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Safety Challenges in Road Vehicle Automation

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Automated driving is here!

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THE ROBOTREPORT
EXPLORING THE BUSINESS AND APPLICATIONS OF ROBOTICS

Mercedes rolls out Level 3 autonomous driving tech in Germany

By Brianna Wessling | May 18, 2022

Mercedes' drive pilot is available to German customers in the company's S-Class and EQS models. | Source: Mercedes-Benz

Mercedes-Benz launched sales of its Drive Pilot system in Germany yesterday. The system is capable of operating at SAE Level 3 autonomy and can be ordered for the company's S-Class and all-electric EQS models.

What is “Automated Driving”?

Lots of terms

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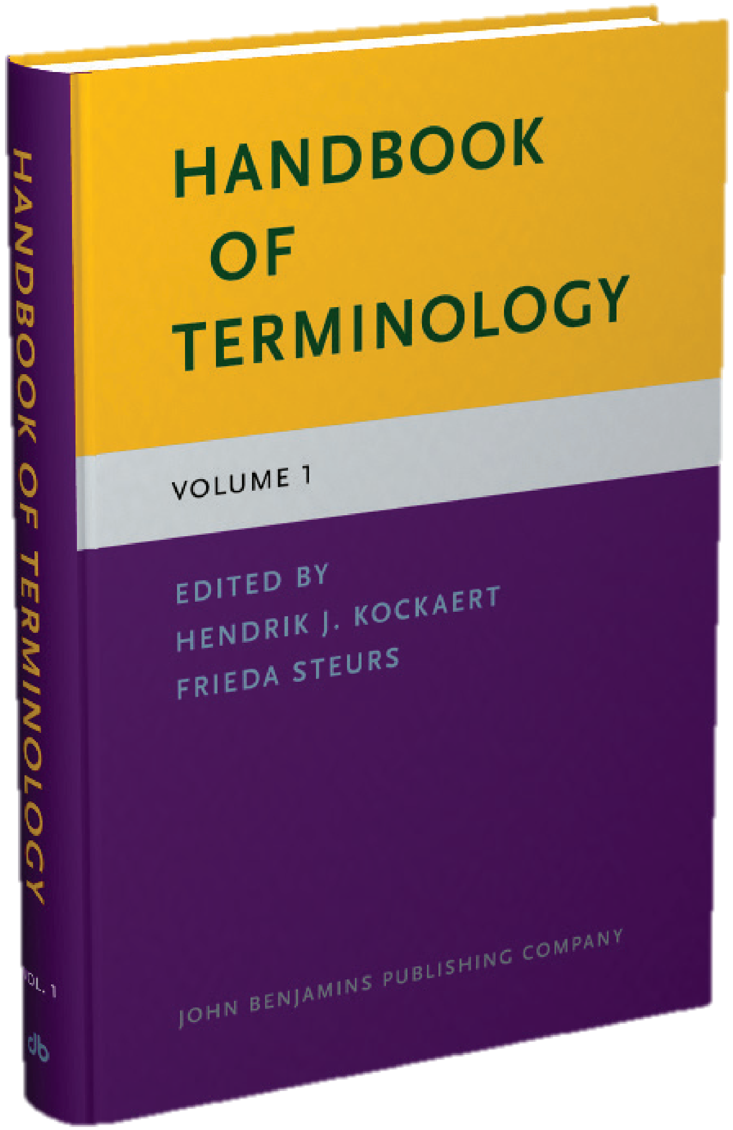
- Driverless
- Self Driving
- Autonomous

What I am going to discuss is:

- Automated Driving Systems (ADS)
- Assisted Driving



Levels of automation (SAE J3016)

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SAE J3016™ LEVELS OF DRIVING AUTOMATION™

Learn more here: sae.org/standards/content/j3016_202104

	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You are not driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			**These are automated driving features**		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering **OR** brake/ acceleration support to the driver	These features provide steering **AND** brake/ acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering **OR** • adaptive cruise control	• lane centering **AND** • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/ steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

Levels of automation (SAE J3016)

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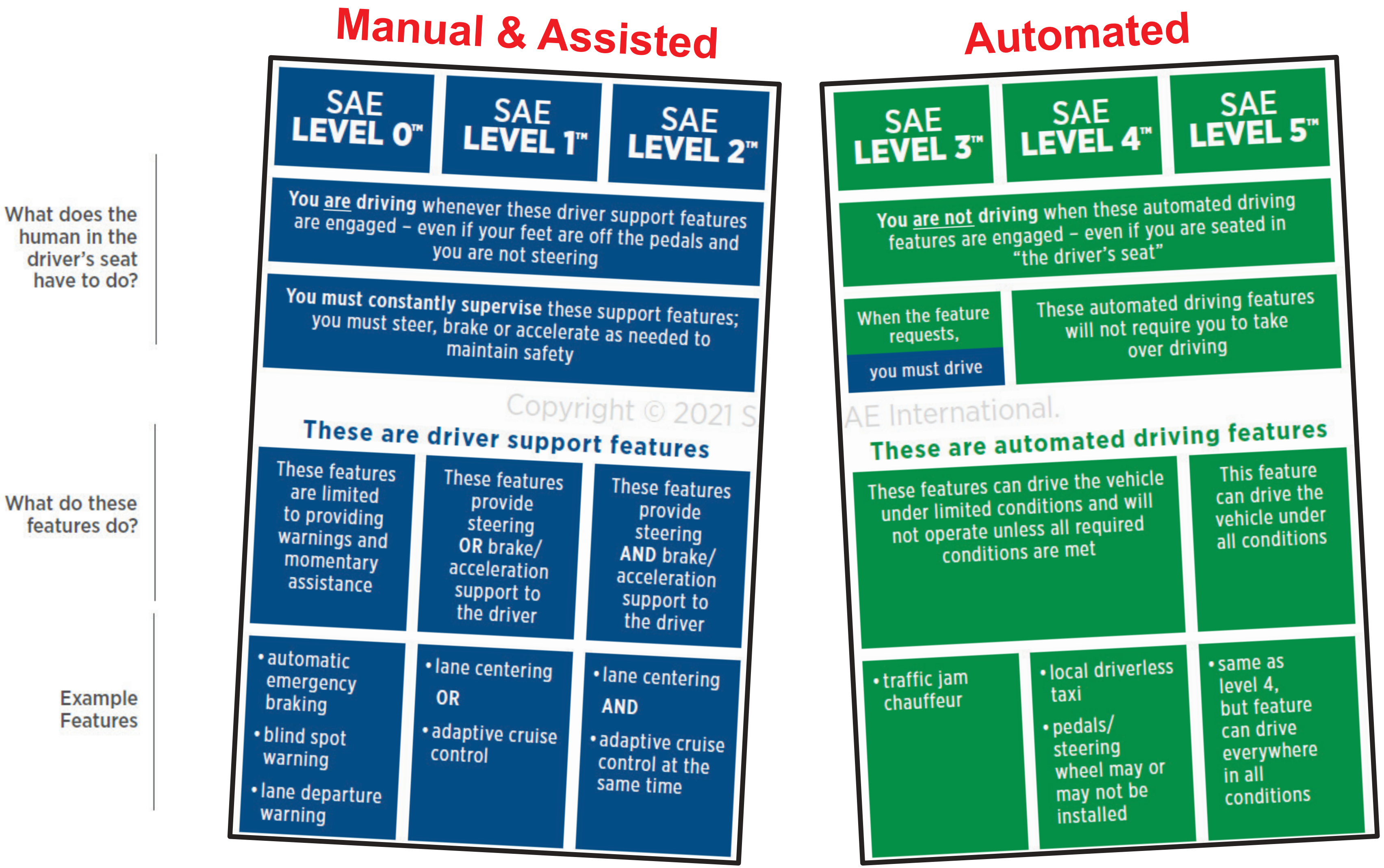

