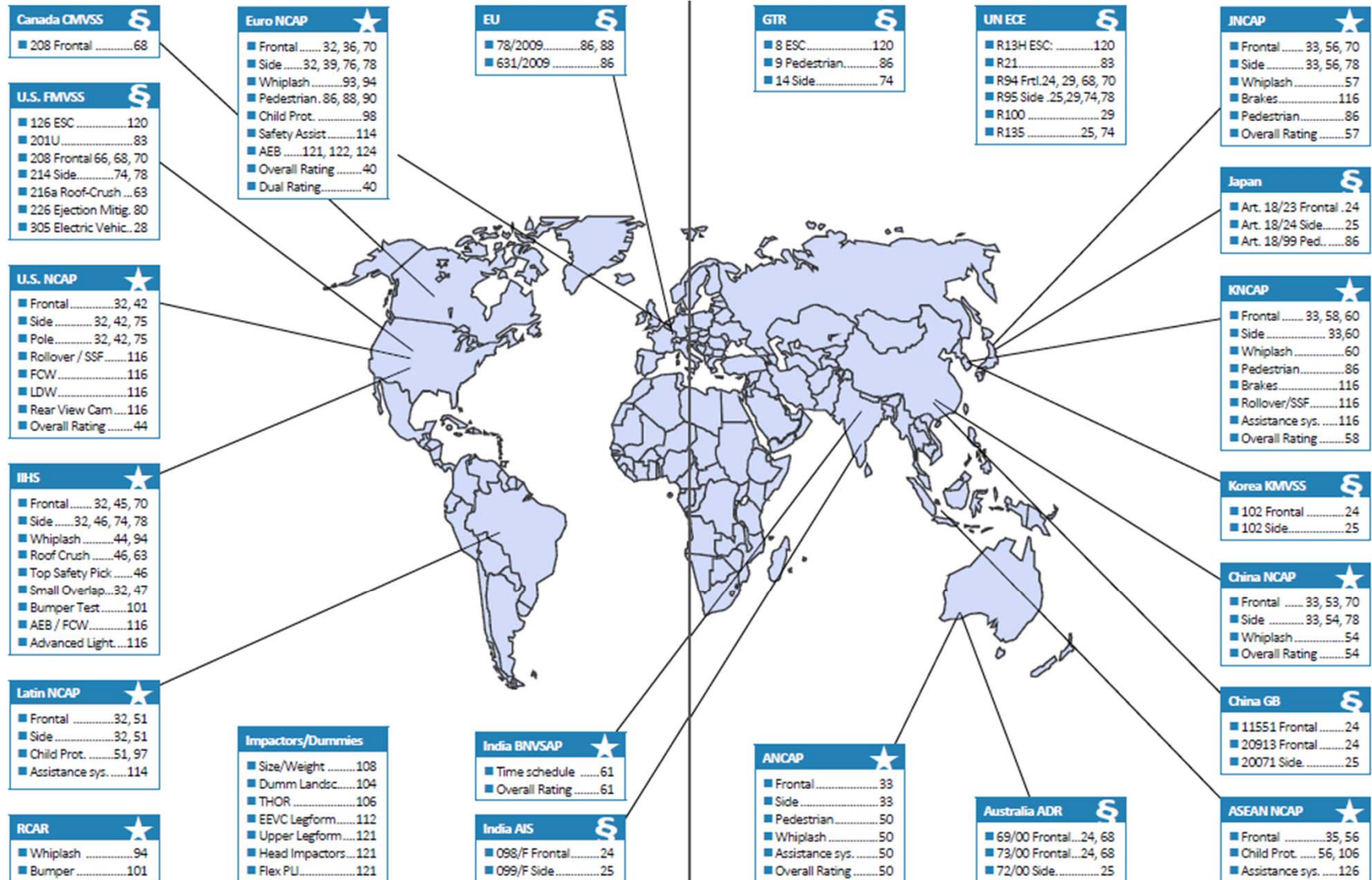
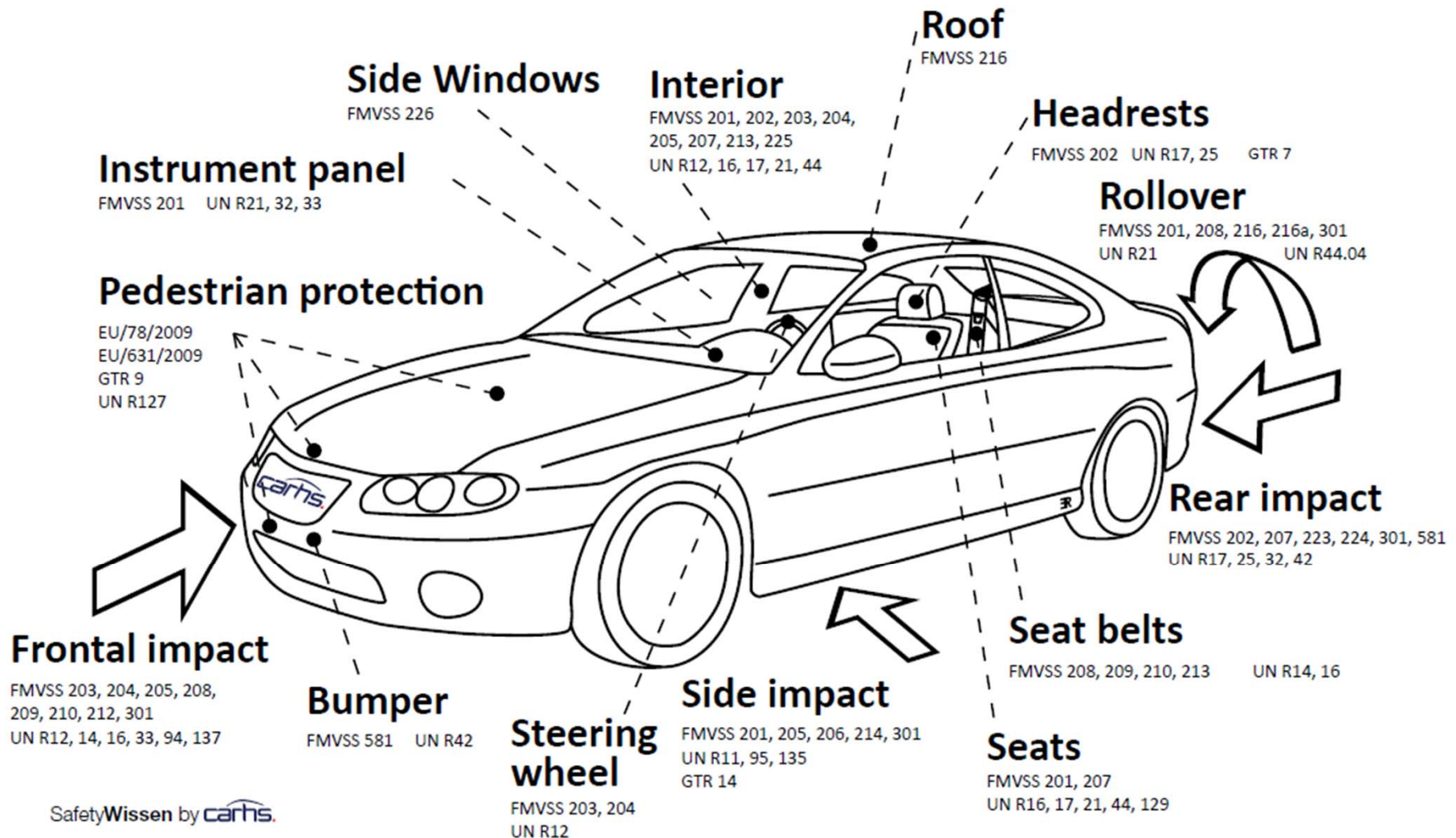


