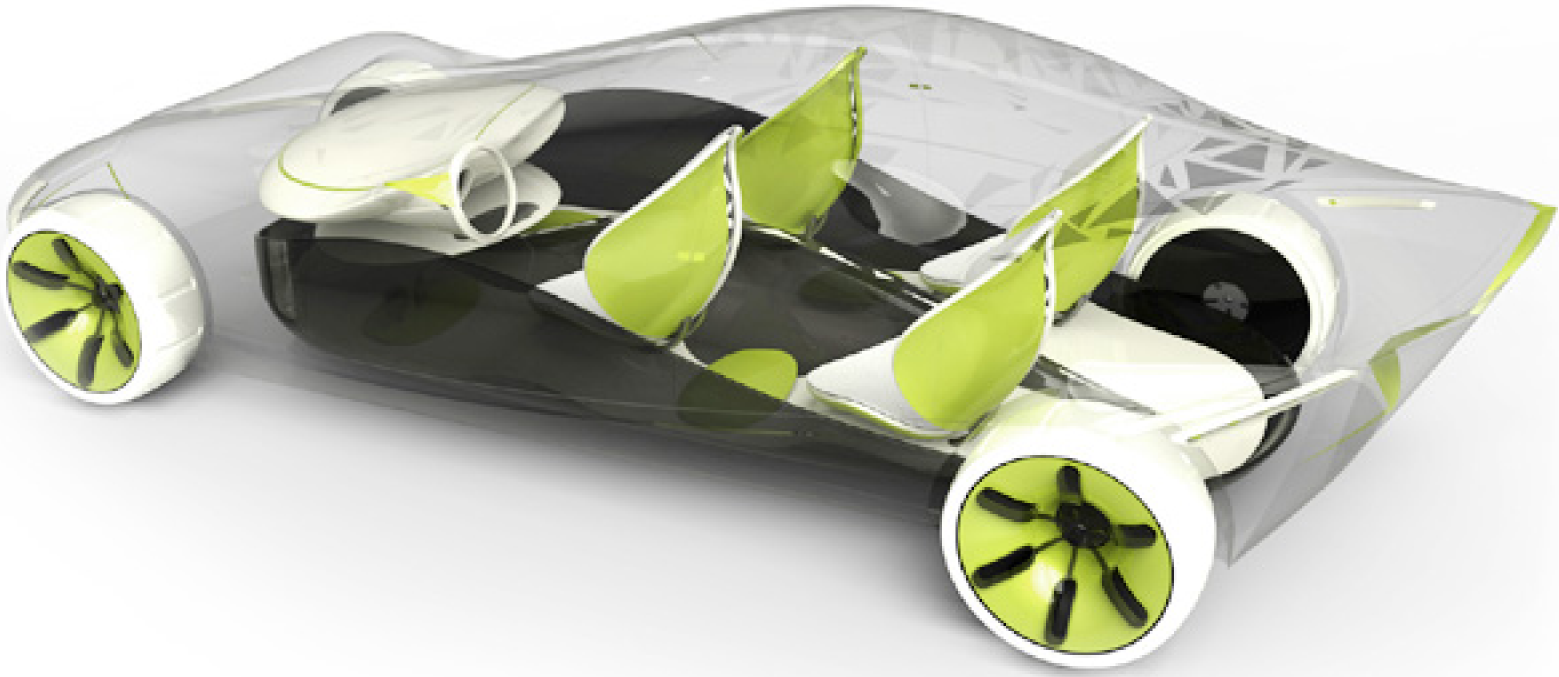
Automotive Design Engineering



Maranda Lavoie

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Chapter 1

Automotive Design

Designers at work in 1961. Standing by the scale model's left front fender is Richard Teague, a famous automobile designer at American Motors Corporation (AMC)

Automotive design is the profession involved in the development of the appearance, and to some extent the ergonomics, of motor vehicles or more specifically road vehicles. This most commonly refers to automobiles but also refers to motorcycles, trucks, buses, coaches, and vans. The functional design and development of a modern motor vehicle is typically done by a large team from many different disciplines included in automotive engineers. Automotive design in this context is primarily concerned with developing the visual appearance or aesthetics of the vehicle, though it is also involved in the creation of the product concept. Automotive design is practiced by designers who usually have an art background and a degree in industrial design or transportation design.

Design elements

A Bertone Birusa concept car on display at an International Car Show. In the Background are some concept sketches

Draft of OScar design proposal

The task of the design team is usually split into three main aspects: exterior design, interior design, and color and trim design. Graphic design is also an aspect of automotive design; this is generally shared amongst the design team as the lead designer sees fit. Design focuses not only on the isolated outer shape of automobile parts, but concentrates on the combination of form and function, starting from the vehicle package.

The aesthetic value will need to correspond to ergonomic functionality and utility features as well. In particular, vehicular electronic components and parts will give more challenges to automotive designers who are required to update on the latest information and knowledge associated with emerging vehicular gadgetry, particularly dashtop mobile devices, like GPS navigation, satellite radio, HD radio, mobile TV, MP3 players, video playback and smartphone interfaces. Though not all the new vehicular gadgets are to be designated as factory standard items, but some of them may be integral to determining the future course of any specific vehicular models.

Exterior design

The stylist responsible for the design of the exterior of the vehicle develops the proportions, shape, and surfaces of the vehicle. Exterior design is first done by a series of digital or manual drawings. Progressively more detailed drawings are executed and approved. Clay (industrial plasticine) and or digital models are developed from, and along with the drawings. The data from these models are then used to create a full sized mock-up of the final design (body in white). With 3 and 5 axis CNC Milling Machines, the clay model is first designed in a computer program and then "carved" using the machine and large amounts of clay. Even in times of high-class 3d software and virtual models on powerwalls the clay model is still the most important tool to evaluate the design of a car and therefore used throughout the industry.

Interior design

The stylist responsible for the design of the vehicle interior develops the proportions, shape, placement, and surfaces for the instrument panel, seats, door trim panels, headliner, pillar trims, etc. Here the emphasis is on ergonomics and the comfort of the passengers. The procedure here is the same as with exterior design (sketch, digital model and clay model).

Color and trim design

The color and trim (or color and materials) designer is responsible for the research, design, and development of all interior and exterior colors and materials used on a vehicle. These include paints, plastics, fabric designs, leather, grains, carpet, headliner, wood trim, and so on. Color, contrast, texture, and pattern must be carefully combined to give the vehicle a unique interior environment experience. Designers work closely with the exterior and interior designers.

Designers draw inspiration from other design disciplines such as: industrial design, fashion, home furnishing, architecture and sometimes Product Design . Specific research is done into global trends to design for projects two to three model years in the future. Trend boards are created from this research in order to keep track of design influences as they relate to the automotive industry. The designer then uses this information to develop themes and concepts which are then further refined and tested on the vehicle models.

Graphic design

The design team also develop graphics for items such as: badges, decals, dials, switches, kick or tread strips, liveries.

Development process

Includes the following steps:

- Concept sketching
- Clay modeling
- Class A surfaces
- Scale model creation
- Prototype development
- Computer-aided design
- Computer modeling
- Powertrain engineering
- Manufacturing process design

History of automobile design in the U.S.

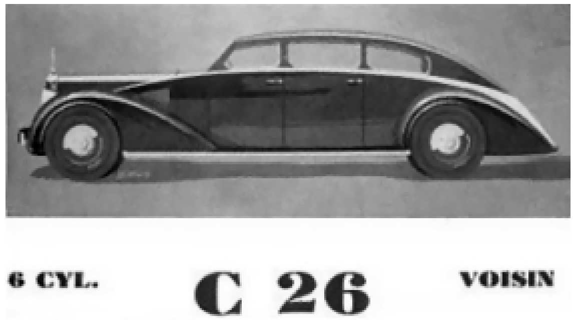
In the United States, automotive design reached a turning point in 1924 when the American national automobile market began reaching saturation. To maintain unit sales, General Motors head Alfred P. Sloan Jr. suggested annual model-year design changes to convince car owners that they needed to buy a new replacement each year, an idea borrowed from the bicycle industry (though Sloan usually gets the credit, or blame). Critics called his strategy planned obsolescence. Sloan preferred the term "dynamic obsolescence". This strategy had far-reaching effects on the auto business, the field of product design, and eventually the American economy. The smaller players could not maintain the pace and expense of yearly re-styling. Henry Ford did not like the model-year change because he clung to an engineer's notions of simplicity, economics of scale, and design integrity. GM surpassed Ford's sales in 1931 and became the dominant company in the industry thereafter. The frequent design changes also made it necessary to use a body-on-frame rather than the lighter, but less flexible, monocoque design used by most European automakers.

In the 1930s Chrysler's innovation with aerodynamics made them launch Chrysler Airflow in 1934, which was quite revolutionary and radical. But lower acceptance of the car forced Chrysler to re-sdesign its later models of 'Airflow' made the industry take note of risks involved in taking major design advancements in short cycles.

One very well-known American auto stylist is Harley Earl, who brought the tailfin and other aeronautical design references to auto design in the 1950s. He is joined among legendary designers by Gordon Buehrig, responsible for the Auburn 851 and iconic Cord 810 and 812 (hence also the Hupmobile Skylark and the Graham Hollywood). Another notable designer who had a markedly different style was Chrysler group's designer Virgil Exner, an early pioneer of cab forward (a.k.a.Forward look) design in mid-1950s later adapted by rest of the industry. He is also credited with introducing the pointed tail fins in the 1956 Plymouth Belvedere later adapted by all other Detroit studios. Personal injury litigation had a dramatic effect on the design and appearance of the car in the 20th century. Raymond Loewy was responsible for a number of Studebaker vehicles, including the Starlight (including the iconic bulletnose). Richard A. Teague, who spent most of his career with the American Motor Company, originated the concept of using interchangeable body panels so as to create a wide array of different vehicles using the same stampings starting with the AMC Cavalier. He was responsible for such unique automotive designs as the Pacer, Gremlin, Matador coupe, Jeep Cherokee, and the complete interior of the Eagle Premier.

In the 1960s Ford's first generation Ford Mustang and Thunderbird marked another era leading into new market segments from Detroit. The Ford Mustang achieved record sales in its first year of production and established the pony car segment.

History of automobile design in Europe



An early radical French Voisin C27

Europe is the continent where the first Automobile was invented, eventually replacing the Horse Drawn Coaches. Till World War I most of the manufacturers were concerned with mechanical reliability rather than its external appearance. Later, luxury and aesthetics became a demand and also an effective marketing tool. Designs from each nation with its own strong cultural identity, reflected in their exterior and interior designs. World War II slowed the progress, but after early-1950s, Italian designers set the trend and remained the driving force until the early part of the 1980s.

France

Citroën DS

In France notable designs came from Bugatti and Avions Voisin. Of the mass selling cars Citroën, launched their vehicles with innovative designs and engineering and mostly aided by the Styling of Flaminio Bertoni as evident from Citroën DS. After World War II with the disappearance of the French coach building industry, with the exception of Citroën, others stuck to following British and other popular trends till they gained financial stability. From the 1980s, manufactures like Renault cultivated their own strong design identities with designers like Patrick Le Quement demanding more freedom from engineering departments. Peugeot, which was dependent on Pininfarina since early post-war period, later established its own brand identity from 1980s onwards. Its other company Citroën still retains it distinctive French innovations in its designs. Today French designs are known for their innovativeness and forward looking.

Great Britain

1981 Ford Sierra with "jelly-mould" or "aero look" (low CD) styling was advanced for its time

Great Britain was Europe's leading manufacturer of automobiles until the late-1960s. During that era there were more British-based automakers than in the rest of Europe combined. The British automobile industry catered to all segments ranging from compact, budget, sports, utility, and luxury-type cars. Car design in Britain was markedly different from other European designs largely because British designers were not influenced by other European art or design movements, as well as the British clay modelers used a different sweep set.

British cars until World War II were sold in most of the British colonies. Innovations in vehicle packaging and chassis engineering combined with global familiarity with British designs meant vehicles were acceptable to public tastes at that time. British skilled resources like panel beaters, die machinists, and clay modelers were also available also partly due their involvement with motorsport industry.

Still during the 1960s British manufacturers sought professional help from the Italians, Giovanni Michelotti, Ercole Spada and Pininfarina.Notable British contributions to automobile designs were Morris Mini by Alec Issigonis, Several Jaguar Cars by Sir William Lyons, Aston Martin DB Series, and several cars from Triumph and MG. Ford Europe based in Great Britain is notable for Ford Sierra, a creation of Uwe Bahnsen, Robert Lutz, and Patrick le Quément.Other well known British designers were William Towns for Aston Martin designs and David Bache, for his Land Rover and Range Rover vehicles.

Germany

The 1972 BMW 2002 by Giovanni Michelotti

Germany is often considered the birthplace of industrial design with Bauhaus School of Design. However, the Nazi regime closed down the design school. Ferdinand Porsche and his family played a significant role in German design. Mercedes Benz passenger cars were also in luxury segment and played more importance to aesthetics. After the 1980s German design evolved into a distinctive Teutonic style often to compliment their high engineered cars suited to Autobahns. But the early German design clues of present day owes some part to Italian designers like Giovanni Michelotti, Ercole Spada, Bruno Sacco and Giorgetto Giugiaro. During Mid and late 20th century one of the most influential coach builder/designer in Germany was Karmann.

German designs started gaining popularity after the 1980s, notable after the formation of Audi. Volkswagen, which was dependent on Marcello Gandini and Giorgetto Giugiaro and Karmann, later formed the contemporary design language along with Audi. BMW's foray into sports sedan marked a new trend in automobile design as it called for a sporty-looking everyday sedan with Giovanni Michelotti , later enhanced by Ercole Spada right into the 1980s, and Klaus Luthe till mid-1990s. The American born designer Chris Bangle hired by BMW in late-1990s to re-define the brand and he used new single press technology for compound curves adding controversial styling elements in his designs.

The Porsche family contribution were instrumental in the evolution of Porsche cars, while the Italian designer Bruno Sacco helped create various Mercedes Models from the 1960s till the 1990s.

Italy

Ferrari Testarossa from Pininfarina Studios by Leonardo Fioravanti

In Italy, where art is often considered a serious profession since Renaissance period, companies like Fiat and Alfa Romeo played a major role in car design. Many coach builders were dependent on these two major manufacturers. Italian manufacturers had a large presence in Motorsports leading to several sport car manufacturers like Ferrari, Lancia, Lamborghini, Maserati, etc. During late-1950s the elegant Italian designs gained global popularity coinciding with the modern fashion and architecture at that time around the world. Various design and technical schools in Turin turned out designers in large scale. By the late-1960s almost all Italian coach builders transformed into design studios catering to automakers around the world. The trend continued in the 1990s when the Japanese and Korean manufacturers sourced designs from these styling studios.One example is Pininfarina.

The most famous Italian designers whose designs services were sought globally are Giovanni Michelotti, Ercole Spada, Bruno Sacco, Marcello Gandini and Giorgetto Giugiaro.All the following designers helped create the design foundations for most of the European brands in the post-world war II period, whose influence is still seen in present times.

Sweden (Scandinavian)

Ursaab, an early Saab concept illustrating an advanced headlamp treatment

Sweden has Volvo and Saab and the Scandinavian landscape required that cars had to be sturdy and withstand Nordic climate conditions. The Scandinavian design elements are known for their minimalism and simplicity. One of the early original Scandinavian designs was the Saab 92001 by Sikstena Sasona and Gunnar Ljungström.

Czechoslovakia

The 1934 Czechoslovakian Tatra T77 is the first serial-produced aerodynamically designed automobile designed by Hans Ledwinka and Paul Jaray

Prior to World War and until early 1990s, Czechoslovakia had strong presence in the automotive industry with manufacturers like Skoda, Jawa, Tatra, CZ, and Zetor. Czech automobiles were generally known for their originality in mechanical simplicity and designs were remarkably Bohemian as evident from Tatra cars and Jawa motorcycles. During the Communist regime, design started falling back and ultimately the domestic automakers ended up as subsidiaries of EU-based companies.

Chapter 2

Ford Kinetic Design

Kinetic Design is the name given to a style of automobile design used by Ford Motor Company for many of its passenger vehicles in the late 2000s and early 2010s. It replaced New Edge, and was first shown in 2005 with the SAV concept. Kinetic Design or Kinetic Design elements have featured on the Ford Ka from the 2008 model onwards, the Ford Fiesta from the 2008 model onwards, the Ford Focus from the 2008 model onwards, the Ford C-MAX from the 2007 model onwards, the Ford Kuga, the Ford Mondeo from the 2007 model onwards, the Ford S-MAX and the Ford Galaxy from the 2006 model onwards.

Kinetic Design is mainly European; making use of interesting surfacing, the design language displays the theme of 'energy in motion.' A common feature of Kinetic Design is the large, lower trapeziodal grille; while many of the vehicles' headlights have a 'stretched back' look to them.

History of Kinetic Design

Ford iosis concept.

The Ford Kinetic Design was first seen when Ford unveiled the Ford iosis concept.

Vehicles with Kinetic Design

The Ford Mondeo features Kinetic styling.

The Ford Focus features Kinetic styling.

2008 Ford Kuga

2008 Ford Ka

2008 Ford Fiesta

The Australian Ford Falcon incorporates Kinetic design, borrowing heavily from the Mondeo.

Chapter 3

Cab Over

Kenworth cab-over dump truck

Tatra T815 8x8 cab-over-in-front autocrane

Land Rover 101 Forward Control with radio-vehicle body

Cab-over, also known as **COE** (Cab Over Engine), **cab forward**, or **forward control**, is a body style of truck or van that has a vertical front or "flat face", with the cab of the truck sitting above the front axle. This truck configuration is currently common among European and Japanese truck manufacturers, because the laws governing overall vehicle lengths are strict and the body style allows longer trailers or a longer cargo area for the same overall length.

Although popular among United States heavy truckers and trucking companies during the 1970s because of strict length laws in many states, when those length laws were repealed, most heavy-truck makers moved to other body styles. It is, however, still very popular in the light- and medium-duty truck segment, with models such as the Isuzu NPR series or the Mitsubishi Fuso FE and FK/FM series.

Most Japanese minivans like the Suzuki Carry, Toyota Hiace and Mitsubishi Delica also use this body layout. It was also used for the (rear engined) Volkswagen Type 2 van, and in military vehicles such as the Land Rover 101 Forward Control and the Pinzgauer High Mobility All-Terrain Vehicle.

History

Vintage COE: 1942 Chevrolet

The Sternberg company of Wisconsin produced cab-over trucks as early as 1907, though by 1914 only their seven-ton model was a cab-over. They reintroduced the cab-over layout in 1933 with their "Camel Back" model, which allowed the cab to be tilted to access the engine.

The introduction of the first modern cab-over layout in the U.S. is credited to industrial designer Viktor Schreckengost, who with engineer Ray Spiller designed a cab-over truck for the White Motor Company in 1932.

The laws of the time limited truck length to 42 feet (12.8 m) on highways. Siting the cab over the engine saved several feet of cab length, which was added to the trailer capacity. Schreckengost patented the design in 1934.

White-Freightliner introduced its first tilting cab-over design in 1958, which allowed the entire cab to tilt forward for access to the engine.

Advantages

1970s Mercedes-Benz truck with tilting cab

In Class 8 tractors, the cab-over design allows the vehicle's wheelbase to be shorter than in the conventional arrangement, wherein the engine is placed in front of the cab, covered by a horizontal or sloping hood that opens to allow engine access. Its shorter wheelbase allows cab-over semi trucks to have a shorter overall length, thereby allowing for longer trailers to be used. For light- and medium-duty solid- or rigid-axle trucks, the cab-over design requires less length for the cab and engine, in a given wheelbase, and therefore allows a greater length for the truck body or load area.

In both class 8 tractors and light- and medium-duty solid-axle trucks, the cab-over-engine design gives the COE model an advantage in maneuverability over a conventional model. And since COEs are generally lighter than conventionals, they can often haul heavier loads, given equal GVWRs (gross vehicle weight rating) and GCWRs (gross combination weight rating). Despite the COE designs' being smaller in general, over-the-road tractors can still be fully equipped with single or bunk beds. Also, lack of a hood gives better visibility to the driver, tighter turning radius and significantly reduces the forward blind spots.

Disadvantages

Some drivers have complained, however, that the shorter wheelbase in the COE semi-trucks gives a rougher ride than those with conventional cabs, as the driver's seat is above the front axle; and that the cabs tend to be noisier because the engine is directly below, though some of this is dependent on the amount of noise-dampening insulation used in the construction of the individual vehicle.

Because of their flat front design, early COE semi-trucks had significantly worse aerodynamics than conventional tractors. Modern cab-over designs, in both semi-trucks and light- and medium-duty models, have improved aerodynamics significantly over early models, but often still have higher drag coefficients than their modern conventional-design counterparts. This works against fuel economy, and offsets some of the improvement in fuel consumption garnered from the lighter weight of the cab-over truck when running less than fully loaded.

Although the tilting cab gives comparatively unobstructed access to the engine, its deployment causes unsecured items in the cab and sleeper (if equipped) to fall onto the windshield or under the instrument panel.

Safety

In early cab-over models, the lack of a safe crush zone in the front made them far more dangerous in the event of a crash. However, modern designs employ stiffening beams in the doors to help prevent collapse during a front-end collision, steering columns are typically collapsible, all models include seat belts, and some models are equipped with airbags. All of these features improve occupant safety during a collision.

Chapter 4

Crossover (Automobile)

2009 Dodge Journey, CUV

2010 Fiat Palio Weekend Adventure Locker

2007 Saturn Outlook XR

2010 Tata Aria by Indian car maker Tata Motors

A **crossover** is a vehicle built on a car platform and combining, in highly variable degrees, features of a sport utility vehicle (SUV) with features from a passenger vehicle, especially those of a station wagon or hatchback.

Using the unibody construction typical of passenger vehicles, the crossover combines SUV design features such as tall interior packaging, high H-point seating, high ground-clearance or all-wheel-drive capability — with design features from an automobile such as a passenger vehicle's platform, independent rear suspension, car-like handling and fuel economy.