Manual & Assisted

- The human driver is responsible for safety

Automated

- The Automated Driving System (ADS) is responsible for safety

The promised land:
Predictions of the safety impact of automated driving

Cruise advertisement in the New York Times, 13 July 2023

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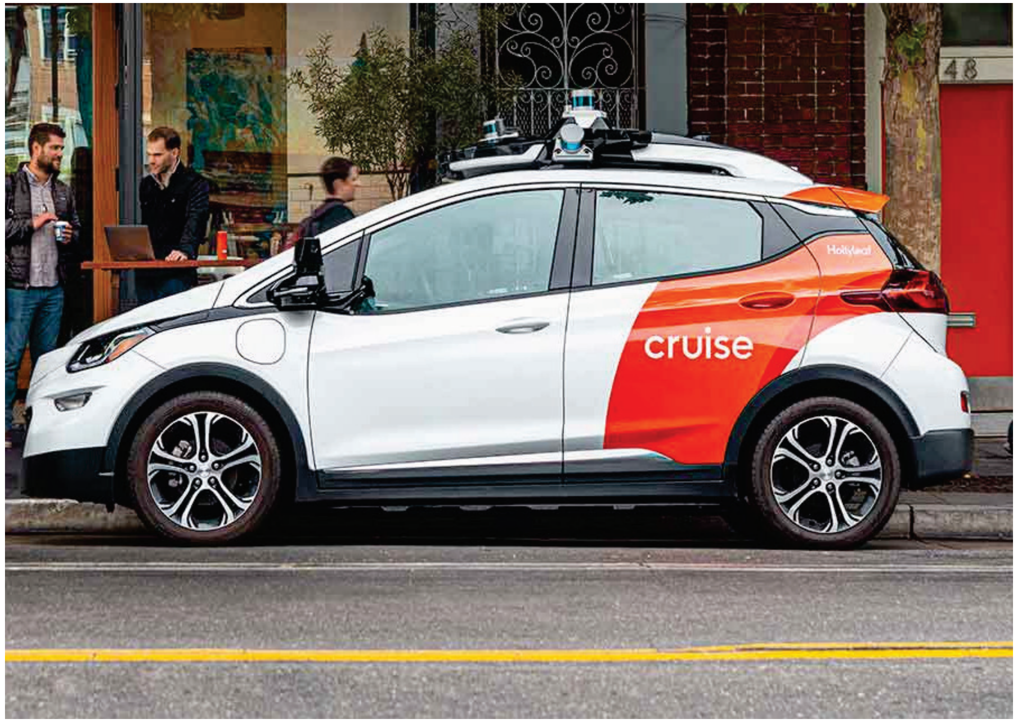

U.S. NHTSA, 2017

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"The major factor in 94 percent of all fatal crashes is human error. So ADSs have the potential to significantly reduce highway fatalities by addressing the root cause of these tragic crashes."

Secretary Elaine L. Chao
U.S. Department of Transportation

Automated Driving Systems 2.0: A Vision for Safety

Automotive Safety Council
Prevent Protect Notify

Benefits of Automation

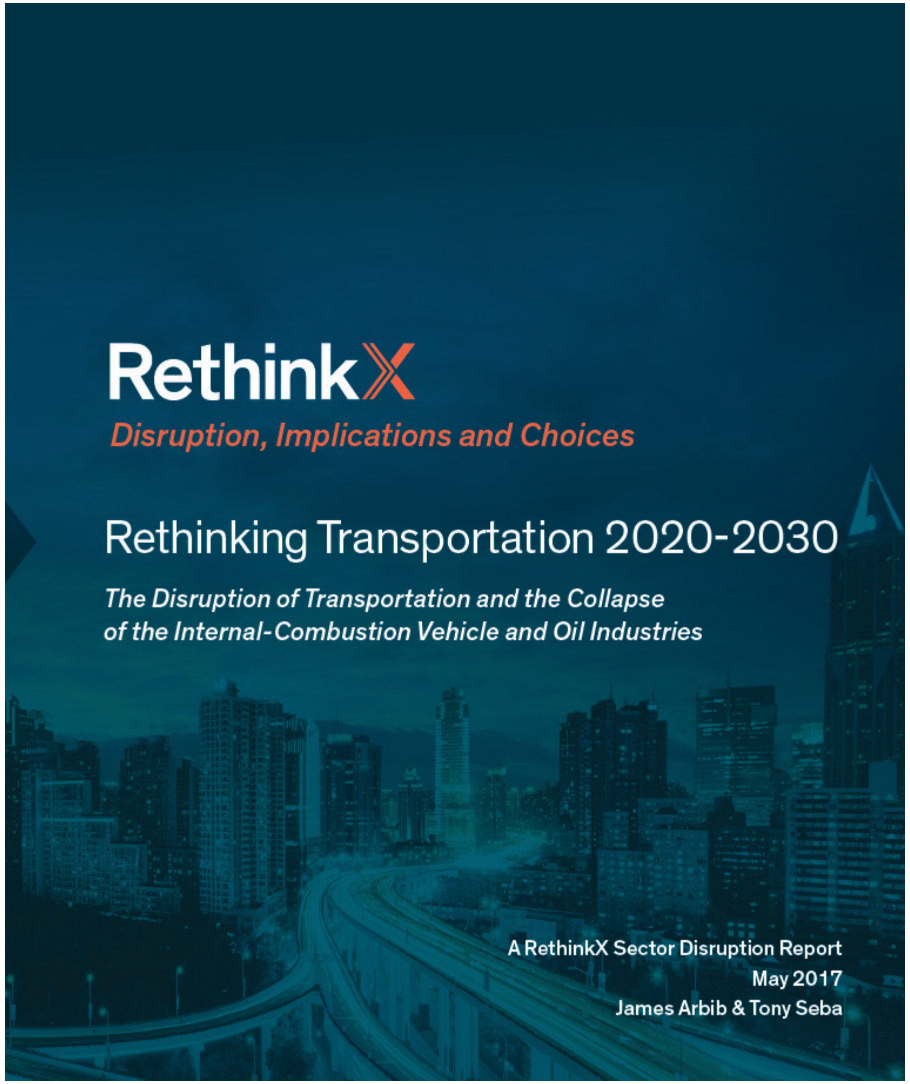
Safety

The safety benefits of automated vehicles are paramount. Automated vehicles' potential to save lives and reduce injuries is rooted in one critical and tragic fact: 94 percent of serious crashes are due to human error. Automated vehicles have the potential to remove human error from the crash equation, which will help protect drivers and passengers, as well as bicyclists and pedestrians. When you consider more than 35,092 people died in motor vehicle-related crashes in the U.S. in 2015, you begin to grasp the lifesaving benefits of driver assistance technologies.