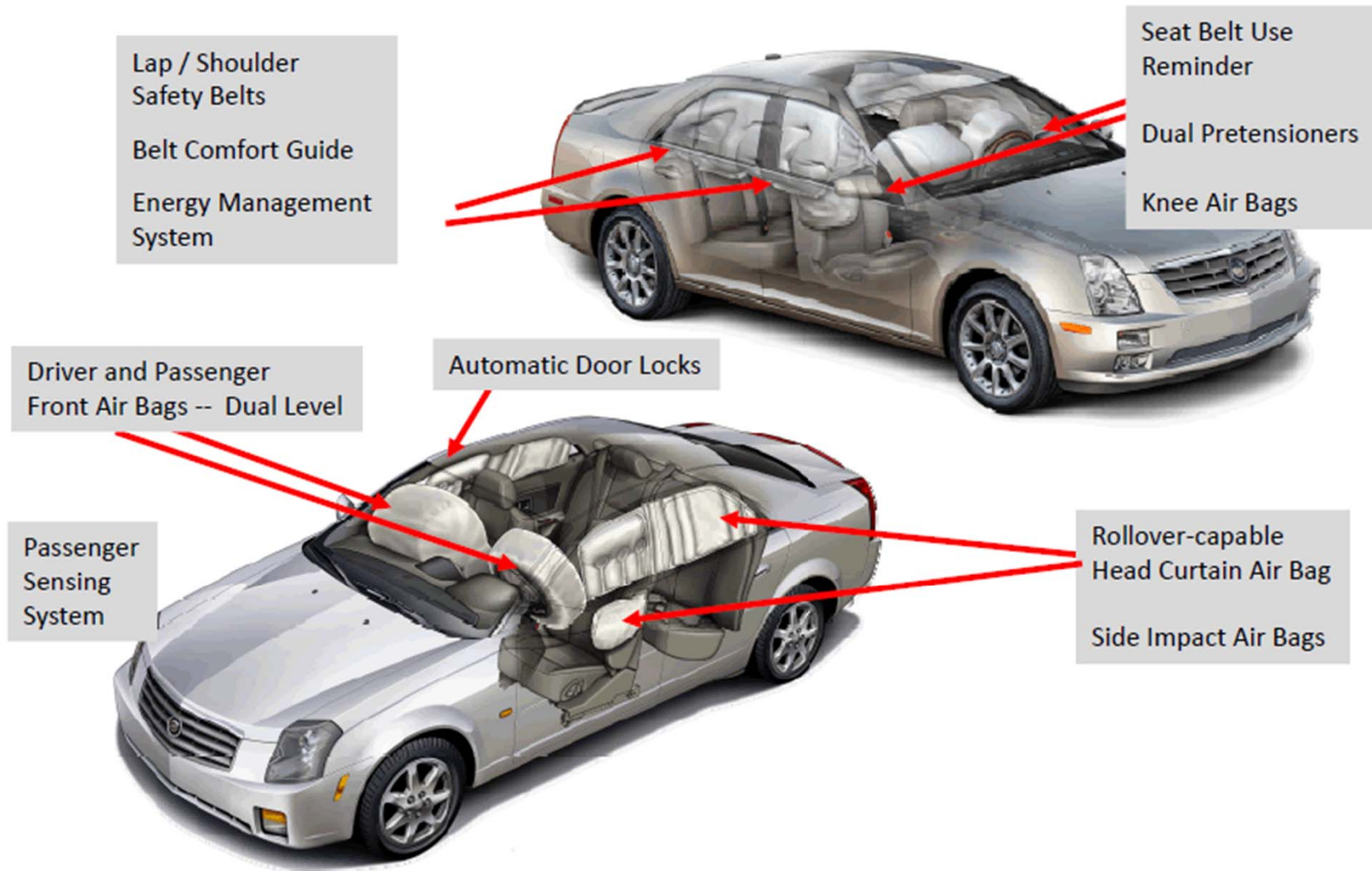
# Navigator



# Crash Regulations in USA(FMVSS)/EU(ECE)

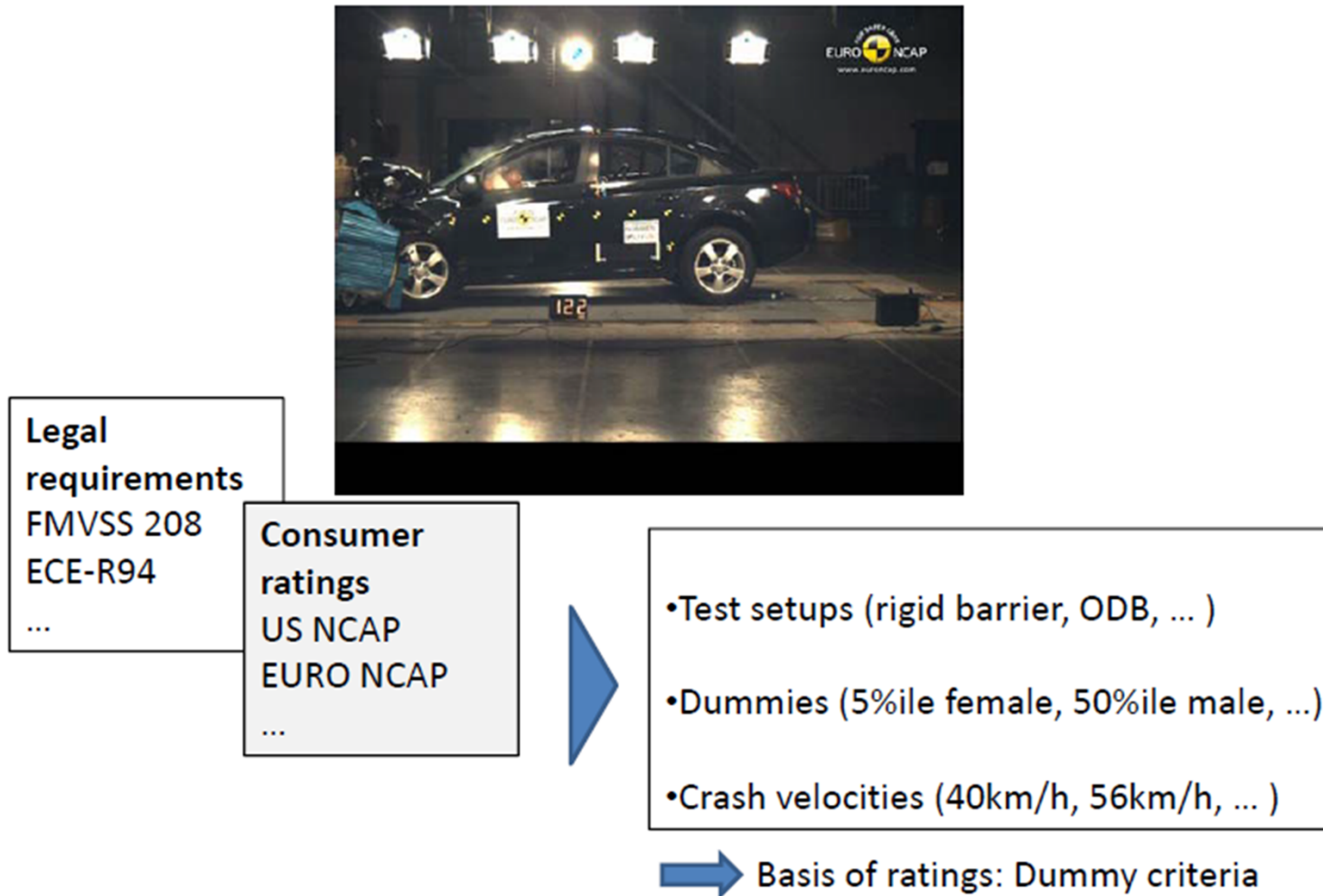


# Crashworthiness Restraint Technologies





# Crash Legal Requirements and Consumer Rating



## Design of Restraint System

Adjustment of belt + airbag systems for best overall performance

## Vehicle Structure

Safety Wissen by carhs

# NCAP-Tests: Europe, America, Asia, Australia

	Euro NCAP	U.S. NCAP	IIHS	Latin NCAP	JNCAP	C-NCAP	KNCAP	ASEAN NCAP	ANCAP
Full Width									
ODB / SOB									
MDB	 ■ Far Side Occupant Protection						 ■ UN R95 for ≥ 3 ★		
Pole				 (prerequisite for 5 star rating)					
Rollover		■ SSF	■ Roof Crush			■ Curtain Airbag	■ SSF		
Pedestrian	■ Flex PLI ■ Upper Legform ■ Headforms ■ AEB VRU Pedestrian ■ AEB VRU Cyclist	■ Flex PLI ■ Upper Legform ■ Headforms ■ AEB Pedestrian ■ Rear Automatic Braking		■ Award	■ Flex PLI ■ Headforms ■ AEB Pedestrian		■ Flex PLI ■ Upper Legform (on bumper only) ■ Headforms ■ AEB Pedestrian		■ Flex PLI ■ Upper Legform ■ Headforms
