Mechatronic systems in terrestrial vehicles

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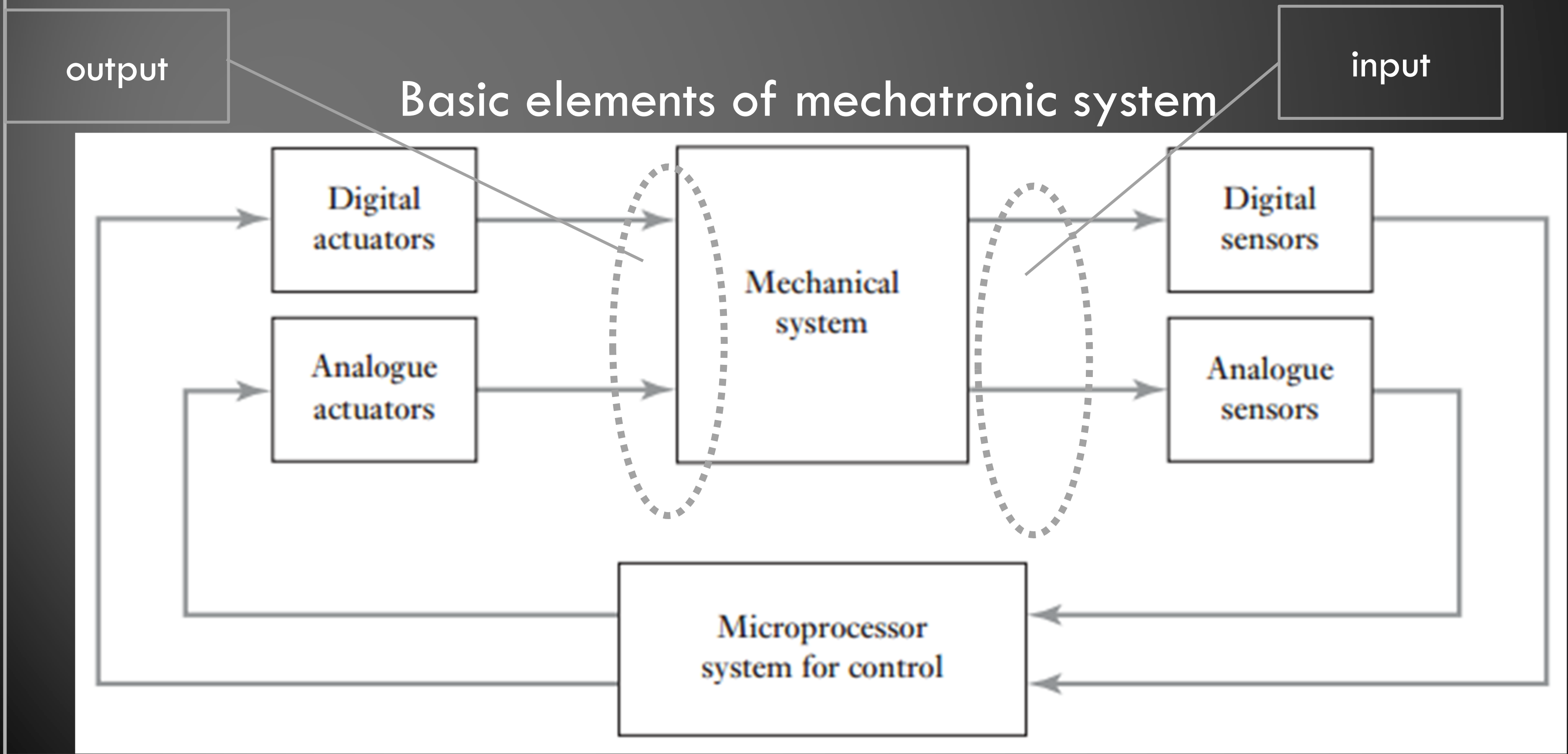
What is a mechatronic system?