A crossover may borrow features from a station wagon or hatchback such as the two-box design of a shared passenger/cargo volume with rear access via a third or fifth door, a liftgate — and flexibility to allow configurations that favor either passenger or cargo volume, e.g., fold-down rear seats. The crossover may include an A, B & C-pillar, as well as a D pillar.

Crossovers are typically designed for only light off-road capability, if any at all.

Origin

The term crossover began as a marketing term, and a 2008 CNNMoney article indicated that "many consumers can not tell the difference between an SUV and a crossover." A January 2008 *Wall Street Journal* blog article called crossovers "wagons that look like sport utility vehicles but ride like cars."

The market segment spans a wide range of vehicles. In some cases, manufacturers have marketed vehicles as *crossovers* simply to avoid calling them station wagons. And while some crossover vehicles released in the early 2000s resembled traditional SUVs or wagons, others have prioritized sportiness over utility—such as the Infiniti FX and BMW X6.

Crossover antecedents include the AMC Eagle, a vehicle that "pioneered the crossover SUV" By 2006, the segment came into strong visibility in the U.S., when crossover sales "made up more than 50% of the overall SUV market." Sales increased in 2007 by 16%. In the U.S., domestic manufacturers were slow to switch from their emphasis on light truck-based SUVs, and foreign automakers developed crossovers targeting the U.S. market, as an alternative to station wagons that are unpopular there. But by the 2010 model year, domestic automakers had quickly caught up. The segment has strong appeal to aging baby boomers.

Crossover examples

The broad spectrum of crossovers includes:

The broad spectrum of CUVs or crossovers includes:

- Compact CUVs: e.g., Audi Q5, BMW X3, Ford Escape, Honda CR-V, Toyota RAV4, Nissan Rogue, Chevy Equinox
- Mid-sized CUVs: e.g., Acura MDX, BMW X5, Lexus RX 350, Mercedes-Benz M-Class, Toyota Highlander, Nissan Murano
- Full-sized CUVs: e.g., Audi Q7, Buick Enclave/Chevrolet Traverse/GMC Acadia, Ford Flex, Honda Pilot, Mercedes-Benz GL-Class (all of which offer three rows of seating for 7 or 8 passengers)
- Mid-sized sedan-derived CUVs: e.g., Honda Accord Crosstour, Toyota Venza, Audi A6 allroad quattro, AMC Eagle, Subaru Outback (the last three being based upon Station wagons)
- Compact sedan-derived hatchback CUVs: e.g. Toyota Matrix/Pontiac Vibe, Suzuki SX4 hatchback
- Minivan-like CUVs: e.g., Dodge Journey, Tata Aria
- Semi-offroaders: e.g. VW Crosspolo, Fiat Palio Adventure, Ford Fiesta Trail, Nissan Livina X-Trail, Peugeot Escapade, etc

The European MPV or large MPV may broadly resemble the crossover, including vehicles such as the Mercedes-Benz R-Class, VW Golf Plus, Ford Kuga, Renault Koleos and Ford S-Max. Notably, during the development of the Dodge Journey CUV, Dodge benchmarked the S-Max.

A short list of current crossovers with their platform genealogy (similar vehicles are grouped together):

Model(s)	Platform
Acura MDX	Honda mid-size "CD" platform (Honda Accord)
Acura RDX	Honda compact "C" platform (Honda Civic)
Acura ZDX	Honda mid-size "CD" platform (Honda Accord)
Audi allroad	Volkswagen Group C5 platform
Audi Q5	Volkswagen Group B8 platform
Audi Q7	Volkswagen Group PL71 platform
BMW X1	BMW 3 Series
BMW X3	BMW 3 Series
BMW X5	BMW 5 series
BMW X6	BMW X5
Buick Enclave/Chevrolet Traverse/GMC Acadia/Saturn Outlook	GM Lambda platform
Buick Rendezvous	GM U platform
Cadillac SRX	GM Theta Premium platform
Chevrolet Captiva/Saturn Vue	GM Theta platform
Chevrolet Equinox	GM Theta platform
Chrysler Pacifica	Chrysler CS platform (Chrysler Town and Country/Dodge Caravan)
Dacia Duster	Nissan B / Dacia B0 platform (Dacia Logan)
Dodge Journey	Mitsubishi GS platform (Dodge Avenger)
Fiat Idea	Fiat Idea Adventure Locker
Fiat Palio	Fiat Palio Weekend Adventure Locker
Fiat Strada	Fiat Strada Adventure Locker
Ford Edge	Ford CD3 platform
Ford Escape/Mazda Tribute/Mercury Mariner	Ford CD2 platform
Ford EcoSport	Ford B3 platform (Ford Fiesta)
Ford Explorer (fifth generation)	Ford D3 platform
Ford Flex	Ford D4 platform
Ford Taurus X / Ford Freestyle	Ford D3 platform (Ford Five

	Hundred/Taurus)
Ford Territory	Ford Falcon
Holden Adventra/HSV Avalanche	Holden Commodore
Holden Crewman/HSV Avalanche XUV	Holden Commodore
Honda CR-V/Honda HR-V	Honda compact "C" platform (Honda Civic)
Honda Element	Honda compact "C" platform (Honda Civic)
Honda Pilot	Honda mid-size "CD" platform (Honda Accord)
Honda Crosstour	Honda mid-size "CD" platform (Honda Accord)
Hyundai Tucson/Kia Sportage (2nd Generation)	Hyundai Elantra
Hyundai Santa Fe/Hyundai Veracruz/Kia Sorento (2nd Generation)	Hyundai Sonata
Infiniti EX	Nissan FM platform
Infiniti FX	Nissan FM platform (Infiniti G35)
Jeep Compass/Jeep Patriot	Mitsubishi GS platform
Lexus RX	Toyota Camry
Lincoln MKX/Ford Edge	Ford CD3 platform (Lincoln Zephyr/MKZ, Ford Fusion)
Mazda CX-7	Mazda 6
Mazda CX-9	Ford CD3 platform (Mazda MPV)
Mercedes-Benz GL-Class	
Mercedes-Benz GLK-Class	Mercedes-Benz W204
Mercedes-Benz M-Class (second generation)	
Mercedes-Benz R-Class	
Mitsubishi Endeavor	Mitsubishi Galant
Mitsubishi Outlander	Mitsubishi Lancer
Nissan Murano	Nissan D platform (Nissan Altima)
Nissan Rogue/Nissan Qashqai/Renault Koleos	Nissan C platform (Nissan Sentra)
Nissan X-Trail	Nissan C platform (Nissan Sentra)
Peugeot 3008	Peugeot 308
Porsche Cayenne	Volkswagen Group PL71 platform
Saab 9-3X	GM Epsilon platform
Saab 9-4X	GM Theta Premium platform
Škoda Octavia Scout	Volkswagen Group A platform
Subaru Forester	Subaru Impreza

Subaru Outback	Subaru Legacy
Subaru Tribeca	Subaru Legacy
Suzuki Grand Vitara (Second generation)	Suzuki SX4
Suzuki XL7 (Second generation)	Chevrolet Equinox
Tata Aria	Tata Indigo Manza
Toyota Matrix	Toyota Corolla
Toyota RAV4	Toyota Corolla
Toyota Venza	Toyota Camry
Toyota Highlander/Kluger	Toyota Camry
Volkswagen Tiguan	Volkswagen Group B platform (PQ46) (Volkswagen Golf)
Volkswagen Touareg	Volkswagen Group PL71 platform
Volvo XC60	Ford EUCD platform
Volvo XC70	Ford EUCD platform
Volvo XC90	Ford D3 platform (Volvo S80)

Chapter 5

Dagmar Bumpers and Driver Visibility

Dagmar bumpers

1953 Mercury Convertible with Dagmars

Buick advertising image of the *Fashion-Aire Dynastar* grille work with reflective squares and Dagmars featured on 1958 Buicks

Lincoln B with Dagmar bumpers

1957 Chevrolet Bel-Air with rubber-tipped Dagmars

Dagmar bumpers, also known simply as **Dagmars** (*dag*-mar), is a slang term for the artillery shell shaped styling elements found on the front bumper/grille assemblies on several makes of cars produced in the 1950s, an era recognized for its flamboyant designs and prominent use of chrome details.

The term was coined by customizers in direct reference to Dagmar, an early 1950s television personality well known for her pronounced cleavage on *Broadway Open House*. Dagmar's physical attributes were further enhanced by low-cut gowns and the shape of her bra cups, which were somewhat conical. She was amused by the tribute.

Evolution

As originally conceived by Harley Earl, GM Vice President of Design, the bumper guard elements would mimick exaggerated artillery shells and were placed at either end of the front bumpers of Cadillacs. Their presence was both as a styling element indicating speed (as in the speeding bullet or projectile) and as bumper guards.

However as the 1950s wore on, the element on the Cadillac grew more pronounced, and in 1957 the Cadillac Eldorado Brougham gained black rubber tips, which were referred to in slang terms as "pasties".

As the 1959 model year designs approached, American car designs were beginning to shed both their rear fins and the missile shaped grille elements. In 1960 the era of the Dagmar bumper ended when Lincoln dropped the element from its 1961 Lincoln Continental.

Dagmars as a massive grille or bumper decoration competed against not only "spinners," as on the 1949 Ford and 1950 Studebaker, but also against a similar decorative element, which had a concave tip. Buick had these in a circular form both before and after the firm's stint with dagmars. Oldsmobile had these in an oval form and never used dagmars.

Vehicles sporting Dagmar bumpers

Postwar Cadillacs began sporting missile pointed bumper elements with their 1946 models. Beginning with the 1951 models, stylists began lifting these bumper guards up into the grille work, however by 1953 their shape and detail began to take on a bullet motif with the tips of the element being scored in the manner in which a bullet casing is shaped. In 1957 black rubber tips were placed on the element which was now placed at the top of the grille, approximately ten inches above the lower bumper. The element continued to become more pronounced in size through 1958, but were eliminated in the 1959 Cadillac redesign.

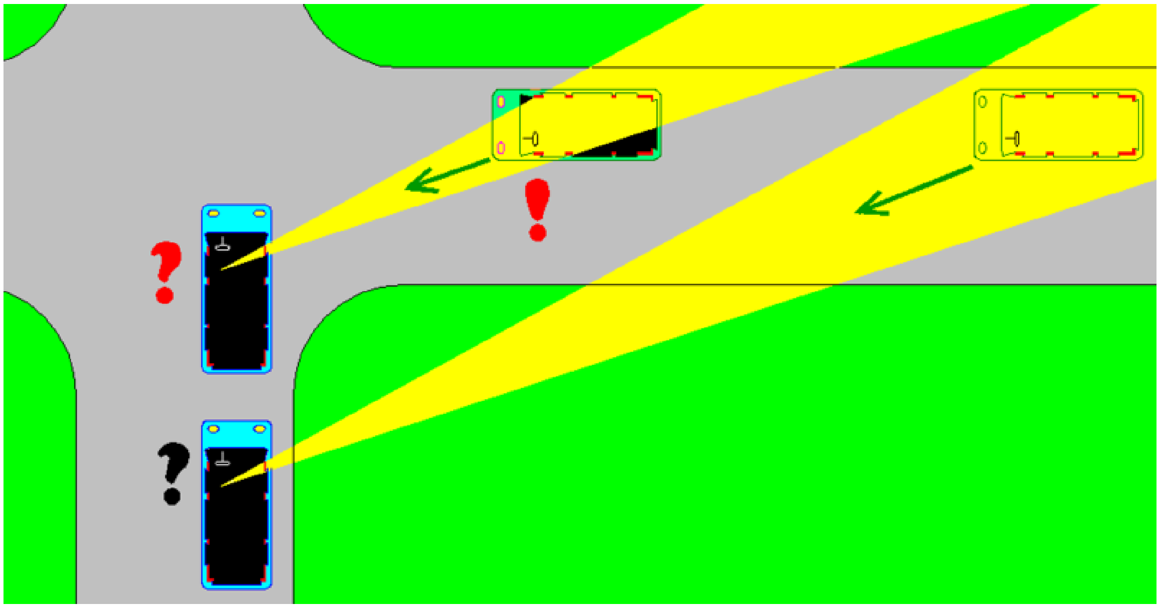
Mercury sprouted prominent Dagmars in 1953 and continued the look through the 1956 model year. Lincoln added Dagmars to its 1960 Lincoln and Continentals. The design took a different approach than GM, with the use of a black rubber ring separating the body of the element from the chrome tip.

Buick sported Dagmars on its 1954 and 1955 models. In 1954 the element was part of the bumper assembly; in 1955 the element moved up into the grille area.

Driver visibility

In transport, **driver visibility** is the maximum distance at which the driver of a vehicle can see and identify prominent objects around the vehicle. Visibility is primarily determined by weather conditions and by a vehicle's design. The parts of a vehicle that influence visibility include the windshield, the dashboard and the pillars. Good driver visibility is essential to safe road traffic.

Blind spots may occur in the front of the driver when the A-pillar (also called the windshield pillar), side-view mirror, and interior rear-view mirror block a driver's view of the road. Behind the driver, there are additional pillars, headrests, passengers, and cargo, that may reduce visibility. Blind spots are affected directed by vehicular speed, since they increase substantially the faster one goes.

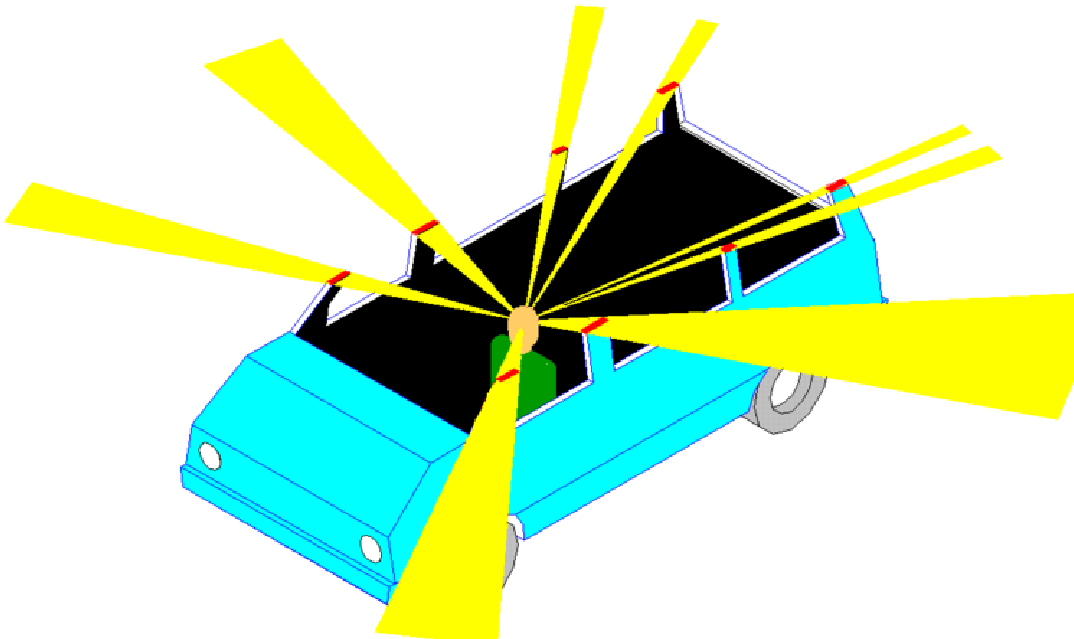


A-pillar blind spot

Forward visibility

This diagram shows the blocked view in a horizontal-plane in front of the driver. The front-end blind spots caused by this can create problems in traffic situations, such as in roundabouts, intersections, and road crossings. Front-end blind spots are influenced by the following design criteria:

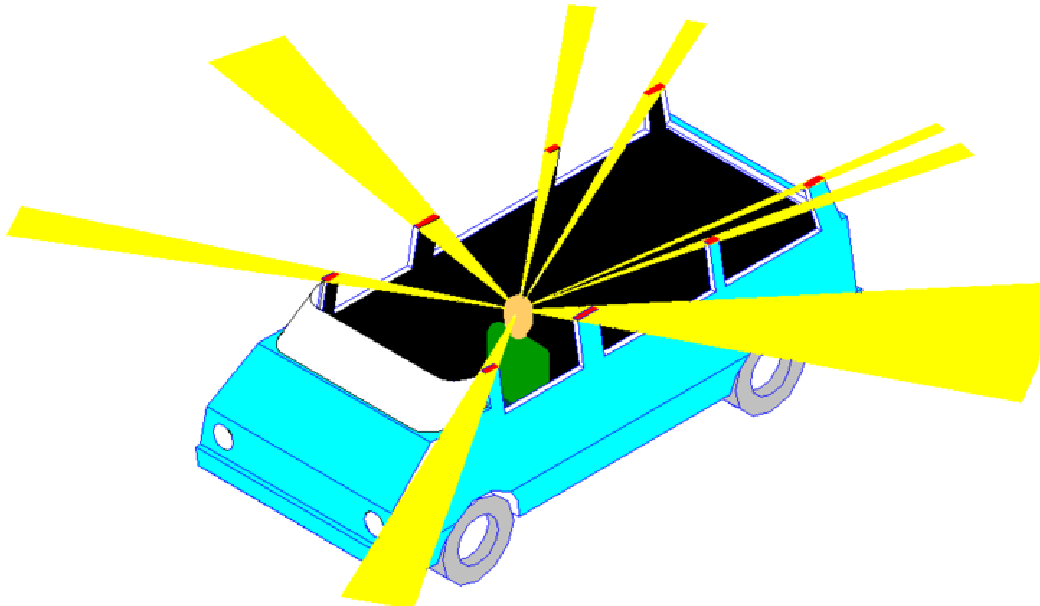
- Distance between the driver and the pillar
- Thickness of the pillar
- The angle of the pillar in a vertical plane side view
- The angle of the pillar in a vertical plane front view
- the form of the pillar straight or arc-form
- Angle of the windshield
- Height of the driver in relation to the dashboard
- Speed of the opposite car



40° angle A-pillar bar blind spots

Effects of A-pillar angle on visibility

Most passenger cars have a diagonal pillar as shown in this side view. The angle between the horizon and A-pillar is approximately 40 degrees with a straight pillar that is not too thick. This gives the car a strong, aerodynamic body with an adequately-sized front door.



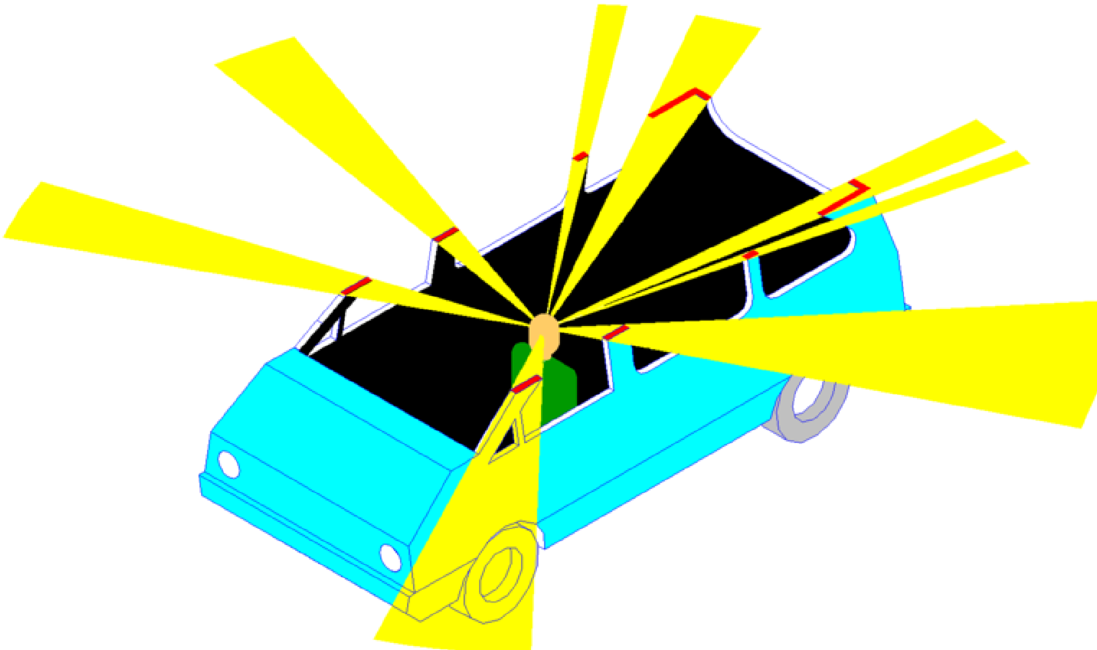
vertical A-pillar having small blind spots

Panoramic windshield

The sides of a **panoramic windshield** are curved, which makes it possible to design vertical A-pillars that give the driver maximum forward visibility. However, it is impossible to design an aerodynamic small car with a vertical A-pillar because the more vertical the A-pillar is, the less space the door opening has, and the greater frontal area and coefficient of drag the vehicle will have.

