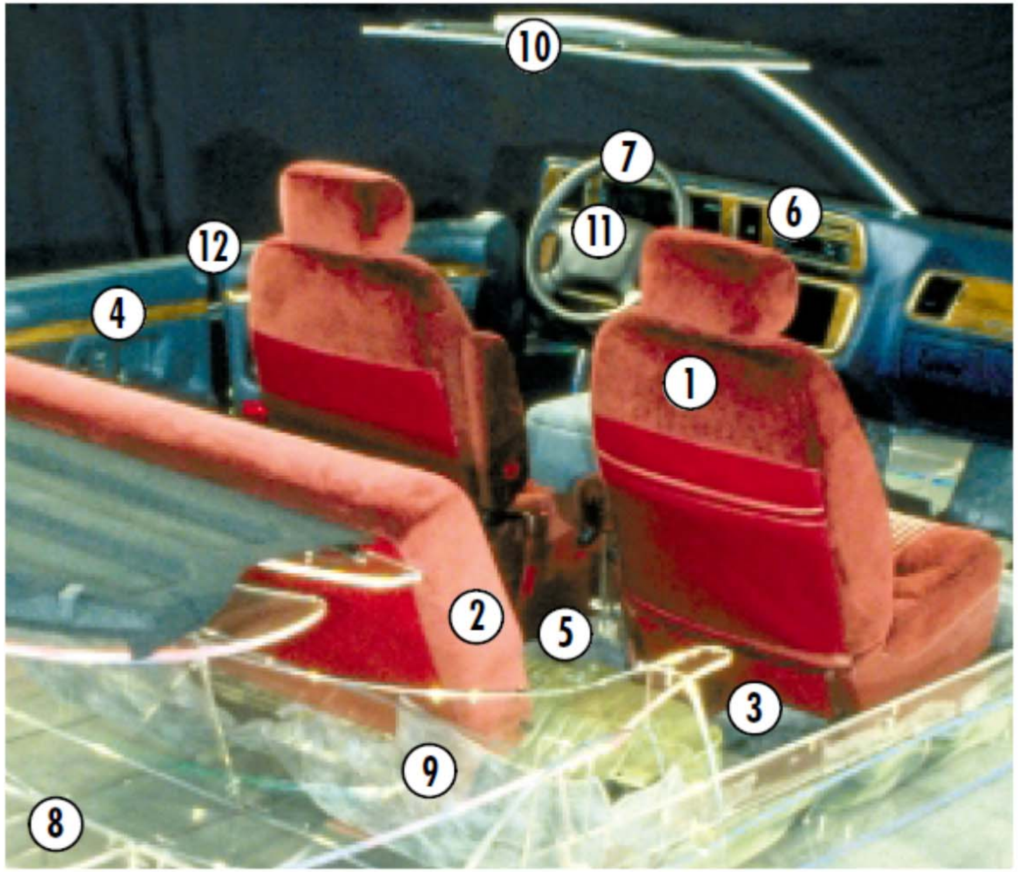
Plastics

PP – polypropylene is extremely chemically resistant and almost completely impervious to water. Black has the best UV resistance and is increasingly used in the construction industry.
Application: automotive bumpers, chemical tanks, cable insulation, battery boxes, bottles, petrol cans, indoor and outdoor carpets, carpet fibers.

Plastics

The Main Applications are:

1. Seat foam
2. Cushion overlay (fabric backing)
3. Carpet backing
4. Door panels
5. Sound absorption and vibration dampening
6. Dashboards
7. Steering wheels
8. Bumpers
9. Energy absorbers
10. Headliners
11. Airbag covers
12. Window encapsulation



PUR–polyurethane materials are widely used in high resiliency flexible foam seating, rigid foam insulation panels, microcellular foam seals and gaskets, durable elastomeric wheels and tires, automotive suspension bushings, electrical potting compounds, hard plastic parts (such as for electronic instruments), cushions.

*Driving with polyurethanes, European Isocyanate Producers Association

Plastics

- PVC – poly-vinyl-chloride has good resistance to chemical and solvent attack. Its vinyl content gives it good tensile strength and some grades are flexible. Colored or clear material is available.
- Application: automobile instruments panels, shielding of electrical cables, pipes,doors, waterproof clothing, chemical tanks

Plastics

- ABS – acrylonitrile-butadiene-styrene is a durable thermoplastic, resistant to weather and some chemicals, popular for vacuum formed components. It is a rigid plastic with rubber like characteristics, which gives it good impact resistance. Application: car dashboards, covers

Plastics

- PA – polyamide is known as nylon 6.6 or nylon 6. Both these nylons have high resistance to abrasion, low friction characteristics and good chemical resistance. They also absorb water easily and components in wet or humid conditions will expand, precluding their use in applications where dimensional stability is required. Application: gears, bushes, cams, bearings, weather proof coatings.

