INTERNATIONAL ORGANIZATION OF MOTOR VEHICLE MANUFACTURERS

Automated Driving
Submitted by the experts of OICA as input to the IWG ITS/AD

June 15, 2015, VDA Berlin

Corrected version 03.11.2015, Geneva
Slides 9, 10, 11 - Basic categories of system functions - harmonized with published categories of BASt
(Federal Highway Research Institute), Federal Republic of Germany
B = automated systems (instead **C**)

C = systems that intervene in emergency (instead **B**)

Agenda

Motivation for automated driving

Driver assistance and automated driving today

Definition of terms: Role of the driver vs. role of the system

Roadmap to automated driving and exemplary functions

Need for action

Conclusion

Agenda

Motivation for automated driving

Driver assistance and automated driving today

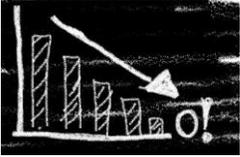**Definition of terms: Role of the driver vs. role of the system**

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Motivation for Automated Driving

1	*Road Safety: Vision Zero*	Road safety improvements by reducing human driving errors	
2	*Traffic management*	- Optimization of traffic flow management - Convenient, time efficient driving via automation	
3	*Reducing Emissions*	Reduction of fuel consumption & CO_2 emission (through optimization of traffic flow management)	
4	*Demographic Change*	- Support unconfident drivers - Enhance mobility for elderly people	
5	*Innovation High technology*	- New economic paradigm – supporting innovation policies of regions, nations - Competitiveness / high skill employment	

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Today's Driver Assistance/Automated Systems - examples

Longitudinal Control	**Lateral Control**	**Parking, Maneuvering**
Adaptive Cruise Control Forward Collision Warning	Lane Keeping Assistance	Automated Parallel Parking Assistance
Longitudinal+Lateral Control	**Longitudinal+Lateral Control**	**Parking, Maneuvering**
ACC combined with Lane Keeping Assistance	Traffic Jam Assist ACC incl. Stop-&Go combined with Lane Keeping Assistance	Automated Cross Parking Assistance

Today's Automated Driving – industrial projects

Bertha Benz drive	Super Cruise	Motorway Pilot	Automated Highway Driving	Traffic Jam Pilot
2013 Mercedes	2014 GM	2011 BMW	2014 HONDA	2012 Audi

Highway Automated Driving	Drive Me	Automated Driving	Field Test on Highway	Automated Highway Driving
2014 PSA	2013 Volvo	2014 Renault	2013 Nissan	2014 Toyota/Lexus

Automated Driving	Automated Highway Driving	Automated Transport Solution	Automated Driving
2015 Future Truck 2025 MB Trucks	2015 Freightliner Inspiration Truck	Scania Autom. Transport Solution	Volvo Trucks

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Basic Categories of System Functions

Category A Information and Warning (classic driver assistance)	Category B: Automated (From advanced driver assistance towards „automated driving")	Category C: Intervening in Emergency (close-to-accident situations)
Only indirect influence on the dynamic driving task by the driver (driver controls everything)	Direct influence on the dynamic driving task (driver can always switch off or override the system)	Direct influence on the dynamic driving task (driver is definitely not able to master the situation)
Examples: • Speed Limit Information • Lane Departure Warning (e.g. steering wheel vibration) • Lane Change Warning/Blindspot Detection (e.g. flashlight in the mirror base)	Examples: • Adaptive Cruise Control • Parking Assistant • Traffic Jam Assistant	Examples: • Automatic Emergency Braking • Emergency Stop Assistant (e.g. in a medical emergency case) • ESC, ABS

Based on a concept of BASt (Federal Highway Research Institute, Germany)

Levels of Automated Driving (Category B)

Level 0-1	Level 2	Level 3	Level 4	Level 5

Level 0-1 — No Automation
Driver Only / Assisted

Level 2 — Partial Automation
Driver monitors the automated driving functions at all times.

Level 3 — Conditional Automation
System monitors its performance limits and transfers to the driver within a transition time when reaching the performance limits.

Level 4 — High Automation
System copes with all tasks within a specific use-case .

Level 5 — Full Automation
System copes with all tasks in all situations.
No driver required.

Levels of Automated Driving (Category B)
Updated from WP29-162-20 (March 2014)

OICA

Driver (vertical axis label)

Automation (vertical axis label)

Level 0 — Driver continuously performs the longitudinal and lateral dynamic driving task

No intervening vehicle system active

Level 1 — Driver continuously performs the longitudinal or lateral dynamic driving task

The other driving task is performed by the system

Level 2 — Driver must monitor the dynamic driving task and the driving environment at all times

System performs longitudinal and lateral driving task in a defined use case

Level 3 — Driver does not need to monitor the dynamic driving task nor the driving environment at all times; however he must be attentive to and follow system's requests / warnings to resume the dynamic driving task.

System performs longitudinal and lateral driving task in a defined use case. Recognizes its performance limits and requests driver to resume the dynamic driving task with sufficient time margin.

Level 4 — Driver is not required during defined use case

System performs the lateral and longitudinal dynamic driving task in all situations in a defined use case.

Level 5 — System performs the lateral and longitudinal dynamic driving task in all situations encountered during the entire journey. No driver required.

→ Autonomous Vehicle

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Driver Only	Assisted	Partial Automation	Conditional Automation	High Automation	Full Automation

Level of automation ➡ *terms acc. to SAE J3016*

Role of the driver and system in Level 0

Driver

can always override or deactivate the system engaged	not applicable
performs the longitudinal and lateral dynamics	
monitors the driving environment	
is attentive to and responds to the vehicle's requests/warnings	

time

Conclusion: The driver is in the loop and performs all tasks:

- Performs the dynamic driving task (longitudinal and lateral dynamics),
- monitors the driving environment,
- is attentive to and responds to vehicle's requests/warnings.

