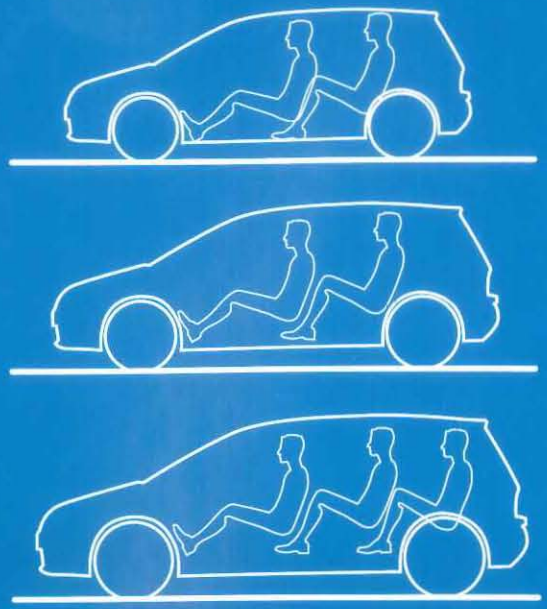


"After the ideation process is complete, the overall dimensions and proportions of the concept should be established. Getting the size right is critical to ensure that the vehicle is as efficient as possible and makes the right statement about its purpose."

SIZE & PROPORTION | 04

INTRODUCTION TO SIZING & PROPORTIONS

Setting up the size and proportion of a vehicle can be approached in several ways.

The first approach may be purely emotional. You may have already decided that the concept will be large or small, high or low, have a short or a long hood. You will be working with a mindset that the vehicle needs to be designed to look a certain way for the customer to accept it. If this is the case, the package can often be designed under the skin, because there will be nothing revolutionary about it. It is taking what we already know today and simply refining it. This is a case of the package being lead by the design.

Another approach may be driven by a specific requirement to meet dimensional legislation or market segmentation. This combined with a challenging set of functional objectives may require some innovative packaging to fit everything into a limited envelope.

The final methodology is to start only with the functional objectives. This involves research into advanced technology to develop innovative solutions before building the package around the occupants and new kinds of componentry. The exterior proportions can define the forms around this fresh architecture.

If some of the functional objectives for the vehicle are to fit into a small footprint and be fuel efficient, then a fully optimized package will develop. If the customer requirements call for a much larger vehicle with an emphasis on making a statement with its size, then the package can be relaxed in some areas.

The vehicle function & segments chapter gave an insight into some of the factors that set up the proportions. As always, the occupant package will have a major influence on the vehicle's size but the powertrain and cargo are often the elements that define the proportions of the main "boxes." If a car is of the three-box layout with a long hood, or long dash-to-axle relationship (front wheel set well forward of the A pillar), there is a good chance that it is a luxury car with a large engine. There may not be a great deal of emphasis on larger cargo space, but room for suitcases and golf clubs might be an important requirement.

A smaller, two-box hatchback will be a more efficient and versatile design with a smaller engine, but larger cargo environment for carrying bulkier objects.

So, proportions are always going to relate to the function of the vehicle. This may be an obvious statement but every time a new project is kicked off, the design team should fully investigate what opportunity there is for the architecture of the vehicle to make an exciting statement about its intended function. Similarly, the designers can consider how new technology could be applied and how that might lead to a redistribution of the masses.

New advanced propulsion systems, for example, are very different in their size, proportion and arrangement to conventional internal combustion engines. So a concept that employs an electric powertrain should not look the same as one with a conventional internal combustion engine.

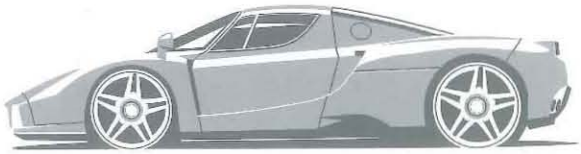
The three sports cars shown below may have similar objectives but look totally different because their engines are in different locations. Performance cars vary a great deal in appearance for this reason.

The left car has a large mid-front engine which creates a long hood, pushing the driver towards the rear of the wheelbase.

The middle car is a mid-rear engine layout with the transaxle behind the engine. This package creates a longer rear end, pushing the rear wheel away from the driver.

The right car has a rear-mounted engine which requires a lot of mass behind the rear wheels but does allow a small amount of room for rear passengers.

