

Testing of Automotive Systems (Part I)

Module 2 Complete Vehicle Testing Overview

David Ludwig , Magna Steyr

WHAT AUTOMOTIVE TESTS YOU CAN THINK OF ?



Alternative Drivetrain

Complete
Vehicle

Vehicle
Architecture

Vehicle
Safety

Body / Doors
& Closures

Exterior /
Interior

Electrics /
Electronics

Software
Development

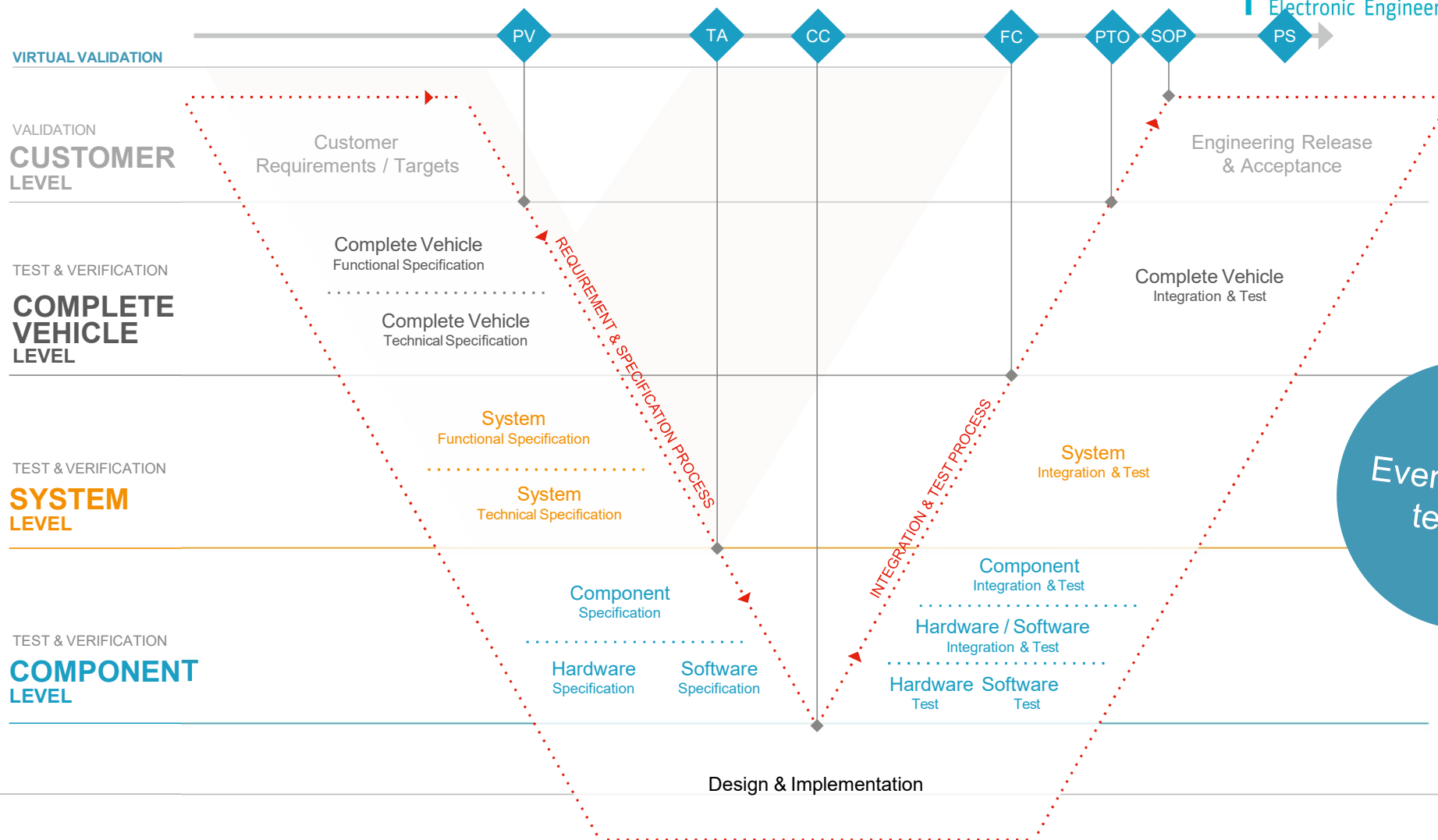
Chassis /
Powertrain

Styling /
Surfacing

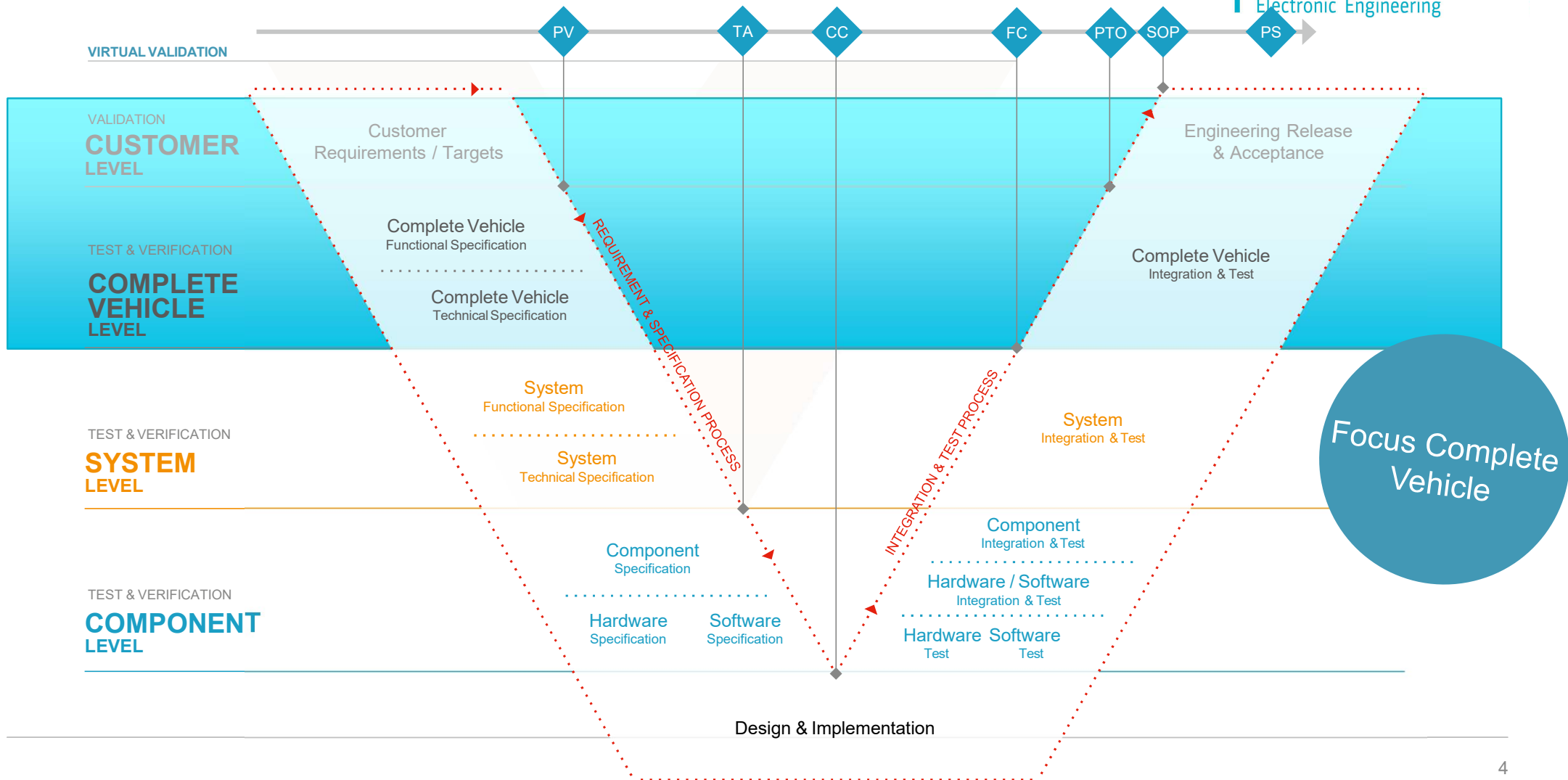
Cubing

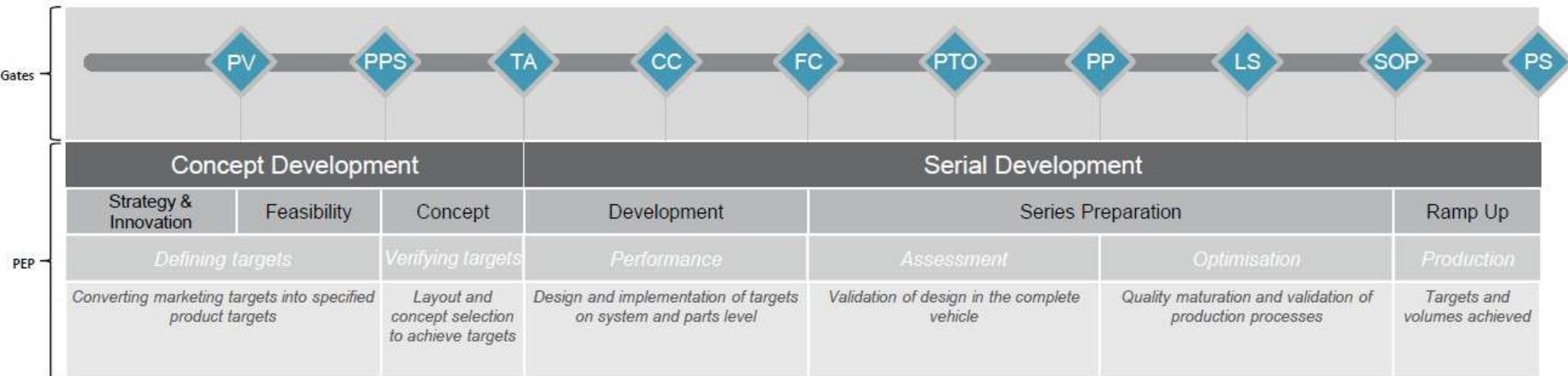
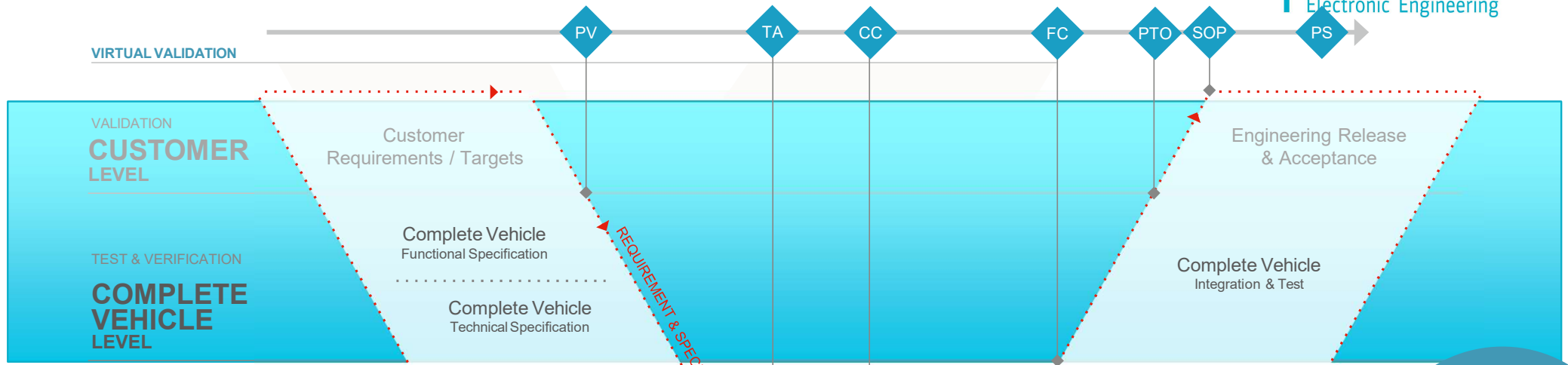
Testing
& Test Tools

Prototype
Shop

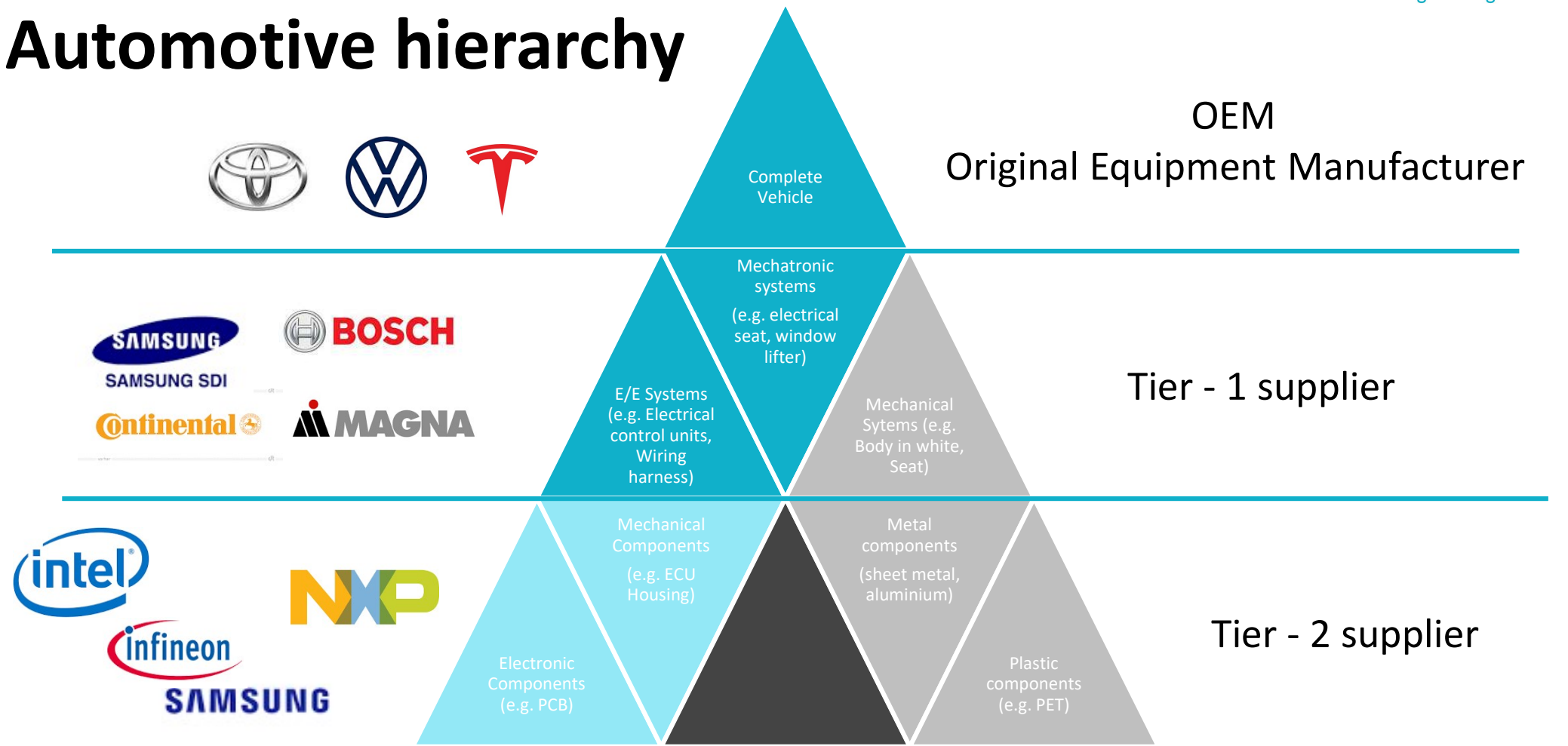


Everybody is testing!