Role of the driver and system in Level 1

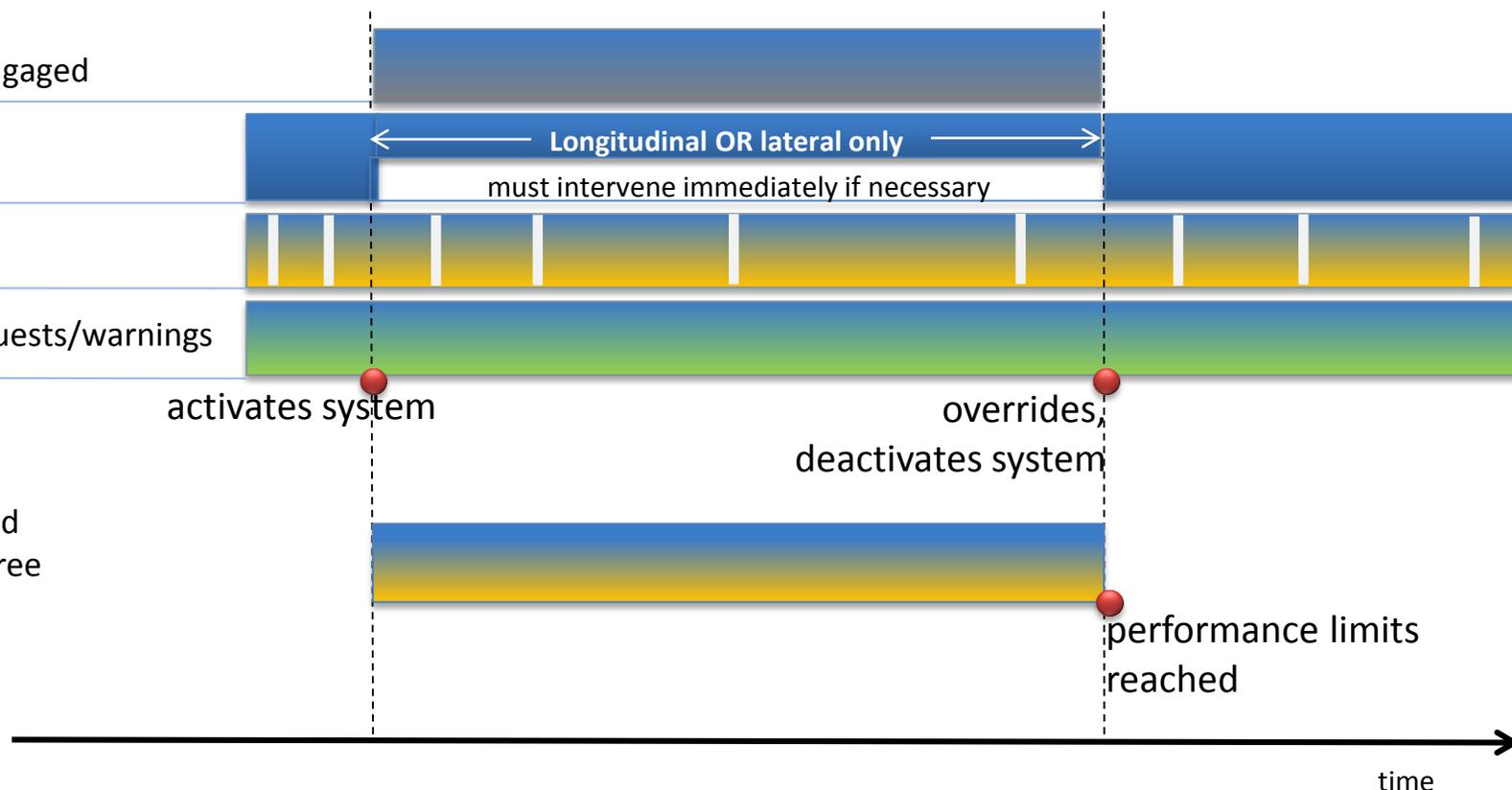## Driver*

can always override or deactivate the system engaged

performs the longitudinal and lateral dynamics

Longitudinal OR lateral only

must intervene immediately if necessary

monitors the driving environment

is attentive to and responds to the vehicle's requests/warnings

activates system

overrides,
deactivates system

System

performs the complementary driving dynamics and
monitors the driving environment to a limited degree

performance limits
reached

time

*The driver must be ready to immediately intervene if necessary, since the system cannot guarantee to recognize its performance limits (e.g. due to weather conditions, missing lane markings, etc.), neither reliably detect the driving environment.

Conclusion: The driver is in the loop because he/she must perform the longitudinal or lateral dynamic driving task and remain ready to intervene at all times in the other driving task.