Child Safety	■ Frontal ODB ■ Side MDB ■ CRS- Installation ■ Vehicle based assessment		■ LATCH (Lower Anchors and Tethers for Children)	■ Frontal ODB ■ CRS- Installation ■ Vehicle based assessment		■ P3 in Full Width Frontal	■ Q6, Q10 in ODB and MDB	■ Frontal ■ CRS-based assessment ■ Vehicle based ass..	■ ODB, MDB (no assessment)
Whiplash	■ static front / rear ■ dynamic (3 pulses) ■ AEB City		■ static ■ dynamic (1 pulse)		■ dynamic (1 pulse)	■ dynamic (1 pulse)	■ static ■ dynamic (1 pulse) ■ rear seats dynamic		■ static ■ dynamic (1 pulse)
Other	■ Assistance systems: SBR, SAS, AEB, LDW, LKA..	■ FCW, LDW, Rear View Cameras, AEB	■ AEB, FCW ■ Headlights	■ SBR (prerequisite for ≥ 3 star rating) ■ ESC (prereq. f. ≥ 4 star)	■ Brakes, SBR, Usability rear belts, LDW, AEB, LKA, Around View	■ ESC ■ SBR ■ AEB, FCW, LDW	■ Brakes, SBR, FCWS, LDWS, SLD, AEB, AEB City, ACC, UKAS	■ ESC, SBR (prerequisite for 5 star rating)	■ Assistance systems 

# Overview Dummies (1)

## Adult Dummies for Frontal / Rear Impact



	Weight (kg)	Seating Height (cm)	Instruction for Calibration
Hybrid II 50 % Male	74.4	90.7	CFR 49 Part 572, Subpart B
Hybrid III 5 % Female	49.1	78.7	SAE Engineering Aid 25 CFR 49 Part 572, Subpart O
Hybrid III 50 % Male	77.7	88.4	CFR 49 Part 572, Subpart E 1999/98/EG
Hybrid III 95 % Male	101.2	93.5	SAE Engineering Aid 26