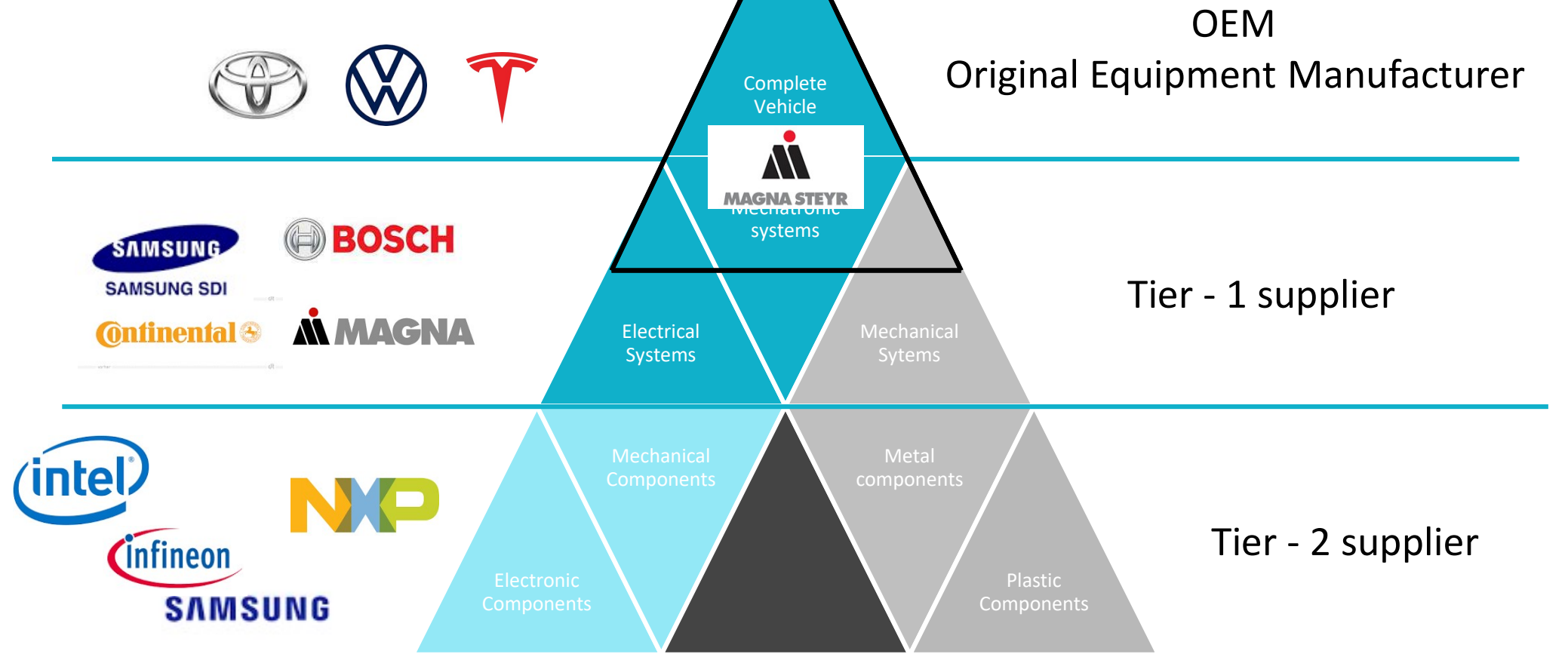




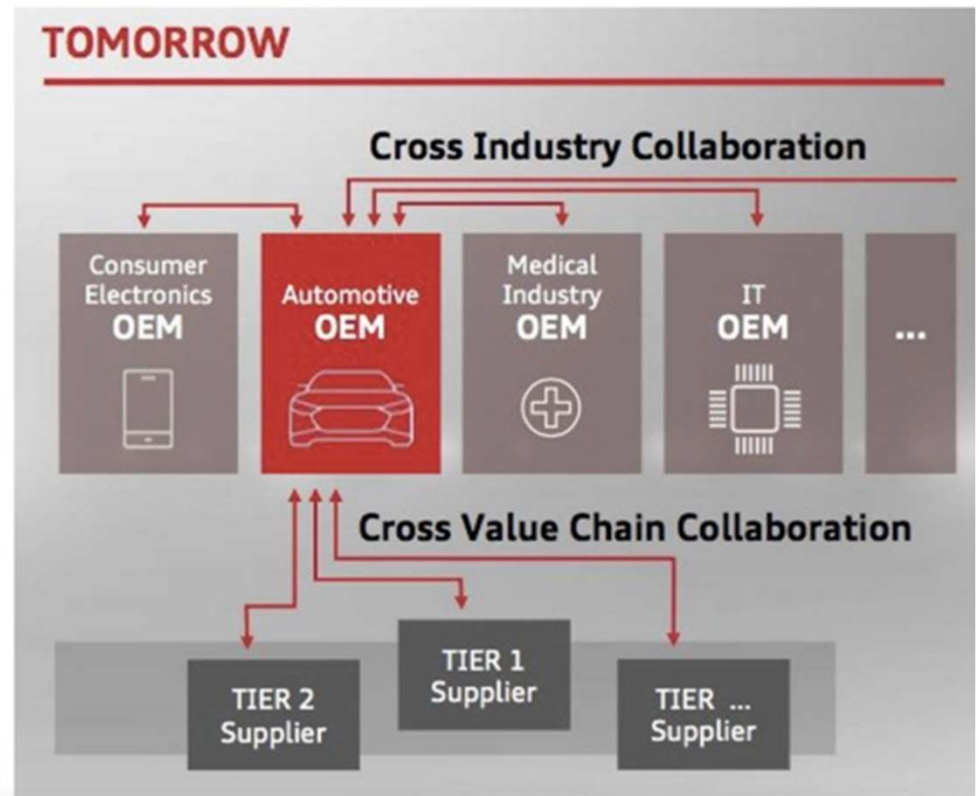
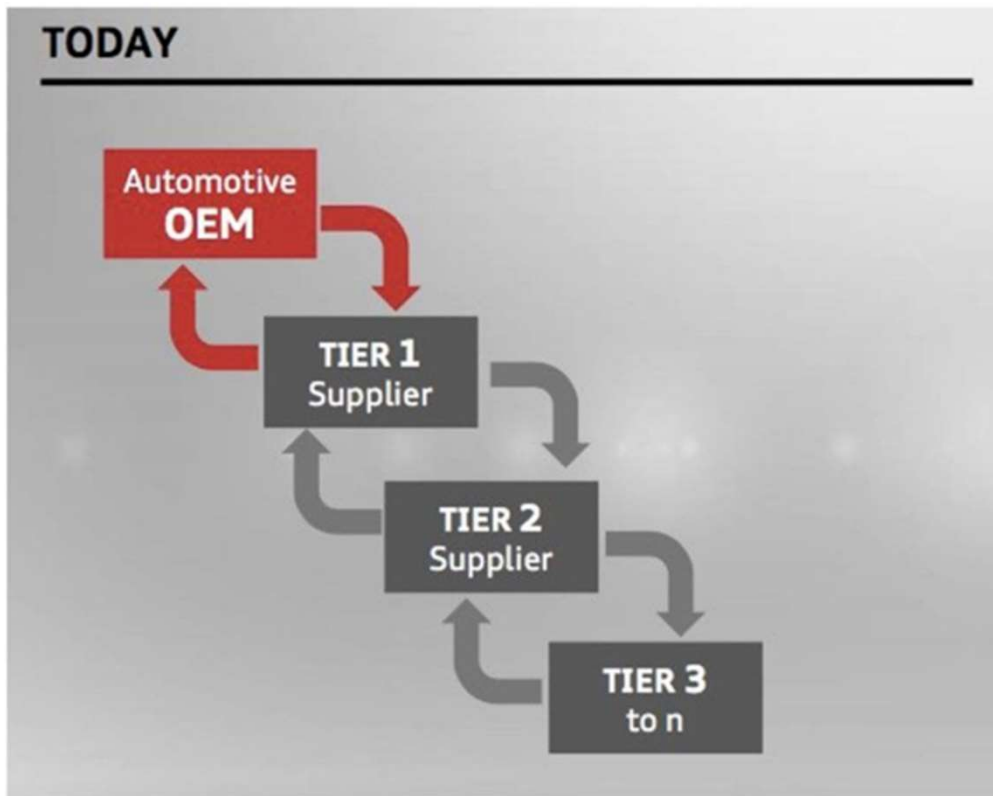
Automotive hierarchy



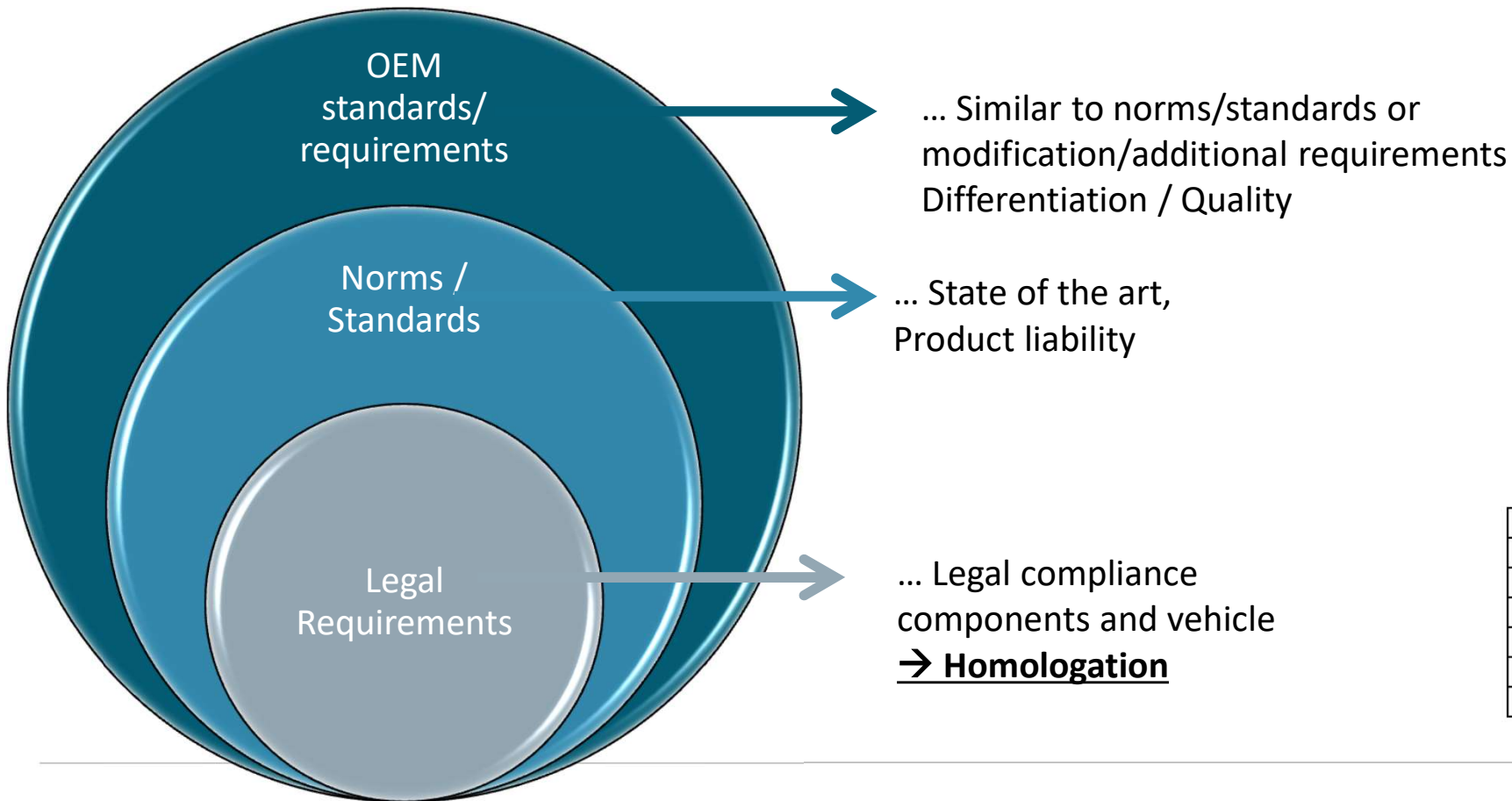
Magna Steyr acts on OEM's behalf



The transition in the automotive industry



Validation Requirements



STELLA AUTO S.P.A
e3*2007/46*0004
ZFS159000AZ000055
1 850 kg
3 290 kg
1 – 1 100 kg
2 – 880 kg



Legal
Requirements

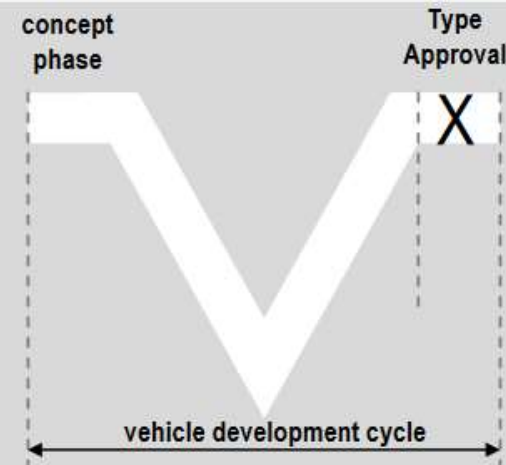
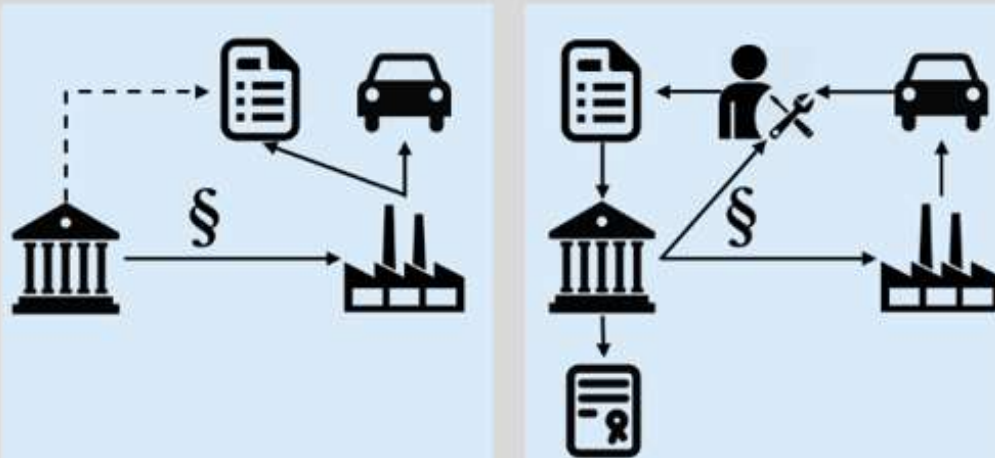
Homologation

Definition

Homologation refers to the certification process of a product (vehicle) granting that it complies with all local standards and legal regulations such as safety and environmental regulation.