Another prediction

"Current safety data suggests at least a 90% reduction in the number of accidents involving A-EVs, relative to ICEs. This is because 94% of ICE collisions are related to human error.

AVs will be five times safer than human-driven vehicles by 2020, and 10 times safer by 2022."



Criticism of the 94 percent

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“You can’t simultaneously say we’re focused on a ‘safe system’ approach — making sure everybody who shares responsibility for road safety is taking action to eliminate fatalities and serious injuries ... — and have a 94% number out there, which is not accurate.”

Jennifer Homendy
Chair of the U.S. National Transportation Safety Board

Jennifer Homendy to AP, 18 January 2022

Two fallacies in these predictions

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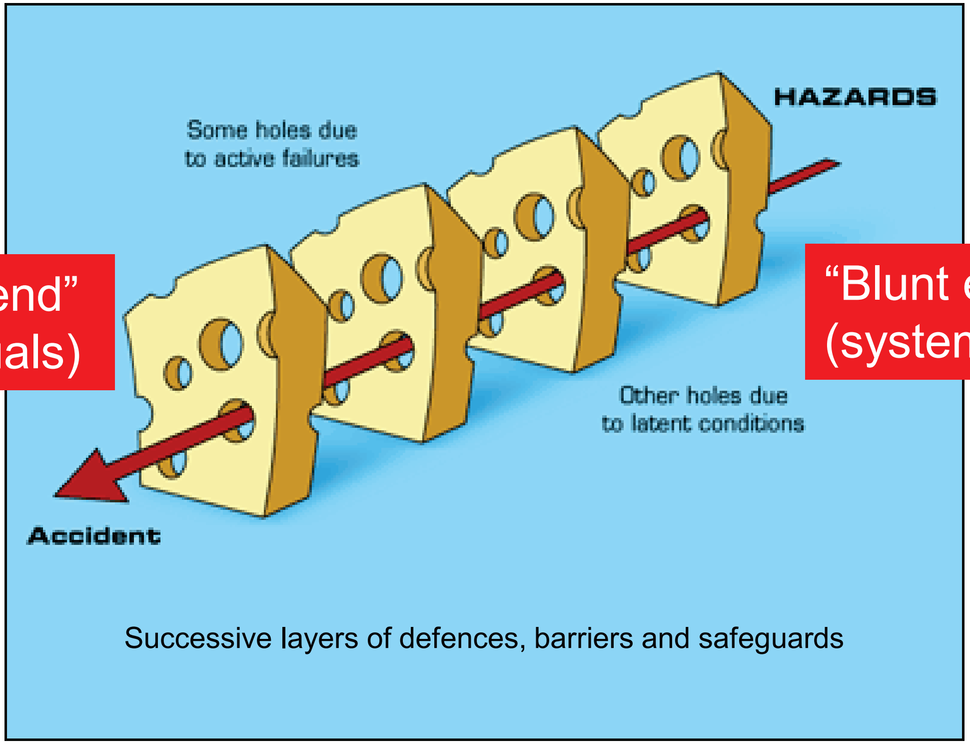
1. 90 or 94 percent of crashes are not in fact “caused by human error”
2. Automation will introduce new errors, whereas they assume it will be perfect

The Swiss cheese model of Reason

Humans make errors; systems should reduce errors and protect against the consequences of error.



“Sharp end” (individuals)

“Blunt end” (systems)

The latest version of the Swiss cheese model (Reason, 2008)

I will focus on some of the major safety holes in road vehicle automation

The United Nations Economic Commission for Europe (UNECE)

UNITED NATIONS
ECONOMIC COMMISSION FOR EUROPE

Responsible for worldwide regulations on inland transport

Working Groups on automation at UNECE

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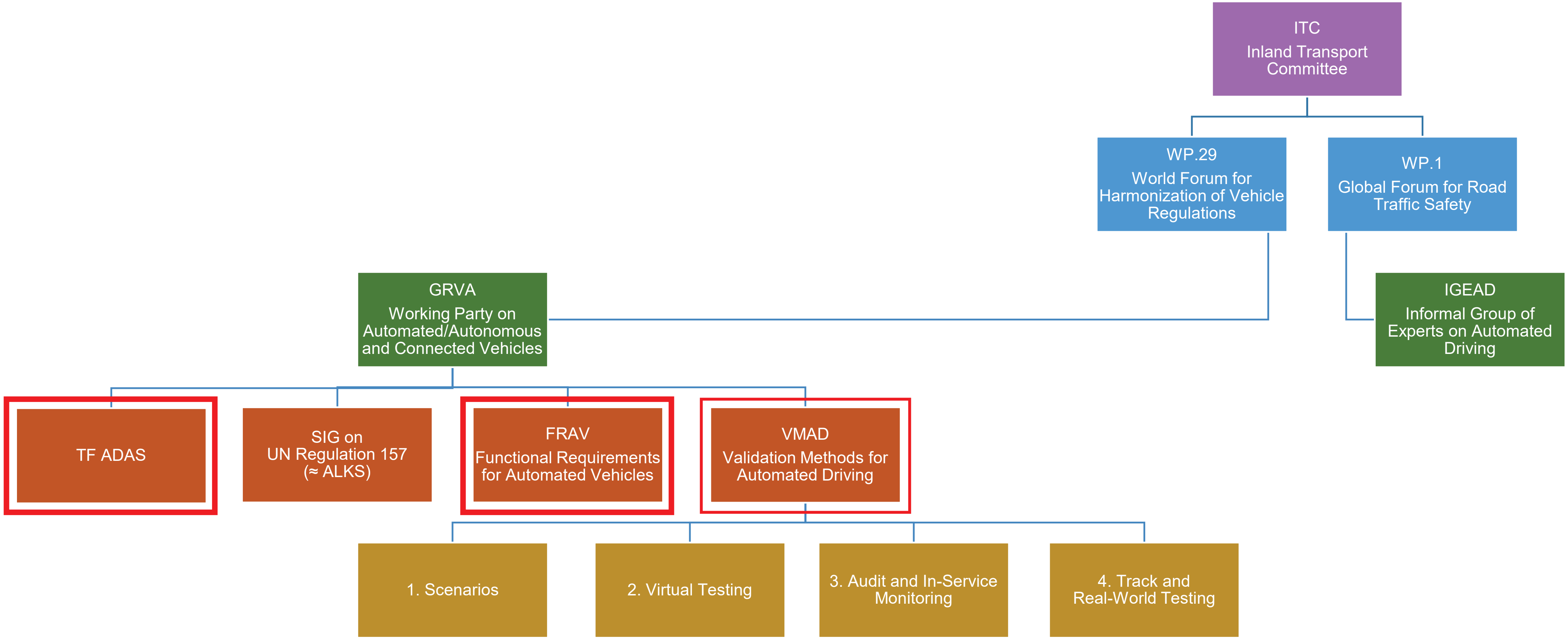