Examples of cars with an almost vertical A-pillar:

- Honda Step Bus Concept
- Saab 900
- School bus
- Almost all Cadillacs from 1954–1959

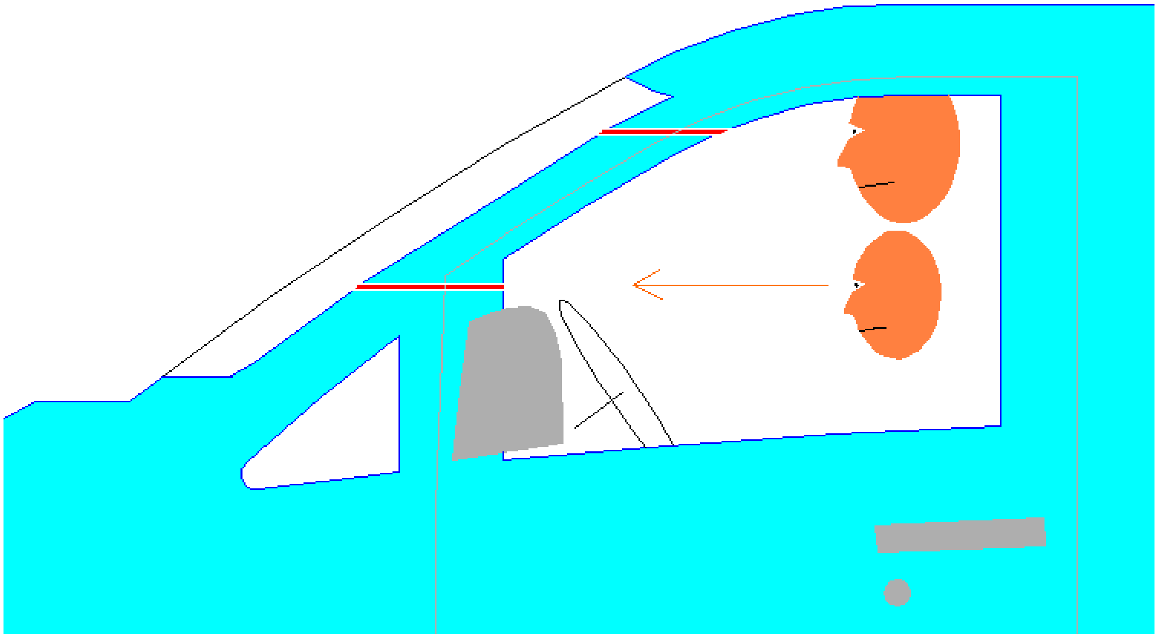


A-pillar bars reduce driver visibility

Flat windshields

Some modern car designs have an extremely flat A-pillar angle with the horizon. For example, the Pontiac Firebird and Chevrolet Camaro from 1993-2002 had a windshield angle of 68° with the vertical, which equals just 22° with the horizon.

A flatter A-pillar's advantages include reducing the overall drag coefficient and making the car body stronger in a frontal collision, at the expense of reducing driver visibility in a 180° field of view from left to right.



Car with a "quarter glass", Visibility of short and tall drivers

Other disadvantages of a flat windshield angle

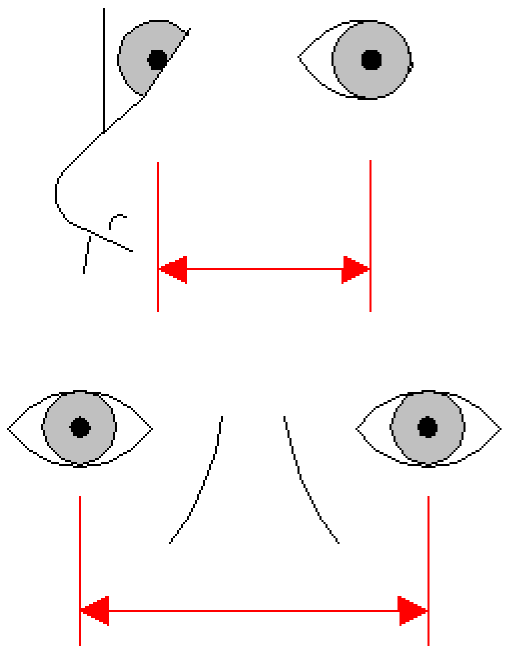
- Other traffic can not see the driver through the reflection if the driver can see them.
- The heater needs more time to heat the bigger window surface.
- The flat windshield angle does not let snow slide off easily.
- The driver cannot reach the whole flat window to clean it easily.

Height of the driver

Driver height can also affect visibility.

An A-pillar that is split up and haves a small triangle window (Front Quarter glass) can give a short driver visibility problems. Some cars the windshield is fillet with the roof-line with a big radius. A fillet round A-pillar can give a tall driver visibility problems. Also sometimes the A-pillar can block the driver from seeing motorcyclists.

Also the B-pillar (car) can block the vision of a tall driver in small 4 door cars.



Turning your head reduces blind spot

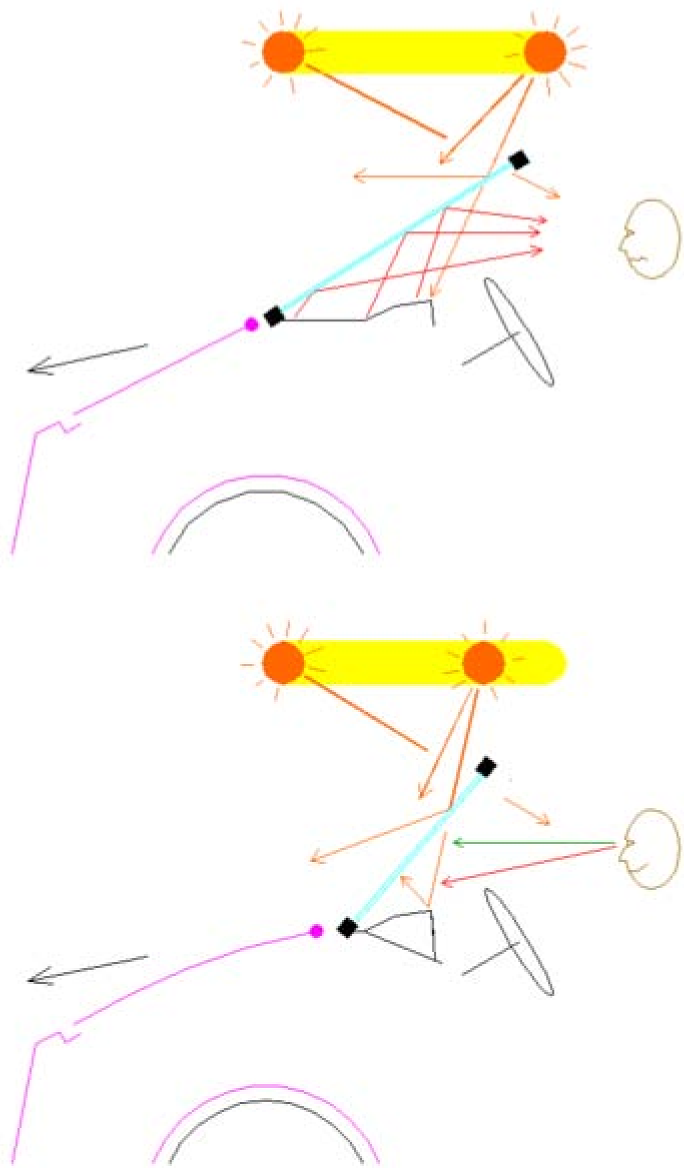
A driver may reduce the size of a blind spot or eliminate it completely by turning their head in the direction of the obstruction. This allows the driver to see better around the obstruction and allows the driver better depth perception.

Visibility in a convertible

Because there is no roof connection between the A- and B- pillar The A-pillars of a convertible automobile have to be stronger and even thicker,

However, with the top down there are no B or C pillars, improving driver visibility behind the driver.

Windshield reflections



Sunlight dashboard reflection

Dashboard reflection

It is best if the dashboard has a non-reflecting dark colored surface.

A small dashboard gives some reflection on the lower part of the windshield.

A big dashboard can give reflection on eye height.

A-pillar reflection

It is best if the inside of the A-pillar has a non-reflecting dark colored surface.

If the side of the window is curved there is less A-pillar reflection.

Light through roof reflection

Some new model cars have a very big sunroof. Sometimes the sunlight through the roof lights up the dashboard and gives a reflection in the windshield.

Other automobile design factors

Other design factors may prevent a manufacturer from maximizing visibility. These include safety, as narrower pillars cannot be made strong as easily as thicker pillars, and size restraints pertaining to aerodynamics, as taller, more vertical windshields create additional drag and reduce fuel efficiency.

Rear-view mirror blind spots

A vehicular blind spot is the area of the road that while driving cannot be seen when looking forward or through either the rear-view or side mirrors. Blind spots can be checked by turning one's head briefly, eliminated by reducing overlap between side and rear-view mirrors, or reduced by adding other mirrors with larger fields-of-view. Detection of vehicles or other objects in blind spots may also be aided by systems such as video cameras or distance sensors, though these are uncommon or expensive options in automobiles generally sold to the public.

Chapter 6

Industrial Plasticine and Ponton (Automobile)

Industrial plasticine

A clay model of a BMW 1 Series

The end result: BMW 125i

Clay or **industrial plasticine** is a modeling material which is mainly used by automotive design studios. It was developed as an industrial version of plasticine or hobby clay.

Industrial plasticine is based on wax and typically contains sulfur, which gives a characteristic smell to most artificial clays. Often, the styled object will be used to create molds. However, largely because sulfur can interfere with some mold-making processes, especially if clay surfaces are unsealed surfaces and platinum-cure RTV (room temperature vulcanizing) silicone rubber is used, sulfur-free variants are now available; these are usually much lighter than sulfur-containing clays.

Design studios

Before a new car model is launched, a long period of finding the right design takes place. Even today, computer models are not sufficient to evaluate the quality of a design. Therefore 1:4 or even 1:1 models are built to get an impression of the final car. These models are created in clay, and usually consist of a wooden or iron frame which is covered with Styrofoam. Clay is loaded on top of the foam. Modelers then use various tools and slicks to finalise the shape of the car.

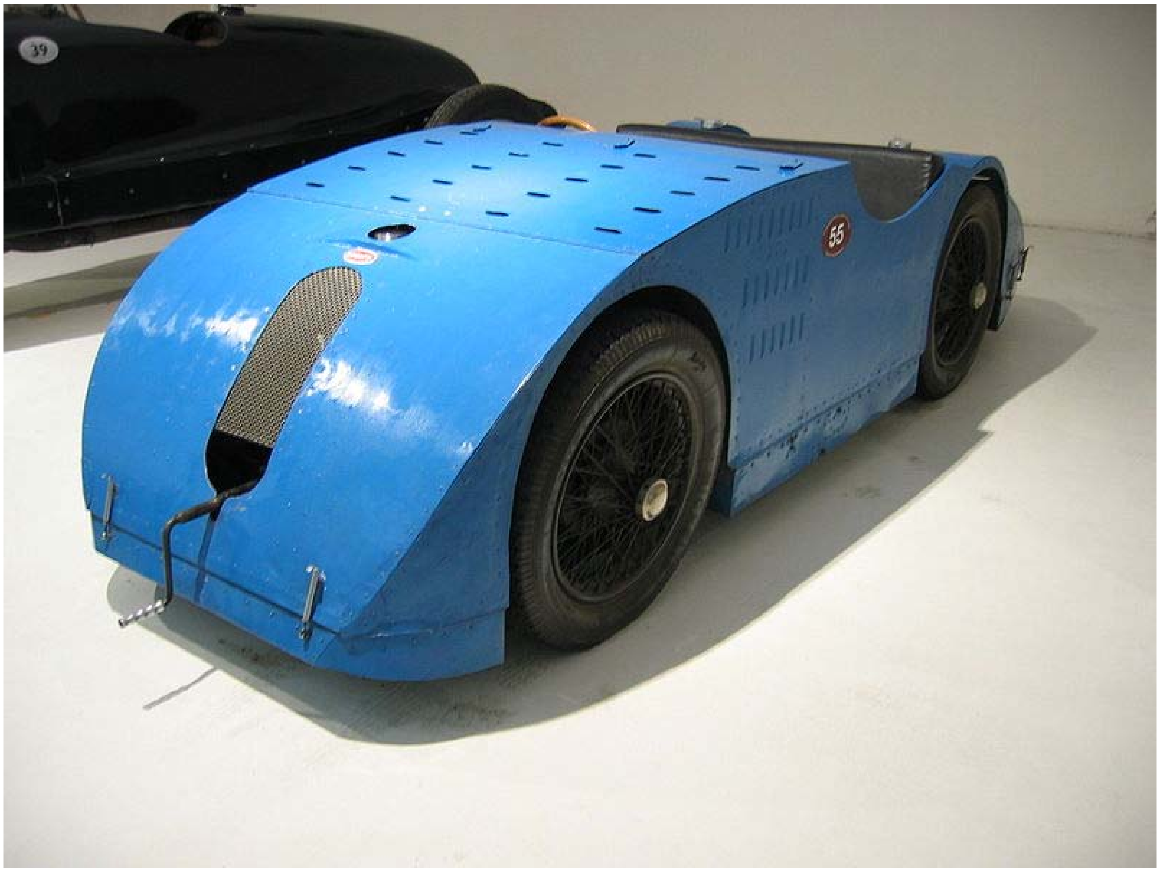
Suppliers

There are three main producers of industrial plasticine operating worldwide.

- Eberhard Faber from Germany, which is also known for FIMO.
- Kolb (Franz Kolb Nachfolger, Kolb Technology and Kolb America), the company of the plasticine inventor Franz Kolb.
- Chavant, which was founded by the French chemist Claude Chavant and is now located in New Jersey.

Ponton (automobile)

1959 Renault Frégate, a typical postwar design with **ponton styling.**



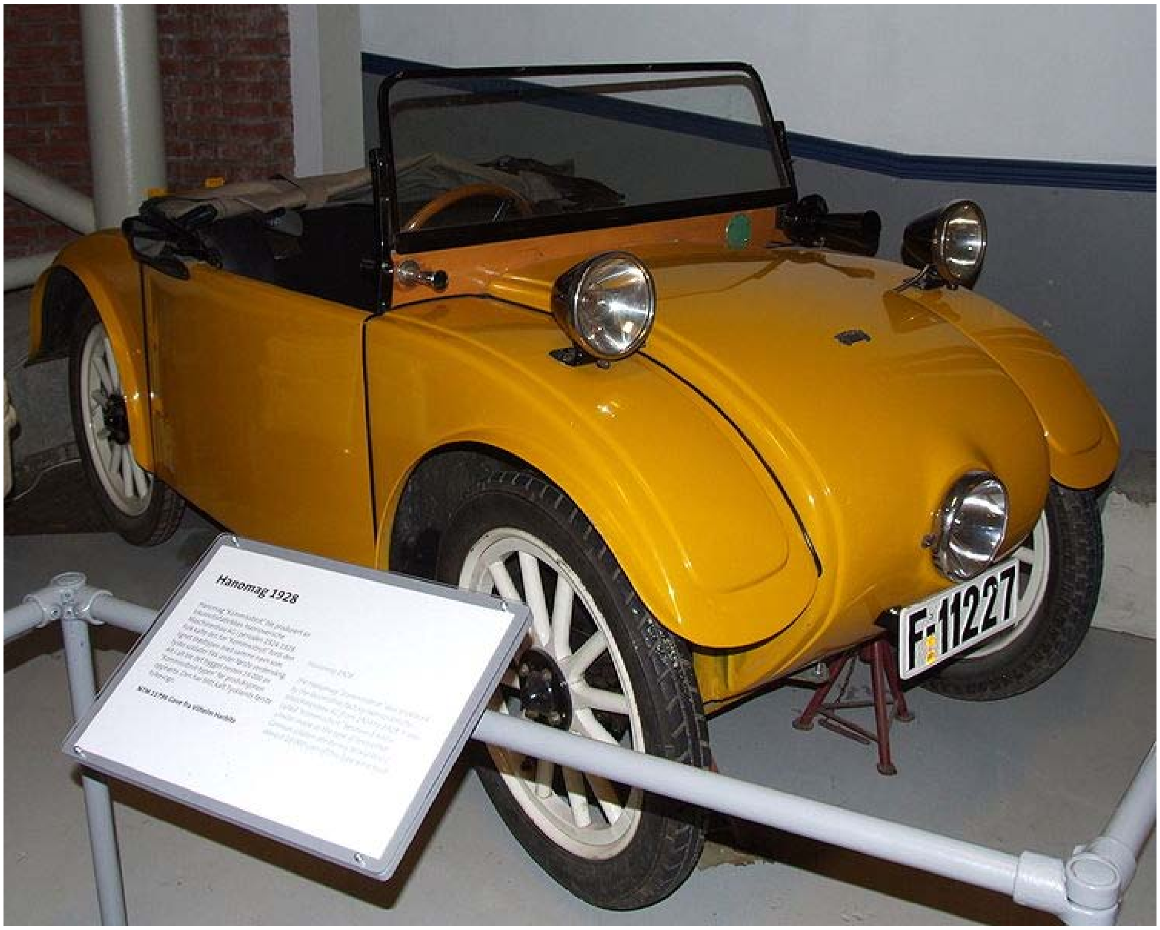
1923 Bugatti Typ 32 'Tank'

Ponton or Pontoon styling refers to a 1930s-1960s design genre — ultimately the precursor of modern automotive styling. The trend emerged as distinct running boards and fully articulated fenders became less common and bodywork began to enclose the full width and uninterrupted length of a car. The trend was also called *envelope styling.*

The term, which is now largely archaic, especially describes the markedly bulbous, slab-sided configuration of postwar European cars, including those of Mercedes-Benz, Opel, Auto Union, DKW, Borgward, Lancia, Fiat, Rover, Renault and Volvo — as well as similar designs from North America.

The term derives from the French and German word **Ponton**, meaning *pontoon*. The Langenscheidt German-English dictionary defines *Pontonkarrosserie* as "all-enveloping bodywork, straight-through side styling, slab-sided styling.

Origin of the trend



1928 The Hanomag 2/10 PS, it "dispensed with running boards and integrated the fenders in the body to save on weight."

The term ponton styling may have derived from the wartime practice in Germany of adding full-length tread armor along each side of a tank, attached primarily on the top edge — which resembled pontoons. As this roughly coincided with automobile styling trend where bodywork, especially running boards and fenders, became less articulated — with cars carrying integrated front fenders and full-width, full-length bodywork — the design took on the "pontoon" or "ponton" descriptor.

One of the first known cars with a ponton body is the Bugatti type 32 "Tank" which participated in the 1923 French Grand Prix at Tours.

In 1924, Fidelis Böhler designed one of the first production cars with a ponton body, the Hanomag 2/10. The car's body resembled a loaf of bread earning it the sobriquet of "Kommissbrot" - a coarse whole grain bread as issued by the army. The economical car was produced from 1924 to 1928. Böhler built the core body around two side-by-side passenger seats. He dispensed with running boards and integrated the fenders in the body to save on weight. The cheap car became a best seller in Germany.

In 1935, Vittorio Jano, working with the brothers Gino and Oscar Jankovitz, created a one-off mid-engine prototype on a Alfa Romeo 6C 2300 chassis, which Jano had shipped to Fiume, Croatia in 1934. The brothers Jankovitz had been close friends with leading Hungarian aerodynamicist Paul Jaray, and the prototype, called the Alfa Romeo Aerodinamica Spider, featured ponton styling — an especially early and clear example of the bulbous, uninterrupted forms that would come to characterize the genre.

See: 1935 Alfa Romeo Aerodinamica Spider, front three quarter view.
See: 1935 Alfa Romeo Aerodinamica Spider, profile view.

In 1937, Pinin Farina designed a flowing ponton-style body for the Lancia Aprilia *berlinetta aerodynamica* coupé, and also the open body on the 1940 Lancia Aprilia Cabriolet.

1936 BMW 328 Mille Miglia

1946 Pinin Farina's Cisitalia 202

The 1946 Cisitalia 202 coupé, which Farina designed from sketches by Cisitalia's Giovanni Savonuzzi, was the car that "transformed postwar automobile design" according to New York's Museum of Modern Art (MoMA). MoMA acquired an example for its permanent collection in 1951, noting that the car's "hood, body, fenders, and headlights are integral to the continuously flowing surface, rather than added on. Before the Cisitalia, the prevailing approach followed by automobile designers when defining a volume and shaping the shell of an automobile was to treat each part of the body as a separate, distinct element." Also introduced in 1947, the Alfa Romeo 6C 2500 was another ponton-style Farina design which, together with those by Touring and others on the same chassis, has also been credited with setting the trend for post-war automotive design.

Rounded, flowing forms, with unbroken horizontal lines between the fenders— the style had identified as "the so-called Ponton Side Design" became "the new fashion in Europe", offered by Alfa-Romeo, Fiat, Rover and other companies.

An inspiration to American and Japanese manufacturers as well as to Europeans, Farina's "ponton line" would be copied round the world. One of the first American cars to adopt it was the 1947 Studebaker Champion, designed by Virgil Exner and Roy Cole but sometimes erroneously attributed to Raymond Loewy. Another, the Howard "Dutch"

Darrin-designed 1947-1950 Kaiser-Frazer, was said to have been the inspiration for the 1949 Borgward Hansa 1500, Germany's first sedan in the ponton style.

In the Soviet Union the GAZ-M20 Pobeda came into production in 1946, about 1 month after the first 1946 Kaiser rolled off the production line, and in Britain the Standard Vanguard went on sale the following year.

Ford and General Motors followed the trend with their own designs in 1949.

Examples of "ponton" in automotive contexts

1954 Mercedes-Benz 180, nicknamed the "Ponton"

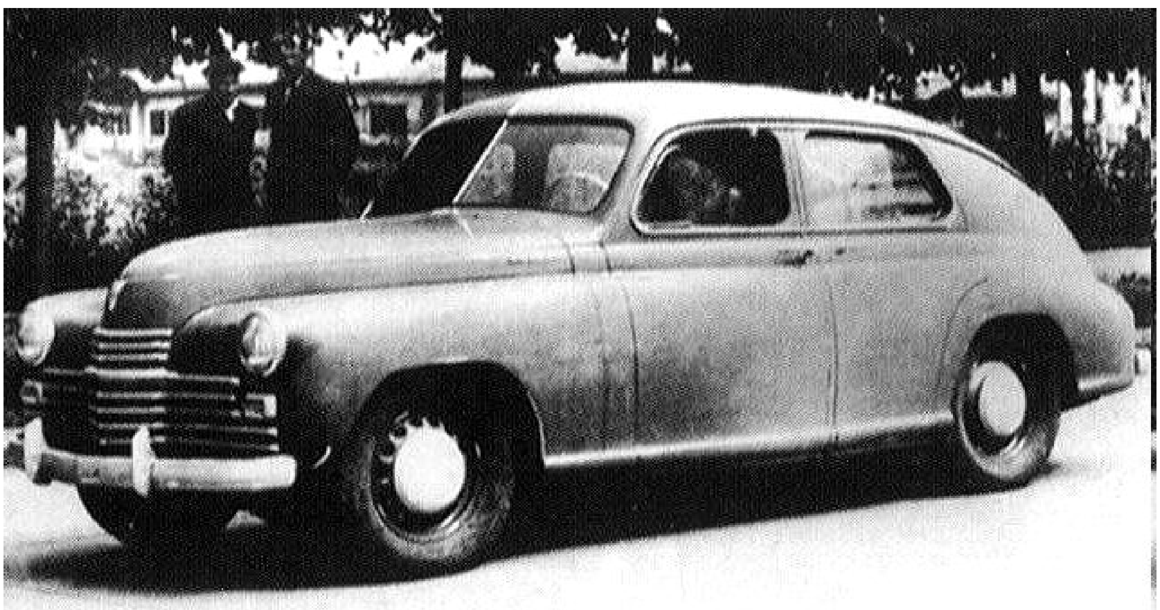
The term is now commonly used in reference to Mercedes-Benz models from 1953-1962. For example a book about the marque refers to "the Ponton", the "Ponton saloon", "Ponton 220", "Ponton 220S and SE coupes and cabriolets", and "the Ponton models".