Role of the driver and system in Level 2

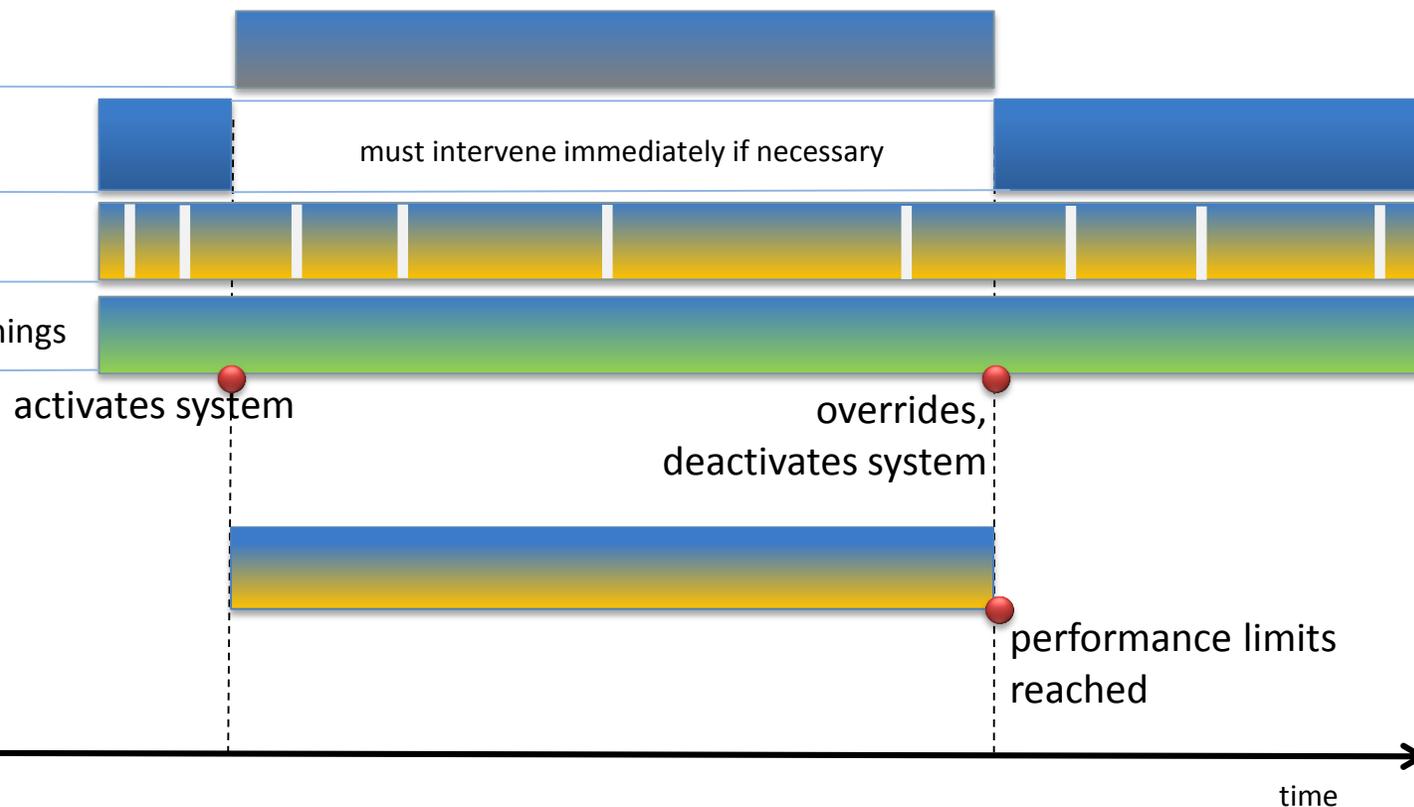## Driver*

can always override or deactivate the system engaged

performs the longitudinal and lateral dynamics

must intervene immediately if necessary

monitors the driving environment

is attentive to and responds to the vehicle's requests/warnings

activates system

overrides,
deactivates system

System

performs the dynamic driving task and
monitors the driving environment

performance limits
reached

time

*The driver must be ready to immediately intervene if necessary, since the system cannot guarantee to recognize its performance limits (e.g. due to weather conditions, missing lane markings, etc.).

Conclusion: The driver is in the loop because he/she must remain ready to intervene at all times in the dynamic driving task.

Role of the driver and system in Level 3

Driver*

can always override or deactivate the system engaged

performs the longitudinal and lateral dynamics

monitors the driving environment

**Driver may naturally look from time to time at the driving environment, however he is not expected to have a response on the driving task.
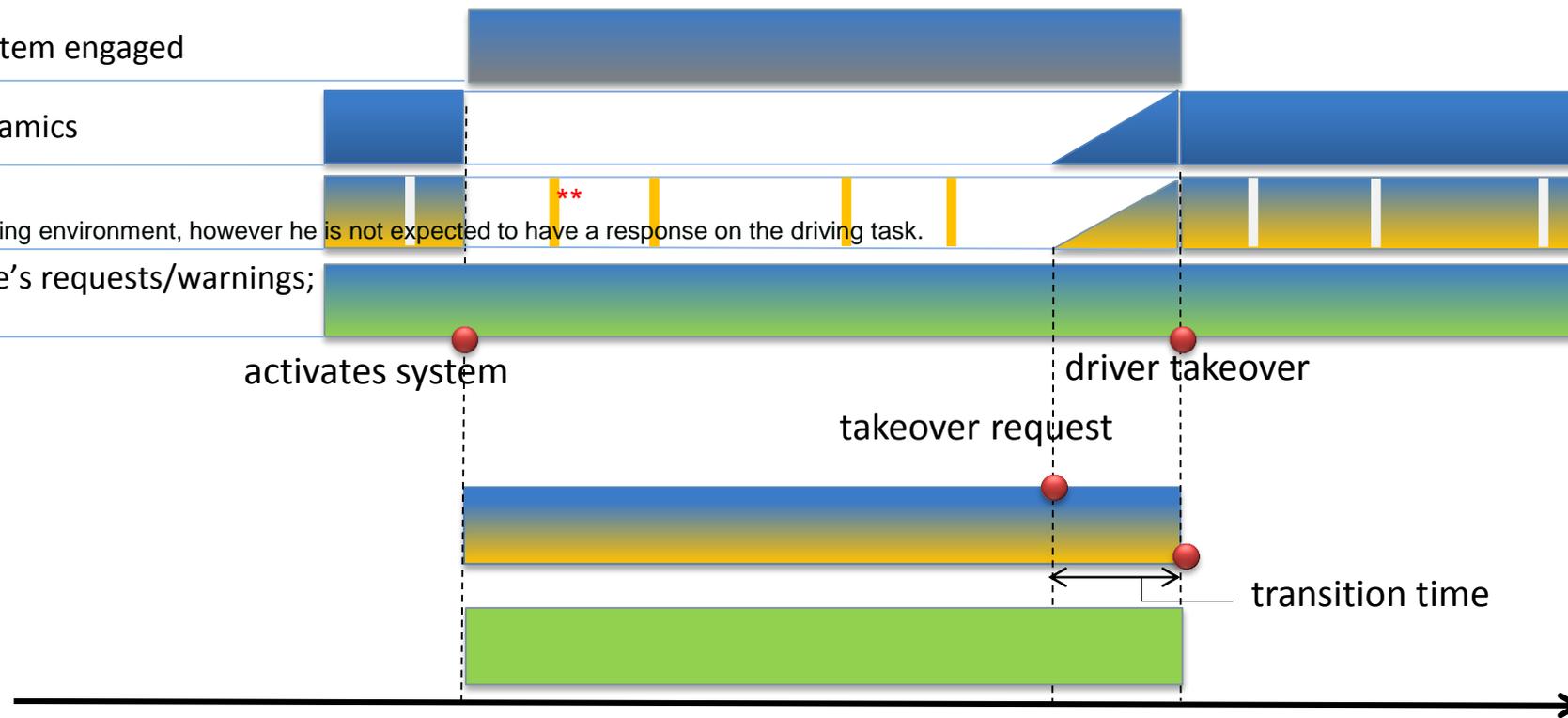
is attentive to and responds to the vehicle's requests/warnings;
is aware of the system status