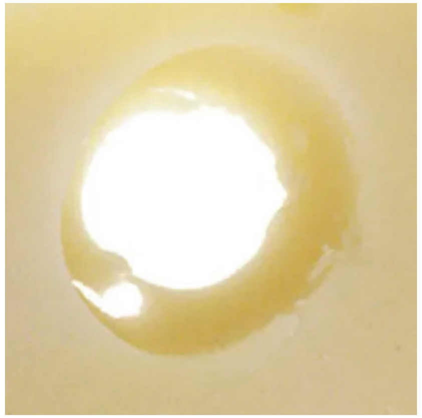

What is safe driving?

UNECE Functional Requirements group definitions

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- ***Nominal driving situations*** are those in which behaviour of other road users and the operating conditions of the given ODD are reasonably foreseeable (e.g. other traffic participants operating in line with traffic regulations)
- ***Critical driving situations*** are those in which the behaviour of one or more road users (e.g., violating traffic regulations, …) and/or a sudden and not reasonably foreseeable change of the operating conditions of the given ODD (e.g. sudden storm, damaged road infrastructure, …) creates a situation that may result in an immediate risk of collision.

My observations

- Aren't some critical situations *reasonably foreseeable*, e.g. speeding vehicles, pedestrians "jaywalking"?
- Should not the ADS be doing its best to avoid the occurrence of critical situations, e.g.:
  - By slowing down on the approach to an intersection even if it has right of way?
  - By reducing its speed when there are pedestrians around in the expectation that one of them might enter the roadway?
- Such anticipatory behaviour is a known quality in good human driving (sometimes termed "roadmanship")
- Otherwise we risk that ADS will be reactive rather than proactive. This would lead to erratic, dodgem-style driving.

FRAV coverage of such anticipatory behaviour

- The notion of learning from the "competent and careful human driver"
- However, this so-called model has no real content at the moment
- This is a gap that needs to be filled in order to ensure that ADS capture the best of human performance

Interaction with vulnerable road users

Some of the proposed external HMIs for interaction with pedestrians

And the latest from the interAct project

360° light band + directed signal lamp

Note that the light band can pulse:

- e.g. slowly to indicate the vehicle is slowing down
- or fast to indicate the vehicle is not yielding

Schieben et al., 2019

The studies on these eHMIs are typically done…

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- With one pedestrian interacting with one vehicle
- In a safe environment:
  - Virtual reality or
  - Campus or
  - Private road

Preferences of study participants

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- The participants generally like having messages
- They favour unambiguous information such as text messages

Problems with some types of message

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- An ADS should not instruct a pedestrian — the pedestrian still has the responsibility and it may not actually be safe to cross
  - The analogy of a traffic signal is not correct
- With text messages, there are challenges of language and literacy

How do pedestrians determine what a vehicle is doing?

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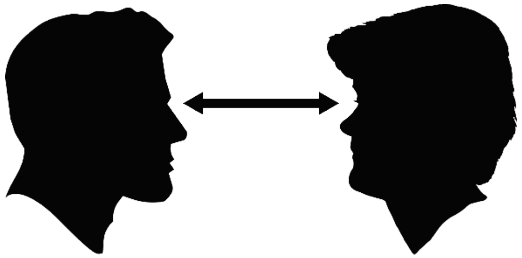
Eight out of ten people seek eye contact

A safe traffic environment is dependent on interactions between people. Today, eight out of ten people seek eye contact with the driver before they cross a busy road [Semcon/Inizio]. But what happens when there is no longer a driver behind the wheel? We decided to find out how people react to self-driving cars.



True?

- In fact in most road crossings, pedestrians do not have explicit communication with a single driver
  - Multiple vehicles
  - Wide roads
  - Higher speeds
  - Night-time
- Implicit communication is far more typical
  (Amini et al., 2019; Dey & Terken, 2017; Fridman et al., 2017; Jayaraman et al., 2019; Lee et al., 2021; Palmeiro et al., 2018; Rasouli and Tsotsos, 2020).

Recommendations from the project *Study on the Effects of Automation on Road User Behaviour and Performance* (2020)

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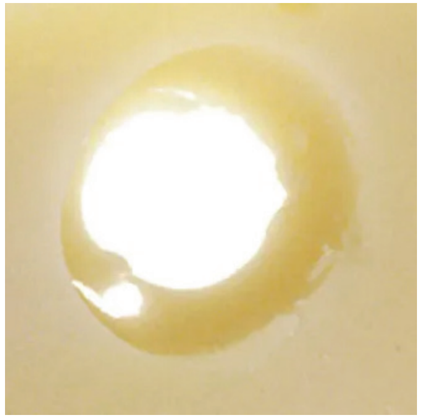
1. Automated Vehicles should use existing eHMI (headlights, indicators, horn, etc.), in order not to make it more complicated for other road users.

2. An exterior Indication that a vehicle is driven under automation could be useful, both for other road users and for enforcement authorities. This could be achieved by a small LED light. The appearance of this indication should be standardised.