Plastics

- PS – polystyrene is very popular, ease to manufacture, but has poor resistance to UV light.
- Application: equipments housings, buttons, car fittings, display bases,

Plastics

- PE – polyethylene has good chemical resistance. Two types are used, low density polyethylene (LDPE) and high density polyethylene (HDPE) can be manufactured in a range of densities. Application: glass reinforced for car bodies, electrical insulation, packaging, where strength and aesthetics are important.

Plastics

- POM – polyoxymethylene (also know as polyacetal or polyformaldehyde) has big stiffness, rigidity and excellent yield, which are stable in low temperatures as well. Very good chemical and fuel resistance. Application: interior and exterior trims, fuel systems, small gears,

Katarína Szeteiová, AUTOMOTIVE MATERIALS PLASTICS IN AUTOMOTIVE MARKETS TODAY,

Plastics

- PC – polycarbonate has good weather and UV resistance, with transparency levels almost good as acrylic. Applications: security screens, aircraft panels, bumpers, spectacle lenses, headlamp lenses,
- PMMA – acrylic is more transparent than glass, has reasonable tensile strength (shatter proof grades are available) and good UV and weather resistance, high optical quality and surface finish with a huge colour range. Application: windows, displays, screens,
- PBT – polybutylene terephthalate has good chemical resistance and electrical properties, hard and tough material with water absorption, very good resistance to dynamic stress, thermal and dimension stability. Easy to manufacture - fast crystallization, fast cooling. Application: foglamp housings and bezels, sun-roof front parts, locking system housings, door handles, bumpers, carburetor components,
- PET – polyethylene terephthalate has similar conditions as PBT, good thermal stability, good electrical properties, very low water absorption, excellent surface properties. Application: wiper arm and their gear housings, headlamp retainer, engine cover, connector housings, ASA – acrylonitrile styrene acrylate material has great toughness and rigidity, good chemical resistance and thermal stability, outstanding resistance to weather, aging and yellowing, and high gloss. Application: housings, profiles, interior parts and outdoor applications.

Plastics

Component	Main types of plastics	Weight in av. car (kg)
Bumpers	PS, ABS, PC/PBT	10,0
Seating	PUR, PP, PVC, ABS, PA	13,0
Dashboard	PP, ABS, SMA, PPE, PC	7,0
Fuel systems	HDPE, POM, PA, PP, PBT	6,0
Body (incl. panels)	PP, PPE, UP	6,0
Under-bonnet components	PA, PP, PBT	9,0
Interior trim	PP, ABS, PET, POM, PVC	20,0
Electrical components	PP, PE, PBT, PA, PVC	7,0
Exterior trim	ABS, PA, PBT, POM, ASA, PP	4,0
Lighting	PC, PBT, ABS, PMMA, UP	5,0
Upholstery	PVC, PUR, PP, PE	8,0
Liquid reservoirs	PP, PE, PA	1,0
Total		**105,0**

- Although up to 13 different polymers may be used in a single car model, just three types of plastics make up some 66 % of the total plastics used in a car: polypropylene (32 %), polyurethane (17 %) and PVC (16 %)

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PLASTICS' USE BY TYPE AND WEIGHT IN AN AVERAGE CAR

PART	MAIN PLASTICS TYPES	WEIGHT IN AVERAGE CAR (kg)
Bumpers	PP, ABS, PC	10.0
Seats	PUR, PP, PVC, ABS, PA	13.0
Dashboard	PP, ABS, PA, PC, PE	15.0
Fuel systems	PE, POM, PA, PP	7.0
Body (including body panels)	PP, PPE, UP	6.0
Under the bonnet components	PA, PP, PBT	9.0
Interior trim	PP, ABS, PET, POM, PVC	20.0
Electrical components	PP, PE, PBT, PA, PVC	7.0
Exterior trim	ABS, PA, PBT, ASA, PP	4.0
Lighting	PP, PC, ABS, PMMA, UP	5.0
Upholstery	PVC, PUR, PP, PE	8.0
Other reservoirs	PP, PE, PA	1.0
Total		**105.0**

Plastics A material of choice for The automotıve ındustry, association of plastics Manufacturers in Europe