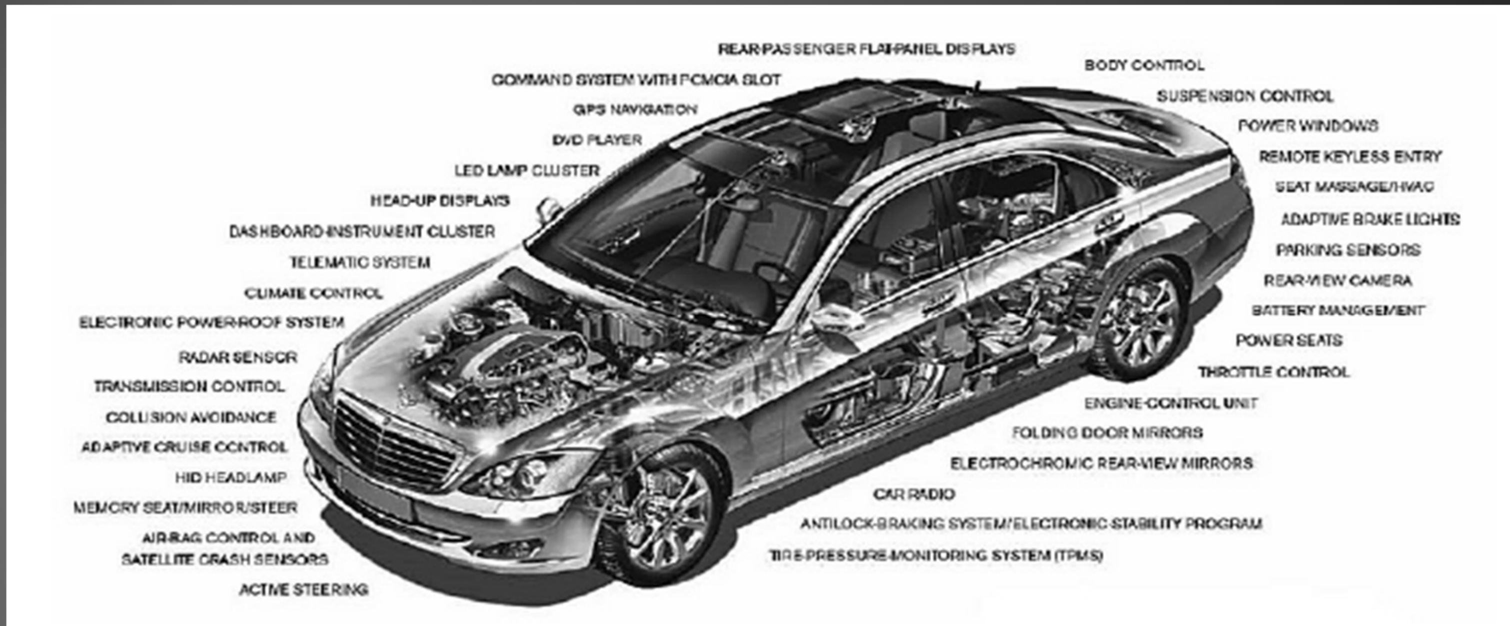
A complex integration of electrical, mechanical and control system