BioRID II	77.7	88.4	User Manual

## Adult Dummies for Side Impact



	Weight (kg)	Seating Height (cm)	Instruction for Calibration
Eurosid 1	72.0	90.4	Eurosid 1 Certification Procedure 96/27/EG, UN R95
ES-2	72.0	90.9	FTSS- User Manual / UN R95
ES-2 re	72.0	90.9	CFR 49 Part 572, Subpart U
US-SID	76.7	89.9	CFR 49 Part 572, Subpart F
US-SID/Sid-H3	77.2	89.9	CFR 49 Part 572, Subpart M
SID IIs	44.5	79.0	User Manual
WorldSID 5% Female	48.27		User Manual
WorldSID 50% Male	74.88	87.0	User Manual

# Overview Dummies (2)

## Child Dummies



	Weight (kg)	Seating Height (cm)	Instruction for Calibration
P0, P¼, P6, P10	3.4- 32.0	34.5- 72.5	User Manual
P3	15.0	56.0	User Manual
P1½	11.0	49.5	P1½ User Manual
Q1	9.6	47.9	Q1 User Manual
Q1½ (18m)	11.1	49.9	Q1,5 User Manual
Q3	14.5	54.4	Q3 User Manual
Q6	23.0	63.6	Q6 User Manual
Q10	35.5	73.4	Q10 User Manual (Rev. A Draft)
CRABI 12m	10.0	46.4	CFR 49 Part 572, Subpart R
Hybrid II - 3 Jahre	15.1	57.2	CFR 49 Part 572, Subpart C
Hybrid II - 6 Jahre	21.5	64.5	CFR 49 Part 572, Subpart I
Hybrid III - 3 Jahre	16.7	54.6	CFR 49 Part 572, Subpart P
Hybrid III - 6 Jahre	23.4	63.5	CFR 49 Part 572, Subpart N
Hybrid III - 10 Jahre	35.2	72.39	CFR 49 Part 572, Subpart T