No homologation → No CoC → No sales

Self certification vs. type approval 3rd party principle



Type Approval in vehicle development

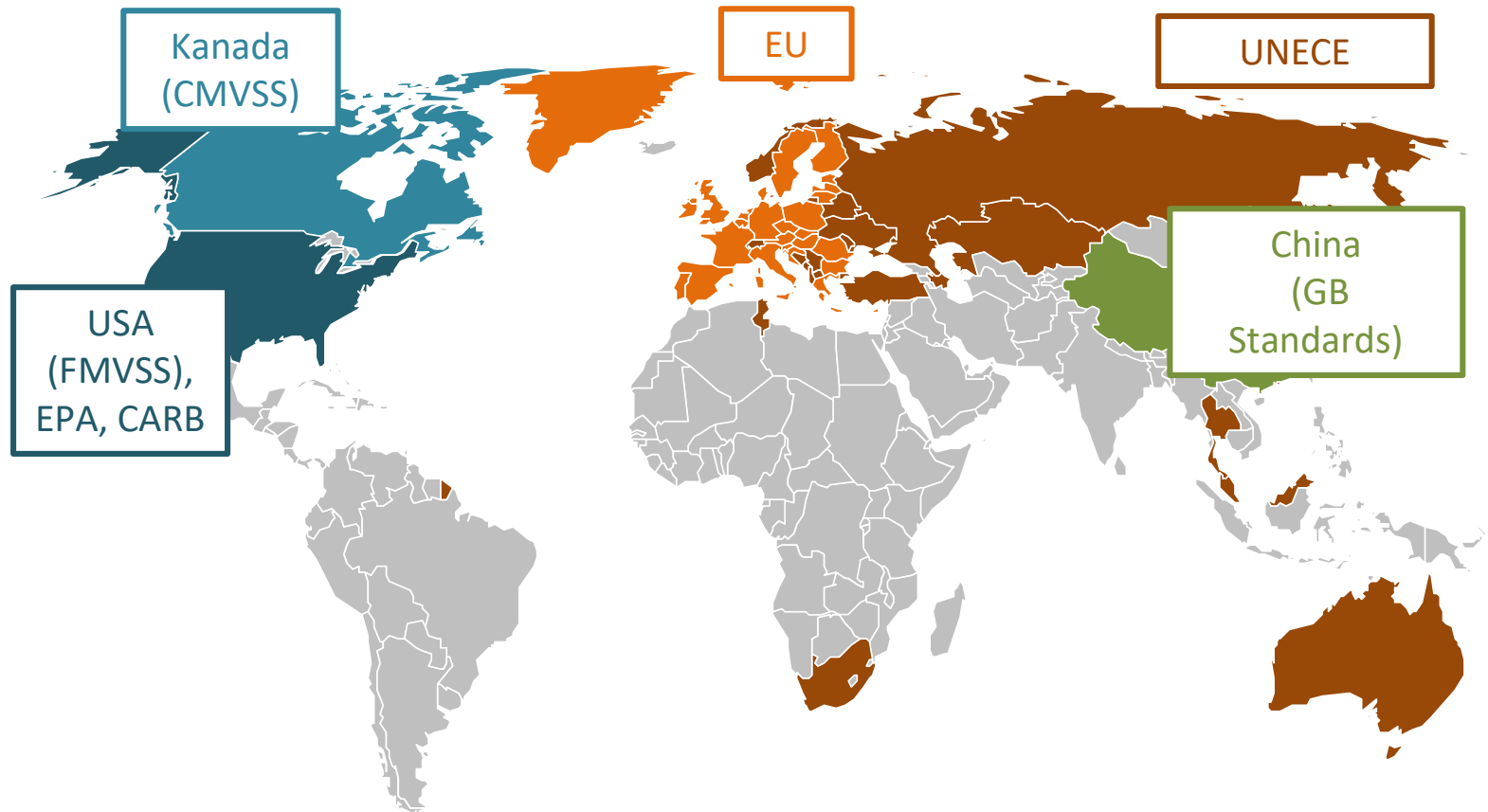
- Last step of development
- Accomplishment of the v-cycle
- legal and technical approval of the concept

- European Union: Directive 2007/46/EC Type approval, tests are based on United Nations Economic Commission for Europe (UN/ECE) procedures;
- North America: Federal Motor Vehicle Safety Standards (FMVSS) regulations released by the NHTSA;
- Australian Design Rules (ADR) regulations;
- Japan follows UN/ECE regulations and their own Test Requirements and Instructions for Automobile Standards (TRIAS) regulations;
- Other countries that accept or base their own regulation on those mentioned above, following the latest release or previous versions of the regulations.

Differences type approval

	Type approval by the authority 	Self certification* 
Development according to legal requirements	Manufacturers and suppliers	Manufacturers and suppliers
Test execution	Technical service	Manufacturers and suppliers
Certification tests...	...have to be carried out with the technical service	... are final backup tests
Documentation of the test results	Manufacturer documentation and report of the technical service	Manufacturer
The documentation will...	... be handed over to the type approval authority	... archived by the manufacturer
Confirmation of the Compliance with regulations	Technical service, Type approval authority	Manufacturer

Worldwide regulations I



Worldwide Regulations II

Advanced driver assistance systems

Advanced emergency braking systems
Brake assist systems (BAS)
Lane departure warning
Tire pressure monitoring
Gear shift indicator
Advanced emergency braking systems
Emergency lane keeping systems
Driver drowsiness and distraction monitoring
Intelligent speed adaptation
Emergency stop signals
Alcohol interlock devices interface
Reversing detection
Blind spot information system
Event data recorder
Advanced driver distraction warning
Driver availability monitoring systems (autonomous vehicles)
Systems to replace the driver's control (autonomous vehicles)
Systems to monitor the area surrounding the vehicle (autonomous vehicles)
Platooning
Systems to provide safety information to other road users (autonomous vehicles)

Chassis

Brake systems
Brake fluids
Brake hoses
Brake linings
Tires, rims
Retreaded pneumatic tyres
Temporary spare tires
Electronic stability control
Steering
Accelerator controls
Maximum speed
Coupling device
Towing system

Operating safety

Speedometer
Controls and displays
Pedals
Transmission
Power window systems
Theft protection
Reverse gear, vehicle access
Speed limitation devices

Lighting and visibility

Direct view
Indirect view / rear visibility
Visual indicators / instrumentation / media
Glazing Material
Defrost / defog
Wipe / wash
Light signaling devices
Headlamp cleaner
Acoustic signaling device
Warning device

Worldwide Regulations III

Passive safety

Frontal protection systems
Pedestrian protection
Bumper
External projections
Front underrun protection
Rear underrun protection
Wheel cover
Side protection device
Splash protection
Hood latch systems
Ejection mitigation
Energy-absorption front
Windshield mounting
Windshield zone intrusion
Energy-absorption rear
Fuel system / underride protection
Energy-absorption side
Energy-absorption roof
Fuel system / container integrity - CNG, LPG
Flammability of interior materials
Interior Fittings
Steering control protection / steering control rearward displacement

Restraint systems / seat belt assemblies
Restraint systems / seat belt anchorage
Seating systems
Head restraints
Child restraints
Door latches / hinges
Internal Trunk Release (door latches)
Partitioning Systems (Luggage)
Emergency exits (bus)
Bus safety