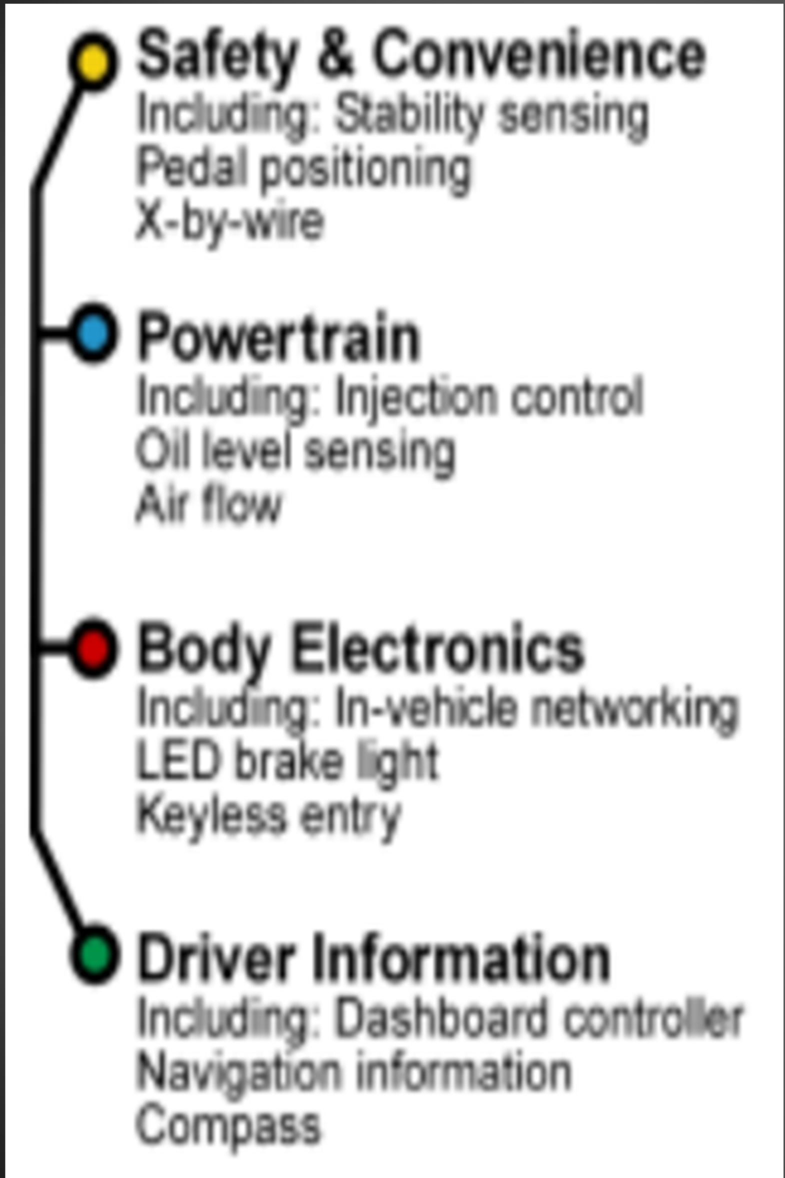
Automotive mechatronics through the years

	1960s	1970s	1980s	1990s	2000s
Body	Intermittent wipers	AC control	Drive computer	Keyless entry	
Engine	Electronic ignition	Electronic fuel injection		Electronic valve timing, Per-cylinder knock control	
Chassis		ABS	Suspension, Power steering	Four-wheel drive and steer	Distance interval control systems
Information					Navigation system

R&D of mechatronic systems in automobiles



Mechatronic sophistication in automotive vehicles is increasing. For example, Mercedes S-Class employs at least 70 networked ECUs (electronic control units).Ten years ago, most automotive vehicles had three ECUs.



Key successes for all is in **sensing** e.g.:

- Steering/Pedal Angle Sensor
- Pressure sensors for Powertrain / Braking
- Position Sensors for Headlight Control
- Gyro Sensors for Stability Control

ECU control loop

SENSORS

Throttle position
Intake air temperature
Manifold air pressure
Mass air flow (MAF)
Fuel pressure
In-cylinder pressure
Coolant temperature
Crankshaft position
Camshaft position
Engine speed
Engine knocking
Exhaust gas oxygen