MID-FRONT ENGINE

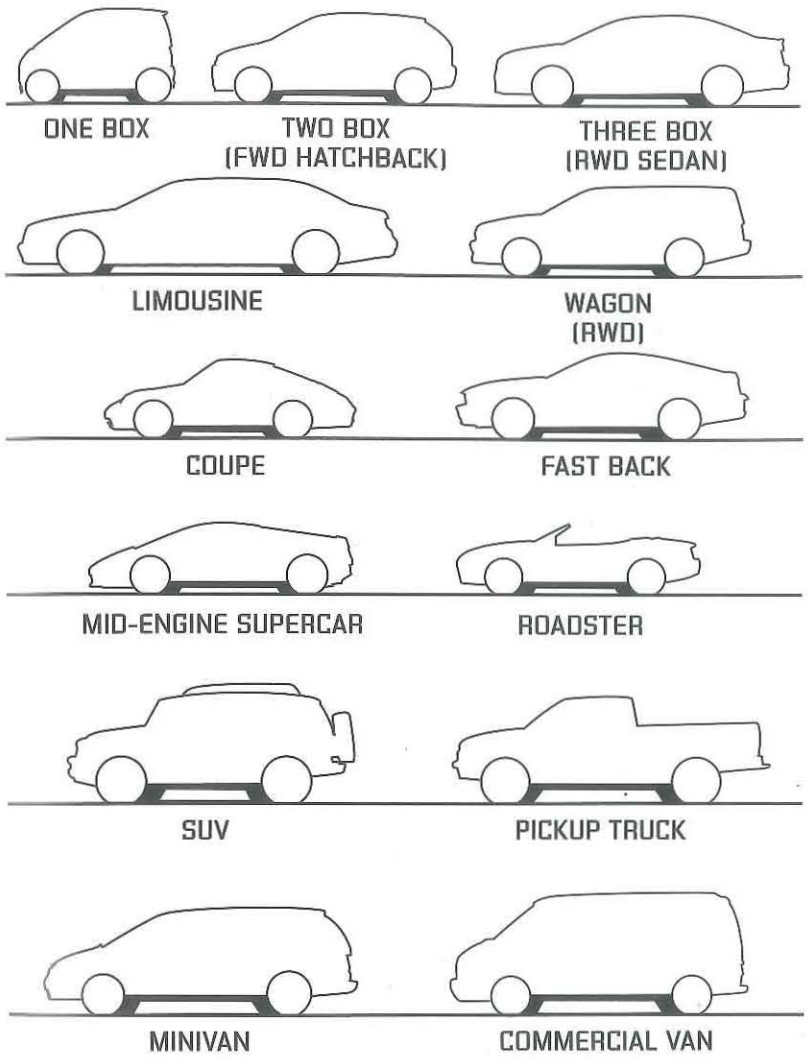


MID-REAR ENGINE

REAR ENGINE

PROPORTIONS & BODY TYPES

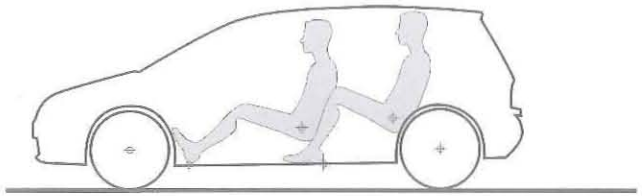
The side-view proportions of the body are influenced by the occupants, cargo and powertrain packages. Additionally, the ground clearance, crash systems and aerodynamics will affect the profile. All of these, in turn, are driven by the functional objectives. Below are some typical examples of various body types and proportions.



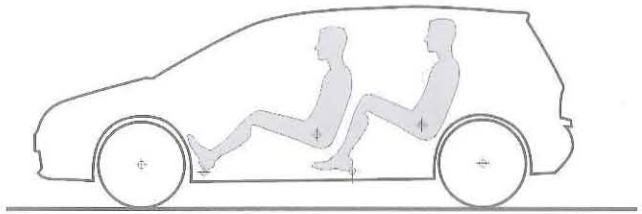
SIZING THE CONCEPT

After the initial ideation phase, the next step is to determine the size of the vehicle. The one consistent component in each package is the scale of the occupants, so the scale of the concept can be set up around the driver and passengers. Benchmarking existing known vehicles will help perform this task.

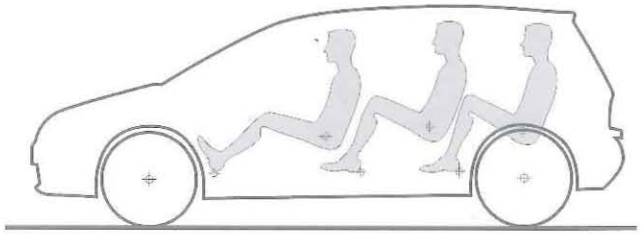
Notice the exterior shape has not changed but the vehicles are different sizes. Using the occupants as the basis for scaling, the size can be adjusted to fit comfortably around them.



MINI CAR



MIDSIZE CAR



MINIVAN

VEHICLE CLASSIFICATION BY SIZE

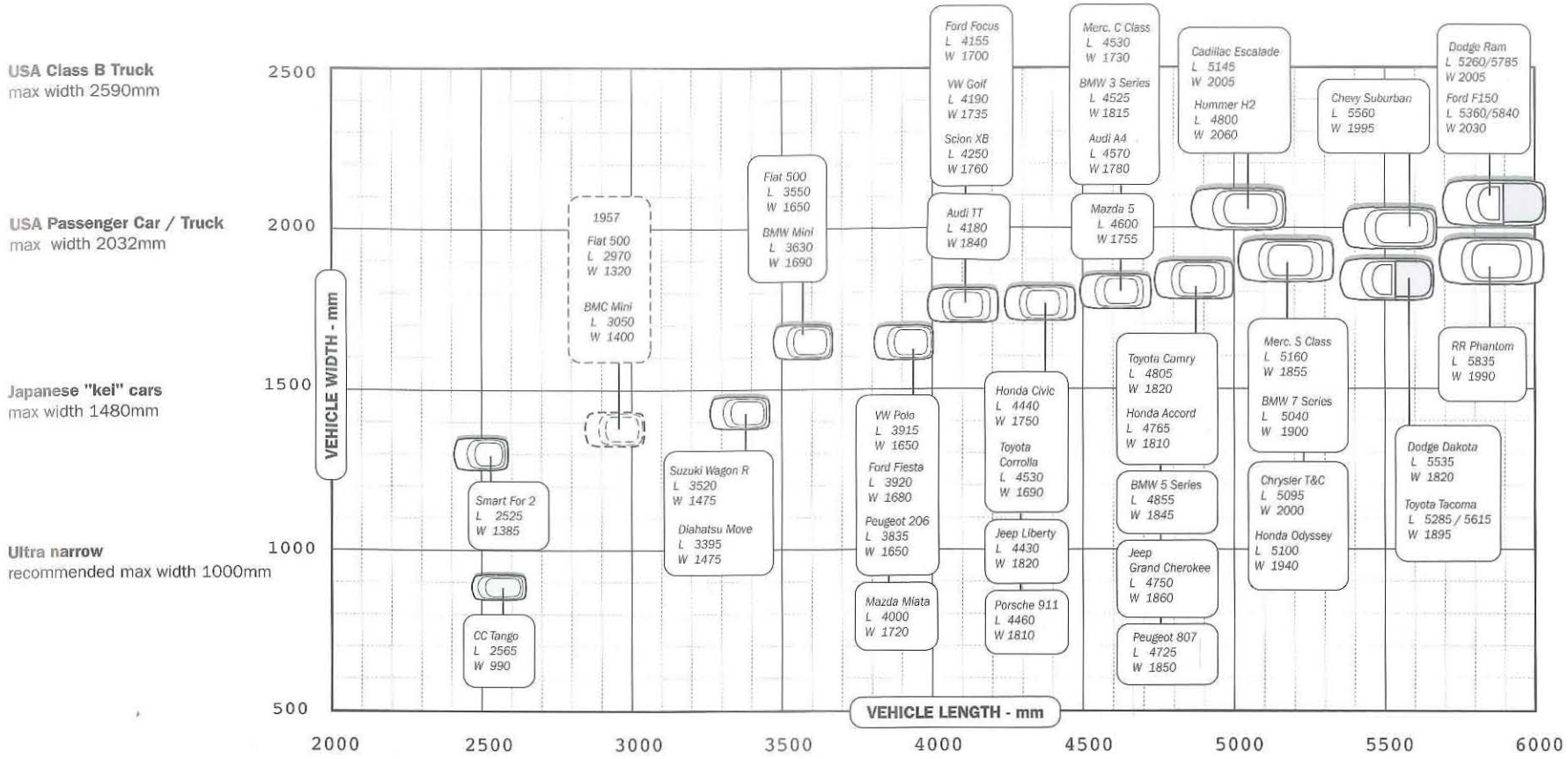
Often the size of a vehicle will put it into a category or market segment. Unfortunately, there is a lot of ambiguity in this area. This can be seen in the matrix on the opposite page, which may appear somewhat confusing.