activates system

driver takeover

takeover request

System

performs the dynamic driving task and
monitors the driving environment

transition time

indicates the system control status

time

*In case of reaching the performance limits (e.g. due to weather conditions, missing lane markings, etc.) the driver is expected to resume the dynamic driving task since he/she is the system's fallback. The driver will be given a transition time for an orderly takeover.

Conclusion: The driver is considered to be part of the loop because he/she must remain sufficiently attentive in order to be able to intervene upon system's request within a transition time for an orderly takeover.

Role of the driver and system in Level 4

Driver

end of use case

can always override or deactivate the system engaged

performs the longitudinal and lateral dynamics

monitors the driving environment

**Driver may naturally look from time to time at the driving environment, however he is not expected to have a response on the driving task.

is attentive to and responds to the vehicle's requests/warnings

activate system

driver takeover

System*

takeover request

performs the dynamic driving task and monitors the driving environment

transition time

indicates the system control status

time

*Minimal risk condition can be achieved in case of a system failure under any driving situation during the entire use case and/or when the human driver fails to respond to the takeover request.

Driver is <u>not in the loop</u> during the use-case but is expected to takeover at the end of the use-case within a transition time.

Role of the driver and system in Level 5

Driver (if present)

start of the trip/ during the trip

end of the trip

can always override or deactivate the system engaged

performs the longitudinal and lateral dynamics

monitors the driving environment

Is attentive to and responds to the vehicle's requests/warnings

activate system

System*

performs the dynamic driving task and monitors the driving environment

time

*In case of system failure, system can achieve the minimum risk condition out of any driving situation during the whole trip. Driver not necessarily present.
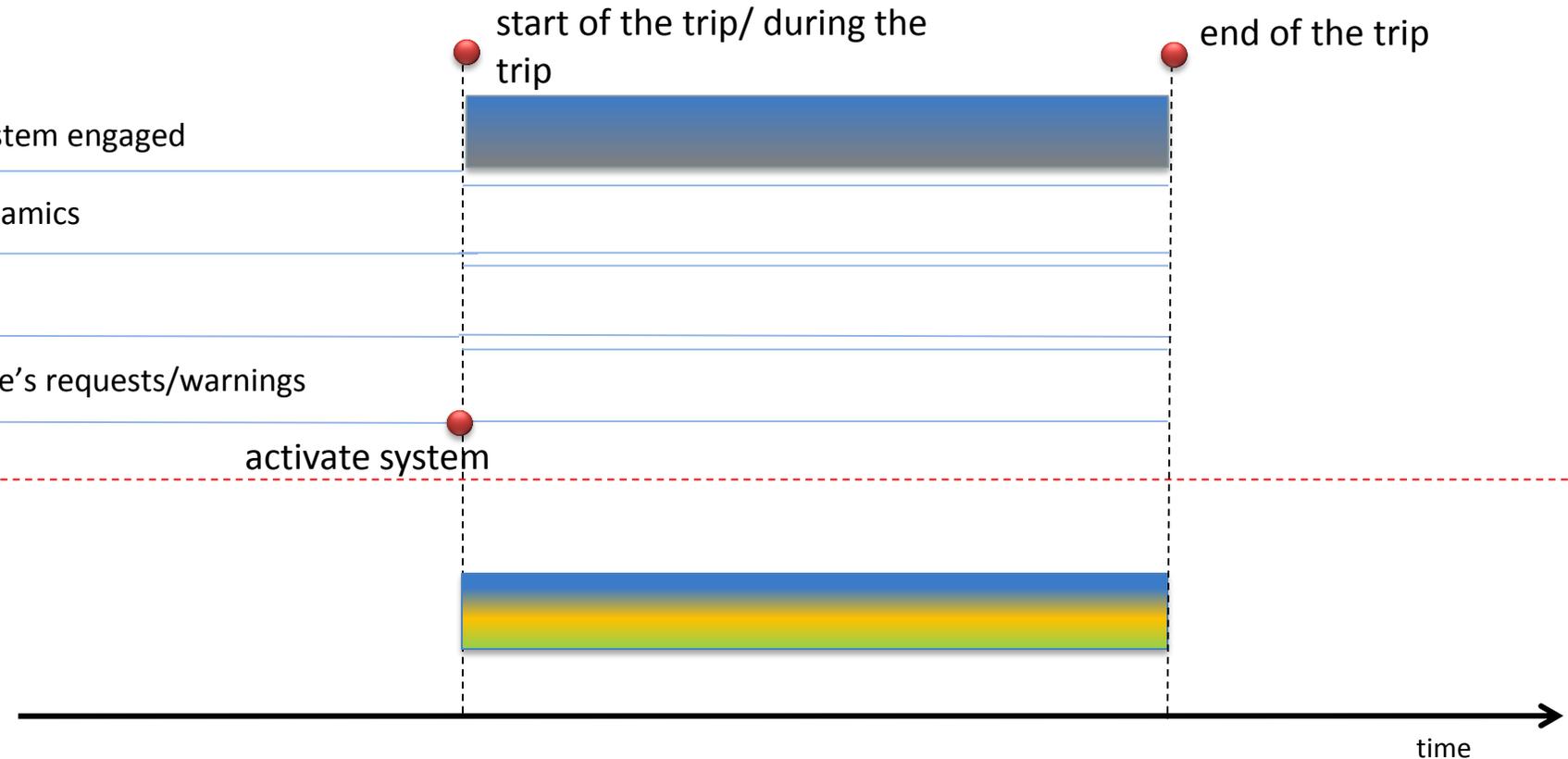
Conclusion: The activated system performs all driving tasks at all times. Driver is not necessarily present anymore and therefore not in the loop.

