Highly automated driving

InteractIVe Summerschool 2012

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Agenda

- Different levels of automation in a highly automated vehicle
- **Technical development** for highly automated driving
- Design of the **Human-Machine-Interaction** for highly automated driving
- Outlook and summary

Imagine…

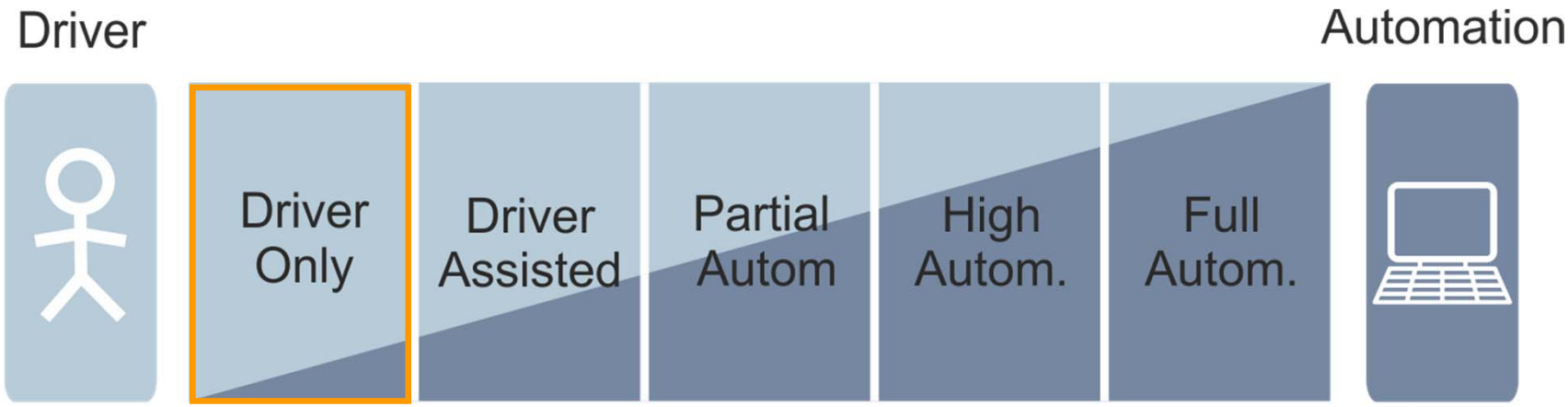
Definition of different levels of automation

- Much discussed e.g. in
  - Projects such as PATH, HAVEit, interactIVe, …
  - BASt group „legal consequences of increasing automation“
  - iMobility Automation Working Group
  - IHRA (International Harmonized Research Association)
  - TRB (Transportation Research Board)
  - …

Gasser, Arzt, Ayoubi, Bartels, Bürkle, Eier, Flemisch, Häcker, Hesse, Huber, Lotz, Maurer, Ruth-Schumacher, Schwarz, Vogt (2012).

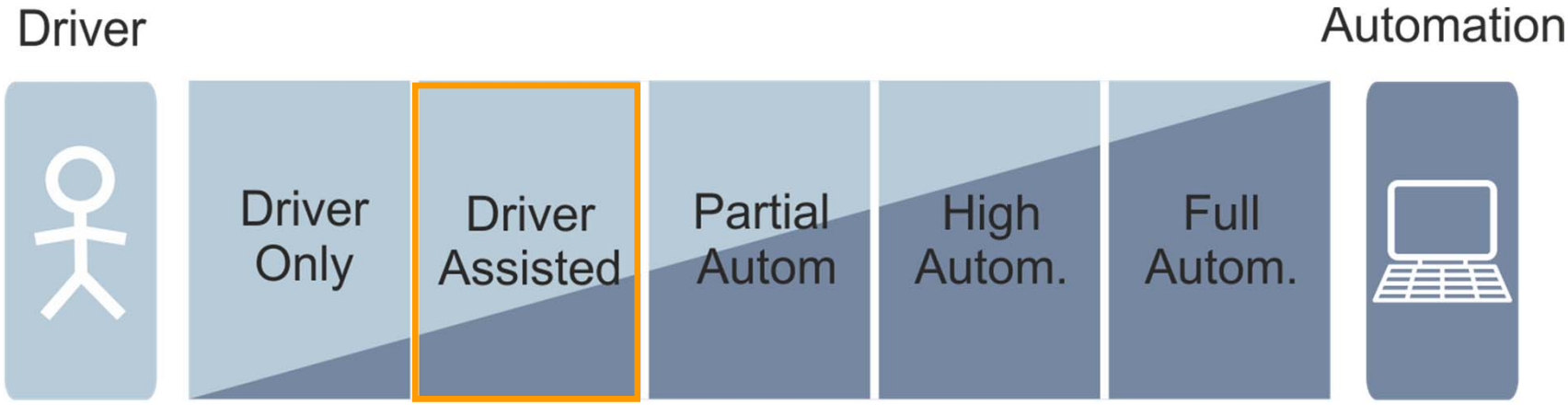
Different levels of automation in one vehicle