A General Motors document refers to the 1953 Olympia Rekord as "the first Opel with a full-width, or ponton, body shell".

In a reference work on alternative-energy vehicles, electrical-engineering academics used the term as a generic for saloon cars with three-box design ; also a 2007 German work on car design and technology mentions a "Rover-Ponton" (ponton-style Rover); and a French book on art and design also used the term in an automotive context in 1996.

Given that the Volkswagen Beetle carried articulated running boards and fenders its entire life, the subsequent Volkswagen Type 3 became known for its ponton styling; in Holland the Volkswagen Type 3 (1961–1974) 2-door notchback sedan from the fastback and wagon versions was called the 'Ponton."

The 1948-1950 Packard had a "'Ponton'-style side section with the fenders running through from front to back", according to a blogger who also describes the 1951 Packard Patrician as "one of the first cars that featured the new Ponton-style *(sic)* with integrated front-fenders *(sic)* at the same level with the hood and a curved onepiece-windscreen *(sic)*."



1944 GAZ-25 Pobeda prototype

Farina-designed 1947 Alfa Romeo 6C 2300 SC

1950-1958 Lancia Aurelia B20

1950 Ford (GB) Consul

1950 Ford (USA) Club Coupe

1950 Studebaker Champion

1951 Standard Vanguard

1952 :Rover 75

1952 Borgward Hansa 1800

1961-1974 Volkswagen Type 3, sometimes called "ponton" in Holland

1956-1970 Volvo Amazon

1956-1967 Renault Dauphine

Chapter 7

Automobile Platform

Identical platform 2007 model year 4-door sedans: Toyota Camry and Lexus ES

An **automobile platform** is a shared set of common design, engineering, and production efforts, as well as major components over a number of outwardly distinct models and even types of automobiles, often from different, but related marques. It is practiced in the automotive industry to reduce the costs associated with the development of products by basing those products on a smaller number of platforms. This further allows companies to create distinct models from a design perspective on similar underpinnings.

Definition and benefits

A basic definition of a platform in automobiles, from a technical point of view, includes: underbody and suspensions (with axles) — where the underbody is made of front floor, underfloor, engine compartment and frame (reinforcement of underbody). Therefore, key mechanical components that define an automobile platform include:

- Floorpan, the collective pieces of the large sheet metal stamping that serves as the primary foundation of the monocoque, of most of the structural and mechanical components (still often informally referred to as the "chassis")
- Wheelbase, the distance between the front and rear axles
- Steering mechanism and type of power steering
- Type of front and rear suspensions
- Placement and choice of engine and other powertrain components

Ford Ka

Fiat Panda

Fiat 500

Fiat Uno (Brasil)

Vehicle platform-sharing combined with advanced and flexible-manufacturing technology enables automakers to sharply reduce product development and changeover times, while modular design and assembly allow building a greater variety of vehicles from one basic set of engineered components. Many vendors refer to this as **product or vehicle architecture**. The concept of product architecture is the scheme by which the function of a product is allocated to physical components.

The use of a platform strategy provides several benefits:

- Greater flexibility between plants (the possibility of transferring production from one plant to another due to standardization),
- Cost reduction achieved through using resources on a global scale,
- Increased use of plants (higher productivity due to the reduction in the number of differences), and
- Reduction of the number of platforms as a result of their localization on a worldwide basis.

The automobile platform strategy has become important in new product development and in the innovation process. The finished products have to be responsive to market needs and to demonstrate distinctiveness while — at the same time — they must be developed and produced at low cost. Adopting such a strategy affects the development process and also has an important impact on an automaker's organizational structure. A platform strategy also offers advantages for the globalization process of automobile firms.

Because the majority of time and money by an automaker is spent on the development of platforms, platform sharing affords manufacturers the ability to cut costs on research and development by spreading the cost of the R&D over several product lines. Manufacturers are then able to offer products at a lower cost to consumers. Additionally, economies of scale are increased, as is return on investment.

Examples

Originally, a "platform" was a literally shared chassis from a previously-engineered vehicle, as in the case for the Citroen 2CV platform chassis used by the Citroen Ami and Citroen Dyane, and Volkswagen Beetle frame under the Volkswagen Karmann Ghia. Platform sharing has been a common practice since the 1960s when GM used the same platform in the development of the Pontiac LeMans, the Buick Regal, the Chevrolet Chevelle, and Oldsmobile Cutlass.

In the 1980s, Chrysler's K-cars all wore a badge with the letter, "K", to indicate their shared platform. In later stages, the "K" platform was extended in wheelbase, as well as use for several of the Corporation's different models.

Fiat Croma

Cadillac BLS

Opel Vectra C

GM used similar strategies with its "J" platform that debuted in mid-1981 in four of GM's divisions. Subsequent to that, GM introduced its "A" bodies for the same four divisions using the same tread width/wheelbase of the "X" body platform, but with larger body work to make the cars seem larger, and with larger trunk compartments. They were popular through the 1980s, primarily. Even Cadillac started offering a "J" body model called the Cimarron, a much gussied up version of the other four brands' platform siblings. A similar strategy applied to what is known as the N-J-L platform, arguably the most prolific of GM's efforts on one platform. Once more, GM's four lower level divisions all offered various models on this platform throughout the 1980s and into the 1990s.

1986 Opel Ascona C

1988 Pontiac Sunbird

1988 Cadillac Cimarron

Japanese carmakers have followed the platform sharing practice with Honda's Acura line, Nissan's Infiniti brand, and Toyota's Lexus marque, as the entry-level luxury models are based on their mainstream lineup. For example, the Lexus ES is essentially an upgraded and rebadged Toyota Camry After Daimler-Benz purchased Chrysler, Chrysler engineers used several M-B platforms for new models including the Crossfire which was based on the M-B SLK roadster. Other models that share platforms are the European Ford Focus, Mazda 3 and the Volvo S40.

Differences between shared models typically involve styling, including headlights, tail lights, and front and rear fascias. Examples also involve differing engines and drivetrains. In some cases such as the Lexus ES that is a Toyota Camry, "same car, same blueprints, same skeleton off the same assembly line in the same factory", but the Lexus is marketed with premium coffee in the dealership's showroom and reduced greens fees at Pebble Beach Golf Links as part of the higher-priced badge.

Platform sharing *may* be less noticeable now, however, it is still very apparent. Vehicle architectures primarily consist of "under the skin" components, and shared platforms can show up in unusual places, like the Nissan FM platform-mates Nissan 350Z sports car and Infiniti FX SUV. Volkswagen A platform-mates like the Audi TT and Volkswagen Golf also share much of their mechanical components but seem visually entirely different. Volkswagen Group and Toyota have both had much success building many well differentiated vehicles from many marques, from the same platforms. One of the least conspicuous recent examples is the Chevy Trailblazer and Chevy SSR; both use the GMT-360 platform. Opel Astra and Chevy HHR also share a platform yet are visually entirely different.

Advantages

- Easier inventory management/smaller number of parts

  Platform sharing allows for fewer parts for different models of vehicles and therefore the task of inventorying those parts is greatly reduced.

- Lower development costs

  Platform sharing allows manufacturers to cover many different market segments when a platform sharing strategy is implemented. This is exemplified by Ford Motor Co. in the case of the Ford Explorer, Mercury Mountaineer and Lincoln Aviator. They are essentially the same only they are considered mass-market, near luxury and luxury vehicles.

- Increased quality and innovation

  Platform sharing allows manufacturers to design parts with fewer variation. A byproduct of this is increased quality, which results in lower defect rates.

- Global standardization

  Platform sharing allows manufacturers to design flexible platforms that can be tailored to a country's specific needs without compromising quality. It also allows for manufacturing standardization and improved logistics.

- Greater product variety

  Platform sharing allows manufacturers to build/design differentiated products faster and cheaper. This is possible because the development and cost of the original platform have already been paid for.

Disadvantages

- Badge engineering

  Manufacturers that practice platform sharing have the ability to create several models based on the same design, but with different names. This leads to the public looking over certain models and cannibalized sales from competing divisions with essentially the same product. This was prevalent among U.S. domestic manufactures from the 1970s onward, e.g., the Chevrolet Trailblazer, GMC Envoy, Buick Rainier, Saab 9-7X, and Isuzu Ascender.

- Incompatible changes to platforms

The two elements of platforms are constant and non-constant. If the non-constant elements are not designed to be easily integrated into the constant elements of the platform, extensive and expensive changes will have to be made in order to make the elements compatible again. Failure to do so negates the purpose of platform sharing in that it increases costs as opposed to reducing them.

- Product dilution

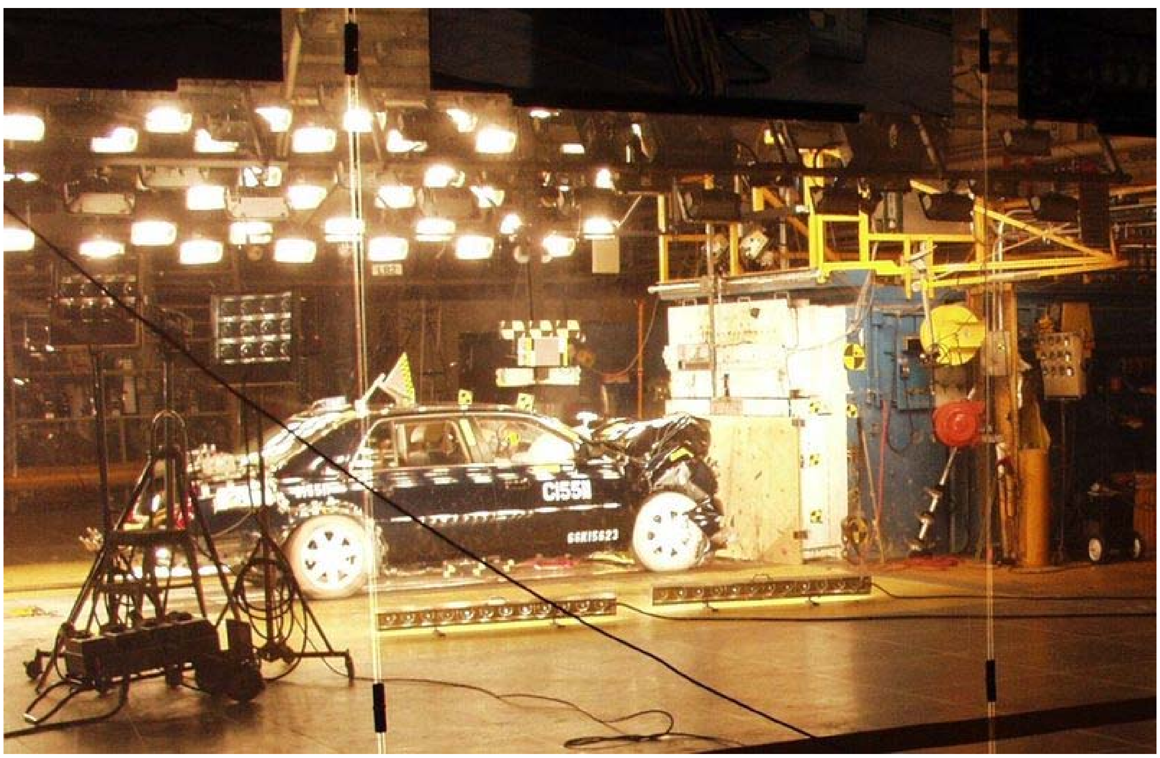
  Platform sharing has the ability to be used in too many different models. However, in the mind of the consumers, the products may be too similar and more expensive products may be perceived to be cheaper. For example, the perceived value of a "luxury" brand may be not as desirable if it is too similar to a mass-market version of the same platform. Conversely, platform sharing may increase the price of the economic models.

- Risk concentration/Higher recall rate

  The propensity for a higher number of recall is greatly increased with platform sharing. If a defect is found in one model and that model shares its platform with ten other models, the recall would be magnified by ten thus costing the manufacturer more time and money to fix. An example of problems spreading across platforms and numerous versions of models are the 2009–2011 Toyota vehicle recalls.

Chapter 8

Crumple Zone



A crash test illustrates how a crumple zone absorbs energy from an impact.

The crumple zone on the front of these cars absorbed the impact of a head-on collision.

Cross section to show the different strength of the metal in a Saab 9000. The safety cell is in stronger metal (red) compared to the crumple zones (yellow).

The **crumple zone** is a structural feature mainly of automobiles. Crumple zones have also been incorporated into railcars in recent years. They are designed to absorb the energy from the impact during an accident by controlled deformation. This energy is much higher than is commonly recognized. The severity of a collision with a pole or tree at 60 km/h is similar to driving over a 10 metre sheer drop and crashing onto a hard surface. Typically, crumple zones are located in the front part of the vehicle, in order to absorb the impact of a head-on collision, though they may be found on other parts of the vehicle as well. According to a British Motor Insurance Repair Research Centre study of where on the vehicle impact damage occurs: 65% were front impacts, 25% rear impacts, 5% left side, and 5% right side. Some racing cars use aluminium or composite/carbon fiber honeycomb to form an impact attenuator that dissipate crash energy using a much smaller volume and lower weight than road car crumple zones. Impact attenuators have also been introduced on highway maintenance vehicles in some countries.

An early example of the crumple zone concept was used by the Mercedes-Benz engineer Béla Barényi on the 1959 Mercedes-Benz *"Fintail"*. This innovation was first patented by Mercedes-Benz in the early 1950s. The patent 854157, granted in 1952, describes the decisive feature of passive safety. Barényi questioned the opinion prevailing till then, that a safe car had to be rigid. He divided the car body into three sections: the rigid nondeforming passenger compartment and the crumple zones in the front and the rear. They are designed to absorb the energy of an impact (kinetic energy) by deformation during collision.

On September 10 2009, ABC News 'Good Morning America' and 'World News' showed a U.S. Insurance Institute of Highway Safety crash test of a 2009 Chevrolet Malibu in an offset head-on collision with a 1959 Chevrolet Bel Air sedan. It dramatically demonstrated the effectiveness of modern car safety design, over 1950s design, particularly of rigid passenger safety cells and crumple zones.

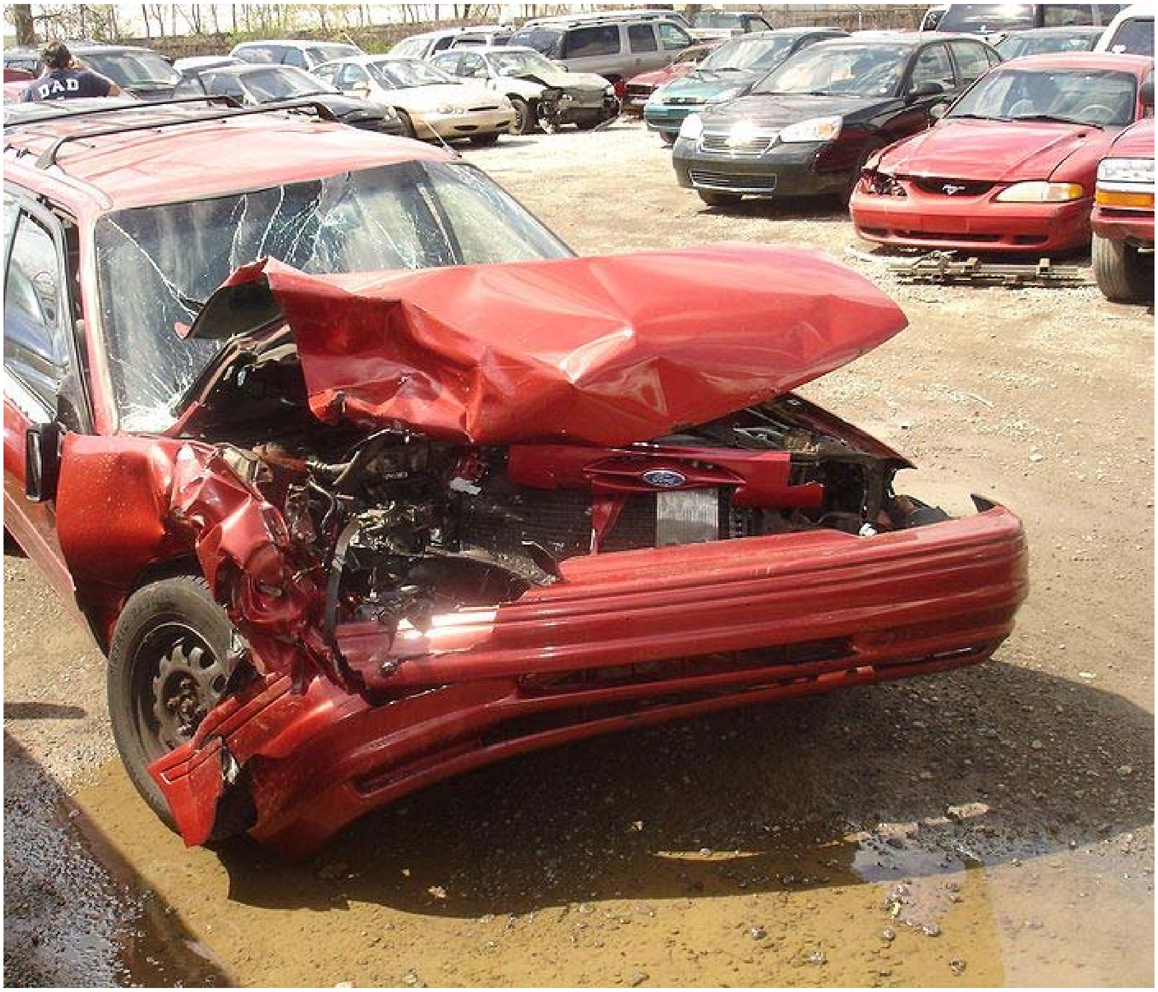
Function

Activated rear crumple zone.

Road Maintenance Truck Impact Attenuator, Auckland New Zealand.

Mazda 121 (re-badged Ford Fiesta) crash test car from the British Transport Research Laboratory.

VW Vento / Jetta activated front crumple zone.



A US Market Ford Escort that has been involved in a head-on collision with a Sport Utility Vehicle - showing the raised point of impact.

Crumple zones work by managing crash energy, absorbing it within the outer parts of the vehicle, rather than being directly transmitted to the occupants, while also preventing intrusion into or deformation of the passenger cabin. This better protects car occupants against injury. This is achieved by controlled weakening of sacrificial outer parts of the car, while strengthening and increasing the rigidity of the inner part of the body of the car, making the passenger cabin into a 'safety cell', by using more reinforcing beams and higher strength steels. Impact energy that does reach the 'safety cell', is spread over as wide an area as possible to reduce its deformation. Volvo introduced the side crumple zone, with the introduction of the SIPS (Side Impact Protection System) in the early 1990s.

When a vehicle and all its contents, including passengers and luggage are travelling at speed, they have inertia which means that they will want to continue forward with that direction and speed (Newton's first law of motion). In the event of a sudden deceleration of a rigid framed vehicle due to impact, unrestrained vehicle contents will continue forwards at their previous speed due to inertia, and impact the vehicle interior, with a force equivalent to many times their normal weight due to gravity. The purpose of crumple zones is to slow down the collision and to absorb energy, to reduce the difference in speeds between the vehicle and its occupants.

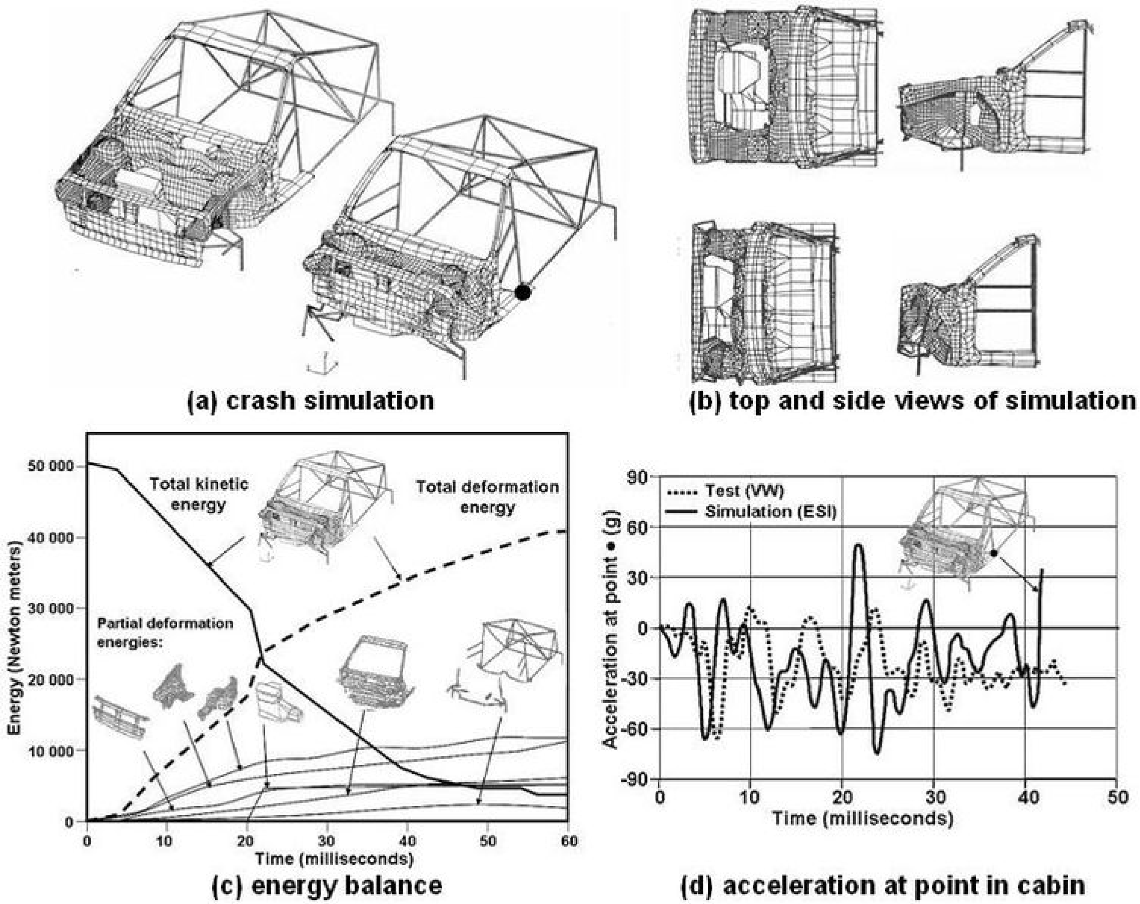
Seatbelts restrain the passengers so they don't fly through the windshield, and are in the correct position for the airbag and also spread the loading of impact on the body. Seat belts also absorb passenger inertial energy by being designed to stretch during an impact, again to reduce the speed differential between the passenger's body and their vehicle interior. In short: A passenger whose body is decelerated more slowly due to the crumple zone (and other devices) over a longer time, survives much more often than a passenger whose body indirectly impacts a hard, undamaged metal car body which has come to a halt nearly instantaneously. It is like the difference between slamming someone into a wall headfirst (fracturing their skull) and shoulder-first (bruising their flesh slightly) is that the arm, being softer, has tens of times longer to slow its speed, yielding a little at a time, than the hard skull, which isn't in contact with the wall until it has to deal with extremely high pressures.