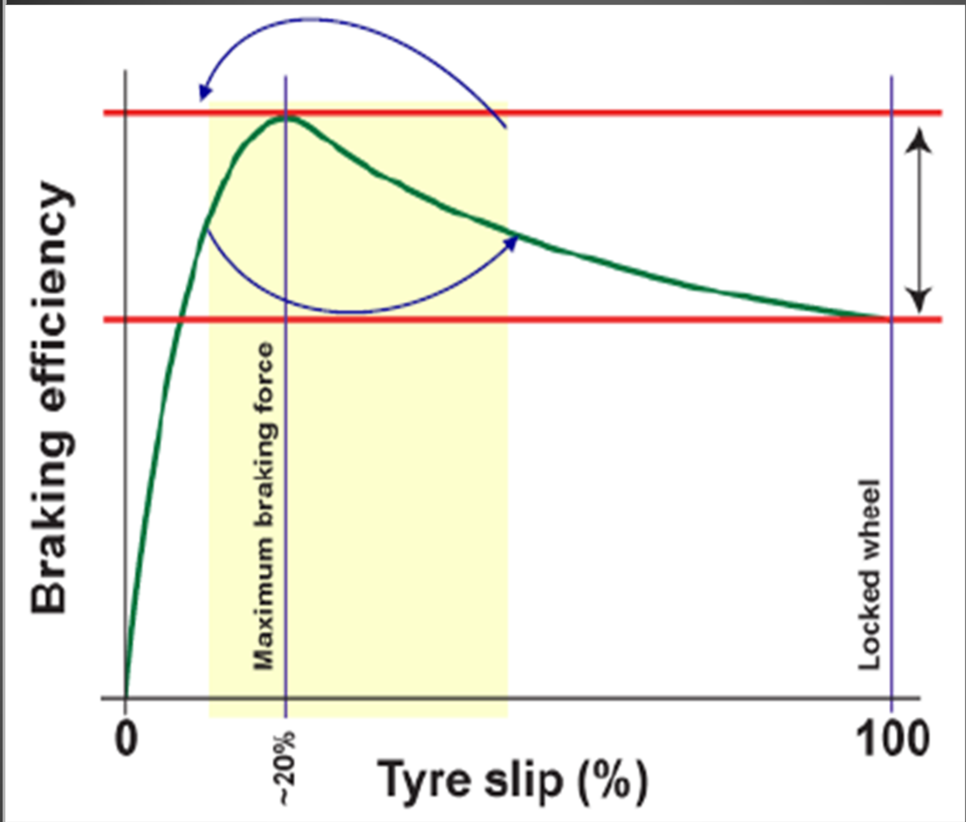
ACTUATORS

Fuel injection
Idle speed control
Ignition timing
Multispark timing
Dwell angle
Valve timing (VVT)
Camless valve actuation
Exhaust gas recirc. (EGR)
Turbo boost
Transmission control

Breaking and stability control systems

Anti-Lock Braking System
Electronic Brake-Force Distribution System
Traction Control System
Electronic Stability Control Sytem

Principle of ABS

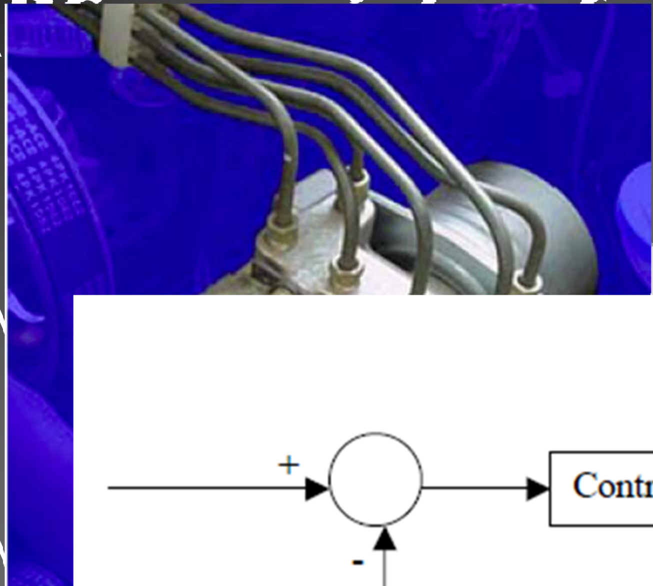


$$\text{Tyre slip} = \frac{\text{Vvehicle} - \text{Vwheel}}{\text{Vvehicle}} \times 100\%$$