		Dummies	Frontal Impact				Side Impact				Rear Impact		Child				
			HiII 50%	HiII 5%	HiII 95%	THOR 50%	ES-2	ES-2re	SID-IIs	World SID	HiII 50%	BioRID II	Crabi	Cami	HiII	P Series	Q Series
Europe	UN R94		●														
	UN R95						●										
	UN R44															●	
	UN R129																●
	UN R135									●							
	UN R137		●	●													
	Euro NCAP		●	●	(●)	●				●		●					●
America	FMVSS 208		●	●									●		●		
	FMVSS 214							●	●	○							
	FMVSS 213												●	●	●	●	○
	FMVSS 202a										●						
	FMVSS xxx (OMDB)					○											
	U.S. NCAP		●	●		●		●	●	●							
	IIHS		●						●			●					
	Latin NCAP		●				●										●
Asia	Japan Regulations		●				●										
	JNCAP		●	●			●					●					
	China Regulations		●				●										
	China NCAP		●	●			●		●	●		●				●	○
	Korean NCAP		●	●			●			●		●					●
	ASEAN NCAP		●				●									●	●
AUS	ADR (Frontal, Side)		●				●			●							
	Australian NCAP		●	●			●			●		●				●	●
GTR	GTR 7		●									●					
	GTR 14 (Pole Side)									●							

2016 2017 2018 2019 2020 ○ = planned, no date specified

SafetyWissen by CarFis.

# FMVSS 305: Safety Requirements for Electric Vehicles



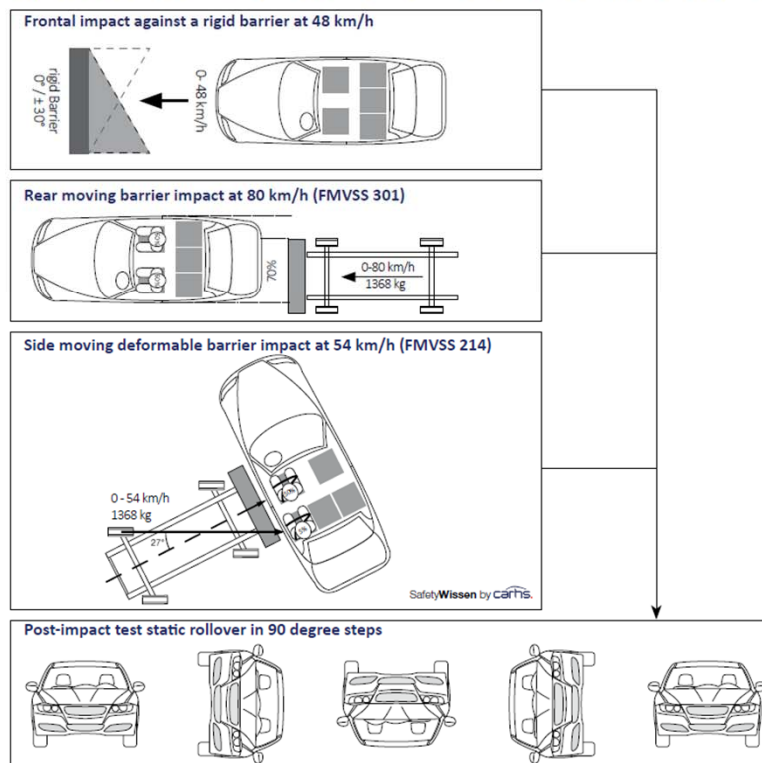
## Scope:

Cars, busses, trucks with a GVWR of 4536 kg or less that use electrical components with working voltages higher than 60 volts direct current (VDC) or 30 volts alternating current (VAC), and whose speed attainable is more than 40 km/h.

## Requirements:

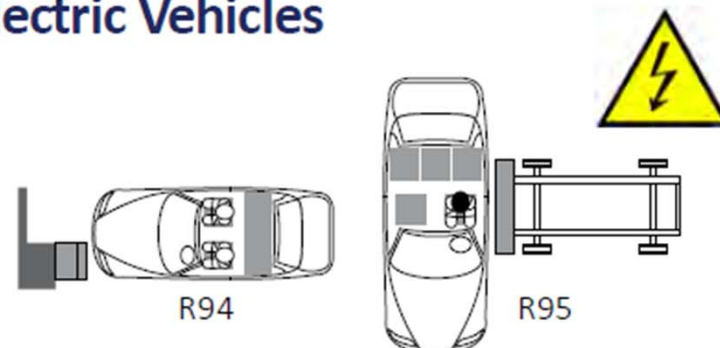
Under the test conditions described below (impact test and subsequent static rollover)

- max. 5 litres of electrolyte may spill from the batteries,
- there shall be no evidence of electrolyte leakage into the passenger compartments,
- all components of the electric energy storage/conversion system must be anchored to the vehicle,
- no battery system component that is located outside the passenger compartment shall enter the passenger compartment,
- electrical isolation must be greater than or equal to:
  - 500 ohms/V for all DC high voltage sources without isolation monitoring and for all AC high voltage sources,
  - 100 ohms/V for all DC high voltage sources with continuous monitoring of electrical isolation,
- the voltage of the voltage source ( $V_b$ ,  $V_1$ ,  $V_2$ ) must be less than or equal to 30 VAC for AC components or 60 VDC for DC components.