BASt Definition: Human driver executes manual driving task



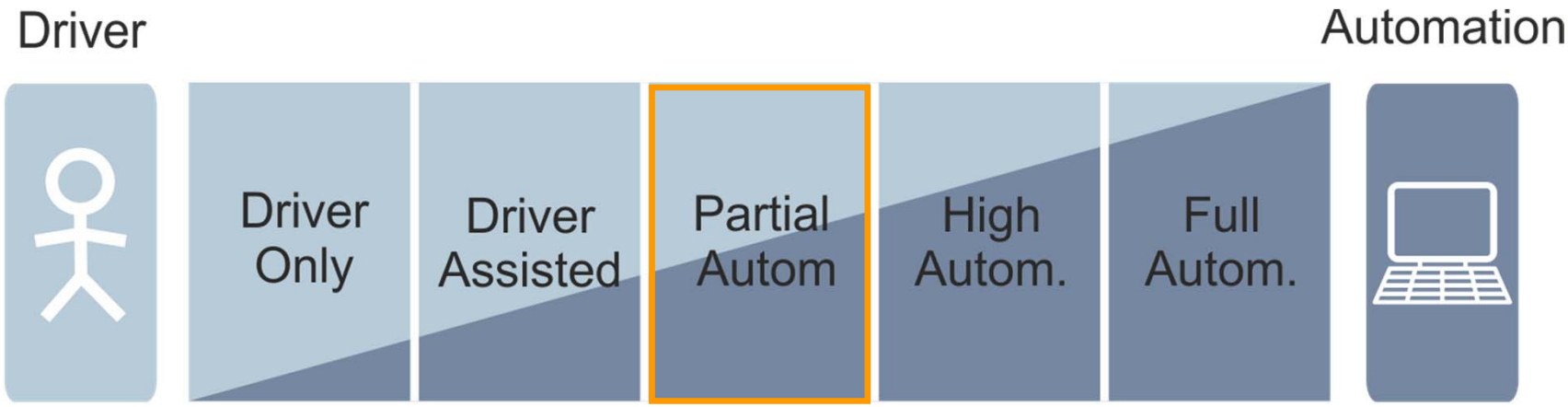
Different levels of automation in one vehicle

BASt Definition: The driver permanently controls either longitudinal or lateral control. The other task can be automated to a certain extent by the assistance system.