Size is relative, so if you are working on a small car in Europe or Japan it will be much smaller than a small car in the USA. The type of vehicle will also make a difference. A small truck, for example, will be much longer than a small car, van or SUV. The market's view of size is constantly changing. Notice (on the opposite page) the size of the original Mini & Fiat 500 is much smaller than the current models. Cars have grown considerably in recent years in both size and weight.

In some markets, legislation will set a mixture of dimensional, functional, weight or power-output division lines. These are usually there to help reduce vehicle size in regions with a dense population or for economical and environmental reasons. Because some vehicles need to be configured a certain way to perform their intended function, they will be exempt from some limitations. Some divisions are mandated and strictly enforced, others are encouraged with tax incentives or penalties. Countries with poor economies, limited oil resources and/or high population densities, will have stricter limitations.

In the USA, personal vehicles have a gross vehicle weight (GVW) of less than 8,500 lbs. Commercial (class A or B) trucks require special licenses to drive them. The main division for non-commercial vehicles is between passenger cars and light trucks. Passenger cars have to meet stricter fuel consumption limits and their bumper design is governed by low-speed impact requirements. To be classified as a truck, the vehicle has to be either primarily designed to carry cargo, carry 9 or more people behind the driver, have an open bed or be designed for off-road use. Much of this criteria is open to interpretation, allowing some vehicles to be classified in either category.

So before starting the project, try to understand the objectives from the customer, brand and environmental perspective. Look at the size of competitive vehicles and the cars and trucks in the showroom of the brand. Check all local legislation and think about how the environment and climate may affect the vehicle's architecture and classification.



Euro NCAP	Cars Minivans SUVs	Super Mini — Small Family Car — Large Family Car — Executive Car (4.8m +) Small MPV — MPV Small Off Roader 4x4 — Large Off Roader 4x4
European Segments	Cars SUVs Vans	Micro — A Class — B Class — C Class — D Class — E Class — F Class C Class — D Class — E Class B Class — C Class — D Class
US EPA Classification (Cars by interior volume) (Trucks by GVWR)	Cars Wagons Trucks	Mini Compact (-85 cu ft) — Sub Compact (85 - 100 cu ft) — Compact (100-110 cu ft) — Midsize (100-120 cu ft) — Large (120 + cu ft) Small Wagon (-130 cu ft) — Midsize Wagon (130-160 cu ft) — Large Wagon (160+ cu ft) Small (under 4500 lb) — Standard (4500-8500 lb)
Consumer Groups (MSN. Autos)	Cars / Wagons Luxury Cars Sports Cars Vans SUVs Trucks	Small — Midsize — Large Entry Luxury Cars — Luxury Cars — Ultra Luxury Cars($100k+) Sports Cars — Exotic Sports Cars ($70k+) Passenger Vans / Cargo Vans Small SUVs — Midsize SUVs — Large SUVs — Luxury SUVs Small Pickups — Large & Heavy Duty Pickups

EXTERIOR LONGITUDINAL PROPORTIONS

Front Impact Structure & Powertrain

The size and orientation of the engine will significantly affect the proportion of the front end. Free crush space for frontal impact is required around the powertrain and chassis components to help meet frontal impact requirements.

Driver Package

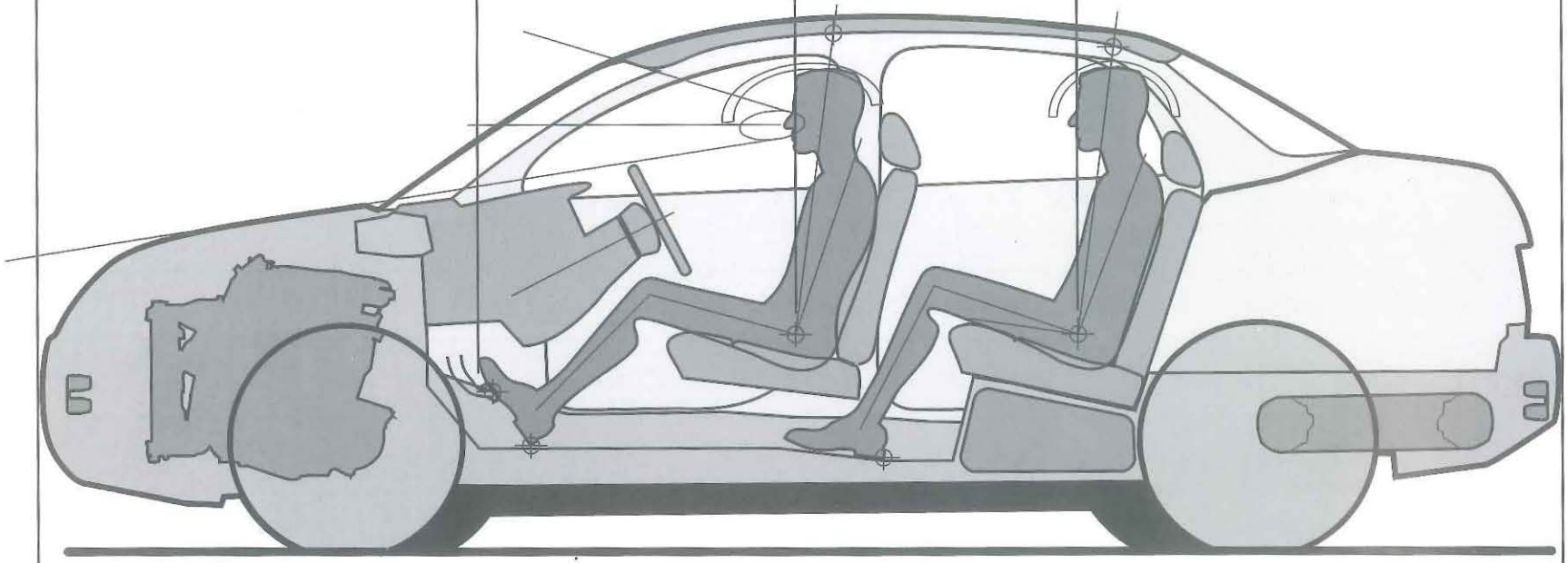
The space occupied by the driver's lower limbs is determined by the chair height. An increase of chair height will shorten the horizontal length between the feet and the hips.