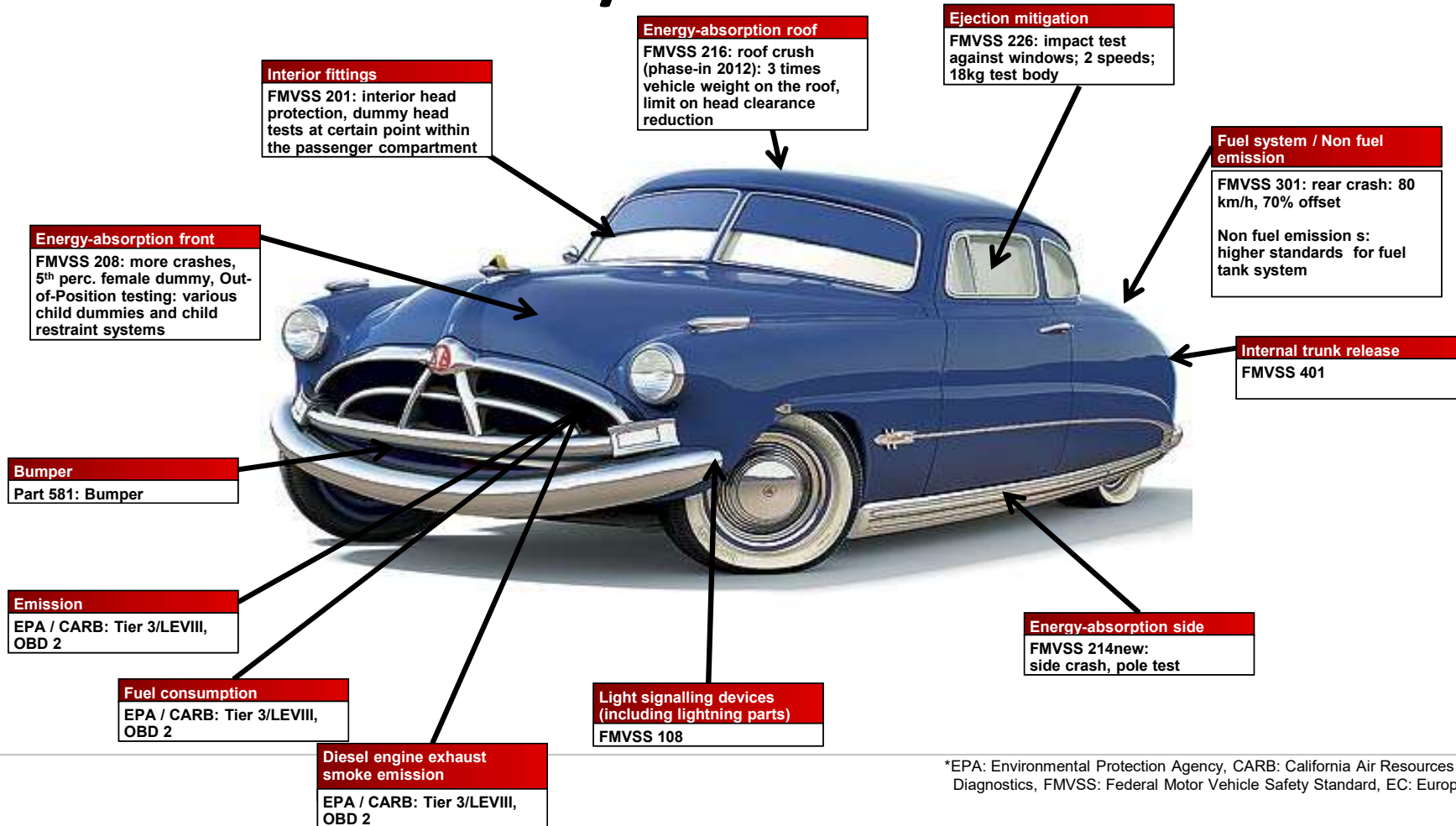
Vehicle in general

Type approval
Identification
Masses and dimensions
Theft protection (labels)
Consumer Information
Electromagnetic compatibility
Electric vehicles
H2 vehicles
Climate control/Heating system
Mounting of rear license plate
eCall / ERA-GLONASS
Vehicle-to-Vehicle (V2V) Communications

Environment

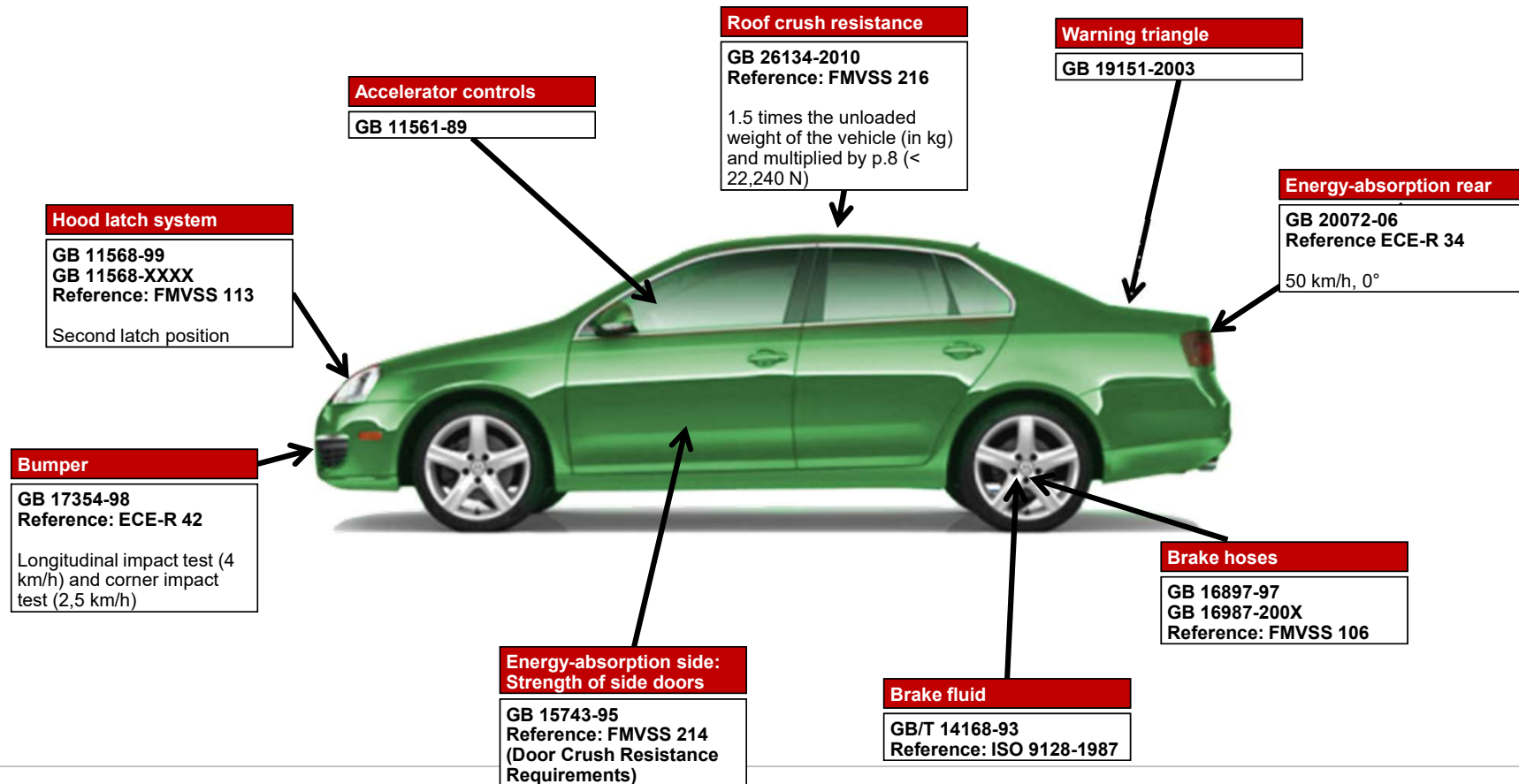
Emission
HC Shed Emission
CO2, fuel consumption
Diesel engine exhaust smoke emission
LPG, CNG
Engine power
Emissions air-conditioning systems
Air Quality Interior
Concentration of hazardous substances (pollutants) in the vehicle passenger compartment
Noise
Interior noise
Replacement silencing systems
Catalyst
Recycling, restriction of chemicals

Main Differences EU/UN ECE and FMVSS



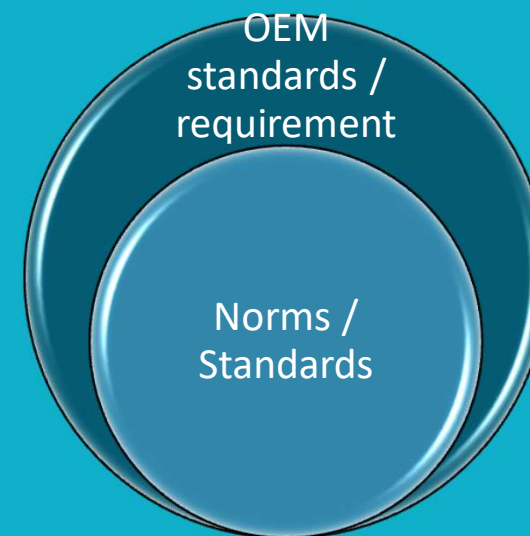
*EPA: Environmental Protection Agency, CARB: California Air Resources Board, OBD: On-Board Diagnostics, FMVSS: Federal Motor Vehicle Safety Standard, EC: European Community

Unique regulations for the Chinese market



Legend:
FMVSS: Federal Motor Vehicle Safety Standard, ECE: Economic Commission for Europe, ISO: International Organization for Standardization

Norms / (OEM) standards



ADAS Systems become homologation relevant

Common Strategy, Europe, U.S. and China - PRIMARY EMPHASIS ON CRASH AVOIDANCE (Active Safety)
HOWEVER, EXPECT NO RELAXATION OF CRASHWORTHINESS STANDARDS (Passive Safety).

Automated vehicle technology development is well ahead of regulation.
Transportation law is so much based on the concept of vehicles driven by humans that many laws do need to be changed.

"Europe on the Move" - reduce traffic fatalities

- Vision, 2020/2030: 50% reduction
- Vision, 2050: 100% reduction



New type approval and general safety regulation enacted with heavy emphasis on **active safety** and **protection of vulnerable road users**. **Personal data protection** is integrated into the requirements. Timelines are aggressive. Some examples:

- Enlarged head impact zone (2024)
- AEB (Auto Emergency Braking), pedestrian & cyclist (2024)
- Reversing detection (2022)
- Heavy duty vehicle direct vision (2026)
- Emergency lane keeping system (2022)
- AEB for light-duty vehicles (2022)
- Protection of vehicle against cyberattacks (2022)
- Intelligent speed assistance (2022)
- Alcohol interlock installation facilitation (2022)
- Driver drowsiness and attention warning (2022)
- Advanced driver distraction warning (2024)
- Driver availability monitoring system (2022)
- Systems to replace driver's control (2022)
- Systems to provide the vehicle with information on state of vehicle and surrounding area (2022)
- System to provide safety info to other road users (2022)

European Automobile Manufacturer's Association (ACEA) has asked Euro NCAP to temporarily suspend 2022 protocol due to Covid-19 industry situation

- Emphasis on **active safety**
- Policy and guidelines have been published
- National legislation moving very slowly
- States are enacting their own AV legislation



- NHTSA's focus has recently turned primarily toward 1) enforcement activities, and 2) to automated vehicle policy and guidelines.
- NHTSA published a Notice of Proposed Rulemaking in March, 2020, that will make it easier for manufacturers to test and deploy highly automated level vehicles without manually operated controls on public roads, by reducing the scope of FMVSS exemptions required, and providing a degree of regulatory certainty.
- Individual states are passing their own automated vehicle rules.
- Upgraded NCAP which includes many **active safety** features and a new crash test (**passive safety**), is years behind schedule.
- Rulemaking for adaptive beam headlamps is moving very slowly

IIHS continues to aggressively push the envelope on consumer information regarding **active and passive safety**.