Different levels of automation in one vehicle

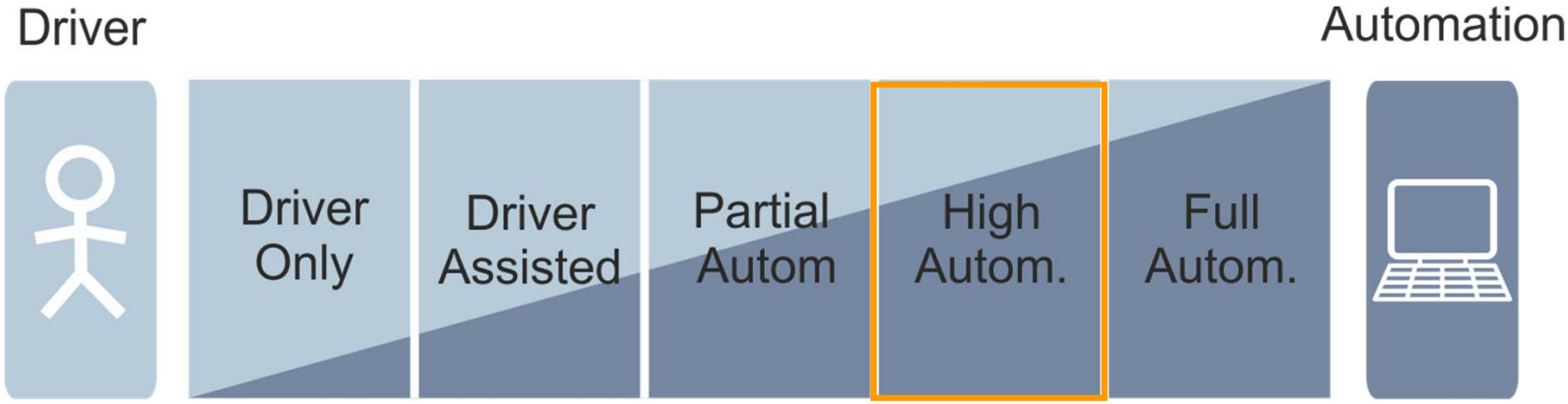
BASt Definition: The system takes over longitudinal and lateral control, the driver shall permanently monitor the system and shall be prepared to take over at any time.

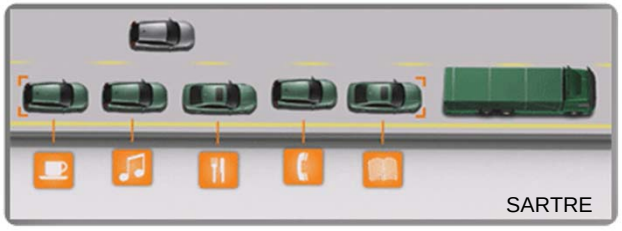



HAVEit

Different levels of automation in one vehicle

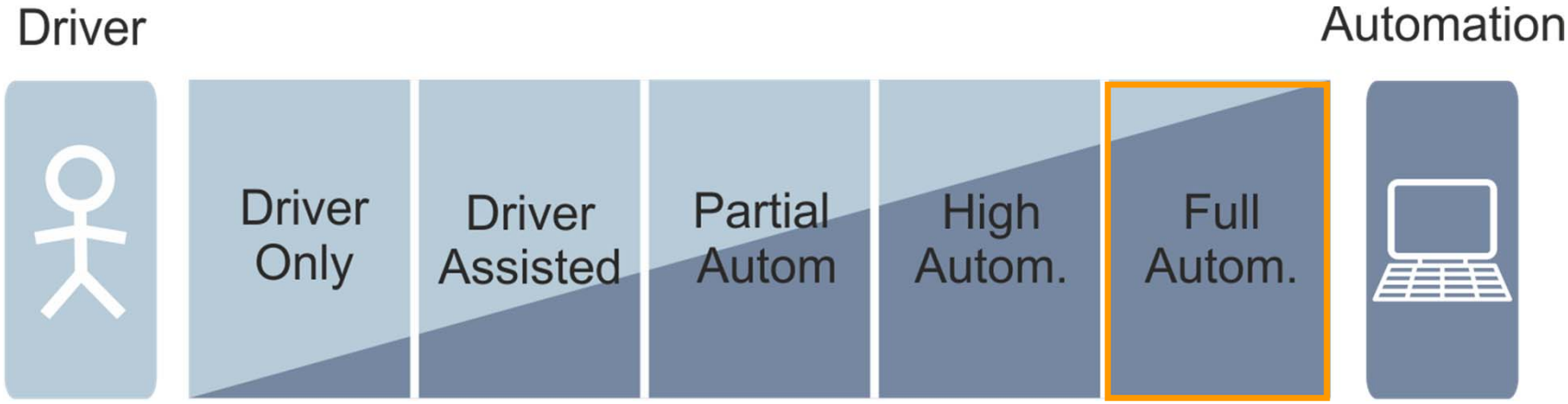
BASt Definition: The system takes over longitudinal and lateral control; the driver must no longer permanently monitor the system. In case of a take-over request, the driver must take-over control with a certain time buffer.