3. It is important to avoid many extra lights and indications on the outside of a vehicle.



Driver monitoring

The Driver Monitoring System

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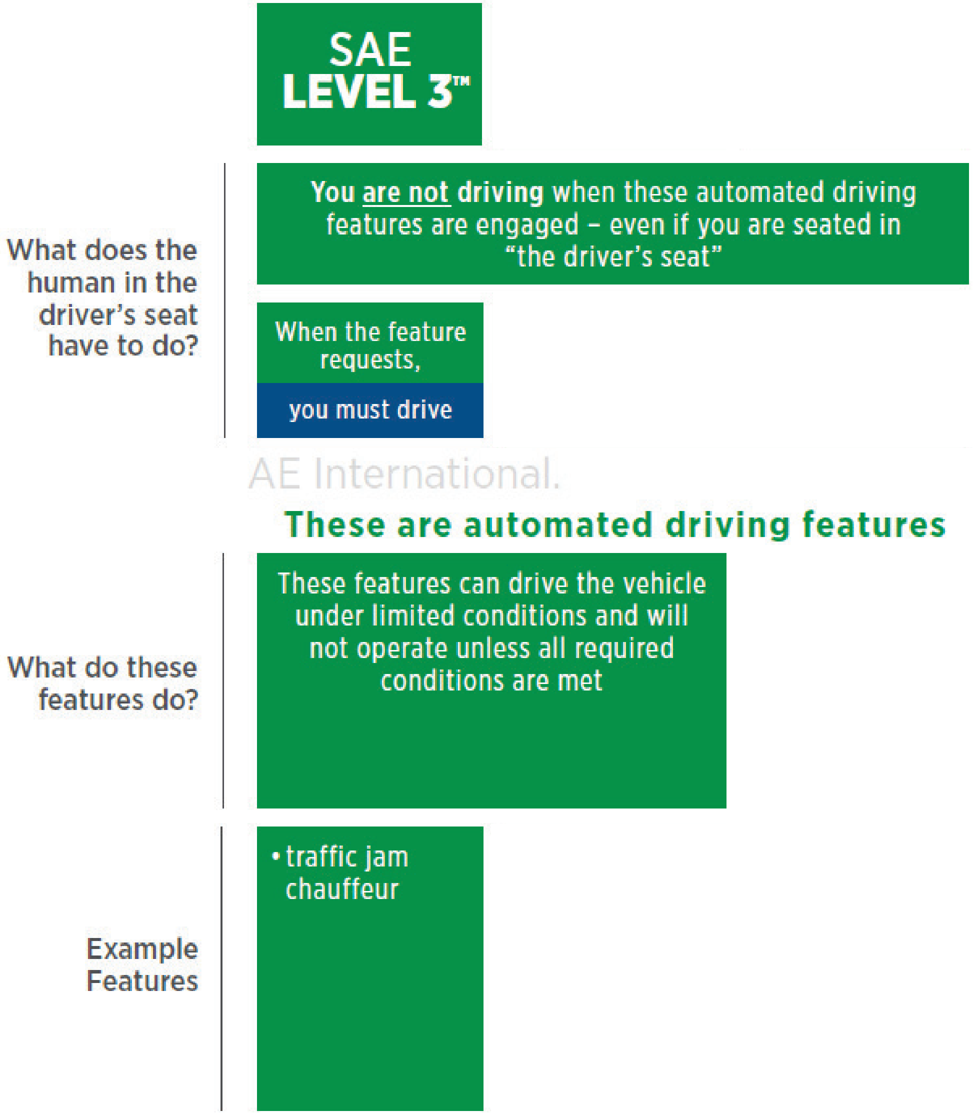
- Mission-critical part of an ADS in which a human may be required to take control

SAE Level 3 Driving, as in the Mercedes Drive Pilot



Fallback user readiness

- UNECE Regulation 157 is the regulation specifying the so-called Automated Lane Keeping System under which Mercedes Drive Pilot is being introduced
- The ADS can only drive in limited conditions and the human has to be ready to take over when instructed by the ADS

Regulation 157 states…

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Driver Availability Recognition System

- *The system shall comprise a driver availability recognition system.*
- *The driver availability recognition system shall detect if the driver is present in a driving position, if the safety belt of the driver is fastened and if the driver is available to take over the driving task.*

Driver availability

- *The system shall detect if the driver is available and in an appropriate driving position to respond to a transition demand by monitoring the driver.*

Criteria for deeming driver availability

- *The driver shall be deemed to be unavailable unless at least two availability criteria (e.g. input to driver-exclusive vehicle control, eye blinking, eye closure, conscious head or body movement) have individually determined that the driver is available in the last 30 seconds.*

Driver not available

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- *At any time, the system may deem the driver unavailable.*
- *As soon as the driver is deemed to be unavailable, or fewer than two availability criteria can be monitored, the system shall immediately provide a distinctive warning until appropriate actions of the driver are detected or until a transition demand is initiated. At the latest, a transition demand shall be initiated… if this warning continues for 15s.*

- If a driver fails to respond to the transition demand, then the system would initiate a “minimum risk manoeuvre”

The end of the transition process back to manual driving

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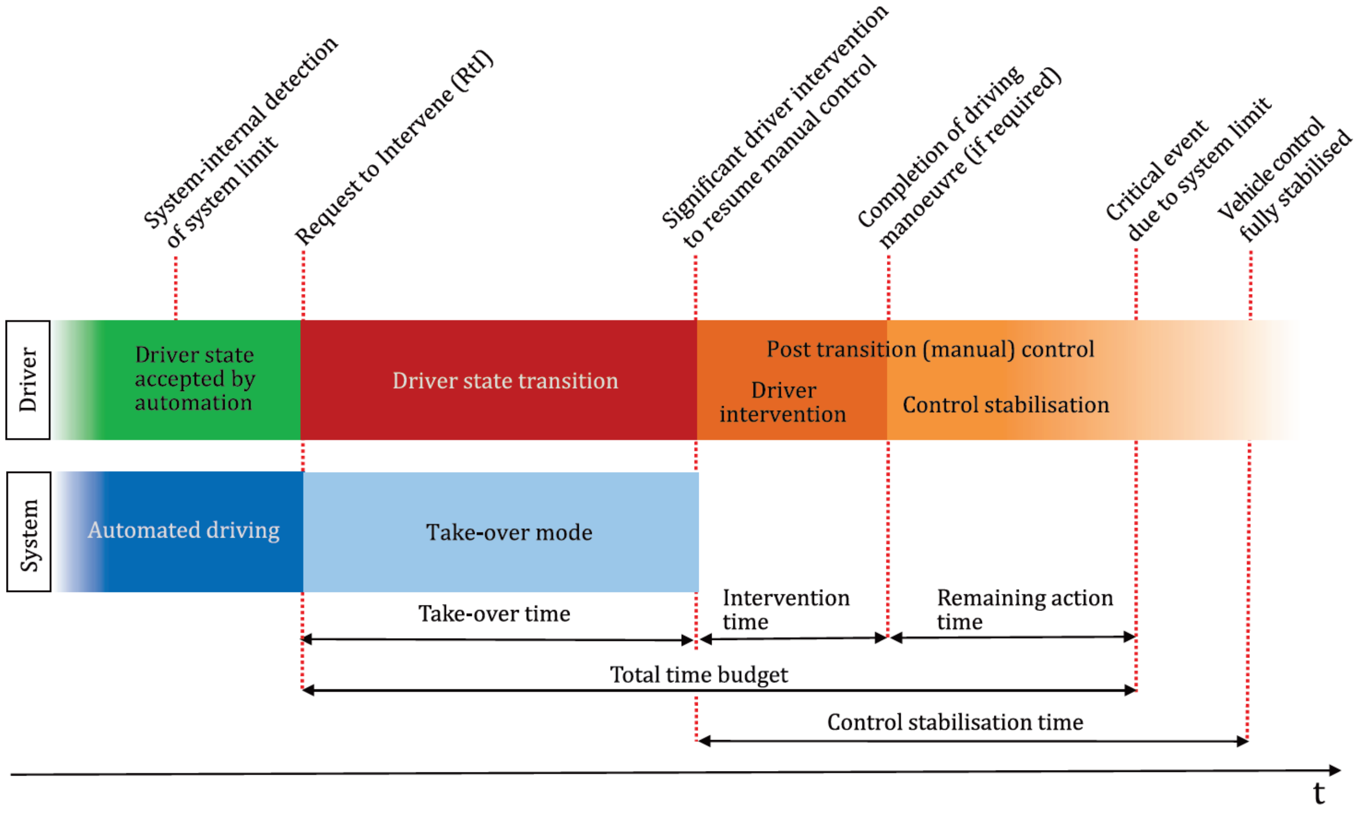
ISO diagram of the system-initiated transition process