During emergency braking, ABS automatically cycles tire slip around point of maximum braking efficiency

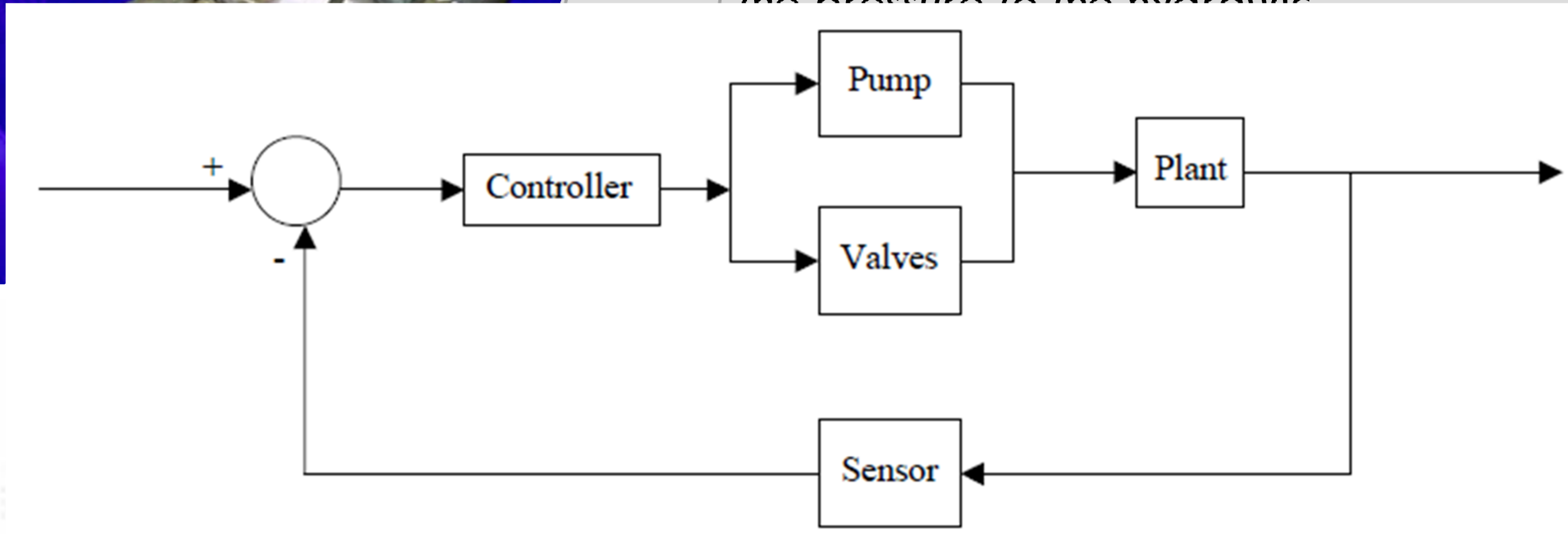
A

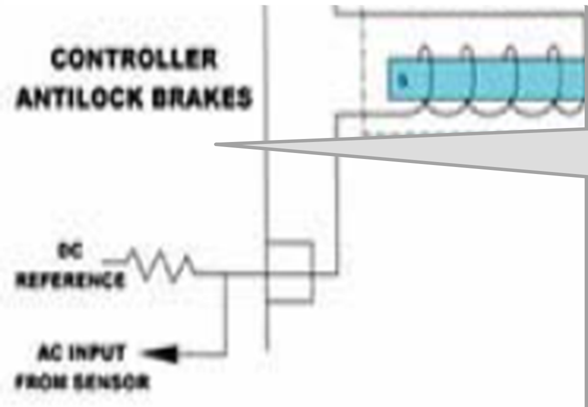
Are used to determine the acceleration or deceleration of the wheel.These sensors use a magnet



The va
functio

The pump in the ABS is used to restore





pumps status in order to provide the
desire amo

valves
is acco
opening the valves
be released from
braking system.