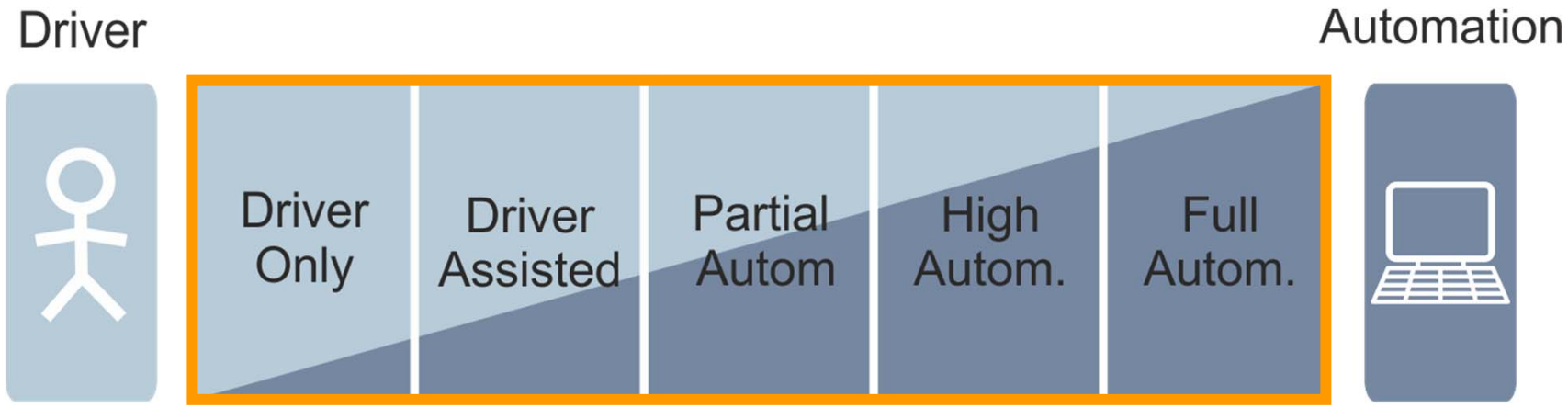


Different levels of automation in one vehicle

BASt Definition: The system takes over longitudinal and lateral control completely and permanently. In case a take-over request that is not carried out, the system will return to a minimal risk condition by itself.