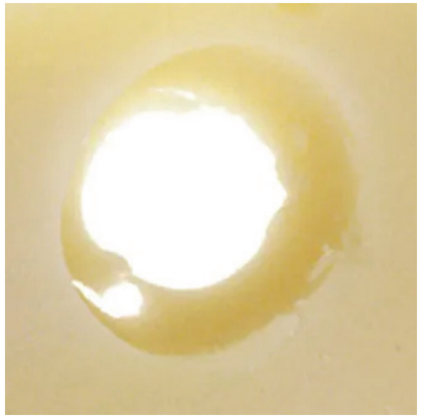
FRAV requirement:

“The ADS shall assess the user is suitably engaged to resume the DDT before completion of the deactivation process.”

This implies a need to monitor driver attention in the final period

My observations

- The UNECE Functional Requirements group has neglected Driver Monitoring
- There are currently no requirements for the operational performance or robustness of a Driver Monitoring System as an inherent part of an ADS



Back to Assisted Driving

Level 2: Assistance

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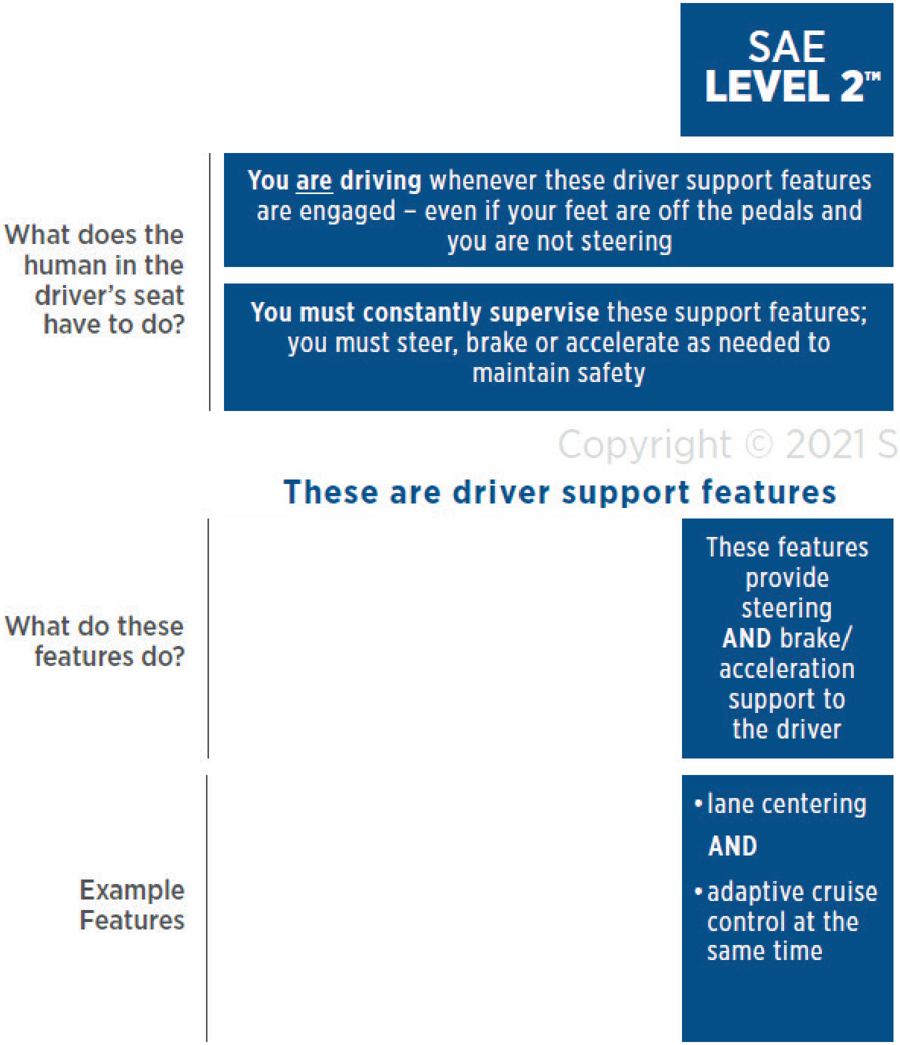

- In Level 2, the human driver is responsible for the safety of the "Dynamic Driving Task" (DDT)

Definition of DDT:

"All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints"

The Draft UNECE regulation for a Driver Control Assistance System (DCAS)

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- Provides both longitudinal and lateral control
- But drivers are still responsible — it's assistance. not automation
- Lots of holes:
  - Very weak on speed limit compliance
    - It is well documented that L2 Assistance leads to more speeding
  - Lack of specification on requirements for driver monitoring (which checks that drivers are attentive)
  - The system will be permitted to initiate a lane change but with the driver still responsible for the safety of the manoeuvre
  - The biggest hole of all is that in the pipeline is permission for hands-off driving