A Toyota Camry after a front impact with a tree. Airbags were deployed.

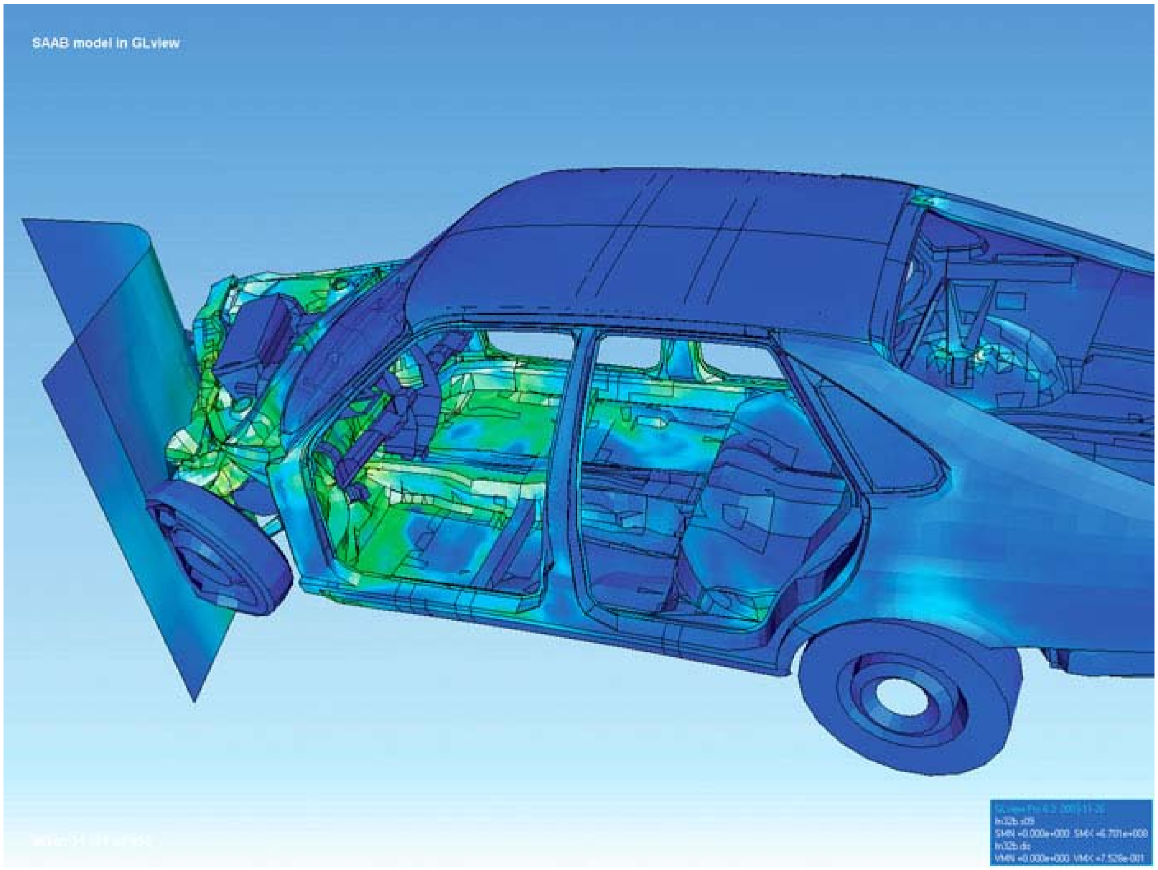
The final impact after a passenger's body hits the car interior, airbag or seat belts, is that of the internal organs hitting the ribcage or skull, due to their inertia. The force of this impact is the way through which many car crashes cause disabling or life threatening injury. Other ways are skeletal damage and blood loss. The sequence of energy dissipating and speed reducing technologies - crumple zone - seat belt - airbags - padded interior, are designed to work together as a system, to reduce the force of the impact on the outside of the passengers body and the final impact of organs inside the body.

A common misconception about crumple zones is that they reduce safety by allowing the vehicle's body to collapse, allowing the crushing of the vehicle occupants. In fact, crumple zones are typically located in front and behind of the main body (though side impact absorption systems are starting to be introduced), of the car (which forms a rigid 'safety cell'), compacting within the space of the engine compartment or boot/trunk. The marked improvement over the past two decades in high speed crash test results and real-life accidents also belies any such fears. Modern vehicles using what are commonly termed 'crumple zones', provide far superior protection for their occupants, in severe tests against other vehicles with crumple zones and solid static objects, than older models or SUVs, that use a separate chassis frame and have no crumple zones. They do tend to come off worse when involved in accidents with SUVs without crumple zones, because most of the energy of the impact is absorbed by the vehicle with the crumple zone. Another problem is 'impact incompatibility' where the 'hard points' of the end of chassis rails of SUVs are higher than the 'hard points' of cars causing the SUV to 'override' the engine compartment of the car. In order to tackle this problem recent Volvo SUV/off-roaders incorporate structures below the front bumper designed to engage lower height car crumple zones.

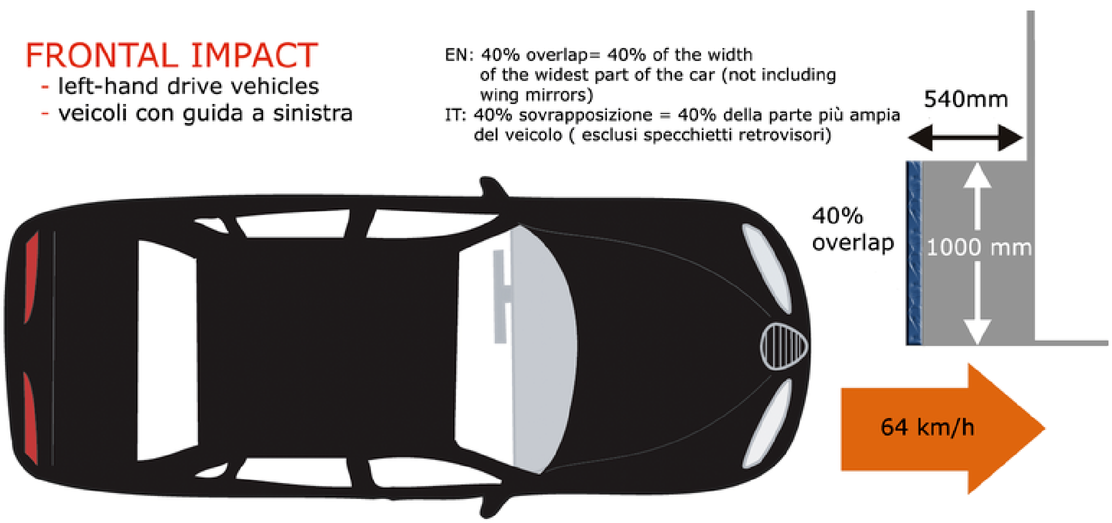
Computer Modelled Crash Simulation



VW POLO first successful frontal full car crash simulation (ESI 1986).



Visualisation of how a car deforms in an asymmetrical crash using finite element analysis.



EuroNCAP FRONTAL IMPACT (left-hand drive vehicles).

Lotus Evora front crash test showing Aluminium chassis crush structure, the height of the rigid front chassis side beams and rigid front cross beam.

In the early 1980s, using technology developed for the aerospace and nuclear industries, German car makers started complex computer crash simulation studies, using finite element methods simulating the crash behaviour of individual car body components, component assemblies, and quarter and half cars at the body in white(BIW) stage. These experiments culminated in a joint project by the Forschungsgemeinschaft Automobil-Technik (FAT), a conglomeration of all seven German car makers (Audi, BMW, Ford, Mercedes-Benz, Opel (GM), Porsche, and Volkswagen), which tested the applicability of two emerging commercial crash simulation codes. These simulation codes recreated a frontal impact of a full passenger car structure (Haug 1986) and they ran to completion on a computer overnight. Now that turn-around time between two consecutive jobsubmissions (computer runs) did not exceed one day, engineers were able to make efficient and progressive improvements of the crash behaviour of the analyzed car body structure. The drive for improved crash worthiness in Europe has accelerated from the 1990s onwards, with the 1997 advent of Euro NCAP, with the involvement of Formula 1 expertise.

The 2004 Pininfarina *Nido* Experimental Safety Vehicle locates crumple zones *inside* the Survival Cell. Those interior crumple zones decelerate a sled-mounted survival cell.

Chapter 9

Spoiler (Automotive)

The Plymouth Superbird is famous for its giant rear spoiler.

1987 Audi Sport QuattroS1 Pikes Peak

A **spoiler** is an automotive aerodynamic device whose intended design function is to 'spoil' unfavorable air movement across a body of a vehicle in motion. Spoilers on the front of a vehicle are often called **air dams**, because in addition to directing air flow they also reduce the amount of air flowing underneath the vehicle which reduces aerodynamic lift. Spoilers are often fitted to race and high-performance sports cars, although they have become common on passenger vehicles as well. Some spoilers are added to cars primarily for styling purposes and have either little aerodynamic benefit or even make the aerodynamics worse.

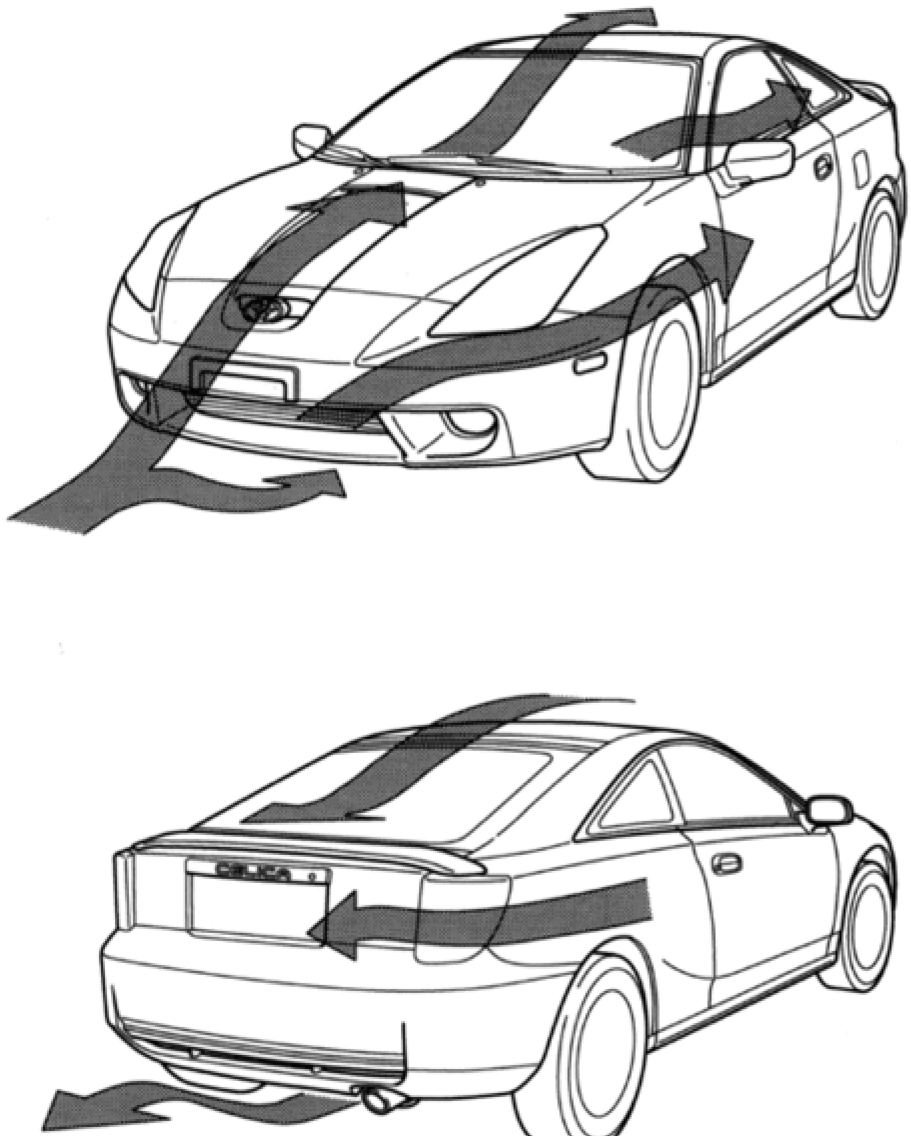
Spoilers for cars are often incorrectly confused with, or the term used interchangeably with, wings. Automotive wings are devices whose intended design is to generate downforce as air passes around them, not simply disrupt existing airflow patterns.

Operation

Spoilers function by disrupting airflow passing over and around a moving vehicle. This diffusion is accomplished by increasing amounts of turbulence flowing over the shape, "spoiling" the laminar flow and providing a cushion for the laminar boundary layer. Often spoilers are added solely for appearance with no thought towards practical purpose.

Passenger vehicles

This Toyota MR2 sports car has a factory-installed rear spoiler.



A rear Spoiler is Standard Equipment on many Celica Models.

The main design goal of a spoiler in passenger vehicles is to reduce drag and increase fuel efficiency. While many often imitate wings and airfoils, these serve mostly decorative purposes. Passenger vehicles can be equipped with front and rear spoilers. Front spoilers, found beneath the bumper, are mainly used to direct air flow away from the tires to the underbody where the drag coefficient is less. Rear spoilers, which modify the transition in shape between the roof and the rear and the trunk and the rear, act to minimize the turbulence at the rear of the vehicle.

Sports cars are most commonly seen with front and rear spoilers. Even though these vehicles typically have a more rigid chassis and a stiffer suspension to aid in high speed maneuverability, a spoiler can still be beneficial. This is because many vehicles have a fairly steep downward angle going from the rear edge of the roof down to the trunk or tail of the car. At high speeds, air flowing across the roof tumbles over this edge, causing air flow separation. The flow of air becomes turbulent and a low-pressure zone is created, increasing drag and instability. Adding a rear spoiler makes the air "see" a longer, gentler slope from the roof to the spoiler, which helps to delay flow separation. This decreases drag, increases fuel economy, and helps keep the rear window clean.

Due to their association with racing, spoilers are often viewed as "sporty" by consumers.

Material types

Spoilers are usually made of:

- ABS plastic – Most original equipment manufacturers create spoilers produced by casting ABS plastic with various admixtures, which bring in plasticity to this inexpensive but fragile material. Frailness is a main disadvantage of plastic, which increases with product age and is caused by the evaporation of volatile phenols.
- Fiberglass – Used in car parts production due to the low cost of the materials. Fiberglass spoilers consist of fiberglass cloth infilled with a thermosettting resin . Fiberglass is sufficiently durable and workable, but has become unprofitable for large scale production due to the amount of labor.
- Silicon – More recently, many auto accessory manufacturers are using silicon-organic polymers. The main benefit of this material is its phenomenal plasticity. Silicon possesses extra high thermal characteristics and provides a longer product lifetime.
- Carbon fiber – Carbon fiber is light weight, durable, but also a very expensive material. Due to the very large amount of manual labor , large scale production cannot widely use carbon fiber in automobile parts production currently.

Other vehicles

Heavy trucks, like long haul tractors, may also have a spoiler dome on the top of the cab in order to lessen drag caused from air resistance from the trailer it's towing, which may be taller than the cab and provide a very non-aerodynamic effect. These spoilers primarily increase fuel economy instead of improving handling, however.

Trains may use spoilers to induce drag (like an air brake). A new prototype Japanese high-speed train, the Fastech 360 is designed to reach speeds of 250 mph. Its nose is specifically designed to spoil a wind effect associated with passing through tunnels, and it can deploy 'ears' which act to slow the train in case of emergency by increasing its drag.

Some modern race cars employ a situational spoiler called a roof flap. These roof flaps deploy when the body of the car is rotated so it is traveling in reverse. The car will then generate lift instead of countering it. The roof flaps deploy because they are recessed into a pocket in the roof. The low pressure above this pocket will cause the flaps to deploy, and counteract some of the lift generated by the car.

Whale tail

Original *whale tail* as introduced on the 1975 3.0 litre Porsche 930 turbo.

An earlier use of the term whale tail, now used to refer to a visible thong, dates back to August 1974, when the Porsche 911 Turbo debuted with large, flared, rear spoilers that were immediately dubbed whale tails. Designed to reduce rear-end lift and so keep the car from oversteering at high speeds, the rubber-edges of the whale tail spoilers were thought to be "pedestrian friendly". The Turbo, with its whale tail, became an instant hit. It also became one of the world's most recognizable sports cars, remaining in production for the next two decades in one form or another, with more than 23,000 sold by 1989, although from 1978, the rear spoiler was redesigned and dubbed 'teatray' on account of its raised sides. The Porsche 911 whale tails were used in conjunction with a chin spoiler attached to the front valence panel, which, according to some sources, did not enhance aerodynamic stability. It has been found to be less effective in multiplying downforce than newer technologies like an airfoil, "rear wing running across the base of the tailgate window", or "an electronically controlled wing that deploys at about 50 mph".

History

Duck tail on a 1973 Porsche 911 Carrera RS.

The whale tail came on the heels of the 1973 "duck tail" or *Bürzel* in German (as a part of the E-program), a smaller and less flared rear-spoiler fitted to 911 Carrera RS (meaning *Rennsport* or race sport in German), optional outside Germany. The whaletail was originally designed for Porsche 930 and Porsche 935 race cars in 1973, and introduced to the Turbo in 1974 (as a part of the H-program), it was also an option on non-turbo Carreras from 1975. Both types of spoilers were designed while Dr. Ernst Fuhrmann was serving as the Technical Director of Porsche AG. In 1976, a rubber front chin spoiler was also introduced to offset the more effective spoiler. By 1978, Porsche introduced another design for the rear spoiler, the 'teatray, a boxier enclosure which accommodated the intercooler, and was also an option for the 911SC.

Other vehicles

These whale tail spoilers of the Porsche 911 caught on as a fashion statement, and the term has been used to refer to large rear spoilers on a number of automobiles, including Ford Sierra RS, Focus, Chevrolet Camaro, and Saab 900. Whale tail spoilers also appear at the rear of tricycles, trucks, boats, and other vehicles.

Dodge Charger Daytona

This Ford Sierra RS Cosworth has a factory-installed rear spoiler.

Porsche 911

Porsche Carrera RSR

Mitsubishi Lancer Evolution aftermarket spoiler

Mercedes CLK GTR

Porsche 911 GT1

Ferrari F50

Chapter 10

Power Window

Power windows or **electric windows** (American English) as well as electric or power window **lifts** (British English) are automobile windows which can be raised and lowered by depressing a button or switch, as opposed to using a hand-turned crank handle.

History

Typical window switches with remote disable control on driver's door (1993 Jeep Grand Cherokee).

Window controls on center console between front seats (2005 Saab 9-5).

Packard introduced the first power windows (along with automotive air-conditioning systems) in the 1940 Packard 180 series. This was a hydro-electric system. In 1941, the Ford Motor Company followed quickly with power windows on the Lincoln Custom (only the limousine and seven-passenger sedans). Cadillac had a straight-electric divider window (but not side windows) on their series 75 limousines immediately prior to World War II.

Power assists originated in the need and desire to move convertible body-style tops up and down by some means other than human effort. The earliest power assists were vacuum-operated and were offered on Chrysler Corporation vehicles, particularly the low-cost Plymouth convertibles in the late 1930s.

Shortly before World War II, General Motors developed a central hydraulic pump for working convertible tops. This system was introduced on 1942 convertibles built by GM. Previously, GM had used a vacuum system which did not have the power to handle increasingly larger and complex (four side-windows vs. only two) convertible top mechanisms.

The June and July 2010 issues of "The Self-Starter", the official magazine of the International Cadillac-LaSalle Club, contain references to the use of various types of power window mechanisms in pre-WWII specially modified Cadillac sedans. These Cadillac-built (as opposed to private coachbuilder) models used three types of power mechanisms - straight electric, straight vacuum (much as the power antenna mechanisms used on Cadillacs through 1955) and the soon-to-be-standard electro-hydraulic system. The July 2010 edition also references a 1941 specially modified Cadillac Model 6219 four-door sedan built for the Chairman of the GM Board, Alfred P. Sloan, that had power window mechanisms, although the type is not specified.

Chief Engineer of the Buick Division, Charles A. Chayne, "...had introduced an electrically controlled hydraulic system into the 1946 Buick convertibles that provided fingertip operation of the top, door windows, and front seat adjustment". Apparently Chayne was a pioneer in these types of systems. These systems were based on major hydraulic advances made in military weapons (tanks, aircraft) in preparation for World War II.