Rear Occupant Package

The distance between the front and rear occupants (couple) will directly affect the vehicle length, which is why the rear passengers suffer the most in smaller cars.

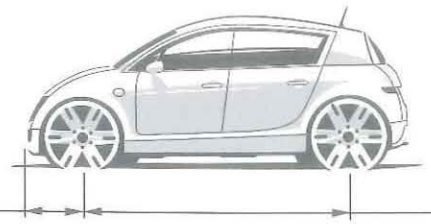
Rear Impact Structure & Cargo Space

This space is mainly used to accommodate cargo, the spare tire and fuel tank. Protecting the rear occupants and fuel from rear impact will also influence this dimension.



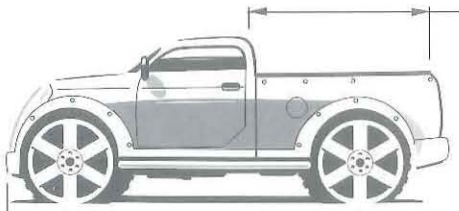
Overall Length Targets & Limitations

The maximum overall length may be a project goal established to ensure the vehicle fits into a particular market segment. Additionally, street/garage parking and maneuverability are also limiting factors. Accommodating a specific spindle location/wheelbase and overhang may also affect the overall length (OAL). Excessive length will add cost and weight and limit performance.



FWD
The front overhang and spindle is set up by the driveshaft location.

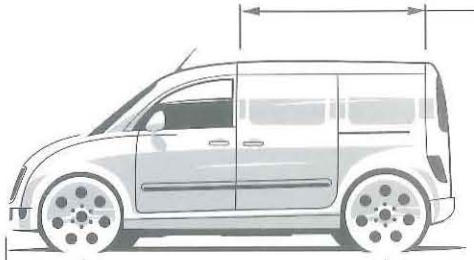
The wheelbase is set up efficiently around the passenger location.



Bed length is determined by function. They range from 850 to 2500mm.

RWD
The front wheel is set forward to improve approach angle and minimize the effects of a heavy load on the steering.

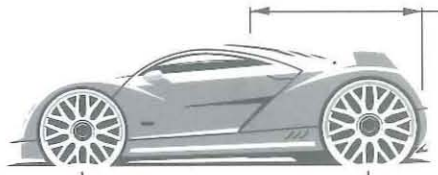
The rear wheel location is set close to the middle of the bed for ideal load distribution and ramp over.



Rear cargo bay length is determined by functional requirements.

RWD / FWD
The front wheel is set forward to allow the driver to be located in a forward location.

The rear wheel location is set behind the side load door which is designed to allow specific items to pass through, which are usually over 1000mm.



The engine, transmission, fuel tank and crush space are all located behind the driver.

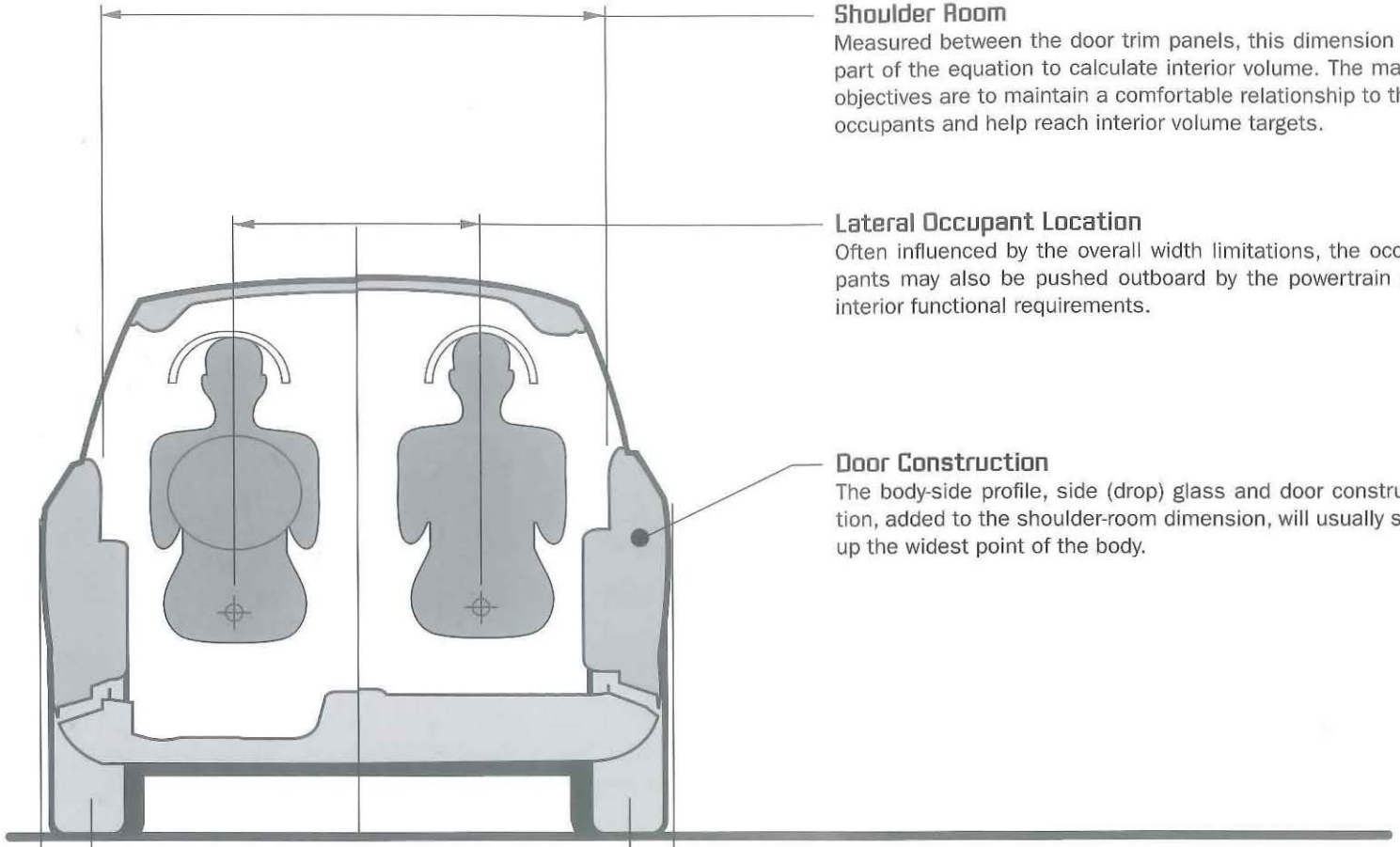
RWD
The front wheel is positioned to establish perfect weight distribution.