Coupled and uncoupled

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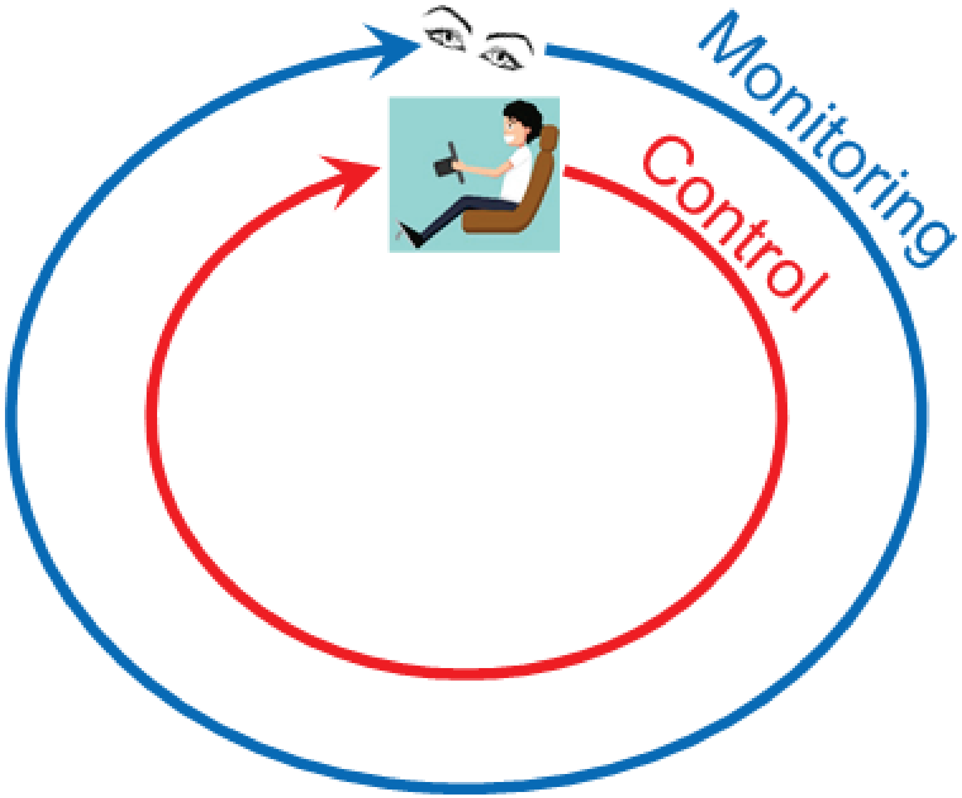

- Engagement in steering promotes attention to the road and traffic

Source: Carsten and Martens, 2019

Known impacts of hands-off driving with Level 2 assistance

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- Hands-free driving leads to longer take-over times than hands-on driving (Gershon et al., 2023)
- Hands-free, compared to hands-on, leads to a substantial increase in non-driving related tasks (Mueller et al., 2022)
- Driver attention to the road and traffic decreases during hands-on L2 driving, even without the presence of a secondary task (Lenné et al., 2019; Noble et al., 2021)
- So what does hands-off L2 deliver for safety?

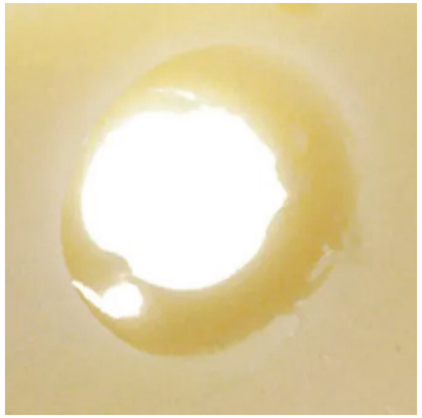
The most clear way to distinguish assisted driving from automated driving is…

- Assisted requires hands on the wheel (and preferably shared control in which the driver still has to put in some steering effort)

  = “You are responsible!”

- Automated means hands off

  = “You are not responsible!”



Human Machine Interaction (HMI)

The joint cognitive system

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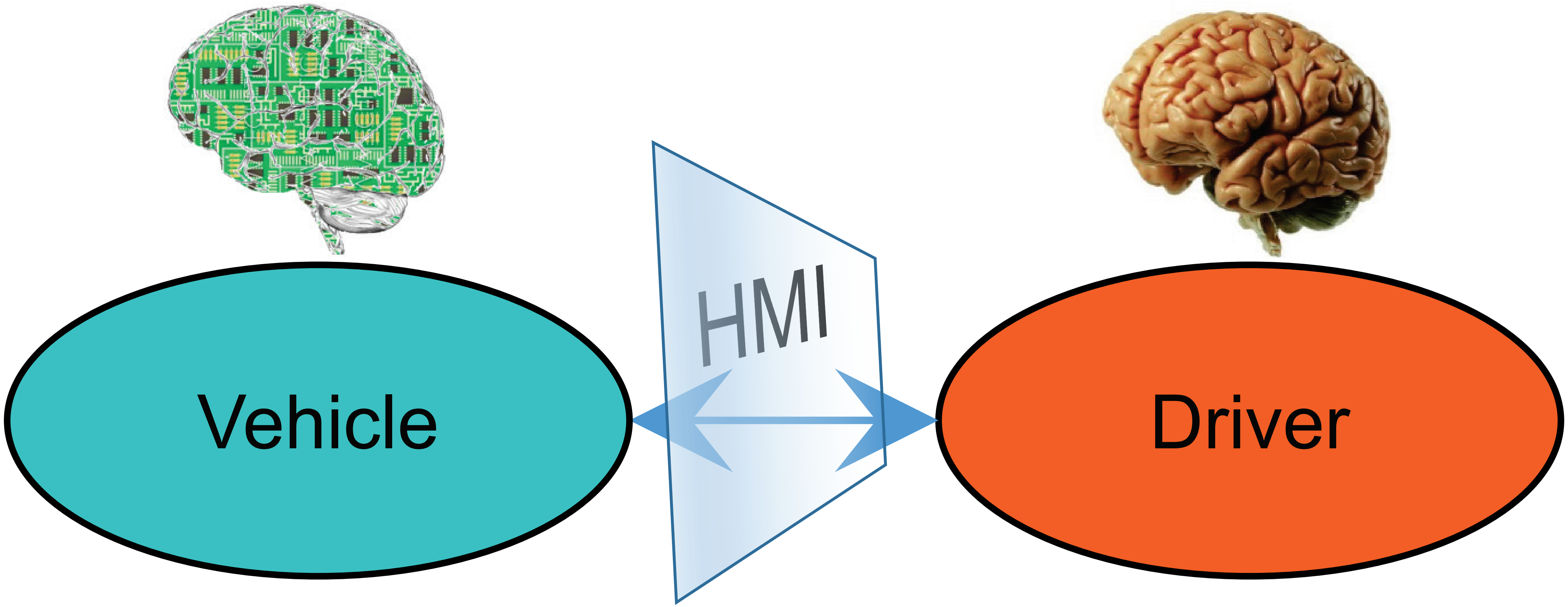


What do users need in HMI?