Overview of existing definitions/terminology

Organisation	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
BASt[1] SAE[2] OICA[3]	Driver Only	Assisted	Partial Automation	Conditional Automation	High Automation	Full Automation
NHTSA[4]	No Automation	Function-Specific Automation	Combined Function Automation	Limited Self-Driving Automation	Full Self-Driving Automation	

➔ BASt, SAE & OICA have consistent understanding of automation levels
➔ NHTSA shows divergence with SAE, OICA and BASt, different terminology, no distinction between level 4 and 5

[1] BASt report, *Legal Consequences of an Increase in Vehicle Automation*, Tom M. Gasser et al., ISBN 978-3-86918-189-9, January 2012.
    The German terms slightly differ due to translation, however the content is identical to SAE/OICA
[2] SAE working draft J3016, *Taxonomy and Definitions for Terms Related to On-Road Automated Motor Vehicles*
[3] OICA working group „Automated Driving". The definitions herein are not intended to supersede any existing regional standards, like for example SAE J3016.
[4] NHTSA's *Policy on Automated Vehicle Development*, published at 30. Mai 2013

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Roadmap to automated driving and exemplary functions

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The technical complexity influences the roadmap to automated driving

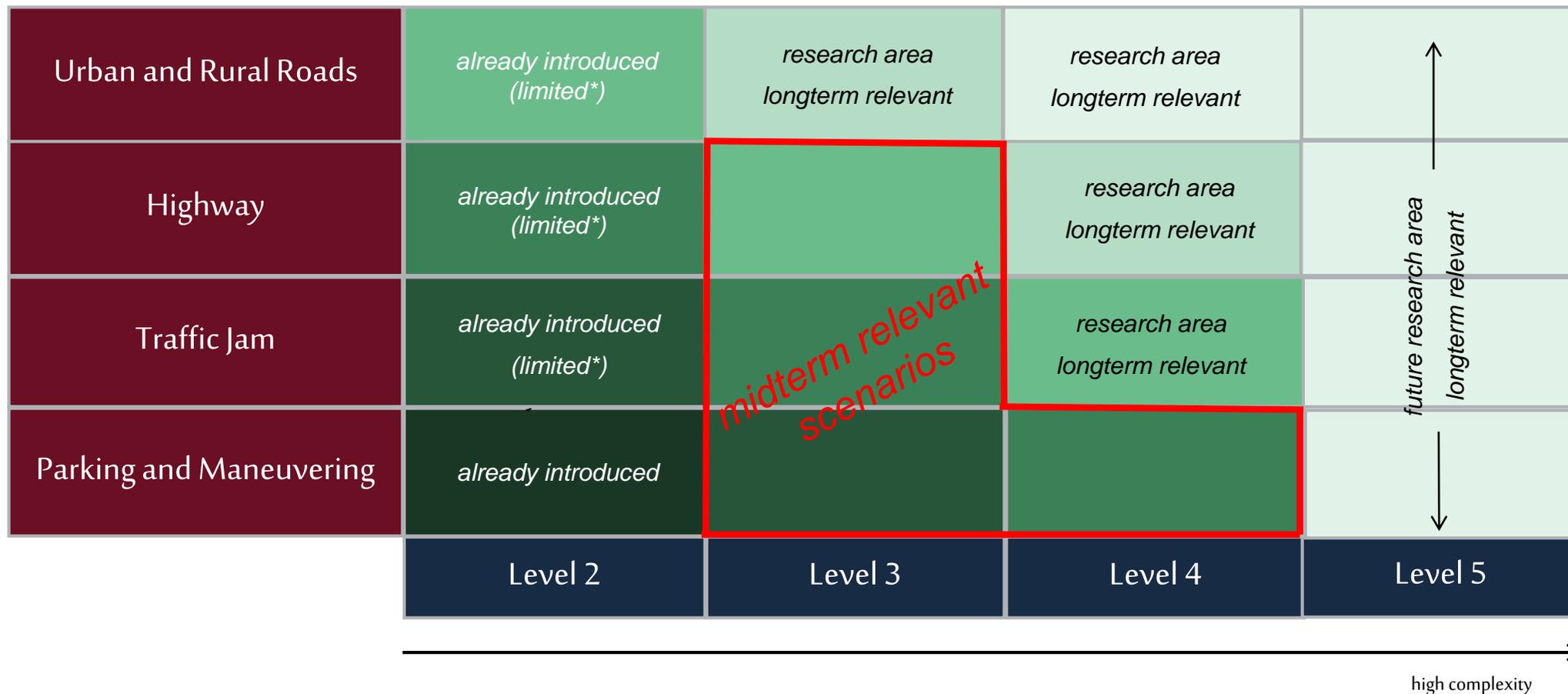|	Low Velocity	High Velocity
Structured Traffic Environment	**Traffic Jam** Level 2 (limited*) already introduced Level 3 in development	**Highways** Level 2 (limited*) already introduced Level 3 in development
Unstructured (complex) Traffic Environment	**Parking and Maneuvering** Level 2 already introduced Level 4 in research/development	**Urban and Rural Roads** Level 2 (limited*) already introduced Level 3 in research

Automated Functions like Traffic Jam-, Highway- and Parking System are currently in development and can be introduced in midterm perspective.