The rear wheel is lined up with the driveshaft location.

The three-box passenger car with a front engine (on p. 76) is quite straightforward in its break up. Other vehicles will have a similar set of requirements governing the length of each chunk of the package, but may end up with different proportions because they have different functions.

Spindle locations are set by several different factors. Often the wheel center is slaved to a driveshaft location, so the driven wheel is usually placed first. The other spindle or axle may be located by the need for an efficient, short package or for optimum weight distribution.

EXTERIOR LATERAL PROPORTIONS



Shoulder Room
Measured between the door trim panels, this dimension is part of the equation to calculate interior volume. The main objectives are to maintain a comfortable relationship to the occupants and help reach interior volume targets.

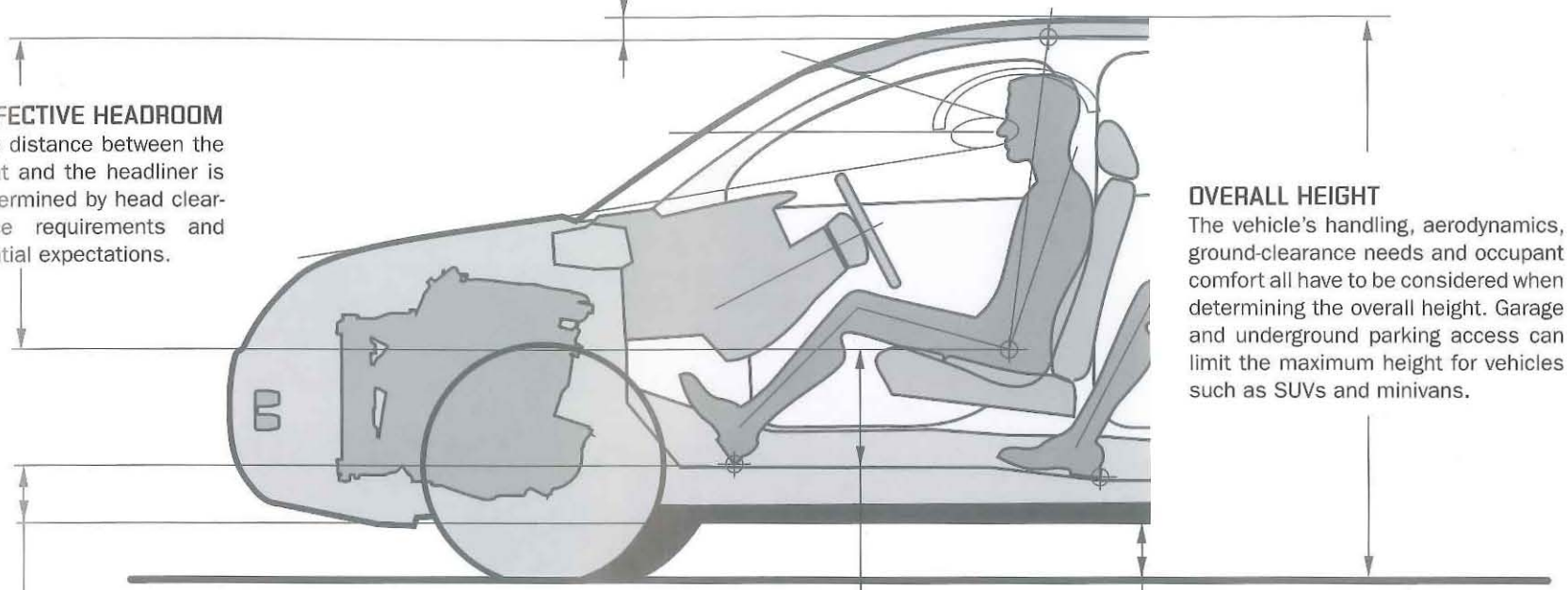
Lateral Occupant Location
Often influenced by the overall width limitations, the occupants may also be pushed outboard by the powertrain or interior functional requirements.

Door Construction
The body-side profile, side (drop) glass and door construction, added to the shoulder-room dimension, will usually set up the widest point of the body.

Track & Tire Profile Width
A wide track will help to stabilize the vehicle and reduce roll. The track and tire width will often establish the overall vehicle width for high performance cars where cornering, acceleration and braking are critical.

Overall Width
The width is the most controlled of the three dimensions and is usually governed by various authorities to ensure that each vehicle can function in its intended environment. Also, the width affects the frontal area of the car, which directly influences the aerodynamic drag.

EXTERIOR VERTICAL PROPORTIONS



HEADLINER & ROOF SYSTEMS
Space is required to accommodate trim and various roof systems such as sunroofs and roof racks.

EFFECTIVE HEADROOM
The distance between the seat and the headliner is determined by head clearance requirements and spatial expectations.

OVERALL HEIGHT
The vehicle's handling, aerodynamics, ground-clearance needs and occupant comfort all have to be considered when determining the overall height. Garage and underground parking access can limit the maximum height for vehicles such as SUVs and minivans.