- Simplicity
- Commonality (harmonisation)
- Unity: an overall HMI design that embraces manual driving, assisted driving and automated driving

Simplicity

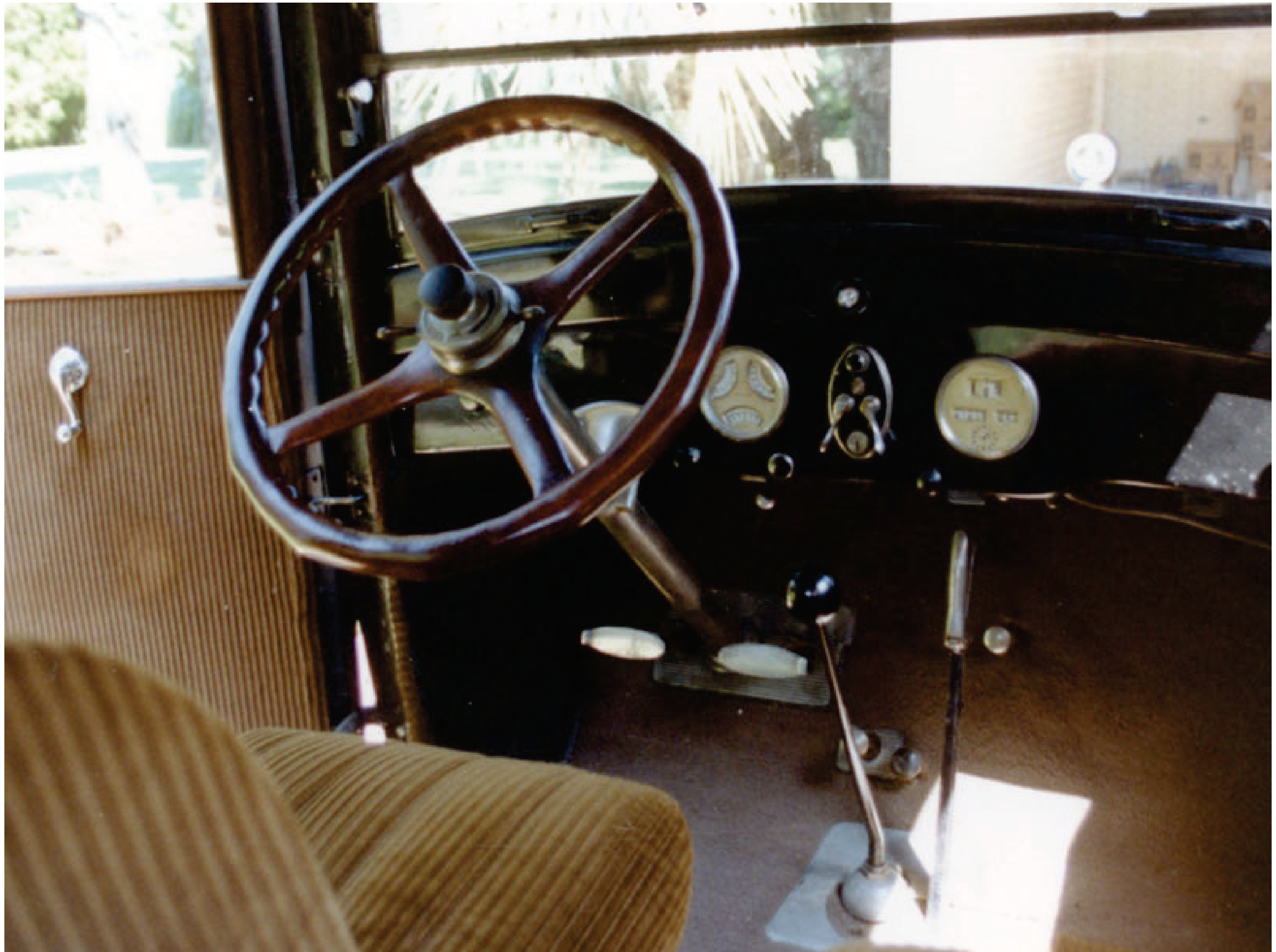
Canada introduced a set of *Human factors principles and procedures for automated vehicle safety* at the October session of UNECE WP.1, the Global Forum for Road Traffic Safety:

1. Clear and Intuitive Displays:
   a. Present information on the user interface clearly, **simply**, and unambiguously.
   b. Continuously display automation mode and status information when active or available.
2. User-Friendly Interaction:
   a. Ensure **simple**, discoverable, and easy-to-learn interaction with the ADS.
   b. Position interfaces for safe and accessible interaction.
   c. Simplify the automation mode structure, settings, and transition types to minimize confusion.

Commonality

- We need a harmonised HMI so that users can easily switch from one vehicle to another
- But no progress

The Cadillac Type 53, 1916



The vehicle that set the template for control layout and dashboard

The 1929 Skoda 422

- Brake pedal on the right
- Accelerator pedal in the middle
- Clutch pedal on the left

The draft DCAS regulation on the need for commonality

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- The introduction states the need for *“the development of a uniform standard (e.g., ISO) setting for DCAS the common HMI, communication techniques, modes of operation, possibilities of overriding, system messages and signals, etc. in addition to this UN Regulation. This will ensure a uniformity of HMI for different DCAS produced by different manufacturers, so that every driver could be prepared to use different DCAS features in a safe way.”*
- Such an aspiration is not present in the latest version of the user requirement for Automated Driving Systems from FRAV

DG Move's *Road Safety Policy Framework*

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- On connected and automated mobility:
  "The Commission will evaluate the need for further complementary actions, such as in promoting the harmonisation of human-machine interfaces fitted to vehicles to ensure all drivers and users can interact with vehicles without compromising safety."
- But no action so far
- We need research to develop a harmonised design

Unity

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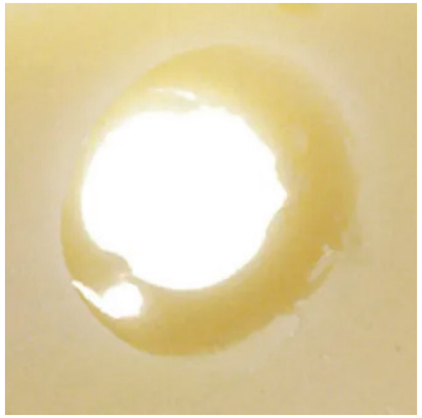
- Such a harmonised design needs to cater to all levels of automation:
  L0, L1, L2 (DCAS), L3, L4 and even L5
- A driver is likely to change roles in a single trip:
  - Driver (L0) → Assisted Driver (L2) → Fallback User (L3) → Passenger (L4) → Driver (L0)



Does regulation work?

Who attends UNECE work on vehicle regulations?

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EXAMPLE: GRVA
Meeting 24 September
2018

Influence of OICA-CLEPA

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- = OEMs and Tier 1 suppliers
- After 18 months of non-controversial discussion on the FRAV user requirements (led by NL), they pretty much argued that such requirements were not needed in view of the manufacturers' Safety by Design approach
- We were only able to fight back to have most of the requirements restored with the help of Canada, Germany and UK

Recommendations

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- More DG MOVE involvement in line with the 2030 strategy
- Research on what constitutes “safe driving”
- Address requirements for Driver Monitoring Systems
- Research to develop a harmonised HMI
- We probably need a single EU type approval authority
  - That could be expanded into giving the same agency responsibility for collecting the information required by In-Service Monitoring and Reporting of incidents and failures of ADS
- We need naturalistic research on how drivers use automation