* Current UN R 79 allows above 10 kph only corrective steering (lateral assistance). Therefore steering capability of today's Level 2 functions is still limited.

Roadmap's influence on the Informal Working Group

→ OICA suggests that the IWG ITS/AD focuses on midterm relevant scenarios as a first priority

	Level 2	Level 3	Level 4	Level 5
Urban and Rural Roads	*already introduced (limited*)*	*research area longterm relevant*	*research area longterm relevant*	
Highway	*already introduced (limited*)*		*research area longterm relevant*	
Traffic Jam	*already introduced (limited*)*	*midterm relevant scenarios*	*research area longterm relevant*	
Parking and Maneuvering	*already introduced*			

future research area longterm relevant

high complexity

* Current UN R79 allows only corrective steering above 10 km/h (lateral assistance). Therefore steering cabability of today's Level 2 functions is still limited.

Roadmap Automated Driving - Example Functions

ADAS new				**Traffic Jam Ass.** **Park Ass.**
ADAS established	**AEBS** **ABS** **ESC**	**FCW** **LKAS**	**ACC** **Park Steer Ass.**	↗
	Intervening only in Emergency	Driver Only	Assisted	Partial Automation
		0	1	2

Existing

Roadmap Automated Driving - Example Functions

Automation Gen. 1					**Highway Traf. Jam-System**
ADAS new				Traffic Jam Ass. / Park Ass.	
ADAS established	AEBS / ABS / ESC	FCW / LKAS	ACC / Park Steer Ass.		
	Intervening only in Emergency	Driver Only	Assisted	Partial Automation	Conditional Automation
		0	1	2	3

Existing   **Low velocity in structured environment**

ADAS Advanced Driver Assistance Systems
AEBS Advanced Emergency Braking
ESC: Electronic Stability Control
ABS: Antilock Braking System

LKAS: Lane Keeping Assistance
FCW: Forward Collision Warning
ACC: Adaptive Cruise Control

Roadmap Automated Driving - Example Functions

	Intervening only in Emergency	Driver Only	Assisted	Partial Automation	Conditional Automation	High Automation
Automation Gen. 2					Highway System	Valet Parking System
Automation Gen. 1					Highway Traf. Jam-System	
ADAS new				Traffic Jam Ass. / Park Ass.		
ADAS established	AEBS, ABS, ESC	FCW, LKAS	ACC, Park Steer Ass.			
	0	1		2	3	4

Existing | **Low velocity in structured environment** | **High velocity in structured environment**

ADAS Advanced Driver Assistance Systems
AEBS Advanced Emergency Braking
ESC: Electronic Stability Control
ABS: Antilock Braking System
LKAS: Lane Keeping Assistance
FCW: Forward Collision Warning
ACC: Adaptive Cruise Control

Roadmap Automated Driving - Example Functions

	Intervening only in Emergency	Driver Only	Assisted	Partial Automation	Conditional Automation	High Automation	Full Automation
Longterm Gens.						Urban & rural roads	Robot Taxi
					Urban & rural roads	Highway System	
Automation Gen. 2					Highway System	Valet Parking System	
Automation Gen. 1					Highway Traf. Jam-System		
ADAS new				Traffic Jam Ass. / Park Ass.			
ADAS established	AEBS, ABS, ESC	FCW, LKAS	ACC, Park Steer Ass.				
	0	**1**	**2**	**3**	**4**	**5**

Legend:
- **Existing** (green)
- **Low velocity in structured environment** (blue)
- **High velocity in structured environment** (red)
- **Unstructured environment** (yellow)

ADAS Advanced Driver Assistance Systems
AEBS Advanced Emergency Braking
ESC: Electronic Stability Control
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Automation Gen. 2					Highway System	Valet Parking System	
Automation Gen. 1					Highway Traf. Jam-System		
ADAS new			Traffic Jam Ass. / Park Ass.				
ADAS established	AEBS / ABS / ESC	FCW / LKAS	ACC / Park Steer Ass.				
	0	**1**		**2**	**3**	**4**	**5**

Existing **Low velocity in structured environment** **High velocity in structured environment** **Unstructured environment**

ADAS Advanced Driver Assistance Systems
AEBS Advanced Emergency Braking
ESC: Electronic Stability Control
ABS: Antilock Braking System

LKAS: Lane Keeping Assistance
FCW: Forward Collision Warning
ACC: Adaptive Cruise Control

Exemplary functions

terms acc. to SAE J3016

	Level 2 *Partial Automation*	**Level 3** *Conditional Automation*	**Level 4** *High Automation*	
Low speed maneuvering	**Parking Assistant** Automated, driver initiated parking. Driver must monitor continuously, intervenes if necessary.		**Valet Parking** Automated valet parking. Driver initiates the function and can leave the scene.	Technology is already available or will be available soon.
Steering maneuvers of limited duration combined with ACC	**Lane Change Assistant** Automated, driver initiated lane change. Limited to motorways. Driver must monitor continuously, intervenes if necessary.			Technology will probably be available as of 2020.
Driving for longer periods	**Traffic Jam / Motorway Systems**			Technology will probably be available as of 2025.
	Automated longitudinal and lateral control. Limited to motorways. Driver must monitor continuously, intervenes if necessary.	Automated longitudinal and lateral control. Limited to motorways. Driver need not monitor continuously; will be requested to take over.	Automated longitudinal and lateral control. Limited to motorways. Driver need not monitor at all. Takeover by the driver is expected before the exit of the motorway.	

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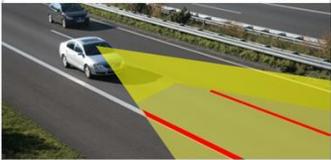Roadmap to automated driving and exemplary functions

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Current regulatory situation for UN Regulation and Road Traffic Code / Law

Lateral Control

Lane Change Assistant
Lane Keeping Assistant

UN R 79 steering equipment

– Automatically Commanded Steering Function allowed only up to 10 km/h (parking maneuvers)
– Beyond 10kph, only „corrective steering function" is allowed (LKAS)

Some Level 2, 3, 4, 5 systems are impossible with current requirements of UN-Regulations R 79 Amendment is necessary and urgent as a prerequisite for automated driving functions.