# UN ECE: Safety Requirements for Electric Vehicles

## Extension of UN R94 / R95:

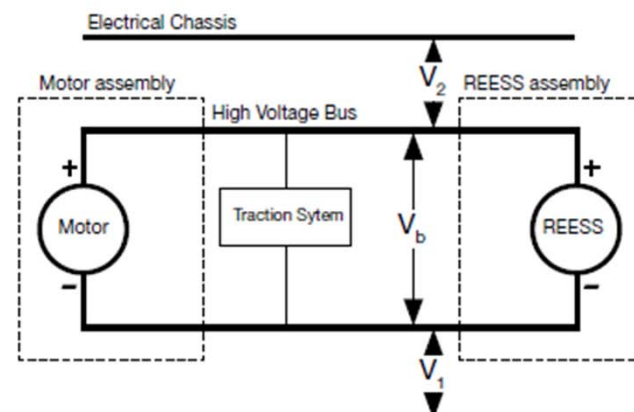


After crash tests according to UN R94 and R95 vehicles with a high voltage electrical powertrain (> 60 V DC or > 30 V AC) must meet the following requirements:

### 1. Protection against electrical shock

at least one of the four criteria specified below shall be met:

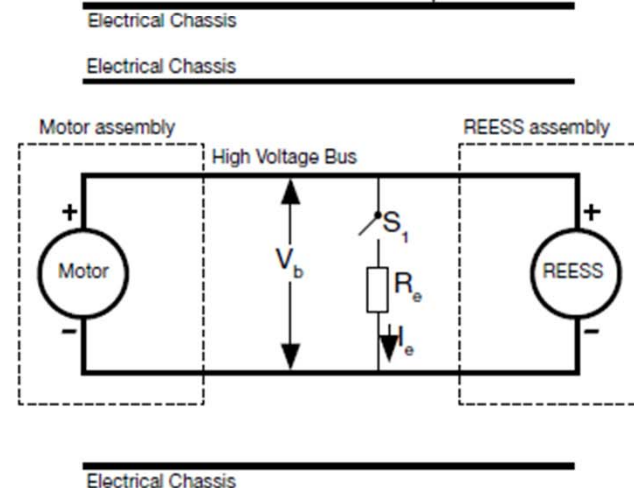
- Absence of high voltage:  
The voltages  $V_b$ ,  $V_1$  and  $V_2$  shall be  $\leq 30$  V AC or  $\leq 60$  V DC :



- Low electrical energy:  
The total energy (TE) on the high voltage buses shall < 2.0 J.  
Prior to the impact a switch  $S_1$  and a known discharge resistor  $R_e$  is connected in parallel to the relevant capacitance .  
Not earlier than 5 s and not later than 60 s after impact  $S_1$  shall be closed while the voltage  $V_b$  and the current  $I_e$  are recorded.  
From this TE is calculated as follows:

$$TE = \int_{tc}^{th} V_b \times I_e dt$$

with  $tc$  = time of closing  $S_1$   
 $th$  = time when voltage drops below 60 V DC



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- Physical protection:

For protection against direct contact with high voltage live parts, the protection IPXXB shall be provided.

- Isolation resistance:

- If the AC HV buses and the DC high voltage buses are galvanically isolated from each other, isolation resistance between the HV bus and the electrical chassis shall be  $\geq 100 \Omega/V$  of the working voltage for DC buses, and  $\geq 500 \Omega/V$  of the working voltage for AC buses.
- If the AC HV buses and the DC HV buses are galvanically connected isolation resistance between the HV bus and the electrical chassis shall be  $\geq 500 \Omega/V$  of the working voltage. (if the protection IPXXB is satisfied for all AC HV buses or the AC voltage is  $\leq 30 V$  after the vehicle impact, the isolation resistance shall be  $R_i \geq 100 \Omega/V$ )

## 2. Electrolyte spillage

- In the period from the impact until 30 minutes after no electrolyte from the REESS (Rechargeable Energy Storage System) shall spill into the passenger compartment and no more than 7% of electrolyte shall spill from the REESS.

## 3. REESS retention


REESS located inside the passenger compartment shall remain in the location in which they are installed and REESS components shall remain inside REESS boundaries. No part of any REESS that is located outside the passenger compartment for electric safety assessment shall enter the passenger compartment during or after the impact test.