The "Hydro-Lectric" system (windows, front seat adjustment and convertible top) was standard on 1947 model year . It was probably standard on the 1946 convertible models. Despite the fact that no specific documentation has been found in sales literature (on internet searches), the January 2011 issue of "The Self-Starter", the official magazine of the Cadillac-La Salle Club, lists a 1946 model 6267D Convertible for sale with "hydraulic windows". This appears to confirm that the accessory (including the electro-hydraulic front bench seat and convertible top) were available on post-war Cadillac models.

The seat and window assist system was optional on closed cars (standard on some Cadillac Series 75 models). The full system was standard only on the high-end GM convertibles made by Oldsmobile, Buick, and Cadillac. It was only available as a package; that is, power assisted windows, front seat and convertible top (where applicable). This feature can be identified in 1948 and later General Motors model numbers with an "X" at the end, such as the 1951 Cadillac Sixty Special sedan, model 6019X .

Ford also had a similar electro-hydraulic system on higher-end convertibles (Mercury and Lincoln) by 1951. These systems were used by other luxury car models (Imperial and Packard) until Chrysler introduced the all-electric operation on the 1951 Imperial. General Motors also followed with full electric operation in 1954. This included four-way and then six-way seats, which were introduced in 1956. Chevrolet introduced the oddity of power front windows (only) in the 1954 model. Ford also introduced full four-door power windows in 1954.

Electrically-operated vent windows were available as early as 1956 on the Continental Mark II. The 1960s Cadillac Fleetwood came standard with power front and rear vent windows, in addition to standard power side windows, for a total of eight power window controls on the driver's door panel.

Modern heavy-duty highway tractors frequently have an option for power window controls; however, these are generally what is referred to as "straight air". That is, the compressed air system used for air brakes is also used for the windows. These types of trucks have long used compressed air cylinders for seat height adjustment. In a similar fashion to the electro-hydraulic system, the compressed air is merely released to lower the window and/or seat. The compressed air is then admitted to the respective cylinder to raise the window or seat.

In a typical auto/light truck installation, there is an individual switch at each window and a set of switches in the driver's door or a-frame pillar, so the driver can operate all the windows. These switches took on many different appearances, from heavy chrome plate to inexpensive plastic.

However, some models like Saab and Holden have used switches located in the center console, where they are accessible to all the occupants. In this case, the door-mounted switches can be omitted.

Operation

Power windows are usually inoperable when the car is not running as the electrical system is not 'live' once the ignition has been turned off. The Hydro-Lectric system; however, could lower the windows at rest, since pressure from the hydraulic system was merely released to lower the window. Raising the windows required the pump to operate (at a fairly high noise level) and introduce pressure at each cylinder. These hydraulic systems also required pressure lines to each cylinder (door, seat and top) and tended to leak.

Many modern cars have a time delay feature, first introduced by Cadillac in the 1980s, called **retained accessory power**. This allows operation of the windows and some other accessories for ten minutes or so after the engine is stopped. Another feature is the **express-down** window, which allows the window to be fully lowered with one tap on the switch, as opposed to holding the switch down until the window retracts. Many luxury vehicles during the 1990s expanded on this feature, to include **express-up** on the driver's window, and recently, some manufacturers have added the feature on all window switches for all passengers convenience. This is done by activating the switch until a "click" response is felt.

Power windows have become so common that by 2008, some automakers eliminated hand cranks from all models. So many vehicles have power windows that some people no longer understand the (formerly) common sign from another driver of using their hand to simulate moving a window crank to indicate that they wish to speak with someone (stopped at a light or in a parking lot).

Safety

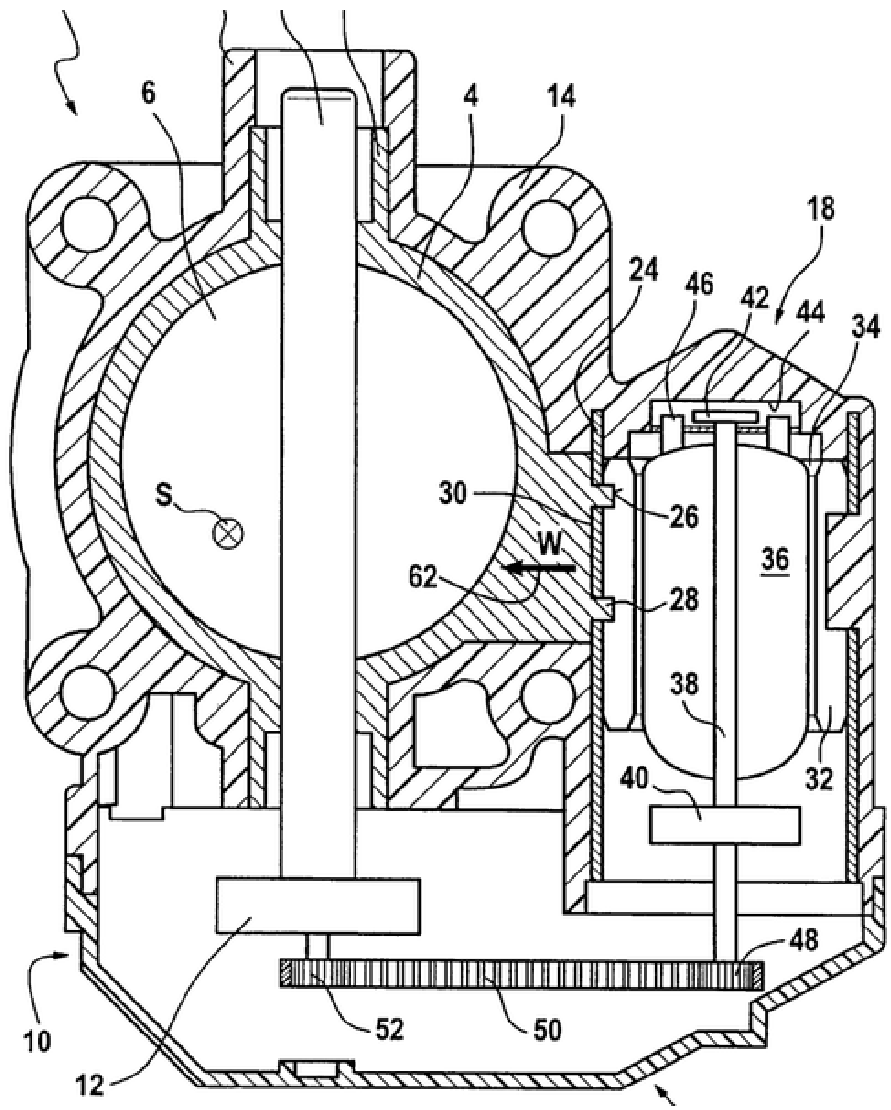
Power windows have come under some scrutiny after several fatal accidents in which children's necks have become trapped, leading to suffocation. Some designs place the switch in a location on a hand rest where it can be accidentally triggered by a child climbing to place his or her head out of the window. To prevent this, many vehicles feature a driver-controlled lockout switch, preventing rear-seat passengers (usually smaller children) from accidentally triggering the switches. This also prevents children from using them as toys and pets riding with their heads out windows from activating the power window switch.

Starting with the 2008 model year, U.S. government regulations required automakers to install power window controls that are less likely to be accidentally activated by children. However, the rules do not prevent all potential injuries to a hand, finger, or even a child's head, if someone holds the switch when the window is closing. In 2009, the U.S. auto safety administration tentatively decided against requiring all cars to have automatic reversing power windows if they sense an obstruction while closing. Proposed requirements concern "one-touch" up window systems, but most vehicles with this feature already have automatic-reversing. The federal government made a written contract that all automakers should make the lever switches (as opposed to the rocker and toggle switches) standard on all new vehicles by 1 October 2010.

Chapter 11

Electronic Throttle Control and Rear-View Mirror

Electronic throttle control



Throttle body with integrated motor actuator

Electronic throttle control (ETC) is an automobile technology which severs the mechanical link between the accelerator pedal and the throttle. Most automobiles already use a throttle position sensor (TPS) to provide input to traction control, antilock brakes, fuel injection, and other systems, but use a bowden cable to directly connect the pedal with the throttle. An ETC-equipped vehicle has no such cable. Instead, the electronic control unit (ECU) determines the required throttle position by calculations from data measured by other sensors such as an accelerator pedal position sensor, engine speed sensor, vehicle speed sensor etc. The electric motor within the ETC is then driven to the required position via a closed-loop control algorithm within the ECU.

The benefits of ETC are largely unnoticed by most drivers because the aim is to make the vehicle power-train characteristics seamlessly consistent irrespective of prevailing conditions, such as engine temperature, altitude, accessory loads etc. However, acceleration response may occasionally be slower than with cable-driven throttle. The ETC is also working 'behind the scenes' to dramatically improve the ease with which the driver can execute gear changes and deal with the dramatic torque changes associated with rapid accelerations and decelerations.

ETC facilitates the integration of features such as cruise control, traction control, stability control, and precrash systems and others that require torque management, since the throttle can be moved irrespective of the position of the driver's accelerator pedal. ETC provides only a very limited benefit in areas such as air-fuel ratio control, exhaust emissions and fuel consumption reduction, working in concert with other technologies such as gasoline direct injection.

A criticism of the very early ETC implementations was that they were "overruling" driver decisions. Nowadays, the vast majority of drivers have no idea how much intervention is happening. Much of the engineering involved with drive-by-wire technologies including ETC deals with failure and fault management. Most ETC systems have sensor and controller redundancy, even as complex as independent microprocessors with independently written software within a control module whose calculations are compared to check for possible errors and faults.

Anti-lock braking (ABS) is a similar safety critical technology, whilst not completely 'by-wire', it has the ability to electronically intervene contrary to the driver's demand. Such technology has recently been extended to other vehicle systems to include features like brake assist and electronic steering control, but these systems are much less common, also requiring careful design to ensure appropriate back-up and fail-safe modes.

Failure modes

Before drive by wire technology was introduced, if a throttle stuck open a driver could generally put a toe under the accelerator and lift up. Occasionally after servicing or repair, the wire or cable between the accelerator and throttle would not be correctly reinstalled causing sudden acceleration. However, with the ETC, the movement is all done by electronic controls moving an electric motor. But just moving the throttle by sending a signal to the motor is an open loop condition and leads to poor control. Most if not all current ETC systems have a closed loop system whereby the ECU tells the throttle to open a certain amount according to an algorithm based on the geometry of the throttle. Then, if due to dirt build up in the throttle bore or a damaged TPS a signal is sent from the TPS to the ECU, the ECU can make appropriate adjustments to compensate, though it might result in surging, hesitation or uneven idle.

There are two primary types of throttle position sensors: a potentiometer or a Hall Effect sensor (magnetic device). The potentiometer is a satisfactory way for non-critical applications such as volume control on a radio, but as it has a wiper contact rubbing against a resistance element, and dirt and wear between the wiper and the resistor can cause erratic readings. The more reliable solution is the magnetic coupling that makes no physical contact, so will never be subject to failing by wear.

This is an insidious failure as it may not provide any symptoms until there is total failure. All cars having a TPS have what is known as a 'limp-home-mode'. When the car goes into the limp-home-mode it is because the accelerator and engine control computer and the throttle are not talking to each other in a way that they can understand. The engine control computer shuts down the signal to the throttle position motor and a set of springs in the throttle set it to a fast idle, fast enough to get the transmission in gear but not so fast that driving may be dangerous.

Recently, ETC has been suspected by some to be responsible for some incidents of unintended acceleration in Toyota and Lexus vehicles. This is fiercely disputed by Toyota, which blames unintended acceleration on owners, weather mats, and most recently defective gas pedals (outsource production).

Rear-view mirror

Rear-view mirror showing cars parked behind the vehicle containing the mirror

Triple mirror in a Irizar Eurorider bus

A **rear-view mirror** is a mirror in automobiles and other vehicles, designed to allow the driver to see rearward through the vehicle's backlight (rear windscreen).

In cars, the rear-view mirror is usually affixed to the top of the windscreen on a swivel mount allowing it to be freely rotated. In the past, some cars had the rear-view mirror mounted on top of the dashboard. Rear-view mirrors are designed to break away to minimize injury to occupants who may be thrown against it in a collision.

For motorcycles and bicycles, the rear-view mirrors are usually mounted to the handlebars, and there are usually two of them, so they are variously referred to as "rear-view mirrors", "side-view mirrors", "side mirrors", or simply "mirrors".

History

Ray Harroun's Marmon "Wasp" with its rear-view mirror mounted on struts above the car on display in the Indianapolis Motor Speedway Hall of Fame Museum.

The rear-view mirror's earliest known use and mention is by Dorothy Levitt in her 1906 book *The Woman and the Car* which noted that women should "carry a little hand-mirror in a convenient place when driving" so they may "hold the mirror aloft from time to time in order to see behind while driving in traffic", thereby inventing the rear view mirror before it was introduced by manufacturers in 1914. The earliest known rear-view mirror mounted on a motor vehicle appeared in Ray Harroun's Marmon racecar at the inaugural Indianapolis 500 race in 1911. Although Harroun's is the first known use of such a mirror on a motor vehicle, Harroun himself claimed he got the idea from seeing a mirror used for the same purpose on a horse-drawn vehicle in 1904.

Elmer Berger is usually credited with inventing the rear-view mirror, though in fact he was the first to develop it for incorporation into production streetgoing automobiles.

Augmentations and alternatives

Rear-view mirrors are usually augmented with side-view mirrors on the driver's and/or passenger's side of the vehicle.

Recently, rear-view video cameras have been built into many new model cars, such as the Mazda Hakaze Concept. This was partially in response to the rear-view mirrors' inability to show the road directly behind the car, due to the rear deck or trunk obscuring as much as 3–5 metres (10–15 feet) of road behind the car. For example, as many as 50 times a year, small children are killed by SUVs in America because the driver cannot see them in their rear-view mirrors. These camera systems are usually mounted to the bumper or lower parts of the car allowing for better rear visibility.

Aftermarket secondary rear-view mirrors are available. They attach to the main rear-view mirror and are independently adjustable to view the back seat. This is useful to parents to monitor their children in the backseat.

Dimming

Glare from a following vehicle's headlamps in a rear view mirror

A prismatic rear-view mirror — sometimes called a "day/night mirror" — can be tilted to reduce the brightness and glare of lights, mostly for headlights shining directly on the eye level at night. This type of mirror is made of a piece of glass that is wedge-shaped in cross section—its front and rear surfaces are not parallel.

On manual tilt versions, a tab is used to adjust the mirror between "day" and "night" positions. In the day view position, the front surface is tilted and the reflective back side gives a strong reflection. When the mirror is moved to the night view position, its reflectorized rear surface is tilted out of line with the driver's view. This view is actually a reflection off the non-reflectorized front surface. Since the non-reflectorized front surface allows most of the light to go through, only a small amount of light is reflected into the driver's eyes.

Automatic dimming

Other rear-view mirrors have electronic auto-dimming feature built in so the driver is not blinded by glare. These systems usually use photo sensors mounted in the actual rear-view mirror to detect light and dim the mirror. These designs include an older mechanical dimming feature and a more modern electrochromic dimming feature. This electrochromic feature has been also incorporated into side-view mirrors allowing them to dim and reduce glare as well. Mirrors containing such features can, however, be not sensitive enough for many drivers.

Several Chrysler Corporation cars offered automatic dimming mirrors as optional equipment as early as 1959, but few customers ordered them for their cars and the item was soon shelved. Several automakers began offering rearview mirrors with automatic dimming again in 1983, and it was in the late 1980s that they began to catch on in popularity.

Motorcycles

Depending on the type of motorcycle, the motorcycle may or may not have rear-view mirrors. Street-legal motorcycles are generally required to have rear-view mirrors. Motorcycles for off-road use only normally do not have rear-view mirrors. Rear-view mirrors come in various shapes and designs, and have various methods of mounting the mirrors to the motorcycle, most commonly to the handlebars. Rear-view mirrors can also be attached to the rider's motorcycle helmet.

Bicycles

A bicycle with rear-view mirrors formerly on an automobile.

Some bicycles are equipped with rear-view mirrors mounted to the handlebars. Cyclists may also choose to mount rear-view mirrors to a helmet or the frame of a pair of eyeglasses, or the basket of the bicycle.

Computers

In an effort to prevent Identity theft, some computer users make use of rear-view mirrors to discourage others from looking over the user's shoulder and seeing sensitive information. These are especially prevalent on automated teller machines.

Chapter 12

Radar Detector

An early radar detector

Car radar detector (Japanese)

A **radar detector** is a passive electronic device used by motorists to detect if their speed is being monitored by a radar gun. Most radar detectors are used so the driver can reduce the car's speed before being ticketed for speeding. Only doppler radar-based devices can be detected — other speed measuring devices including those using ANPR, piezo sensors, and VASCAR technology cannot be detected. LIDAR devices require a different type of sensor, although many modern detectors include LIDAR sensors. Most of today's radar detectors detect signals across a variety of wavelength bands: usually X, K, and K_a. In Europe the K_u band is common as well.

Description

One of the technologies that law enforcement agencies can use to measure the speed of a moving vehicle uses doppler radar to beam a radio wave at the vehicle, and then infer the vehicle's speed by measuring the Doppler effect-moderated change in the reflected wave's frequency. Radar guns can be hand-held, vehicle mounted or mounted on a fixed object, such as a traffic signal.

Radar detectors use a superheterodyne receiver to detect these electromagnetic emissions from the radar gun, and raise an alarm to notify the motorist when a transmission is detected. False alarms can occur however due to the large number of devices, such as automatic door openers (such as the ones at supermarkets), that operate in the same part of the electromagnetic spectrum as radar guns.

In recent years some radar detectors have added GPS technology. This allows users to manually store the locations where police frequently monitor traffic, with the detector sounding an alarm when approaching that location in the future (this is accomplished by pushing a button and doesn't require coordinates to be entered). These detectors also allow users to manually store the coordinates of sites of frequent false alarms, which the GPS enabled detector will then ignore. Some GPS enabled detectors can download the GPS coordinates of speed monitoring cameras and redlight cameras from the internet, which are contained in the Trinity database. A traveler from out of state, passing through Arizona for example, would receive an alarm when approaching the location of a speed monitoring camera.

Counter technology

Radar guns and detectors have evolved alternately over time to counter each other's technology in a form of civilian electronic "warfare". For example, as new frequencies have been introduced, radar detectors have initially been "blind" to them until their technology too has been updated. Similarly, the length of time and strength of the transmissions have been lowered to reduce the chance of detection, which in turn has resulted in more sensitive receivers and more sophisticated software counter technology. Lastly, radar detectors may combine other technologies, such as GPS-based technology with a point of interest database of known speed trapping locations, into a single device to improve their chances of success.

Radar detector detectors

The superheterodyne receiver in radar detectors has a local oscillator that radiates slightly, so it is possible to build a radar-detector detector, which detects such emissions (usually the frequency of the radar type being detected, plus about 10 MHz). The VG-2 Interceptor was the first device developed for this purpose, but has since been eclipsed by the Spectre III. This form of "electronic warfare" cuts both ways - since detector-detectors use a similar superheterodyne receiver, many early "stealth" radar detectors were equipped with a radar-detector-detector-detector circuit, which shuts down the main radar receiver when the detector-detector's signal is sensed, thus preventing detection by such equipment. This technique borrows from ELINT surveillance countermeasures. In the early 1990s, BEL-Tronics, Inc. of Ontario, Canada (where radar detector use is prohibited) found that the local oscillator frequency of the detector could be altered to be out of the range of the VG-2 Interceptor. This resulted in detector manufacturers responding by changing their local oscillator frequency. Today, practically every radar detector on the market is immune to the VG-2 Interceptor.

Radar scrambling

Although some companies advertise that their radar detectors can passively 'scramble' or 'absorb' radar (such as Rocky Mountain Radar), many or all of their products do not affect radar and laser equipment due to the low power intake from the device versus the high power that bounces off a vehicle.

It is illegal in many countries to sell or possess any products that actively transmit radar signals intended to jam radar equipment. In the United States, actively transmitting on a frequency licensed by the Federal Communications Commission (FCC) without a license is a violation of FCC regulations, which may be punishable by fines up to $10,000 and/or up to one year imprisonment.

Passport x50 Radar/Laser detector.

LIDAR Detection

Newer speed detection devices use pulsed laser light, commonly referred to as LIDAR, rather than radio waves. Radar detectors, which detect radio transmissions, are therefore unable to detect the infrared light emitted by LIDAR guns so a different type of device called a LIDAR detector is required. LIDAR detection, however, is not nearly as effective as radar detection because the output beam is very focused. While radar's radio waves can expand to 85 feet (26 m) across at 1,000 feet (300 m) from their source, LIDAR's light beam diffuses to only about 6 feet (1.8 m). Also, a police officer targeting a car will most likely aim for the center mass or headlight of the vehicle and, because radar detectors are mounted on the windshield away from the beam's aim, they may not alert at all. Lastly, with such a focused beam, an officer using a LIDAR gun can target a single car in close proximity to others at ranges of up to 3,000 feet (910 m).

Despite the advent of LIDAR speed detection, radar remains more prevalent because of its lower price relative to LIDAR equipment and the amount of radar equipment already in service.

Legality

Using or possessing a radar detector or jammer is illegal in certain countries, and it may result in fines, seizure of the device, or both. These prohibitions generally are introduced under the premise that a driver who uses a radar detector will pose a greater risk of accident than a driver who does not. However the 2001 Mori report suggests that radar detector users posed a 28% less risk of accident. The table below provides information about laws regarding radar detectors in particular nations. In 1967 devices to warn drivers of radar speed traps were being manufactured in the United Kingom; they were deemed illegal under the Wireless Telegraphy Act 1949.