- Moderate overlap frontal crash
- Small overlap frontal crash
- Side crash
- Rear impact and head restraint
- Roof strength
- Front crash prevention (low speed)
- Rear crash prevention (parking lot)
- Headlights
- LATCH

- Accelerating focus on **active safety**
- Generally following Europe (with some delay) on **passive safety**



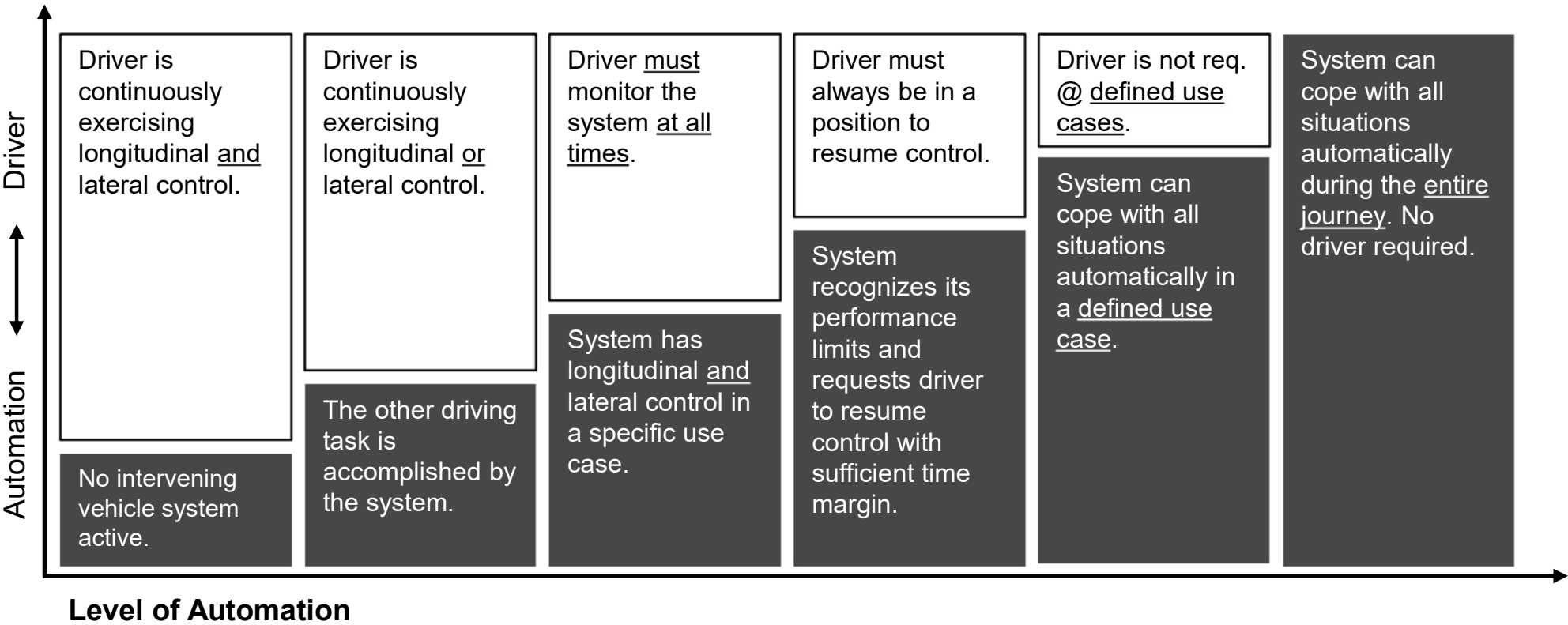
- Brief mention of **safety** in 13th 5-year plan
- Tighten safety management over transportation
- Promote the internet-based operation of transportation infrastructure
- Press ahead with vehicle automation

CNCAP upgrade proposal under review, to be effective 2022

- Driver/passenger protection
 - Increased frontal deformable barrier overlap
 - Side pole crash test for NEV
 - Added second row whiplash and child safety
 - Added side-airbag technical requirements, emergency call, seatbelt reminder, and protection from vehicle's electronic systems
- Pedestrian Protection
 - Advanced leg-form impactor
 - Increased pedestrian head protection area
- ADAS System Safety
 - Additional tests and requirements for Auto Emergency Braking, Lane Keeping Assist, Lane Departure Warning, Blind Spot Detection, and Speed Assist System
- Increased ADAS system weighting from 15% to 25%

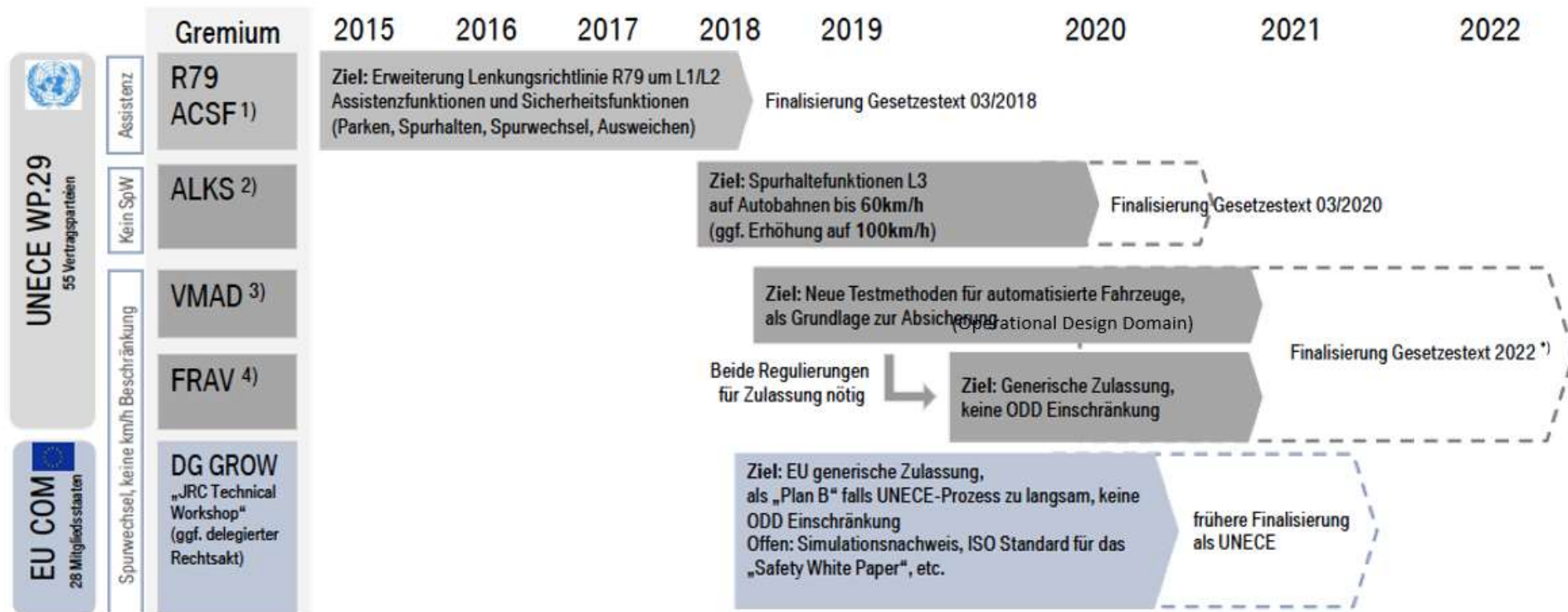
Evolution of CNCAP requirements sometimes forecast future regulatory trends

Levels of Automated Driving



SAE	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
BASt	Driver Only	Assisted	Partially Aut.	Highly Aut.	Fully Automation	-

But regulation is slow (Europe!) ...



20.01.2020

- 1) ACSF = Automatically Commanded Steering Function
 2) ALKS = Automated Lane Keeping System
 3) VMAD = Validation Method for Automated Driving
 4) FRAV = Functional Requirements for Automated Driving

SpW = Spurwechsel

*) Absicherungsmethoden voraussichtlich 2022
 als Entwicklungsgrundlage verfügbar

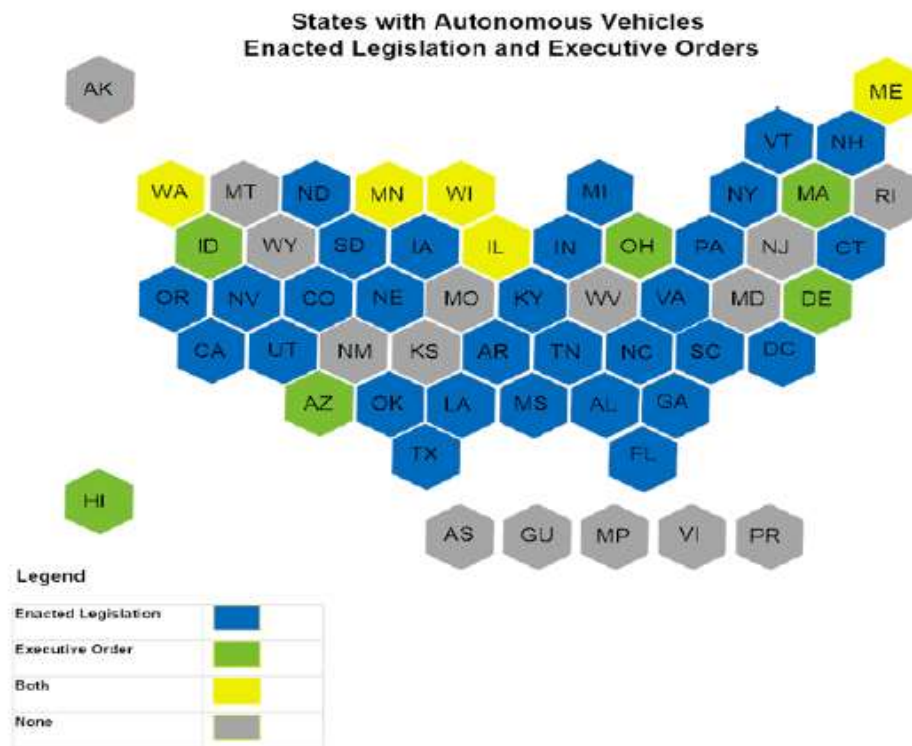
Planstand

Risiko aufgrund bisherigen Fortschritts

Seite 1

S. 12

... or complicated (USA)



Mercedes Drive Pilot Level 3 ADAS Approved For Use In California

The first Drive Pilot-equipped cars in the US – the 2024 S-Class and EQS Sedan models – will be delivered to customers in late 2023.