### UN R100:

M and N class vehicles with a maximum speed  $> 25 \text{ km/h}$  must also comply with UN R100 Rev. 2



# Euro NCAP Rating: 2016 - 2020

 Adult Occupant Protection				 Child Occupant Protection				 Pedestrian Protection				 Safety Assist						
	2016	2018	2020		2016	2018	2020		2016	2018	2020		2016	2018	2020			
	max. score				max. score				max. score				max. score					
Offset Frontal impact ➡ Page 36	8	8	8	Dyn. Tests Frontal ➡ Page 98	16	16	16	Head Impact ➡ Page 86	24	24	24	Seat Belt Reminder ➡ Page 114	3	3	3			
Full-width Frontal impact ➡ Page 36	8	8	8	Dyn. Tests Side ➡ Page 98	8	8	8	Leg Impact ➡ Page 86	6	6	6	Speed Assistance Syst. ➡ Page 114	3	3	3			
Side impact (MDB) ➡ Page 39	8	8	8	CRS Installation ➡ Page 98	12	12	12	Upper Leg Impact ➡ Page 86	6	6	6	ESC	-	-	-			
Side impact (Pole) ➡ Page 39	8	8	8	Vehicle ➡ Page 98	13	13	13	AEB VRU-Pe ➡ Page 122	6	6	6	LDW / LKD / LSS ➡ Page 114	3	4	4			
Whiplash Front seats ➡ Page 94	2	1.5	1.5					AEB VRU-Cy	-	6	6	AEB Inter-Urban ➡ Page 114	3	3	4			
Whiplash rear seats ➡ Page 93	1	0.5	0.5									Junction Assist						2
AEB City ➡ Page 121	3	4	4															
max. score (1)	38	38	38	max. score (1)	49	49	49	max. score (1)	42	48	48	max. score (1)	12	13	16			
normalised score (2)	actual score / (1)			normalised score (2)	actual score / (1)			normalised score (2)	actual score / (1)			normalised score (2)	actual score / (1)					
weighting (3)	40%			weighting (3)	20%			weighting (3)	20%			weighting (3)	20%					
weighted score (4)	(2)x(3)			weighted score (4)	(2)x(3)			weighted score (4)	(2)x(3)			weighted score (4)	(2)x(3)					
Balancing: minimum normalised score (2) by box for the respective star rating:																		
★★★★★	80%	80%	80%	+	75%	80%	80%	+	60%	60%	60%	+	50%	70%	70%			
★★★★	70%	70%	70%		60%	70%	70%		50%	50%	50%		40%	60%	60%			
★★★	60%	60%	60%		30%	60%	60%		40%	40%	40%		25%	50%	50%			
★★	50%	50%	50%		25%	50%	50%		30%	30%	30%		15%	40%	40%			
★	40%	40%	40%		15%	40%	40%		20%	20%	20%		10%	30%	30%			
Overall score (5) = Σ(4)																		
As of 2016 the overall score is used only for ranking the results within vehicle categories.																		

# U.S. NCAP: Rating Scheme

Frontal Crash Test		Side Pole Test	Side MDB Test		Rollover Test
Driver	Passenger	Front Seat	Front Seat	Rear Seat	
Injury Criteria	Injury Criteria	Injury Criteria	Injury Criteria	Injury Criteria	
▼	▼	▼	▼	▼	
Probability of Injury (Risk Curves) $P_{joint}$	Probability of Injury (Risk Curves) $P_{joint}$	Probability of Injury (Risk Curves) $P_{joint}$	Probability of Injury (Risk Curves) $P_{joint}$	Probability of Injury (Risk Curves) $P_{joint}$	Probability of Rollover $P_{roll}$
▼	▼	▼	▼	▼	▼
$RR^*=P_{joint}/base^{**}$	$RR^*=P_{joint}/base^{**}$	$RR^*=P_{joint}/base^{**}$	$RR^*=P_{joint}/base^{**}$	$RR^*=P_{joint}/base^{**}$	$RR^*=P_{roll}/base^{**}$
▼	▼	Stars (20%)	Stars (80%)	▼	▼
Driver Stars (50%)	Passenger Stars (50%)	Front Seat Stars (50%)		Rear Seat Stars (50%)	Overall Rollover Star Rating (3/12)
▼	▼	▼		▼	
Overall Frontal Star Rating (5/12)		Overall Side Star Rating (4/12)			
SafetyWissen by carlis					
Vehicle Safety Score (VSS)					

## Rating procedure

Using the Injury Risk Curves on page 42 and page 43, the risk of a serious injury (AIS 3+) can be calculated from the injury criteria measured in the crash test. The joint risk for an occupant can be determined using the following formulae:

$$\text{Frontal Impact: } P_{joint} = 1 - (1 - P_{head}) \times (1 - P_{neck}) \times (1 - P_{chest}) \times (1 - P_{femur})$$

$$\text{Side Impact: } P_{joint} = 1 - (1 - P_{head}) \times (1 - P_{chest}) \times (1 - P_{abdomen}) \times (1 - P_{pelvis})$$

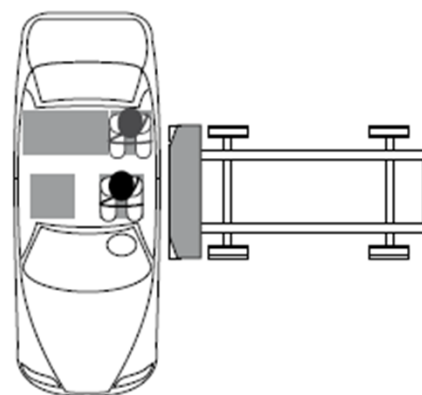
This risk is compared to a so called baseline risk which was set to 15 %. This ratio is called relative risk (RR) from which the star rating is determined using the following table:

RR	0	0.67	1	1.33	2.67
Stars	★★★★★	★★★★★	★★★	★★	★

# Protection Criteria for Frontal Impact Tests

Configuration	Criterion	Rigid Barrier In-Position					Deformable Barrier In-Position		Out of Position			
Requirements		CMVSS 208 (old), ADR 69/00, FMVSS 208 (old)	FMVSS 208 CMVSS 208		UN R137		UN R94, ADR 73/00, FMVSS 208 (old)	FMVSS 208 CMVSS 208	FMVSS 208 CMVSS 208			
Dummy		Hybrid III	Hybrid III	Hybrid III	Hybrid III	Hybrid III	Hybrid III	Hybrid III	Hybrid III	Hybrid III	Hybrid III	CRABI
Size		50% male	50% male	5 % female	50% male	5 % female	50% male	5 % female	5 % female	6 year	3 year	1 year
Head	HIC <sub>36</sub> /HPC <sub>36</sub> [-]	1000 (FMVSS, ADR)			1000	1000	1000					
	HIC <sub>15</sub> [-]	700 (CMVSS)	700	700				700	700	700	570	390
	a <sub>3ms</sub> [g]				80	80	80					
Neck	N <sub>ij</sub> [-] (4 Values)		1.0	1.0				1.0	1.0	1.0	1.0	1.0
	F <sub>x, shear</sub> [kN]				3.1	2.7	3.1 @ 0 ms 1.5 @ 25-35 ms 1.1 @ ≥ 45 ms					
	F <sub>z, tension</sub> [kN]		4.17	2.62	3.3	2.9	3.3 @ 0 ms 2.9 @ 35 ms 1.1 @ ≥ 60 ms	2.62	2.07	1.49	1.13	0.78
	F <sub>z, compr.</sub> [kN]		4.0	2.52				2.52	2.52	1.82	1.38	0.96
	M <sub>y</sub> [Nm]				57	57	57					
Chest	a <sub>3ms</sub> [g]	60 g	60	60				60	60	60	55	50
	Deflection [mm]	76.2 (FMVSS, ADR) 50 (CMVSS)	63	52	42	42 [34] <sup>1</sup>	50	52	52	40	34	30 <sup>2</sup>
	VC [m/s]				1.0	1.0	1.0					
Femur	Axial Force [kN]	10	10	6.805	9.07	7	9.07 @ 0 ms 7.58 @ > 10 ms	6.805	6.8			
Knee	Displacement [mm]						15					
Tibia	TI [-]						1.3 (4 Values)					
	Axial Force compr. [kN]						8.0					

Requirement	UN R95	Euro NCAP	IIHS
Impact angle	lateral 90°		
MDB velocity	50 km/h		
Barrier (MDB)	EEVC	AE-MDB	IIHS
Mass	950 kg	1300 kg	1500 kg
Ground clearance	300 mm	300 mm (bumper 350 mm)	379 mm (bumper 430 mm)
Upper edge height	800 mm	800 mm	1138 mm
Width	1500 mm	1700 mm	1676 mm
Dummy	1 ES-2 frontal seat on impact side	1 WS 50% frontal seat on impact side on rear seat Q10 on impact side and Q6 far side	2 SID IIs on impact side
Protection Criteria	Head HPC < 1000 Chest VC < 1.0 m/s Rib deflection D < 42 mm Abdomen sum of APF < 2.5 kN Pelvis PSPF < 6.0 kN	➤ page 39 (Adults) ➤ page 98 (Children)	Different weight in assessment driver and passenger values for HIC <sub>15</sub> , Neck-Tens./Compr., Head kinematics, Shoulder, Chest deflection, VC, Pelvis and Femur; Car body evaluation, B-pillar ➤ page 46



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Requirement	FMVSS 214 old rule	FMVSS 214 new rule	U.S. NCAP
Impact angle	lateral 90°, 27° crab angle		
Impact velocity	53±1 km/h (33.5 mph) (~47 km/h in 90° direction)		61.9 ±0.8 km/h (~55 km/h in 90° direction)
Barrier	NHTSA MDB		
Mass	1368 kg		
Ground clearance	279 mm (bumper 330 mm)		
Upper edge height	838 mm		
Width	1676 mm		
Dummy	2 DOT-SID	Front seat: ES-2 re / Back seat: SID IIs (Build Level D) (impact side)	Front seat: ES-2 re / Back seat: SID IIs (Build Level D) (impact side)
Protection Criteria	Chest TTI < 85 g (4-doors) Chest TTI < 90 g (2-doors) Pelvis acceleration < 130 g	SID IIs: HIC <sub>36</sub> < 1000 Chest acceleration < 82 g Pelvis force < 5.525 kN ES-2 re: HIC <sub>36</sub> < 1000 Chest deflection < 44 mm Abdominal force < 2.5 kN Pelvis force < 6 kN	➤ page 42 SafetyWissen by carhs.