The entire system is observed and manipulated by the ABS controller.

Electronic Break-Force Distribution (EBD)

- Braking causes a dynamic weight transfer to the front wheels, depending on vehicle construction (geometry), decleration and aerodynamic drag
- EBD is adjusting the break-force more to the fro heels
- EBD bases rear wheel control on slip rather th
- EBD is operating before ABS, altough they sh hardware

If the break-force distribution is 50:50 (F:R), the front wheels will lock first

Traction Control System (TCS) or Anti-Slip Regulation (ASR)

- Limits the torque applied to wheels to prevent spinning
- Shares the electro-hydraulic brake actuator and the wheel speed sensors with the ABS
- Methods to achieve traction control:
  1. Brake one or more wheels
  2. Delay or suppress spark to one or more cylinders
  3. Reduce fuel supply to one or more cylinders
  4. Closed throttle
  5. Actuate boost control solenoid in turbocharged engines
- Brake-only systems are simpler, but less functional

Electronic Stability Control (ESC, ESP, DSC...)

- ESC works in the background and continuously monitors steering and vehicle direction
- It compares the driver's intended direction to the vehicle's actual direction
- Today considered the most important safety feature since the seat belt, studies show ESC reduces fatal car accidents by about 35%
- National Highway Traffic Safety Administration (NHTSA) requires ESC on all new light passenger vehicles in US after 2012

ESC's sensors:

- Steering wheel angle sensor
- Yaw rate sensor
- Roll rate sensor
- Lateral acceleration sensor
- Longitudinal acceleration sensor
- Wheel speed sensor

Determines the driver's intended rotation.

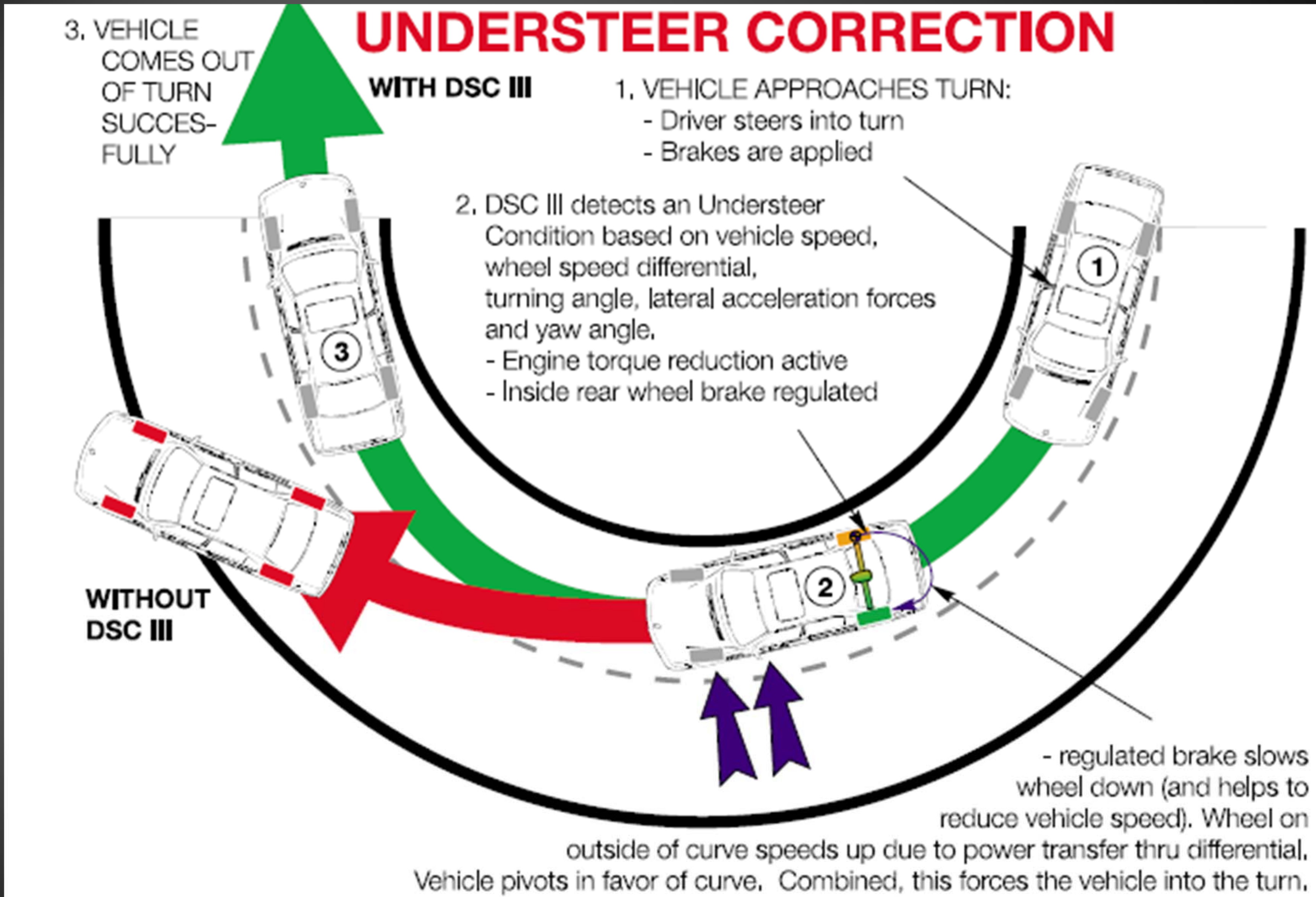
Measures the rotation rate of the car. The data from the yaw sensor