California has become the second US state to certify Mercedes-Benz's Drive Pilot SAE Level 3 conditionally automated driving technology after Nevada in January.

State regulators have approved the system for use in California in standard-production vehicles – **EQS Sedan** and S-Class – making Mercedes-Benz the first car manufacturer with authorization to introduce such a SAE Level 3 system in a production car for use on public freeways in America's most populous state.

Drive Pilot will be available in the US as an option for 2024 Mercedes-Benz S-Class and **2024 EQS Sedan models**, with the first cars equipped with the system to be delivered to customers in late 2023.

[Mercedes Drive Pilot Level 3 ADAS Approved For Use In California \(insideevs.com\)](https://insideevs.com)

... and standardization is still under construction!!

Ongoing and planned ISO projects:

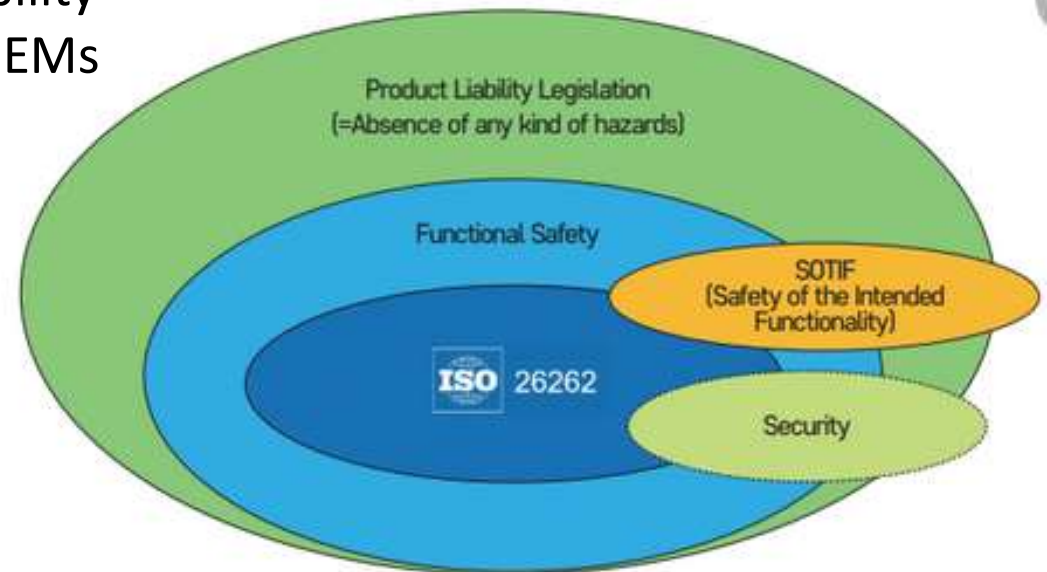
TC	ISO-No.	2015	2017	2019	2021	2023	2025	Description of function:
TC204/WG14	20035	CACC						Cooperative ACC system incl. V2V and V2I
TC204/WG14	19237	PDCMS						Pedestrian protection
TC204/WG14	22078	BDCMS						Bicyclist protection
TC204/WG14	15622			ACC-rev				ACC systems with external input of speed
TC204/WG14	19638	RBDPS						Road Boundary Departure Prevention System
TC204/WG14	21717	PADS						Partially automated in-lane driving system
TC204/WG14	21202	PALS						Partially Automated Lane Change System
TC204/WG14	22737		LSAD					L4 driving at low speeds
TC204/WG14	23375		CELM					Collision evasive lateral manoeuvre system
TC204/WG14	20901	EEBL						Emergency electronic brake light system
TC204/WG14	23376		VVICW					V2V intersection collision warning system
TC204/WG14	22377			FSV2V*				Functional safety for V2V cooperative functions
TC204/WG14	Open			Truck Platooning*				Controlstrategy for truck platooning
TC204/WG14	23792-1			MCS-1				Motorway chauffeur – general specification
TC204/WG14	23792-2			MCS-2				Motorway chauffeur without lane-change (L3)
TC204/WG14	23792-3			MCS-3*				Motorway chauffeur with lane-change (L3)
TC204/WG14	23792-4			MCS-4*				Motorway chauffeur including merging (L3)
TC204/WG14	23792-5			MCS-5*				Motorway chauffeur including routing (L3 or L4)

TC204/WG14	23792-5								MCS-5*	Motorway chauffeur including routing (L3 or L4)
TC204/WG14	Open								Highway pilot*	Highly automated driving on highways (L4)
TC204/WG14	Open								Robot-Taxi*	Urban automated taxi (L4)
TC204/WG14	23793-1								Fallback-1	Fallback functions – general specification
TC204/WG14	23793-2								Fallback-2	Fallback functions for L3-systems
TC204/WG14	23793-3								Fallback-3*	Fallback functions for L4-systems
TC204/WG14	20900								PAPS	Partially automated parking systems incl. remote
TC204/WG14	23374								AVPS	Valet parking
TC22/SC33/WG16	22133								TOMC	Kommunikation for functional tests
TC22/SC33/WG16	19206-1								ASTE-1	Test-target for rear-end of passenger cars
TC22/SC33/WG16	19206-2								ASTE-2	Test-target for pedestrian
TC22/SC33/WG16	19206-3								ASTE-3	Test-target for 3D-passenger cars
TC22/SC33/WG16	19206-4								ASTE-4	Test-target for cyclist
TC22/SC33/WG16	19206-5								ASTE-5	Test-target for motorcycles
TC22/SC33/WG16	19206-6								ASTE-6	Test-target for animals
TC22/SC33/WG3	22735								LKAS-Test	Test for lane keeping
TC22/SC33/WG3	22733-1								AEBS-Test-C2C	AEB-Test method Car-to-Car
TC22/SC33/WG3	22733-2								AEBS-Test-C2V	AEB-Test method Car-to-Vulnerable Road User
TC22/SC33/WG9	Open								AD-Testing	Set of standards for test scenarios

Level ≤ 1 Level 2 Level 3 Level 4 *start of project not confirmed.

Norms and Standards are part of product liability

- Norms and standards are not needed for type approval (homologation), BUT
 - Norms and standards describe the „State of the art“
 - Serve as a reference for product liability
 - Are requested (differently) by the OEMs



Example: Safety Standards

Product Safety

Functional Safety

Safety of Use

SOTIF
(ISO 21488)

Mechanic Safety

Electric Safety

Chem. Safety

..... Safety

Functional
Safety of
E/E
Systems
(ISO
26262)

Intended use

Unintended misuse

Focus on
Emergency
intervention
systems and ADAS

Mechanical

Electrical

Chemical

Correct
Performance
of intended
Functionality

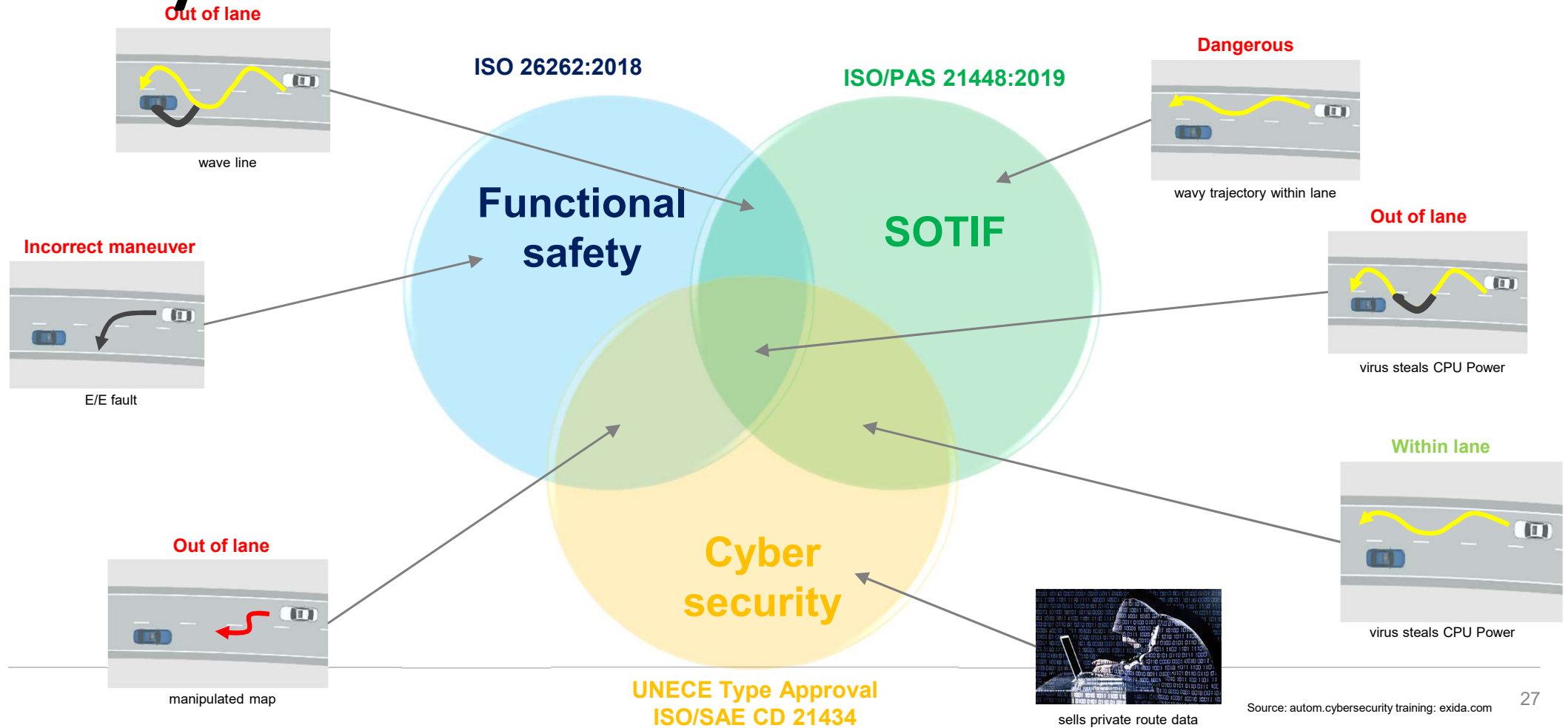
Foreseeable
Misuse

Cyber Security
(ISO/SAE 21434)