Country	Legality	Comment	Radar Bands
Australia	Illegal in all states besides Western Australia	They are illegal to use in a moving vehicle (as stated by the traffic laws in) SA, NSW, ACT and Victoria as well as NT, Queensland and Tasmania. Heavy fines apply, ranging from $200 – $1200 AUD, up to 9 demerit points, and confiscation of the Radar Detector. However, importing a unit is permitted under Australian customs regulations. Queensland = up to 40 penalty units (x$75 =$3000) for being in or on a vehicle whether or not the device is operating or in working order.	K, Ka, Laser
Belgium	Illegal	In July 2006, a provisional seizure of a vehicle worth over 75.000 EUR itself was ordered by the courts, destruction of the radar detector itself and the	

		driver's license was suspended for 3 months.	
Brazil	Illegal in all states.		
Bulgaria	Detectors legal, jammers illegal.	Radar jammers are illegal.	X, K (fixed camera+radar)
Canada	• Illegal: Newfoundland & Labrador, Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, Manitoba, the Yukon Territory, the Northwest Territories: • Legal: Alberta, British Columbia, Saskatchewan	Regardless of whether they are used or not, police there may confiscate radar detectors, operational or not, and impose substantial fines in provinces where radar detectors are illegal.	
Croatia	Detectors and jammers are illegal.	HRK 2000 (€ 270) fine.	
Czech Republic	Detectors legal, jammers illegal.	Fine up to CZK 200,000 (€ 7750), penalty points.	Ka
Egypt	Detectors and jammers are illegal.		
Estonia	Illegal to use or have in a motor vehicle.	Fine up to 18000 EEK (€ 1150) as well as confiscation of the device.	
France	*Illegal	Regardless of whether they are used or not, police there may confiscate radar detectors, operational or not, and impose substantial fines.	
Finland	Illegal to use or have in a motor vehicle on a public road.	The fine depends on income. The detector will be confiscated.	POP Ka
Germany	Legal to own, illegal to use in a moving vehicle	75€ fine , 4 Points, destruction of the radar detector.	
Greece	Illegal	2000€ fine , 30 day driver's license suspension, 60 days car registration license suspension and 5 SESO penalty points	
Hungary	Legal, no limitations		

India	Legal		
Iceland	Legal	Radar jammers are illegal.	
Ireland	Illegal (Republic of Ireland, Éire)	Law Refers to 'Speed Meter Detectors', Introduced 1991. No fixed penalty for possession, expect confiscation and Hefty fine.	
Israel	Legal	Some cellular providers such as Pelephone actually provide radar detecting as a service powered by GPS	
Italy	Illegal		
Japan	Legal		
Jordan	Illegal	Regardless of whether they are used or not, police there may confiscate radar detectors, operational or not.	Laser (possibly others)
Latvia	Illegal		K, POP Ka
Lithuania	Illegal		X, POP K, Laser
Malaysia	Illegal to possess, purchase, sell or use. Heavy fines apply.	Radar detectors are also prohibited items under customs laws.	
Netherlands	Illegal	250€ fine and seizure of the device (since 2004)	
New Zealand	Legal	Ka and Laser used also fixed speed camera and speed camera vans (Low Powered K Band)	
Norway	Illegal to use. (Legal to own, sell, and buy)	8000-10000 krone fine and seizure of the device.	
Pakistan	Legal		
Poland	Legal to own, illegal to use in a moving vehicle	Jammers illegal	X, K, Pulse K, Ka Narrow, Laser
Romania	Legal since 2006	Radar jammers still illegal	Instant-On K
Russia	Legal		Instant-On (Pulse) X, POP K, Laser (0,8 mkm)
Saudi Arabia	Illegal		

Serbia	Illegal to use, possess, sell or advertise	Illegal to use or have in possession in a vehicle in traffic, to sell or advertise: an apparatus or any other means of detecting or interfering with operation of vehicle speed measuring devices, or any other apparatus used for discovering and reporting traffic violations	
Singapore	Illegal to possess, purchase, sell or use. Heavy fines apply.	Radar detectors are also prohibited items under customs laws.	
South Africa	Illegal to use in a moving vehicle	Importing a unit is permitted under South African customs regulations.	
Spain	Radar Detectors legal, jammers illegal.	Radar and Laser jammers fine up to 6000€	Ka narrow, laser, Autovelox
Switzerland	Illegal	Radar detectors are confiscated and destroyed. The use of any GPS-based device to locate speed cameras is also illegal.	
Turkey	Illegal	Radar jammers are illegal	
UAE	Illegal		
United Kingdom	Legal	Legal to own, but technically illegal to use under the Wireless Telegraphy Act 1949 until 1998, due to legal loophole causing them to be legalized suddenly.	
United States	Law varies from state to state, but detectors are generally legal in private vehicles under the Communications Act of 1934 and illegal in commercial vehicles by DOT regulation (49 CFR 392.71). Exceptions: • *Illegal in all vehicles*: Virginia, Washington D.C., U.S. military	Confiscation and/or destruction of the detector was once a common practice but lawsuits raised by drivers arguing violation of property rights have resulted in temporary removal while a citation is written, then return of the device after its description (make, model and serial number) has been entered on the ticket -	

bases • *Illegal in commercial vehicles under state law*: Illinois, New York, New Jersey (specifically, commercial vehicles over 10,000 pounds (4,500 kg) and *all* vehicles over 18,000 pounds (8,200 kg)) Also illegal in all commercial vehicles over 10000 lbs under US federal law • Prohibitions against affixing items to windshield - "obstructing vision"): Minnesota, California • *Repealed*: Connecticut (repealed in 1992)	usually for speeding and possession/operation of detector. Use of a radar/lidar detector on a military installation is prohibited. Persons entering a military installation with one visibly mounted to the sun visor or windshield will be asked to remove it and put it away. Those who refuse will be denied entry onto the installation at that time. Military law enforcement may not solely stop a vehicle for a detector being in use but, along with being stopped for another moving violation, the person using the detector may be ordered to report the violation to his/her unit commanding officer (active duty ONLY). Radar jammers are illegal under federal law, but laser jammers aren't specifically banned. Some states, such as Minnesota, have state laws banning laser jammers.

Chapter 13

Airbag

The driver and passenger front airbags, after having been deployed, in a Peugeot 306 car.

An **airbag** is a vehicle safety device. It is an occupant restraint consisting of a flexible envelope designed to inflate rapidly during an automobile collision, to prevent occupants from striking interior objects such as the steering wheel or a window. Modern vehicles may contain multiple airbags in various side and frontal locations of the passenger seating positions, and sensors may deploy one or more airbags in an impact zone at variable rates based on the type and severity of impact; the airbag is designed to only inflate in mild to severe frontal crashes. Airbags are normally designed with the intention of supplementing the protection of an occupant who is correctly restrained with a seatbelt. Most designs are inflated through pyrotechnic means and can only be operated once.

The first commercial designs were introduced in passenger automobiles during the 1970s with limited success. Broad commercial adoption of airbags occurred in many markets during the late 1980s and early 1990s with two airbags for the front occupants, and many modern vehicles now include four or more units.

Terminology

Various manufacturers have over time used different terms for airbags. General Motors' first bags, in the 1970s, were marketed as the *Air Cushion Restraint System (ACRS)*. Common terms in North America include *Supplemental Restraint System (SRS)* and *Supplemeboobntal Inflatable Restraint (SIR)*; these terms reflect the airbag system's nominal role as a supplement to active restraints, i.e., seat belts. Because no action by the vehicle occupant is required to activate or use the airbag, it is considered a *passive* device. This is in contrast to seat belts, which are considered *active* devices because the vehicle occupant must act to enable them. Note that this is not related to active and passive safety, which are, respectively, systems designed to prevent accidents in the first place and systems designed to minimize accidents once they occur. For example, the car's Anti-lock Braking System will qualify as an active-safety device while both its seatbelts and airbags will qualify as passive-safety devices. Further terminological confusion can arise from the fact that passive devices and systems — those requiring no input or action by the vehicle occupant — can themselves operate in an active manner; an airbag is one such device. Vehicle safety professionals are generally careful in their use of language to avoid this sort of confusion, though advertising principles sometimes prevent such syntactic caution in the consumer marketing of safety features.

History

1975 Buick Electra with ACRS

In 1994, Ford of Europe made airbags standard equipment in all the cars they built

Invention

An American inventor, John W. Hetrick, an industrial engineer and member of the U.S. Navy, designed (1952) and patented (1953) the original safety cushion commonly referred to as an airbag. It was designed based on his experiences with compressed air from torpedoes during his service in the U.S. Navy, as well as a need to provide protection for his family in their automobile during accidents. Mr. Hetrick worked with the major American automobile corporations at the time, but they were not interested in investing in safety devices until decades later when they became mandatory. Allen K. Breed invented and developed an alternative component for crash detection. Breed Corporation then marketed this innovation first in 1967 to Chrysler. A similar "Auto-

Ceptor" crash-restraint, developed by Eaton, Yale & Towne Inc. for Ford was soon offered as an automatic safety system in the USA, while the Italian Eaton-Livia company offered a variant with localized air cushions.

As a supplement to seat belts

Airbags for passenger cars were introduced in the United States in the mid-1970s, when seat belt usage rates in the country were quite low. Ford built an experimental fleet of cars with airbags in 1971, followed by General Motors in 1973 on Chevrolet vehicles. The early fleet of experimental GM vehicles equipped with airbags experienced seven fatalities, one of which was later suspected to have been caused by the airbag.

In 1974, GM made the ACRS or "Air Cushion Restraint System" available as a regular production option (RPO code AR3) in some full-size Buick, Cadillac and Oldsmobile models. The GM cars from the 1970s equipped with ACRS have a driver side airbag, a driver side knee restraint (which consists of a padded lower dashboard) and a passenger side airbag. The passenger side airbag, protects both front passengers and unlike most newer ones, it integrates a knee cushion, a torso cushion and it also has dual stage deployment which varies depending on the force of the impact. The cars equipped with ACRS have lap belts for all seating positions but they do not have shoulder belts. These were already mandatory equipment in the United States on closed cars without airbags for the driver and outer front passenger seating positions.

The automotive industry's first passenger side knee airbag (not separate) was already used on the 1970s General Motors cars, it was integrated in the passenger airbag that had a knee cushion and a torso cushion.

The development of airbags coincided with an international interest in automobile safety legislation. Some safety experts advocated a performance-based occupant protection standard rather than a standard mandating a particular technical solution, which could rapidly become outdated and might not be a cost-effective approach. As countries successively mandated seat belt restraints, there was less emphasis placed on other designs for several decades.

Manufacturers emphasize that an airbag is not, and can not be an alternative to seatbelts. They emphasize that they are only supplemental to a seatbelt. Hence the commonly used term "Supplemental Restraint System" or SRS. It is vitally important that drivers and passengers are aware of this. In the majority of cases of death caused by air bags, seat belts were not worn.

As a supplemental restraint

Frontal airbag

The auto industry and research and regulatory communities have moved away from their initial view of the airbag as a seat belt replacement, and the bags are now nominally designated as **Supplemental Restraint System (SRS)** or **Supplemental Inflatable Restraints**.

In 1981, Mercedes-Benz introduced the airbag in Germany as an option on its high-end S-Class (W126). In the Mercedes system, the sensors would automatically pre-tension the seat belts to reduce occupant's motion on impact (now a common feature), and then deploy the airbag on impact. This integrated the seat belts and airbag into a restraint system, rather than the airbag being considered an alternative to the seat belt.

In 1987, the Porsche 944 turbo became the first car in the world to have driver and passenger airbags as standard equipment. The Porsche 944 and 944S had this as an available option. The same year also saw the first airbag in a Japanese car, the Honda Legend.

Airbags became common in the 1980s, with Chrysler and Ford introducing them in the mid-1980s; it was Chrysler that made them standard equipment across its entire line in 1990 (except for trucks until 1994).

Audi was relatively late to offer airbag systems on a broader scale; until the 1994 model year, for example, the 80/90, by far Audi's 'bread-and-butter' model, as well as the 100/200, did not have airbags in their standard versions. Instead, the German automaker until then relied solely on its proprietary procon-ten restraint system.

In Europe, airbags were almost entirely absent from family cars until the early 1990s. The first European Ford to feature an airbag was the facelifted Escort MK5b in 1992; within a year, the entire Ford range had at least one airbag as standard. By the mid 1990s, European market leaders such as Vauxhall/Opel, Rover, Peugeot, Renault and Fiat had included airbags as at least optional equipment across their model ranges. By the end of the decade, it was very rare to find a mass market car without an airbag, and some late 1990s products, such as the Volkswagen Golf Mk4 also featured side airbags. The Peugeot 306 was a classical example of how commonplace airbags became on mass market cars during the 1990s. On its launch in early 1993 most of the range did not even have driver airbags as an option. By 1999 however, side airbags were available on several variants.

During the 2000s side airbags were commonplace on even budget cars, such as the smaller-engined versions of the Ford Fiesta and Peugeot 206, and curtain airbags were also becoming regular features on mass market cars. The Toyota Avensis, launched in 1998, was the first mass market car to be sold in Europe with a total of nine airbags. Although in some countries, such as Russia, airbags are still not standard equipment on all cars, such as those from Lada.

Variable force deployment front airbags were developed to help minimize injury from the airbag itself.

Shaped airbags

The Citroën C4 provides the first "shaped" driver airbag, made possible by this car's unusual fixed hub steering wheel.

Side airbag

Side airbag inflated permanently for display purposes

A deployed curtain airbag in a Opel Vectra

There are essentially two types of side airbags commonly used today, the side torso airbag and the side curtain airbag.

Most vehicles equipped with side curtain airbags also include side torso airbags. However some exceptions such as the Chevrolet Cobalt, 2007-09 model Chevrolet Silverado/GMC Sierra, and 2009-10 Dodge Ram do not feature the side torso airbag.

Side torso airbag

Side-impact airbags or side torso airbags (side thorax/abdomen airbags) are a category of airbag usually located in the seat, and inflate between the seat occupant and the door. These airbags are designed to reduce the risk of injury to the pelvic and lower abdomen regions. Some vehicles are now being equipped with different types of designs, to help reduce injury and ejection from the vehicle in rollover crashes. More recent side airbag designs include a two chamber system; a firmer lower chamber for the pelvic region and softer upper chamber for the ribcage.

The Swedish company Autoliv AB, was granted a patent on side airbags, and they were first offered as an option in 1994 on the 1995 model year Volvo 850, and as standard equipment on all Volvo cars made after 1995.

Side tubular or curtain airbag

In late 1997 the 1998 model year BMW 7-series and E39 5-series were fitted with a tubular shaped head side airbags, the "Head Protection System (HPS)" as standard equipment. This is an industry's first in offering head protection in side impact collisions. This airbag also maintained inflation for up to seven seconds for rollover protection. However, this tubular shaped airbag design has been quickly replaced by an inflatable 'curtain' airbag for superior protection.

In May 1998 Toyota began offering a side curtain airbag deploying from the roof on the Progrés. In 1998 the Volvo S80 was given seat-mounted curtain airbags to protect both front and rear passengers later made standard equipment on all new Volvo cars from 1998 and while initially seat-mounted later versions deployed from the roof.

Roll-sensing side curtain airbags found on vehicles more prone to rollovers such as SUV's and pickups will deploy when a rollover is detected instead of just when an actual collision takes place. Often there is a switch to disable the feature in case the driver wants to take the vehicle offroad.

Curtain airbags have been said to reduce brain injury or fatalities by up to 45% in a side impact with an SUV. These airbags come in various forms (e.g., tubular, curtain, door-mounted) depending on the needs of the application. Many recent SUVs and MPVs have a long inflatable curtain airbag that protects all 3 rows of seats.

Knee airbag

The second driver's side and separate knee airbag was used in the 1996 model Kia Sportage vehicle and has been standard equipment since then. The airbag is located beneath the steering wheel. The Toyota Avensis became the first vehicle sold in Europe equipped with a driver's knee airbag. The EuroNCAP reported on the 2003 Avensis, "There has been much effort to protect the driver's knees and legs and a knee airbag worked well." Since then certain models have also included front passenger knee airbags, which deploy near or over the glove compartment in a crash. Knee airbags are designed to reduce leg injury. The knee airbag has become increasingly common in the 2000s, with a large minority of cars featuring them on the driver side by 2010. Passenger knee airbags remain extremely rare.

Rear curtain airbag

In 2008, the Toyota iQ launched featuring the first production rear curtain shield airbag to protect the rear occupants' heads in the event of an rear end impact.

Center airbag

In 2009, Toyota developed the first production rear-seat center airbag designed to reduce the severity of secondary injuries to rear passengers in a side collision. This system deploys from the rear center console first appearing in on the redesigned Crown Majesta.

Seat belt airbag

In 2009, the S-class ESF safety concept car showcased seatbelt airbags. They will be included standard on the production Lexus LFA in late 2010, and the 2011 Ford Explorer will offer rear seatbelt airbags as an option. Cessna Aircraft also now feature seatbelt airbags. They are now standard on the 172, 182, and 206.

On motorcycles

Airbag on a motorcycle

Various types of airbags were tested on motorcycles by the UK Transport Research Laboratory in the mid 1970s. In 2006 Honda introduced the first production motorcycle airbag safety system on its Gold Wing motorcycle. Honda claims that sensors in the front forks can detect a severe frontal collision and decide when to deploy the airbag, absorbing some of the forward energy of the rider and reducing the velocity at which the rider may be thrown from the motorcycle.

Airbag suits have also been developed for use by Motorcycle Grand Prix riders. They are connected to the motorcycle by a cable and deploy when the cable becomes detached from its mounting clip, inflating to protect the back.

How airbags work

An ACU from a Geo Storm.

The design is conceptually simple; a central "Airbag control unit" (ACU) (a specific type of ECU) monitors a number of related sensors within the vehicle, including accelerometers, impact sensors, side (door) pressure sensors, wheel speed sensors, gyroscopes, brake pressure sensors, and seat occupancy sensors. When the requisite 'threshold' has been reached or exceeded, the airbag control unit will trigger the ignition of a gas generator propellant to rapidly inflate a nylon fabric bag. As the vehicle occupant collides with and squeezes the bag, the gas escapes in a controlled manner through small vent holes. The airbag's volume and the size of the vents in the bag are tailored to each vehicle type, to spread out the deceleration of (and thus force experienced by) the occupant over time and over the occupant's body, compared to a seat belt alone.

The signals from the various sensors are fed into the Airbag control unit, which determines from them the angle of impact, the severity, or force of the crash, along with other variables. Depending on the result of these calculations, the ACU may also deploy various additional restraint devices, such as seat belt pre-tensioners, and/or airbags (including frontal bags for driver and front passenger, along with seat-mounted side bags, and "curtain" airbags which cover the side glass). Each restraint device is typically activated with one or more pyrotechnic devices, commonly called an initiator or electric match. The electric match, which consists of an electrical conductor wrapped in a combustible material, activates with a current pulse between 1 to 3 amperes in less than 2 milliseconds. When the conductor becomes hot enough, it ignites the combustible material, which initiates the gas generator. In a seat belt pre-tensioner, this hot gas is used to drive a piston that pulls the slack out of the seat belt. In an airbag, the initiator is used to ignite solid propellant inside the airbag inflator. The burning propellant generates inert gas which rapidly inflates the airbag in approximately 20 to 30 milliseconds. An airbag must inflate quickly in order to be fully inflated by the time the forward-traveling occupant reaches its outer surface. Typically, the decision to deploy an airbag in a frontal crash is made within 15 to 30 milliseconds after the onset of the crash, and both the driver and passenger airbags are fully inflated within approximately 60-80 milliseconds after the first moment of vehicle contact. If an airbag deploys too late or too slowly, the risk of occupant injury from contact with the inflating airbag may increase. Since more distance typically exists between the passenger and the instrument panel, the passenger airbag is larger and requires more gas to fill it.

Front airbags normally do not protect the occupants during side, rear, or rollover accidents. Since airbags deploy only once and deflate quickly after the initial impact, they will not be beneficial during a subsequent collision. Safety belts help reduce the risk of injury in many types of crashes. They help to properly position occupants to maximize the airbag's benefits and they help restrain occupants during the initial and any following collisions.

In vehicles equipped with a rollover sensing system, accelerometers and gyroscopes are used to sense the onset of a rollover event. If a rollover event is determined to be imminent, side-curtain airbags are deployed to help protect the occupant from contact with the side of the vehicle interior, and also to help prevent occupant ejection as the vehicle rolls over.

Triggering conditions

Airbags are designed to deploy in frontal and near-frontal collisions more severe than a threshold defined by the regulations governing vehicle construction in whatever particular market the vehicle is intended for: U.S. regulations require deployment in crashes at least equivalent in deceleration to a 23 km/h (14 mph) barrier collision, or similarly, striking a parked car of similar size across the full front of each vehicle at about twice the speed. International regulations are performance based, rather than technology-based, so airbag deployment threshold is a function of overall vehicle design.

Unlike crash tests into barriers, real-world crashes typically occur at angles other than directly into the front of the vehicle, and the crash forces usually are not evenly distributed across the front of the vehicle. Consequently, the relative speed between a striking and struck vehicle required to deploy the airbag in a real-world crash can be much higher than an equivalent barrier crash. Because airbag sensors measure deceleration, vehicle speed is not a good indicator of whether an airbag should have deployed. Airbags can deploy due to the vehicle's undercarriage striking a low object protruding above the roadway due to the resulting deceleration.

The airbag sensor is a MEMS accelerometer, which is a small integrated circuit with integrated micro mechanical elements. The microscopic mechanical element moves in response to rapid deceleration, and this motion causes a change in capacitance, which is detected by the electronics on the chip that then sends a signal to fire the airbag. The most common MEMS accelerometer in use is the ADXL-50 by Analog Devices, but there are other MEMS manufacturers as well.

Initial attempts using mercury switches did not work well. Before MEMS, the primary system used to deploy airbags was called a "rolamite". A rolamite is a mechanical device, consisting of a roller suspended within a tensioned band. As a result of the particular geometry and material properties used, the roller is free to translate with little friction or hysteresis. This device was developed at Sandia National Laboratories. The rolamite, and similar macro-mechanical devices were used in airbags until the mid-1990s when they were universally replaced with MEMS.

Nearly all airbags are designed to automatically deploy in the event of a vehicle fire when temperatures reach 150-200 °C (300-400 °F). This safety feature, often termed auto-ignition, helps to ensure that such temperatures do not cause an explosion of the entire airbag module.