UNDERBODY STRUCTURE
Provides space for an appropriate structure. Heavy-duty vehicles may require a separate frame system. Most unibody cars will require an integrated rail system under the driver's feet.

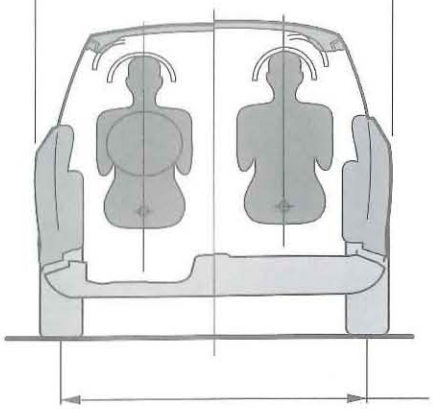
CHAIR HEIGHT
Lowering the chair height will help to lower the center of gravity and minimize the frontal area to reduce drag. Minivans & SUVs utilize a higher seating posture to provide command-of-the-road seating positions.

GROUND CLEARANCE
Off-road vehicles require high ground and "ramp over" clearances to avoid bottoming out on rough terrain. Sports cars will have minimal ground clearance to lower their center of gravity and improve aerodynamic performance.

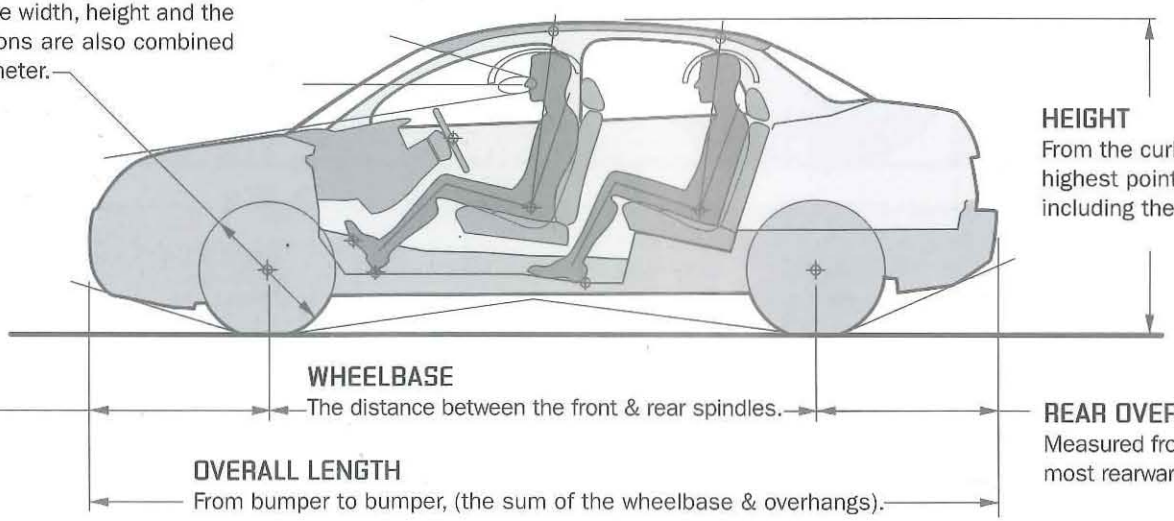
KEY DIMENSIONS

These key dimensions are used to set up and communicate the size and attributes of the package. Developing concepts are under continuous scrutiny and these measurements help to keep the design team informed. Additional dimensions may need to be added depending on the type of vehicle and its functional objectives. An off-road truck, for example, may need to record ground clearance and bed length.

- Length
- Width
- Height
- Wheelbase
- Front Track
- Rear Track
- Front Overhang
- Rear Overhang
- Tire Size
- Tire O.D.



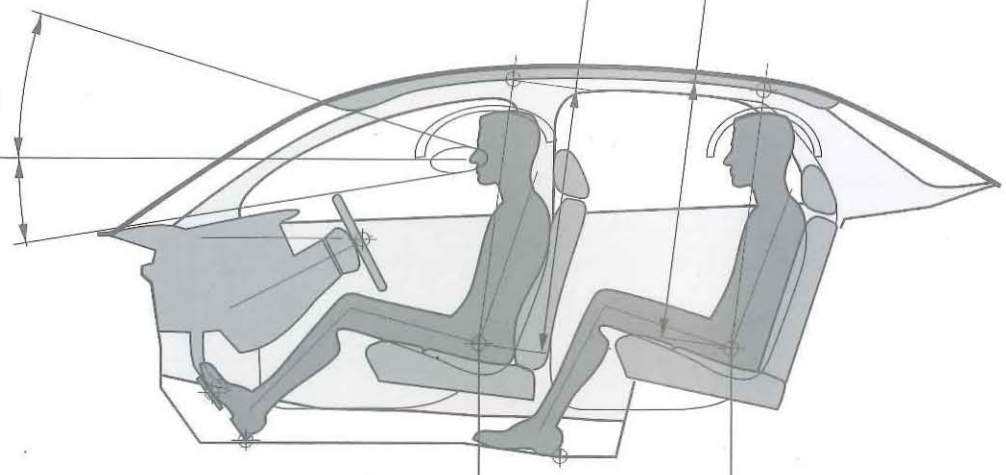
TIRE SIZE & TIRE OUTSIDE DIAMETER (O.D.)
Tires are specified by their profile width, height and the wheel diameter. These dimensions are also combined to produce the tire outside diameter.



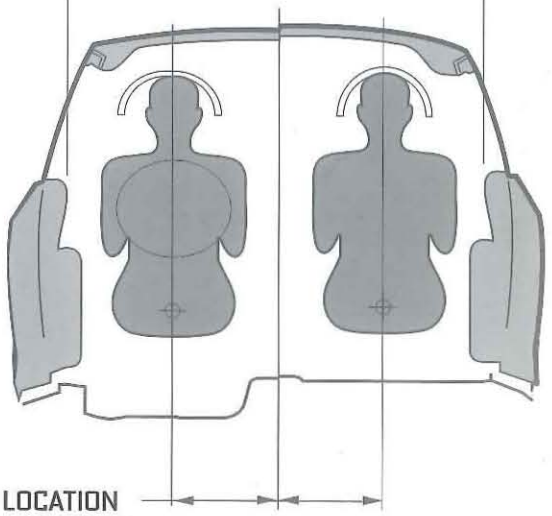
- Front Headroom
- Front Shoulder Room
- Driver Lateral Location
- Forward Up Angle
- Forward Down Angle
- Couple
- Rear Headroom
- Rear Shoulder Room

EFFECTIVE HEADROOM
Measured from H-point to the headliner along an 8° line (from vertical), plus 102mm.