Similar to the lateral acceleration sensor in design, but provides additional information about road pitch and also provide another source of vehicle acceleration and speed

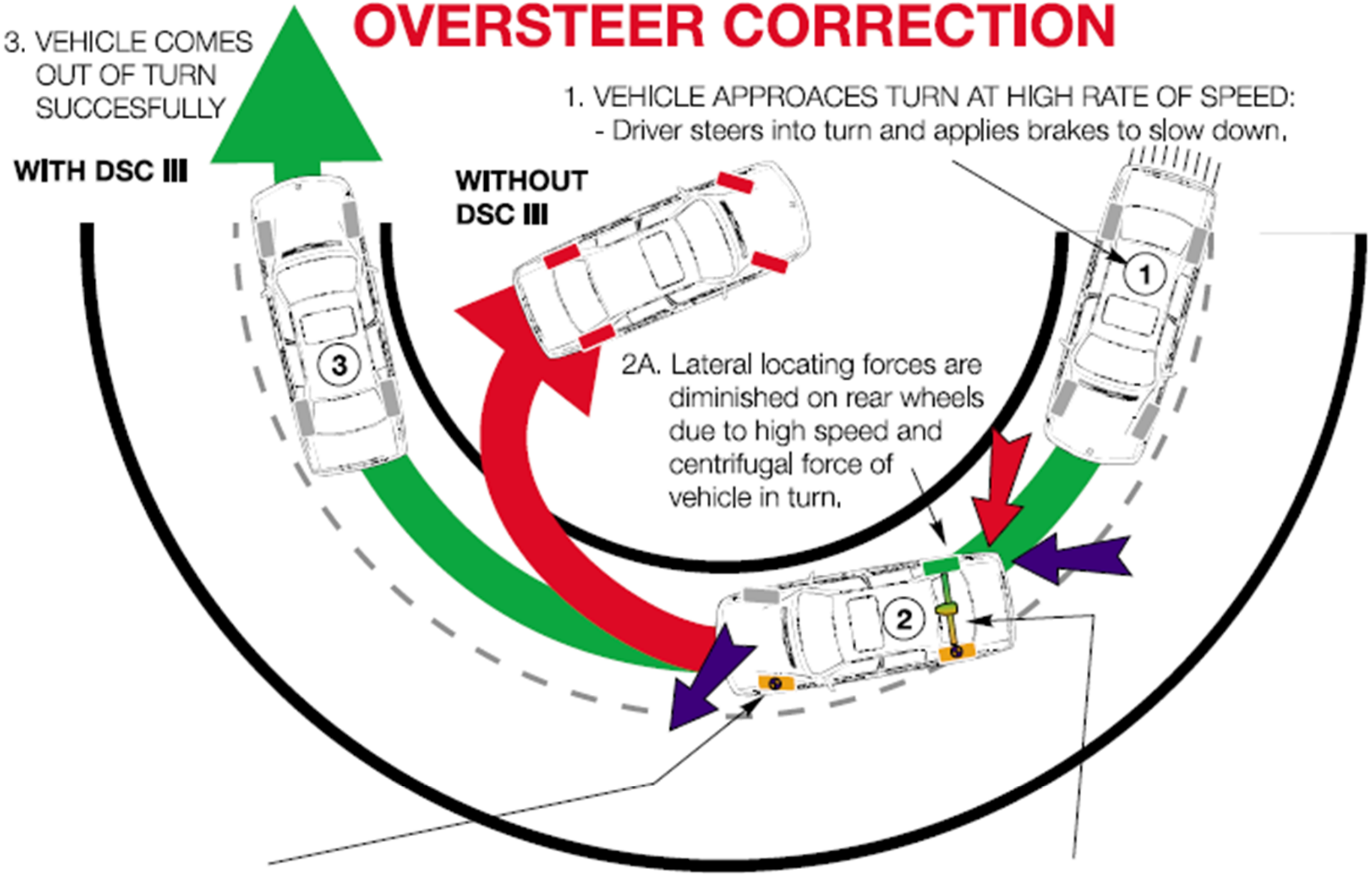
ESC intervention

- The following figures representing the typical mistakes by the drivers
- Both of understeer and oversteer can occurs at low speeds if the surface is slippery

figures courtesy by BMW AG.


UNDERSTEER CORRECTION
3. VEHICLE COMES OUT OF TURN SUCCES-FULLY
WITH DSC III
1. VEHICLE APPROACHES TURN:
- Driver steers into turn
- Brakes are applied
2. DSC III detects an Understeer Condition based on vehicle speed, wheel speed differential, turning angle, lateral acceleration forces and yaw angle.
- Engine torque reduction active
- Inside rear wheel brake regulated
1
2
3
WITHOUT DSC III
- regulated brake slows wheel down (and helps to reduce vehicle speed). Wheel on outside of curve speeds up due to power transfer thru differential. Vehicle pivots in favor of curve. Combined, this forces the vehicle into the turn.

OVERSTEER CORRECTION



2D. The torque reduction and rear brake regulation should stabilize the vehicle at this point. If not the left front wheel has a high degree of lateral locating force and is momentarily regulated.

This action deliberately causes the wheel to shed a calculated degree of it's locating force. This counteracts oversteer yaw at this wheel and also aids in slowing the vehicle down to correct it.

2B. Driver tries to compensate by oversteering which diminishes lateral locating force even further. Simultaneously, rear of car starts to slide out.

2C. DSC III determines an OVERSTEER condition. Engine torque is reduced via CAN Bus signalling. Outside rear wheel is momentarily regulated to counteract severe yaw angle (also helps to reduce drive torque further.)

Sources

1. Automotive Mechatronics - Operational and Practical Issues (Vol 1) - B. Fijalkowski
2. Automotive Mechatronics - Operational and Practical Issues (Vol 2) - B. Fijalkowski
3. ABS Braking Systems – Matt Terek, Dr. Nader Sadegh
4. Adaptive Control of Mechatronic Vehicle Suspension - Guido P. A. Koch
5. Pacejka, Hans B. - *Tire and Vehicle Dynamics* (2nd ed.)

Thank You for your kind attention