Longitudinal Control

ACC   Traffic Jam Assistance
Forward Collision Warning

VIENNA Convention & GENEVA Convention

– The VIENNA Convention includes harmonized minimum requirements for the signatories
– A driver shall at all times be able to control his vehicle (Vienna Convention Art. 8 and 13)
– Requires a driver (Vienna Convention Art. 1 and 8)

Future Level 4 and 5 systems are mostly impossible with the current Vienna Convention and with the amendment from 2014, because a driver may not be required. Therefore, further evolution is necessary.
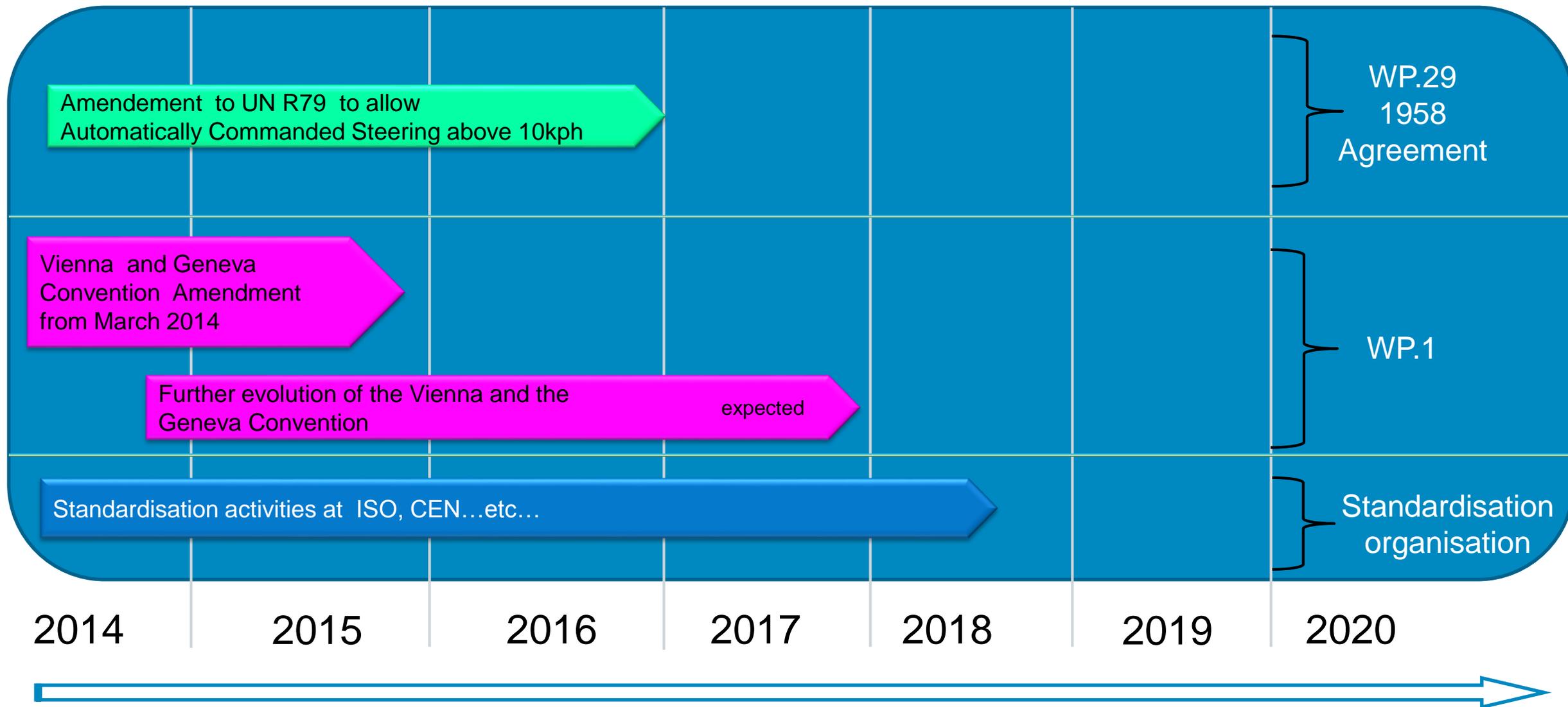
Longitudinal+Lateral Control

Traffic Jam Assist
ACC incl. Stop-&Go combined
with Lane Keeping Assistance

National Traffic Laws

– Often based on the VIENNA Convention, but details can be different for each country.

Level 3, 4 and 5 require evaluation for each country. Amendments may become necessary.

Roadmap/Principles on how to treat Automated Driving in UN regulations

Amendement to UN R79 to allow
Automatically Commanded Steering above 10kph

Vienna and Geneva
Convention Amendment
from March 2014

Further evolution of the Vienna and the
Geneva Convention

expected

Standardisation activities at ISO, CEN…etc…

WP.29
1958
Agreement

WP.1

Standardisation
organisation

2014 2015 2016 2017 2018 2019 2020

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Conclusion

- Levels of automation as presented are widely used

- Views on short/medium/long term introduction of systems are becoming clearer: level 4 (except some systems) and level 5 are not coming soon

- The higher the speed and the more complex the driving environment, the longer it will take to introduce automated driving

- Introduction of Automated Driving functions is expected to happen step-by-step and in an evolutionary way

- OICA reviewed all relevant elements in driving tasks and presented its understanding of DIL/DOL applied to the Levels of Automation

- OICA suggests that the IG ITS-AD:

  - uses the levels as presented as basis for further discussion

  - focusses on systems/levels that will be introduced in the short or medium term

- OICA aims at actively cooperating with UN stakeholders to jointly and positively advance the topic of automated driving and to make this a reality.