Different levels of automation in one vehicle



SPARC
SECURE PROPULSION USING ADVANCED REDUNDANT CONTROL

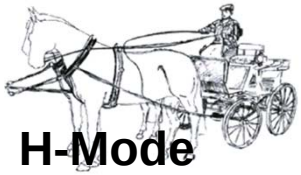
CityMobil

HAVEit

Famos

IMoST
Integrated Modelling for Safe Transportation

interactIVe



H-Mode

DLR
Basefunding

ISi-PADAS

D3CoS

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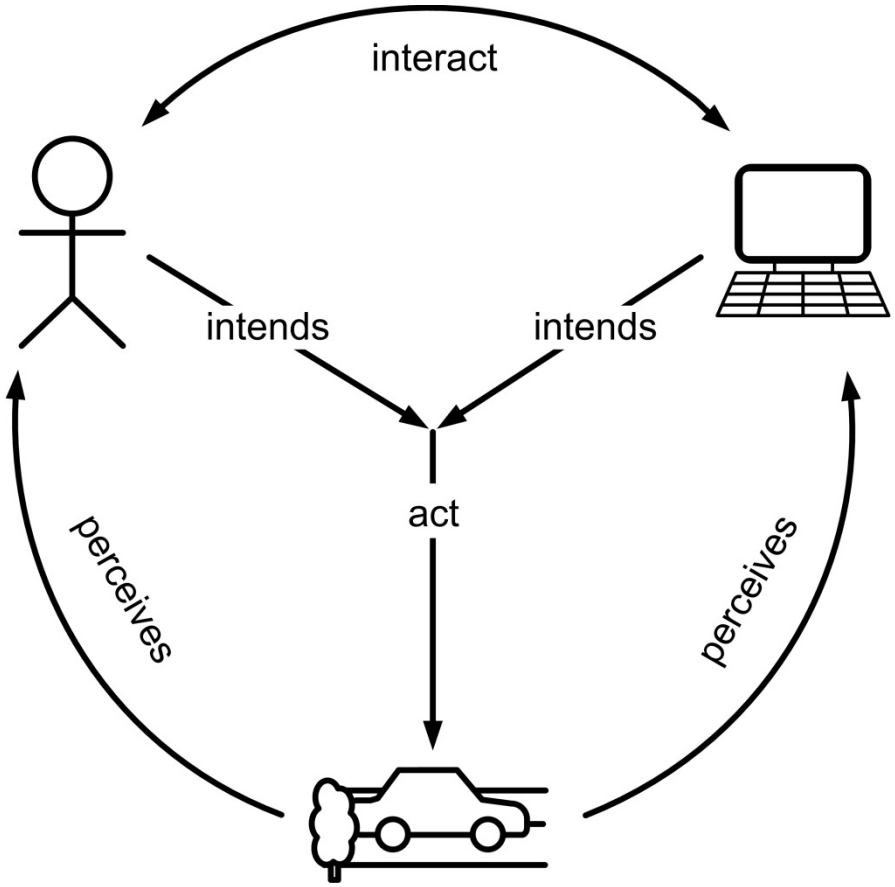
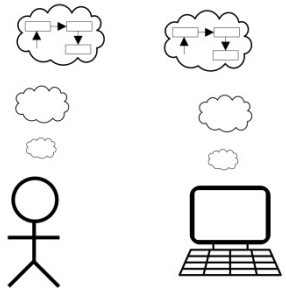
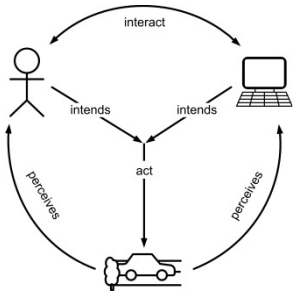
Concept of Cooperative Automation