FORWARD VISION ANGLES
Measured tangent to the eye ellipse, to the cowl or header trim.



SHOULDER ROOM
Distance across the interior trim, 256mm above the H-points.



COUPLE
Horizontal distance between the front & rear H-points.

OCCUPANTS LATERAL LOCATION
From the centerline of vehicle to the centerline of the manikin.

BENCHMARKING

Benchmarking is the most empowering packaging tool a designer can use. It provides the key building blocks to set up the proportions quickly and with confidence.

After the functional objectives have been established, start to research existing vehicles with similar attributes. If the intended market segment is mature, this should be a straightforward process. If the concept is reaching into new and unknown areas, benchmarking will require more thought and creativity.

The illustrations on pages 84–85 show a simple benchmarking study, where several products have been selected for comparison and are superimposed with the basic package of the new concept. Although this looks quite primitive, a great deal can be learned from this simple study. Because an existing car or truck is the result of a huge amount of research and development, benchmarking serves to provide a sound foundation to launch a new concept study, as long as the design team doesn't just follow the same paradigms.

Before starting the study, it is a good idea to examine a comparison vehicle and understand its design philosophy. Get to know the vehicle as intimately as possible by reading various consumer reports and test driving if possible. After this, elements of the package can be dissected and used where they make sense.

Break up each package according to the information on pages 76–79. Giving separate consideration to key elements that make up the overall dimensions.

Ultimately, you will need several benchmark studies to prove the new concept. The overall dimensions, the occupant package, the powertrain package, crashworthiness, cargo storage and any other innovative features incorporated into the design can be validated by demonstrating their similarity to other vehicles.

Line up each comparison according to the story it tells. For example, if headroom is the focus, line up the occupant's heads to each comparison vehicle. If it is the H-point to ground dimension, line up the ground lines of the vehicles.

Add the relevant dimensions to each study to add a higher level of accuracy to the comparison.

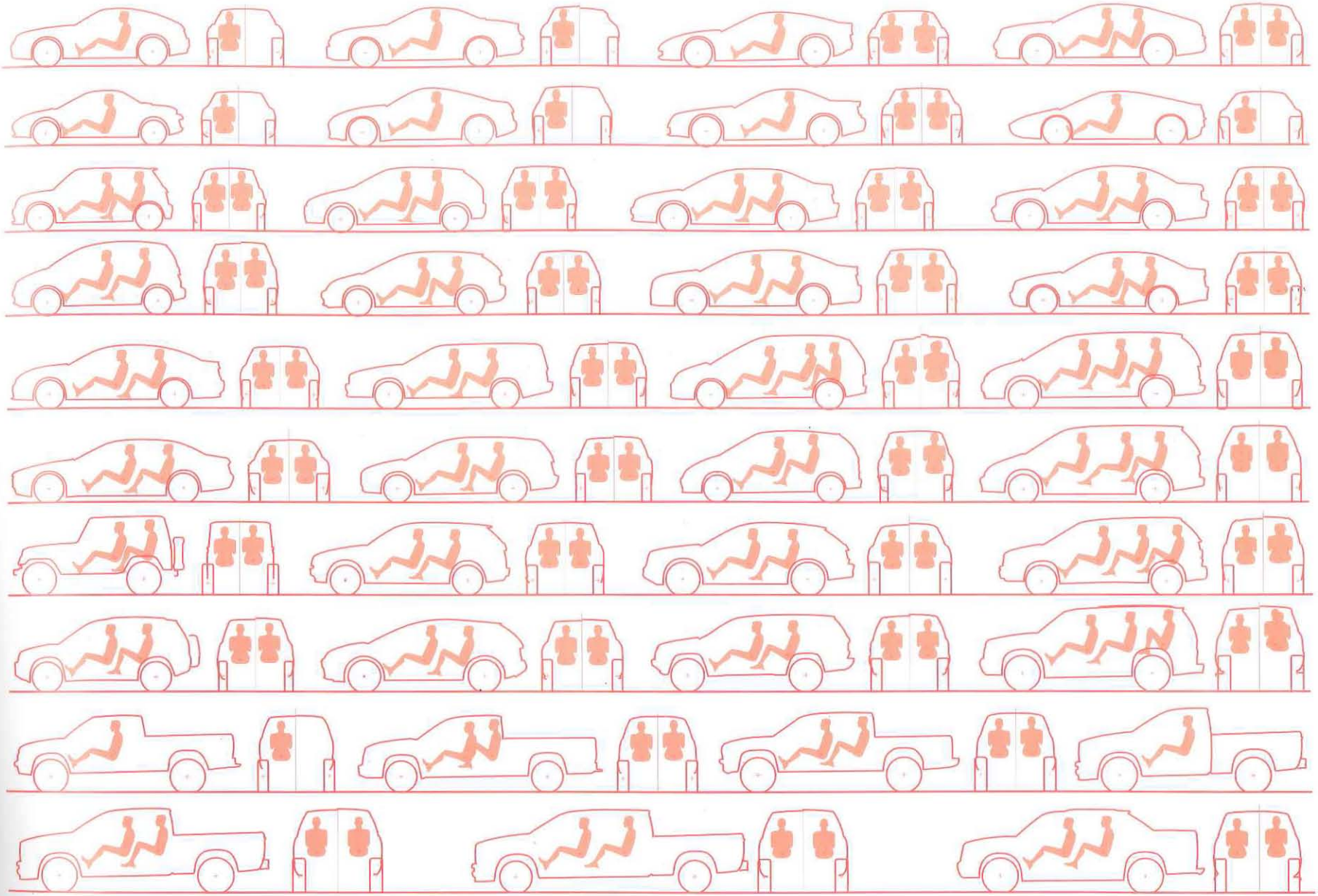
It is always advantageous to have access to a database of packages. Most companies will either buy these from organizations who specialize in vehicle measurement or they measure competitive vehicles and maintain their own database of package drawings.

