

Vehicle Systems Overview

How the major systems of a car work together, who engineers them, and how they interact

Major Vehicle Systems

System	Primary Function	Example Components
Powertrain	Generate and deliver propulsion	Engine, transmission, driveline
Brakes	Decelerate and control the vehicle	Rotor, caliper, pads, ABS
Suspension	Control wheel and body motion	Springs, dampers, sway bars
Steering	Control vehicle direction	Steering gear, column, power-assist motor
Body Structure	Support and protect the vehicle	Body-in-white, rails, pillars
Electrical	Power and control onboard electronics	Battery, alternator, ECUs, wiring
Thermal (HVAC)	Manage cabin and system temperatures	Radiator, HVAC unit, cooling loops
Exhaust	Manage combustion gases	Manifold, O ₂ sensors, catalytic converter, resonator, muffler
Fuel	Deliver fuel from tank to engine	Pump, lines, pressure regulator, filter, injectors
Safety	Protect occupants and avoid crashes	Airbags, seatbelts, collision-avoidance sensors

System Interaction Chains

- **More vehicle mass** → bigger brakes → bigger wheels to clear calipers → bigger, heavier tires → more unsprung mass → new suspension tuning → more mass (the loop continues).
- **Larger battery** → more mass → new spring/damper loads → more kinetic energy for brakes → new crash-structure needs → new thermal management needs.
- Every team works from the same vehicle-level requirements; a decision in one group shows up as a constraint in another.

Key Numbers

~40%

Fuel energy lost as exhaust heat (exhaust ≈ 500 °C)

up to 25%

Fuel economy loss from A/C use (EPA / DOE)

35 / 30 / 25%

Transport share of atmospheric CO / HC / NO_x

4-8 s / 60 s

FMVSS 208 unbelted audible / visual warning

up to 77%

Fire-risk reduction in rear impacts, tank ahead of rear axle

MY1998 / 1999

Dual front airbags required: cars / light trucks

0.5-20 Hz

ISO 2631 vibration range linked to health effects

-80.5%

Driver serious head-injury risk with belts + airbags

Quick Definitions

Steer-by-wire	Removes the mechanical link between steering wheel and actuator; inputs travel as electrical signals.
Body-on-frame	Separate load-carrying frame with the body bolted on. Space for suspension and powertrain.
Unibody	Body panels and load-bearing members form one structure. Lighter and more cohesive.
Cross-car beam (CCB)	I/P support frame joining the A-pillars; adds stiffness and absorbs crash energy.
Active vs passive safety	Active uses cameras/sensors to help avoid crashes; passive (airbags, belts) acts when a crash occurs.
Charging system	Battery + alternator + voltage regulator.

Who Engineers What

Role	Responsibility
Chassis	Suspension, steering and braking
Body Structures	Body-in-white, crash structure, closures
Powertrain	Engine, transmission, driveline
Electrical	Battery, wiring, ECUs, sensors
Thermal	Engine cooling, battery cooling, HVAC
Vehicle Integration	Interfaces and trade-offs between all systems
CAE	Simulation to validate designs before testing
Systems & Controls	Software and control logic tying electronics together
Manufacturing	How the vehicle is built and assembled

Development flow: Customer Requirements → Vehicle Requirements → Architecture → Packaging → Subsystem Requirements → Component Design → CAE & Simulation → Prototypes → System Validation → Vehicle Validation → Manufacturing → Production. Requirements flow down the systems-engineering V-model (via QFD and benchmarking) and validation flows back up.