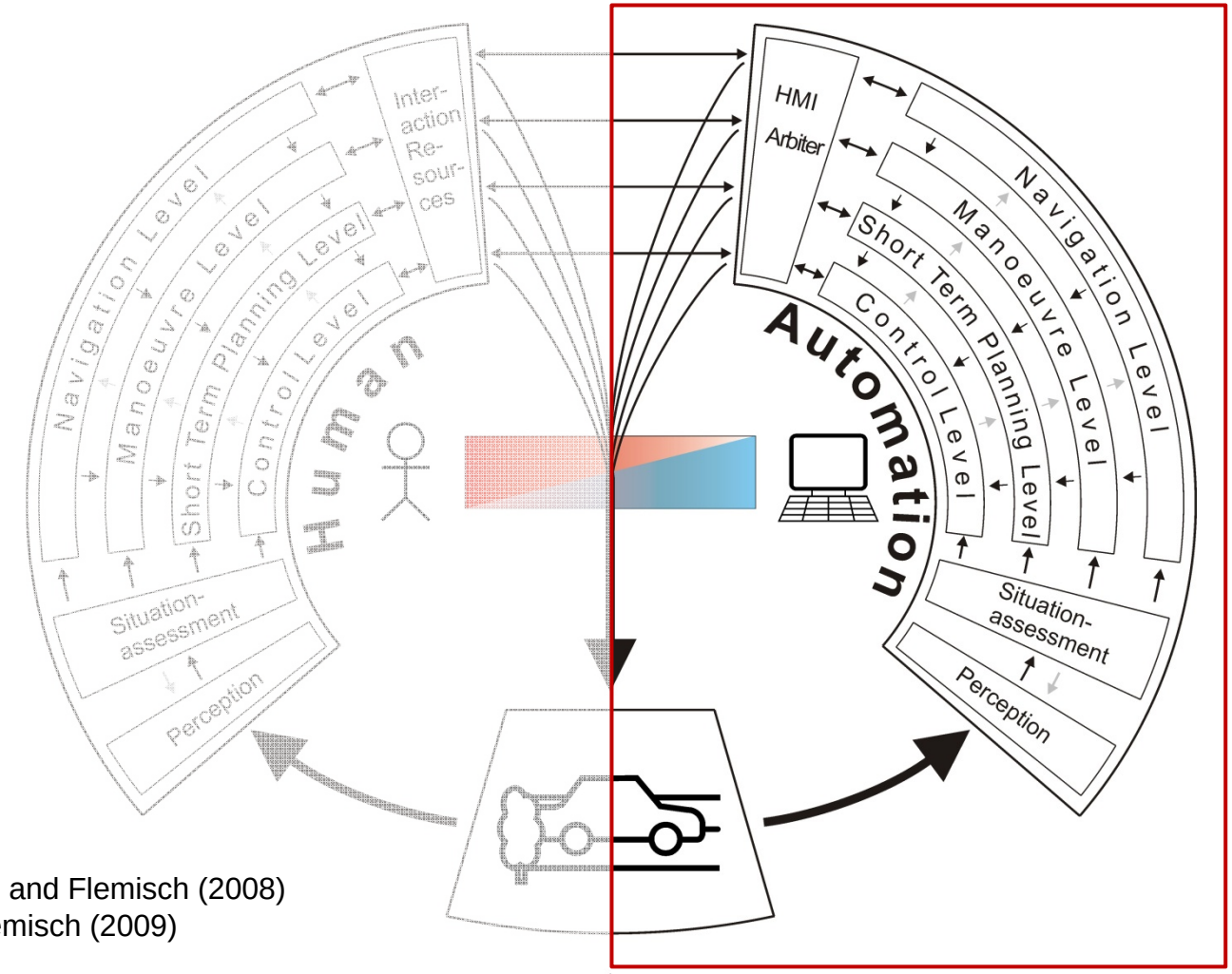


- Common action execution
- Common action planning
- Compatibility
  - External compatibility
  - Internal compatibility
    - Cognitive compatibility
    - Compatibility of values



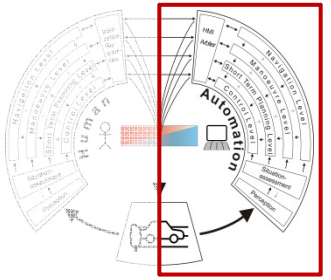
Cooperative Automation: Cognitive Compatibility



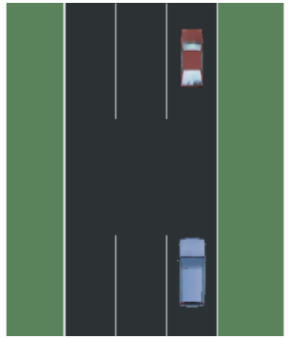


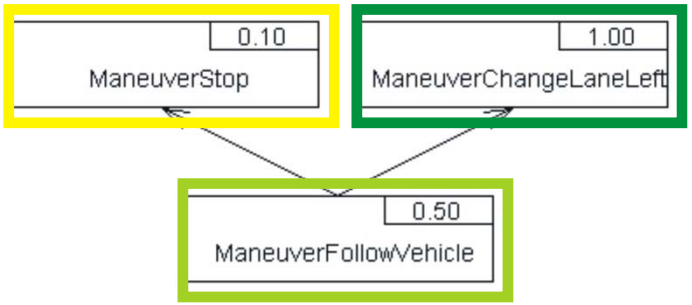
Löper, Kelsch and Flemisch (2008)
Löper and Flemisch (2009)

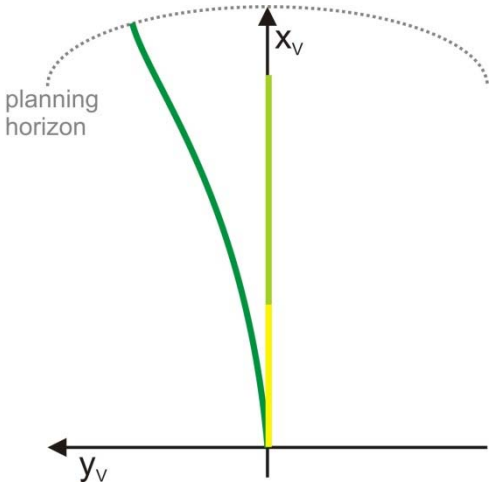
Representation of Cooperative Automation Behaviour on Layers