For basic benchmark studies, each package should contain the vehicle outline, tire O.D. (outside diameter), spindles, occupants, h-points and heel location. These should be drawn in side and front views. A full set of dimensions is also very helpful.

There are many online resources which provide valuable information. The manufacturers' websites have all their vehicle specifications and measurements. Websites like www.autos.msn.com have tons of information and can create dimensional comparisons quickly. This information can be cross-referenced with vehicle-safety information from www.euroncap.com, www.safercar.gov or www.safecarguide.com.

A GRAPHIC PACKAGE DATABASE

The database should contain packages which contain the outlines, tires, and occupants drawn in side views and rear views.



BENCHMARK STUDIES

The example shown here is an off-road sports truck concept with a V12 engine. The five comparisons shown below demonstrate how elements of several different vehicles can be used to build and communicate the new concept.

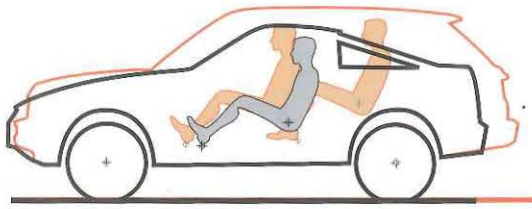
To set up the basic package for a concept, several comparisons are usually necessary. Each comparison will help the design team understand the various features and attributes of the architecture. The comparisons below show the following:

1. Ground clearance, wheelbase and driver heel height.
2. Driver posture, head environment and windshield location.
3. Engine/Transmission envelope.
4. Cargo storage.
5. Overall dimensions.

After developing the concept to this level, start to consider other large elements in the package, such as the fuel tank, spare tire, and stowing seats. Do not get too hung up on these components but respect the space they will occupy. As the project moves forward, an engineering team will become more involved and adjust the package accordingly. The main goal is to translate the emotion of the sketch into a rational model.

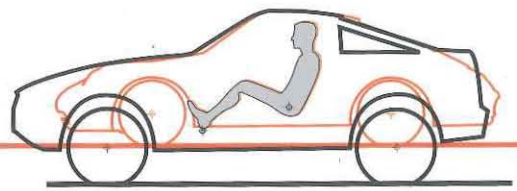
V12 OFF-ROAD SPORTS TRUCK - IDEATION SKETCH

1. The concept has the same wheelbase and ground clearance as the Range Rover so it should have a similar off-road capability. The driver's heel is also a similar height, providing room for a strong and durable underbody structure suitable for off-road use.



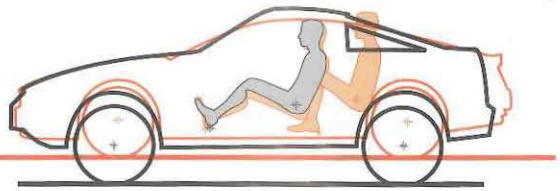
RANGE ROVER SPORT
(Similar wheelbase & ground clearance)

2. The occupant has a similar posture and relationship to the 911 interior environment—i.e., the roof and windshield. Note: The packages are lined up at the driver H-Point.

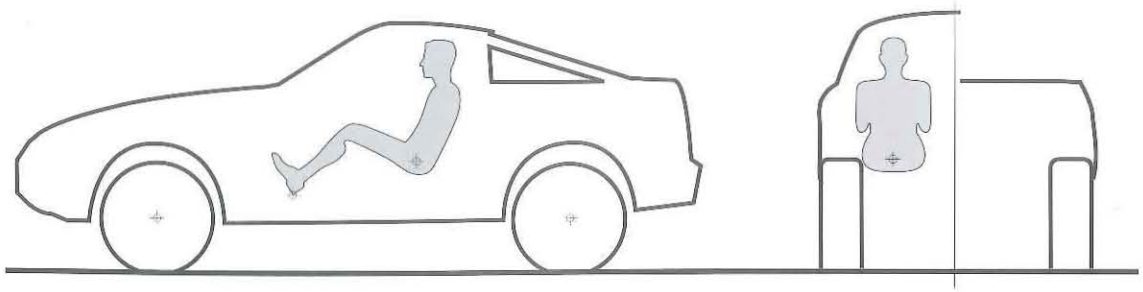


PORSCHE 911
(Similar head environment & driver posture)

3. The DB9 has a similar V12 engine. This front end comparison shows a similar hood profile and front end to driver's foot relationship, proving the engine should fit. Note: The packages are lined up at the driver's ball of foot.



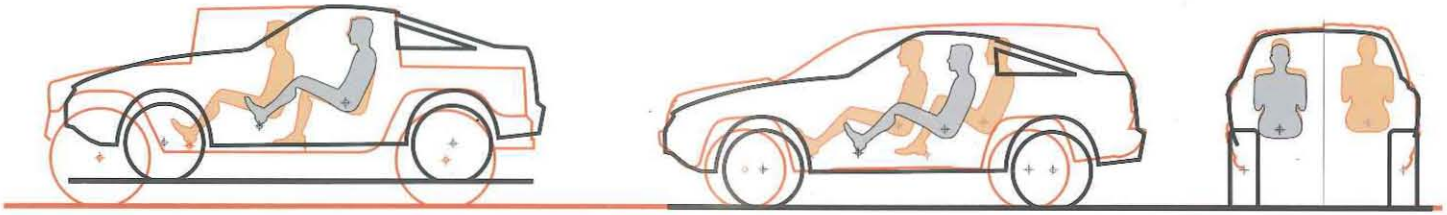
ASTON MARTIN DB9
(Similar engine size & location)



BASIC PACKAGE ORTHOGRAPHIC DRAWING
This initial package may look primitive but it is enough to start a scale model with confidence. Most of the main slab surfaces—i.e., the side glass, body side, hood, roof and windshield—can be blocked in from these side- and end-view profiles. The package will become more complex as the model develops, but should be kept very simple at the start.

4. The concept will have a similar bed size as the Hummer H1. Note: the packages are lined up at the occupant's shoulder.

5. Although the new concept is a different type of vehicle than the Jeep, the overall dimensions are similar, helping to communicate the size. The occupants' lateral location (the transmission will pass between them) and the tracks are also similar. Note: the packages are lined up at the ground and bumpers.



HUMMER HI
(Similar bed size)

JEEP GRAND CHEROKEE
(Similar overall length and width)