Backup

Role of the Driver/System Proposal

		Level0	Level1	Level2	Level3	Level4	Level5
Role of the driver	Dynamic driving task	Yes	Yes （Lateral or ongitudinal）	n.a. （Use case）	n.a. （Use case）	n.a. （Use case）	n.a. （All case）
	Driving environment monitoring	Yes	Yes （At all times）	Yes （At all times）	Yes, but not at all times	n.a. （use case）	n.a.
	Be attentive to and follow system's requests / warnings to resume the DDT	n.a.	Yes	Yes	Yes	Yes, but only at the end of the use-case)	No
Role of the system	Driving dynamics	n.a.	Yes （Lateral or Longitudinal）	Yes （Lateral/ Longitudinal combination）	Yes （Lateral/ Longitudinal combination）	Yes （Lateral/ Longitudinal combination）	Yes （Lateral/ Longitudinal combination）
	Driving environment monitoring	n.a.	Yes	Yes	Yes	Yes	Yes
	Request the driver with sufficient lead time to control when performance limits are reached	n.a.	n/a*	n/a*	Yes	Yes （only at the end of the use-case)	n.a.
	Recognize Performance Limits	n.a.	No	No	Yes	Yes	Yes
	Achieve minimum risk condition	n.a.	No	No	No**	Yes	Yes

*since driver has to react immediately
** System can not achieve minimal risk condition at all times. Fallback Performance of dynamic driving task is with the driver.

Exemplary Level Comparison for a Motorway Scenario

- System relieves driver and potentially enhances safety to traffic
- Driver must deliberately activate system and can override/switch off the system at any time
- Longitudinal and lateral control is performed by the system
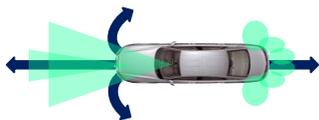
Motorway System (Level 2)

Driver

Monitors the driving environment at all times, must be ready to intervene immediately if necessary.
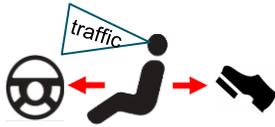
traffic

System

Performs longitudinal and lateral control on motorways in simple traffic situations with well developed infrastructure.
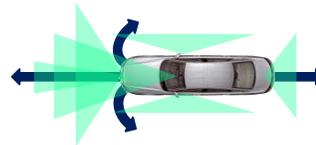
Motorway System (Level 3)

Driver

Does not need to monitor the driving environment at all times but must remain attentive to system's requests and warnings in order to takeover within a transition time.

!Attentive to system requests and ready to take over!

System

Performs longitudinal & lateral control (as well in emergency situations) in typical traffic situations like long distance driving, traffic jams, tunnels, high curvature geometry. Warns the driver when performance limits are reached - takeover is necessary.
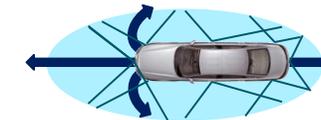
Motorway System (Level 4)

Driver

Driver is not required, has however the possibility to override/switch off at any time.

System

Performs longitudinal & lateral control in all encountered traffic situations on motorways. Request the driver to takeover at the end of the use case. A risk-minimal maneuver is guaranteed if the driver fails to takeover the driving tasks.

Glossary of Terms

- **Dynamic Driving Task**: Performing the lateral and the longitudinal driving task by considering the driving environment.

- **Driving Environment**: The outside surrounding of the vehicle in on-road traffic e. g.:
    - Road markings, road signs, road infrastructure
    - Other vehicles, objects on the road/roadside, other traffic members (pedestrians, cyclists, etc…)

- **Monitoring (according to SAE J3016)**: The activities and/or automated routines that accomplish comprehensive object and event detection, recognition, classification, and response preparation, as needed to competently perform the dynamic driving task.

- **Defined Use Case**: A driving scenario (including e. g. the driving environment, expected velocities) for which the dynamic driving task (longitudinal and lateral control) is automated. Example: Highway Chauffeur – a function that performs only on a highway, up to a max. velocity and limited or not to certain manoeuvers (according to the system limitations and thus the level of automation).

	ADAS Principle: RE3 Annex5-Appendix 3 (Extract)
Driver in the Loop	The notion of driver-in-the-loop means that a driver is involved in driving task and is aware of the vehicle status and road traffic situation. Being in-the-loop means that the driver plays an active role in the driver-vehicle system. They actively monitor information, detect emerging situations, make decisions and respond as needed.

	Regulatory Road Law: Vienna Convention (Extract) Article 8 and 13
Driver in Control	*"Every driver shall at all times be able to control his vehicle or to guide his animals."* *"Every driver of a vehicle shall in all circumstances have his vehicle under control so as to be able to exercise due and proper care and to be at all times in a position to perform all manoeuvres required of him."* The above mentioned articles require the driver to be in control at all times. According to the recent proposal for amendment from 2014 , systems are deemed to be in combliance with this requirement as long as they can be overriden or deactivated by the driver at any time. If stipulted different by other UNECE/GTR vehicle regulation, the system is also in compliance with this requirement.

Vienna Convention on Road Traffic

With regard to automated driving, following requirements are important:

Control:

Article 8, Paragraph 5:
„*Every driver shall at all times <u>be able to control </u>his vehicle or to guide his animals.*"

Article 13 (Speed and distance between vehicles), Paragraph 1:
"*Every driver of a vehicle shall in all circumstances have his vehicle <u>under control </u>so as to be able
to exercise due and proper care and to be at all times in a position to perform all manoeuvres required of him. [...]*"

adressed by the amendment from 2014

Driver:

Art. 8.1:
"*Every moving vehicle or combination of vehicles <u>shall have a driver</u>.*"

Art. 1 Definition (v):
"*Driver" means any person who drives a motor vehicle or other vehicle (including a cycle), or who guides cattle,…., on a road.*

Art. 1 Definition (d):
"*Road" means the entire surface of any way or street open to public traffic*