Passive Vehicle Safety
(Legal, Consumer ratings)

Homologation

Safety Standards



Consumer organization protocols

- **Ratings are no standards!**
- NCAP: new car assessment program
- IIHS: Insurance Institute for Highway Safety
- HLDI: Highway Loss Data Institute



Vehicle Safety Strategy E-NCAP 2021

Euro NCAP 4 & 5 stars strategy and actual status

EURO NCAP		Adult Occupant Protection					Child Occupant Protection					Vulnerable Road Users					Safety Assist				
Version	2021		Status	Strategy 4 Star	Strategy 5 Star	Max.		Status	Strategy 4 Star	Strategy 5 Star	Max.		Status	Strategy 4 Star	Strategy 5 Star	Max.		Status	Strategy 4 Star	Strategy 5 Star	Max.
		Frontal RW	6	7	7	8	Dyn. FC	11	13	13	16	Head Impact	14	14	14	24	SBR	2	2	2	2
		Overall Rating	6	7	7	8	Dyn. SC	8	8	8	8	Upper legform	2.4	2.4	2.4	6	Occupant Status	1	1	1	1
		2 stars	6	6	6	6	CRS Installation	7.25	12	12	12	FlexPLI	6	6	6	6	SAS	1.5	3	3	3
			4.5	5	5	6	Vehicle Based	3	5	7	13	AEB Pedestrian	2	7	7	9	LSS C2C	2	3	4	4
		Far-Side	0	0	3	4						AEB Bicyclist	0	0	2	9	AEB JA C2C	1.24	2	2	2
Project	N60AB	Whiplash Front	1	2.5	2.5	3											AEB/AES CCR	0	0	3	4
Series	600km High-equip	Whiplash Rear	0	1	1	1															
Year	2020	Rescue/eCall	0	0	2	2															
		Sub Sum[P]	23.5	28.5	33.5	38	Sub Sum[P]	29.25	38	40	49	Sub Sum[P]	24.4	29.4	31.4	54	Sub Sum[P]	7.74	11	15	16
		Sub Score[%]	61.8%	75.0%	88.16%	-	Sub Score[%]	59.7%	77.6%	81.6%	-	Sub Score[%]	45.2%	54.4%	58.1%	-	Sub Score[%]	51.6%	68.8%	93.8%	-
		Sub Star	3	4	5	5	Sub Star	2	4	5	5	Sub Star	3	4	5	5	Sub Star	3	4	5	5
		Min. For 4 star	26.6 70%				Min. For 4 star	34.3 70.0%				Min. For 4 star	27 50.0%				Min. For 4 star	9.6 60%			
		Gap to 4 star BOX	-3.1	1.9			Gap to 4 star BOX	-5.05	3.7			Gap to 4 star BOX	-2.6	2.4			Gap to 4 star BOX	-1.86	1.4		

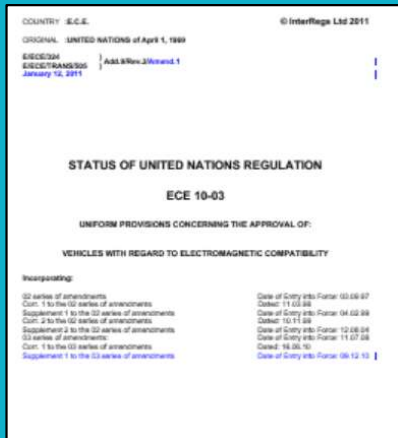
Standards can become regulation



Complete vehicles **require** cyber security type approval since 2022.

OEM Norms can exceed regulations (EMC)

OEM 1



ECE R10

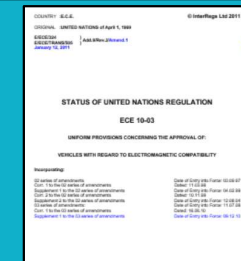
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GS 95002

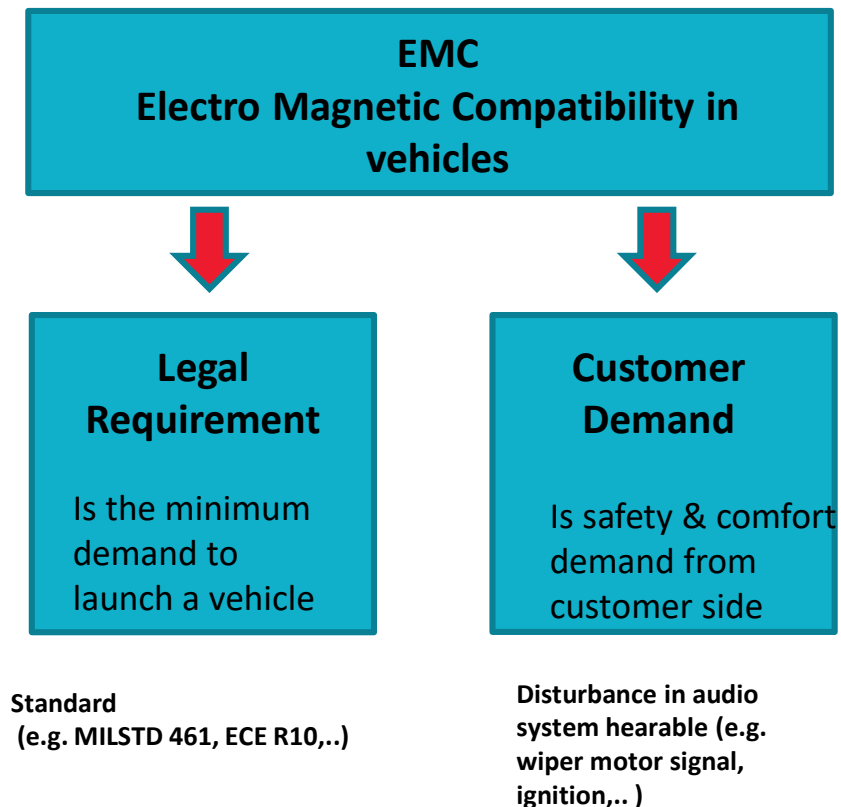
OEM 2

Only legal requirements



ECE R10

EMC complete vehicle



Electro Magnetic Compatibility refers to the use of components in electronic systems that do not electrically interfere with each other and the environment

ECU HW Testing for E/E



- ISO-16750 Road vehicles — Environmental conditions and testing for electrical and electronic equipment
 - *Part 1: General* (2006)
 - *Part 2: Electrical Loads* (2012) (very similar to ISO 21848) (\$149)
 - *Part 3: Mechanical loads* (2012)
 - *Part 4: Climatic loads* (2010)
 - *Part 5: Chemical loads* (2010)

INTERNATIONAL
STANDARD

ISO
16750-2

Fourth edition
2012-10-01

Road vehicles — Environmental
conditions and testing for electrical
and electronic equipment —

Part 2:
Electrical loads



Design Verification Plan (DVP) Complete Vehicle

Complete Vehicle DVP (Design Verification Plan)

- Based on development strategy (virtual, conventional, variants)
- Which variant will be validated in which generation
- Validation contents not only vehicles, but also bucks, principal testbenches (e.g. laboratory vehicle)
- Referring to DVP (exclusive use, shared, test duration, etc...) the needed HW per generation will be derived

		Gen.1			Gen.2			Gen.3				
		Var.1	Var.2	Var.3	Var.1	Var.2	Var.3	Var.1	Var.2	Var.3	Var.4	Var.5
Validation 1					2							
Validation 2		1			1			1				
Validation 3			2									
Validation Catalogue											1	
			1									
			1									
								1			2	
		1		1								3

Example Vehicle DVP

DVP: VINFast Sedan

Project Relevant	Key Test	Homologation Relevant	Safety Goal Testing						TEST & TOOL INFO	VIRTUAL	MULE	PTO	PP	PTO SOP2 (Serial Vehicles)
x=yes	x=yes	x=yes		ID	I-Team	Dep.	I-Team function + Test Description	Responsible + further description	Remark	Remark	Remark	Remark	Remark	Remark
x	x	x		EV_NV	10	Simu / Testing	NVH & Driving Comfort	P. Scheikl, 4565		x	x	x	x	x
x	x	x		EV_NV	10	Simulation				x				
x				EV_NV	10	Simulation	CAD check of speaker location, audio acoustics	check the position of speakers and possible sound paths to ensure performance of audio system		x				
x				EV_NV	10	Simulation	CAD squeek and rattle investigation (DMU check)	preventive check of material combinations and gaps		x				
x				EV_NV	10	Simulation	CAD windnoise - investigation	analyses of sections, sealings, gaps; conceptual layout		x				
x	x	x		EV_NV	10	Testing					x	x	x	x
x				EV_NV	10	Testing	Benchmark investigations for total vehicle	subjective and objective evaluation, demonstrations, press event preparations and			x			
x				EV_NV	10	Testing	power train comfort (engine/ e-motor noise)	mounting: engine/ e-motor + inverter, gear box air borne noise, structure borne noise integration			x	2	2	
x				EV_NV	10	Testing	functional NVH check regarding powertrain components (eg whoop) measurement of mounting: engine, gear box, global modes, modal analysis, Running mode analysis air borne noise, structure borne noise, integration	mounting, engine, gear box, air borne noise, structure borne noise integration unbalance, structure: prop shaft, drive shaft, PTO, front/rear axle air borne noise, structure borne noise (e.g. gear noise) integration			x	2	2	
x				EV_NV	10	Testing	exhaust system	mounting, bending, air borne noise, structure borne noise, tailpipe noise			x	x	x	
x				EV_NV	10	Testing	experimental modal analysis	general measurement and analysis of eigenfrequencies, global and local dyn. stiffness insulation: wheel arches (inside/outside) trim			x	x	x	