Today, airbag triggering algorithms are becoming much more complex. They try to reduce unnecessary deployments and to adapt the deployment speed to the crash conditions. The algorithms are considered valuable intellectual property. Experimental algorithms may take into account such factors as the weight of the occupant, the seat location, seatbelt use, and even attempt to determine if a baby seat is present.

Inflation

When the frontal airbags are to deploy, a signal is sent to the inflator unit within the airbag control unit. An igniter starts a rapid chemical reaction generating primarily nitrogen gas (N_2) to fill the airbag making it deploy through the module cover. Some airbag technologies use compressed nitrogen or argon gas with a pyrotechnic operated valve ("hybrid gas generator"), while other technologies use various energetic propellants. Propellants containing the highly toxic sodium azide (NaN_3) were common in early inflator designs. However, propellants containing sodium azide were widely phased out during the 1990s in pursuit of more efficient, less expensive and less toxic alternatives.

The azide-containing pyrotechnic gas generators contain a substantial amount of the propellant. The driver-side airbag would contain a canister containing about 50 grams of sodium azide. The passenger side container holds about 200 grams of sodium azide.

The alternative propellants may incorporate, for example, a combination of nitroguanidine, phase-stabilized ammonium nitrate (NH_4NO_3) or other nonmetallic oxidizer, and a nitrogen-rich fuel different than azide (e.g. tetrazoles, triazoles, and their salts). The burn rate modifiers in the mixture may be an alkaline metal nitrate (NO_3-) or nitrite (NO_2-), dicyanamide or its salts, sodium borohydride ($NaBH_4$), etc. The coolants and slag formers may be e.g. clay, silica, alumina, glass, etc. Other alternatives are e.g. nitrocellulose based propellants (which have high gas yield but bad storage stability, and their oxygen balance requires secondary oxidation of the reaction products to avoid buildup of carbon monoxide), or high-oxygen nitrogen-free organic compounds with inorganic oxidizers (e.g., di or tricarboxylic acids with chlorates (ClO_3-) or perchlorates ($HClO_4$) and eventually metallic oxides; the nitrogen-free formulation avoids formation of toxic nitrogen oxides).

From the onset of the crash, the entire deployment and inflation process is about 0.04 seconds. Because vehicles change speed so quickly in a crash, airbags must inflate rapidly to reduce the risk of the occupant hitting the vehicle's interior.

Variable-force deployment

Advanced airbag technologies are being developed to tailor airbag deployment to the severity of the crash, the size and posture of the vehicle occupant, belt usage, and how close that person is to the actual airbag. Many of these systems use multi-stage inflators that deploy less forcefully in stages in moderate crashes than in very severe crashes. Occupant sensing devices let the airbag control unit know if someone is occupying a seat adjacent to an airbag, the mass/weight of the person, whether a seat belt or child restraint is being used, and whether the person is forward in the seat and close to the airbag. Based on this information and crash severity information, the airbag is deployed at either a high force level, a less forceful level, or not at all.

Adaptive airbag systems may utilize multi-stage airbags to adjust the pressure within the airbag. The greater the pressure within the airbag, the more force the airbag will exert on the occupants as they come in contact with it. These adjustments allow the system to deploy the airbag with a moderate force for most collisions; reserving the maximum force airbag only for the severest of collisions. Additional sensors to determine the location, weight or relative size of the occupants may also be used. Information regarding the occupants and the severity of the crash are used by the airbag control unit, to determine whether airbags should be suppressed or deployed, and if so, at various output levels.

Post-deployment view of a SEAT Ibiza airbag

Post-deployment

A chemical reaction produces a burst of nitrogen to inflate the bag. Once an airbag deploys, deflation begins immediately as the gas escapes through vent(s) in the fabric (or, as it's sometimes called, the cushion) and cools. Deployment is frequently accompanied by the release of dust-like particles, and gases in the vehicle's interior (called effluent). Most of this dust consists of cornstarch, french chalk, or talcum powder, which are used to lubricate the airbag during deployment.

Newer designs produce effluent primarily consisting of harmless talcum powder/cornstarch and nitrogen gas. In older designs using an azide-based propellant (usually NaN_3), varying amounts of sodium hydroxide nearly always are initially present. In small amounts this chemical can cause minor irritation to the eyes and/or open wounds; however, with exposure to air, it quickly turns into sodium bicarbonate (baking soda). However, this transformation is not 100% complete, and invariably leaves residual amounts of hydroxide ion from NaOH. Depending on the type of airbag system, potassium chloride (often used as a table salt substitute) may also be present.

For most people, the only effect the dust may produce is some minor irritation of the throat and eyes. Generally, minor irritations only occur when the occupant remains in the vehicle for many minutes with the windows closed and no ventilation. However, some people with asthma may develop a potentially lethal asthmatic attack from inhaling the dust.

The dust-like particles and gases can cause irreparable cosmetic damage to the dashboard and upholstery, so minor collisions which result in the deployment of airbags can be costly accidents, even if there are no injuries and there is only minor damage to the vehicle exterior.

Regulatory specifications

United States

On 11 July 1984, the U.S. government amended Federal Motor Vehicle Safety Standard 208 (FMVSS 208) to require cars produced after 1 April 1989 to be equipped with a passive restraint for the driver. An airbag or an automatic seat belt would meet the requirements of the standard. Airbag introduction was stimulated by the U.S. National Highway Traffic Safety Administration. However, airbags were not mandatory on light trucks until 1997.

In 1998, FMVSS 208 was amended to require dual front airbags, and de-powered, or second-generation airbags were also mandated. This was due to the injuries caused by first-generation airbags, though FMVSS 208 continues to require that bags be engineered and calibrated to be able to "save" the life of an *unbelted* 50th-percentile size and weight "male" crash test dummy.

Outside the U.S.A.

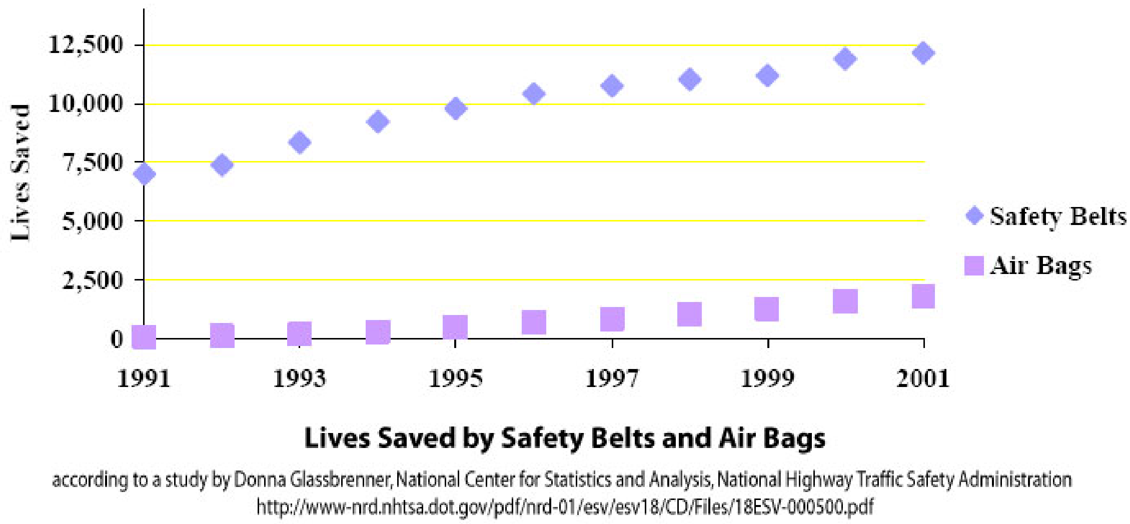
Most countries outside North America adhere to internationalized European ECE vehicle and equipment regulations rather than the U.S. Federal Motor Vehicle Safety Standards. ECE airbags are generally smaller and inflate less forcefully than U.S. airbags, because the ECE specifications are based on *belted* crash test dummies. In the United Kingdom, and most other developed countries there is no direct legal requirement for new cars to feature airbags. Instead, the Euro NCAP vehicle safety rating encourages manufacturers to take a comprehensive approach to occupant safety; a good rating can only be achieved by combining airbags with other safety features. Thus almost all new cars now come with at least two airbags as standard.

Maintenance

Inadvertent airbag deployment while the vehicle is being serviced can result in severe injury, and an improperly installed or defective airbag unit may not operate or perform as intended. Some countries impose restrictions on the sale, transport, handling, and service of airbags and system components. In Germany, airbags are regulated as harmful explosives; only mechanics with special training are allowed to service airbag systems. Under German Federal Law, used but intact airbags are to be detonated under secure conditions, must not be passed on to third parties in any way, and no untrained person is permitted to handle airbags. Purchase is restricted to buying a new replacement unit for immediate installation by the seller's qualified personnel.

Some automakers (such as Mercedes-Benz) call for the replacement of undeployed airbags after a certain period of time to ensure their reliability in an accident. One example is the 1992 S500 which has an expiry date sticker attached to the door pillar. Škoda vehicles say 14 years from the date of manufacture. In this case replacement would be uneconomic as the car would have negligible value at 14 years old, far less than the cost of fitting new airbags. Volvo, on the other hand, has stated "airbags do not require replacement during the lifetime of the vehicle," though this cannot be taken as a guarantee on the device.

Injuries and fatalities



Lives saved by seat belts and airbags

Airbags can injure or kill vehicle occupants. To provide crash protection for occupants not wearing seat belts, U.S. airbag designs trigger much more forcefully than airbags designed to the international ECE standards used in most other countries. Recent airbag controllers can recognize if a belt is used, and alter the bag deployment parameters accordingly.

Injuries such as abrasion of the skin, hearing damage from the extremely loud 165-175 dB deployment explosion, head injuries, eye damage, and broken nose, fingers, hands or arms can occur as the airbag deploys. Most vehicle airbags are inflated using hot gas generated by a chemical process. Using hot gas allows the required pressure to be obtained with a smaller mass of gas than would be the case using lower temperatures. However, the hot gas can pose a risk of thermal burns if it comes in contact with the skin during deployment and occupant interaction. Burns are most common to the arms, face and chest. These burns are often deep dermal or second-degree burns that take longer to heal and risk scarring.

In 1990, the first automotive fatality attributed to an airbag was reported, with deaths peaking in 1997 at 53 in the United States. TRW produced the first gas-inflated airbag in 1994, with sensors and low-inflation-force bags becoming common soon afterwards. Dual-depth (also known as dual-stage) airbags appeared on passenger cars in 1998. By 2005, deaths related to airbags had declined, with no adult deaths and two child deaths attributed to airbags that year. Injuries remain fairly common in accidents with an airbag deployment.

Serious injuries are less common, but severe or fatal injuries can occur to vehicle occupants very near an airbag or in direct contact when it deploys. Such injuries may be sustained by unconscious drivers slumped over the steering wheel, unrestrained or improperly restrained occupants who slide forward in the seat during pre-crash braking, and properly belted drivers sitting very close to the steering wheel.

The increasing use of airbags may actually make rescue work for firefighters, emergency medical service and police officers more dangerous, because of the risk of deployment while the emergency responder is assisting or extracting vehicle occupants. As a result of this, along with the risk of fuel fires, emergency responders will cut the battery cables to prevent any un-detonated airbags from inflating after impact.

Improvements in sensing and gas generator technology have allowed the development of third generation airbag systems that can adjust their deployment parameters to size, weight, position and restraint status of the occupant. These improvements have demonstrated a reduced injury risk factor for small adults and children who had an increased risk of injury with first generation airbag systems.

Airbag fatality statistics

From 1990 to 2008, the U.S. National Highway Traffic Safety Administration identified 175 fatalities caused by air bags. Most of these (104) have been children, while the rest are adults. About 3.3 million air bag deployments have occurred and the agency estimates more than 6,377 lives saved and countless injuries prevented.

A rear-facing infant restraint put in the front seat of a vehicle places an infant's head close to the airbag, which can cause severe head injuries, or death if the airbag deploys. Some modern cars include a switch to disable the front passenger airbag (although not in Australia, where rear-facing child seats are prohibited in the front where an airbag is fitted), in case a child-supporting seat is used there.

In vehicles with side airbags, it is dangerous for occupants to lean against the windows, doors, and pillars, or to place objects between themselves and the side of the vehicle. Articles hung from a vehicle's clothes hanger hooks can be hazardous if the vehicle's side curtain airbags deploy. A seat-mounted airbag may also cause internal injury if the occupant leans against the door.

Glossary of Automotive Design

0-9

1-box form
: A categorization based on overall form design using rough rectangle volumes. In the case of the 1-box, it is a single continuous volume. Slight wedge formed front or rear are still generally placed in this category. e.g., Bus, original Ford Econoline.

2-box form
: A categorization based on overall form design using rough rectangle volumes. In the case of the 2-box form, there is usually a "box" representing a separate volume from the a-pillar forward and second box making up the rest. e.g., Station Wagon, Shooting-brake, Scion xB(2006)

3-box form
: A categorization based on overall form design using rough rectangle volumes. In the case of the 3-box form, there is a "box" delineating a separate volume from the a-pillar forward, a second box comprising the passenger volume, and third box comprising the trunk area — e.g., a Sedan.

A

A-line
: The line running over the car, from headlight to taillight, tracing the car's silhouette.

Axis-to-dash ratio
: The critical relationship between front wheels and the windshield. The most notable differences can be seen between cars with front-engine, front-wheel drive layout and front mid-engine, rear-wheel drive layout: the former tend to have longer front overhangs with a smaller axis-to-dash ratios, while the latter have shorter front overhangs with much greater axis-to-dash ratios.

B

Backlight
: The rear glass window glass.

Beltline

The line going from the hood which usually follows the bottom edge of the windows and continues to the trunk.

Bling

(contemporary) See brightwork. May also refer to the strong use of jeweled lighting. Comes from the term bling-bling.

Bonnet

The hood of the vehicle.

Boot

The trunk or liftgate of the vehicle.

Brightwork

Anything reflective added to a car to enhance appearance. May also be called chrome.

C

Cab

Short for cabin. The enclosed compartment of a vehicle which contains the driver and passengers.

Cab back

The cab of the vehicle is moved to the rear of the vehicle. Cars such as a 1970's Corvette could be considered cab back design.

Cab forward

The cab of the vehicle is pushed forward. This design aesthetic was popular with Chrysler in the 1990s with the introduction of their LH platform cars.

Character line

A line creased into the side of a car to give it visual interest. (interchangeable with swage line)

Chrome

Brightwork using chrome plating.

Cladding

Material (usually plastic) added to exterior of the car which isn't structurally necessary. May be functional to keep out dirt/debris as in underbody cladding, or may be cosmetic.

Control Panel

Generally used in a Car/Truck for heating and cooling inside car environment according to the passenger requirements. Basically it is divided in to Different modes, Blower speed functions, AC, Temperature, Fresh recirculation of air. World wide control panel manufacturers are BHTC, Delphi, Visteon, Valeo, etc.

Cowl

The base of the windshield.

D

Daylight Opening (DLO)

US DOT Term: For openings on the side of the vehicle, other than a door opening, the locus of all points where a horizontal line, perpendicular to the vehicle longitudinal centerline, is tangent to the periphery of the opening.

US DOT Term: For openings on the front and rear of the vehicle, other than a door opening, daylight opening means the locus of all points where a horizontal line, parallel to the vehicle longitudinal centerline is tangent to the periphery of the opening.

Dead Cat Hole
: The space between a car's tire and the wheel well. Currently there is a trend towards smaller dead cat holes.

Deck
: The horizontal surface at the rear of the car, which usually serves as the trunk lid.

Down Road Graphic
: The styling of the front end of the car, which people will instantly recognize and associate with a manufacturer. For example, the grille, lights and sometimes the DLO.

Droptop
: A convertible.

F

Fascia
: The body-skin panel at the front of the car.

Fender (wings, UK)
: Term for cowl covering the wheels of the vehicles. In more modern automobiles, this refers generally to the body panel or panels starting at the front "bumper" to the first door line excluding the engine hood. The opposite of the fender is the "quarter panel".

Frame-on-rail
: A design used in older (pre-unibody) cars, trucks, and SUVs. The power train and body are mounted to a rigid structural framework called a rail.

G

Gill
: A vent on the side of the fender that can be used as hot-air outlet, but usually decorative.

Greenhouse
: The glassed-in upper section of the car's body. Daylight Opening (DLO) in turn describes the actual window areas only.

H

Hardtop
: a coupe or sedan lacking a center window post between the front windshield post and the rearmost window post or body section.

Header
: (1) The structural roof beam above the windshield. (2) The section of exhaust piping attached to the cylinder head.

Hofmeister kink
: BMW's trademark reverse-sweep kick at the bottom of last roof pillar.

HP (Hip Point or H-point)

A conceptual plane parallel with ground that aligns to the vehicle passengers' hip/thigh join. This helps to describe the "seat" height of a vehicle design, relative to either the ground or the vehicle floor.

Hood (Bonnet in English speaking countries outside North America with the exception of the Canadian Maritimes)

The engine cover on vehicles when the engine is located forward or aft of the passenger compartment.

I

IP

Instrument Panel. The Dashboard is termed as Instrument Panel in Automotive Industries, sometimes this term is confused with the Instrument Cluster that is the group of speedometer, odometer and similar devices generally behind the steering wheel.

N

NACA duct

A distinctively shaped inlet that is flush and begins with a narrow, shallow inset and becomes progressively wider and deeper.

O

Overhang

The distance which the car's body extends beyond the wheelbase at the front (front overhang) and rear (rear overhang). In car style design terms, this is the amount of body that is beyond the wheels or wheel arches.

P

Phaeton

An open vehicle, usually with 4 doors, with a removable and/or retractable cloth top and a windshield characterized by the lack of integrated glass side windows. Contemporary uses of this name do not always follow this original description or apply to an open vehicle.

Pillar

A structural member that connects the roof to the body of the car. Pillars are usually notated from front to back alphabetically (e.g. A-pillar joins the windshield to the frontmost side windows, B-pillar is next to the front occupants' heads, etc.).

US DOT Term: Means any structure, excluding glazing and the vertical portion of door window frames, but including accompanying molding, attached components such as safety belt anchorages and coat hooks, that (1) supports either a roof or any other structure (such as a roll-bar) above the driver's head or (2) is located along a side edge of a window.

Plenum

The area at the base of the windshield where the wipers are parked. Also refers to the main chamber in an intake manifold.

Ponton styling
: a 1930s–1960s design genre when distinct running boards and fully articulated fenders became less common and bodywork began to enclose the full width and uninterrupted length of a car in a markedly bulbous, slab-sided fashion.

Plug-in hybrid electric vehicle
: A hybrid vehicle that can be plugged into the electric grid to recharge its battery to reduce gasoline usage.

Powertrain
: All the components that generate power and deliver it to the tires.

Q

Quarter-panel
: (or rear quarter panel) refers to the panel at the back sides starting at the rear edge of the rearmost doors, bordered by at top by the trunk (boot) lid and at bottom by the rear wheel arches ending at the rear bumper. This is the opposite of the fender. Literally, the term originally referred to the rear quarter or the car's length.

R

Rake
: The tilt of a windshield. An extremely low or flat rake angle is considered to be "fast", as in fastback. Note that a "steeply raked" windscreen is close to horizontal.

Roadster
: An open vehicle, usually with 2 doors, with a removable and/or retractable cloth top and a windshield characterized by the lack of integrated glass side windows. Contemporary uses of this name do not always follow this original description.

Rocker
: The body section below the base of the door openings sometimes called the "rocker panels".

Rocker Rail
: Body armor protecting the Rocker, found mostly in off road vehicles. Term coined by engineers at MetalCloak.

S

Scoop
: Inset or protusion that implies the intake of air. May be functional for cooling/ventilation or purely ornamental.

Scowling headlamps
: Headlamps styled along a V-shape as viewed from the front, giving the impression of a scowl.

Shoulder line
: The line or "shoulder" formed by the meeting of top and side surfaces extending from hood/fender shoulder to boot-lid/quarter-panel shoulder. The strongest example of this feature can be found on more modern of Volvo Cars.

Sill line
: Imaginary line drawn following the bottom edge of the greenhouse glass.

Six line
: A line extending from the C-pillar down and around the rear wheel well.

Softtop
: a convertible top which is made out of flexible materials like PVC or textile.

Spoiler
: A raised lip or wing which is used to 'spoil' unfavorable air movement across the body. Some designs are more functional than others.

Staggered wheel fitment
: The front and rear wheels are different widths. On sporty rear wheel drive cars, the rear tires are usually wider than the front.

Strake
: Crease in the sheet metal intended as a "speed line" styling feature. Exemplified in the doors of the Ferrari Testarossa.

Suicide door
: rear-hinged type, opening from the front of the car. If accidentally opened while driving at a high speed, doors would be blown backward.

Swage line
: Crease or curvature in the side of the body used to create visual drama. Sometimes the crease is functional and improves rigidity of the outer body (interchangeable with character line).

T

Track
: The distance across the car between the base of the left and right wheels. (Like wheelbase, but side to side.)

Truck
: A typically large vehicle built using frame-on-rail construction consisting of a cab and a separate bed for cargo.

Trunk
: (Boot in UK) Compartment for storage of cargo which is separate from the cab.

Tube Fender
: Replacement fenders found on off road vehicles designed as part of body armor for off road vehicles. Used to protect the thin sheet metal bodies from damage while off-roading.

Tumblehome (tumble home)
: Generally refers to the way the sides of a car rounds inward toward the roof, specifically of the greenhouse above the beltline. This term is borrowed from nautical description of naval vessels.

Turn under
: The shape of the rocker panel as it curves inward at the lower edge.

V

Valvetrain
: The mechanisms and parts which control the operation of the valves.

W

Wedge

Shape of the car as seen in the side profile. May be positive, negative or neutral. If the front is lower than the rear, then it is wedge-positive. If the rear is lower it is wedge-negative. If the car appears level from front to rear, then it is wedge neutral.

Wheel arch

The visible opening in the side of a car allowing access to the wheel.

Wheelbase

The distance front to back measured from where the front and rear wheels meet the ground.

Wheel well (or bucket)

The enclosure or space for the wheel.

Windshield Trim

US DOT Term: Molding of any material between the windshield glazing and the exterior roof surface, including material that covers a part of either the windshield glazing or exterior roof surface.