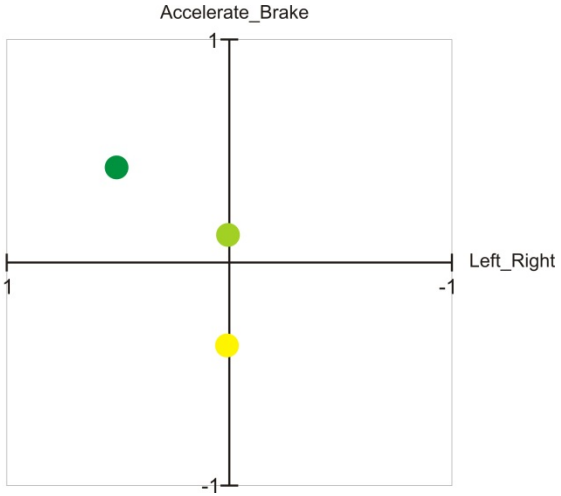


- Valential (from Valency + Potential)
  - Value of feasible action
    (e.g. of available manoeuvre)
- Manoeuvre planning: Manoeuvre Tree
- (Shortterm)Trajectory planning: Trajectory Valential Field
- Control: Actuation Valential Field

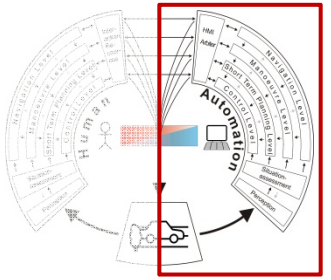


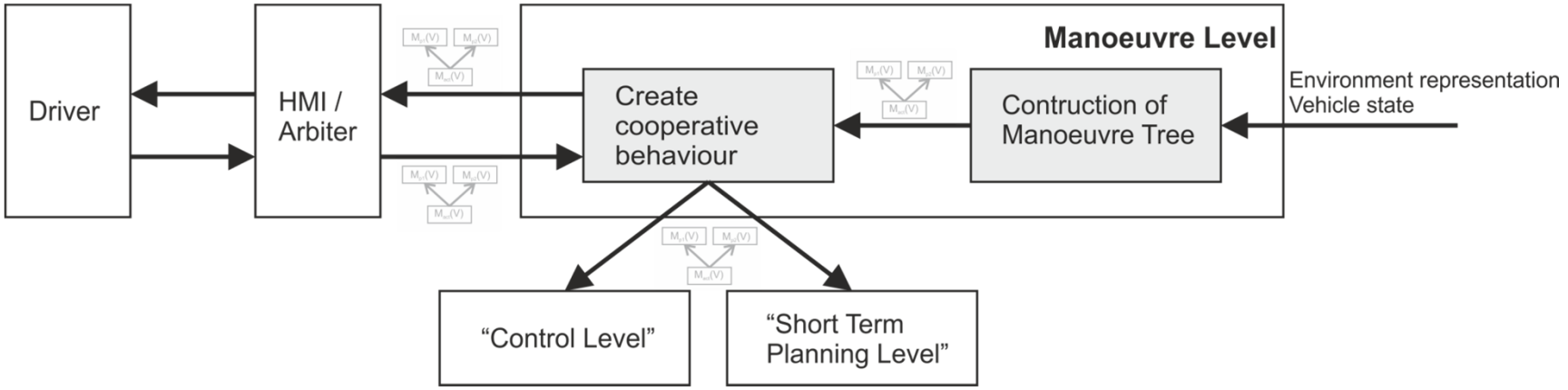


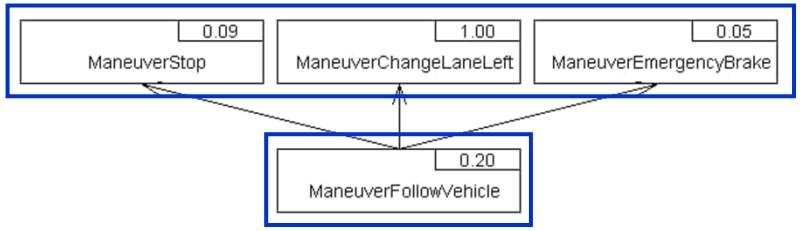




Implementation on Manoeuvre Level

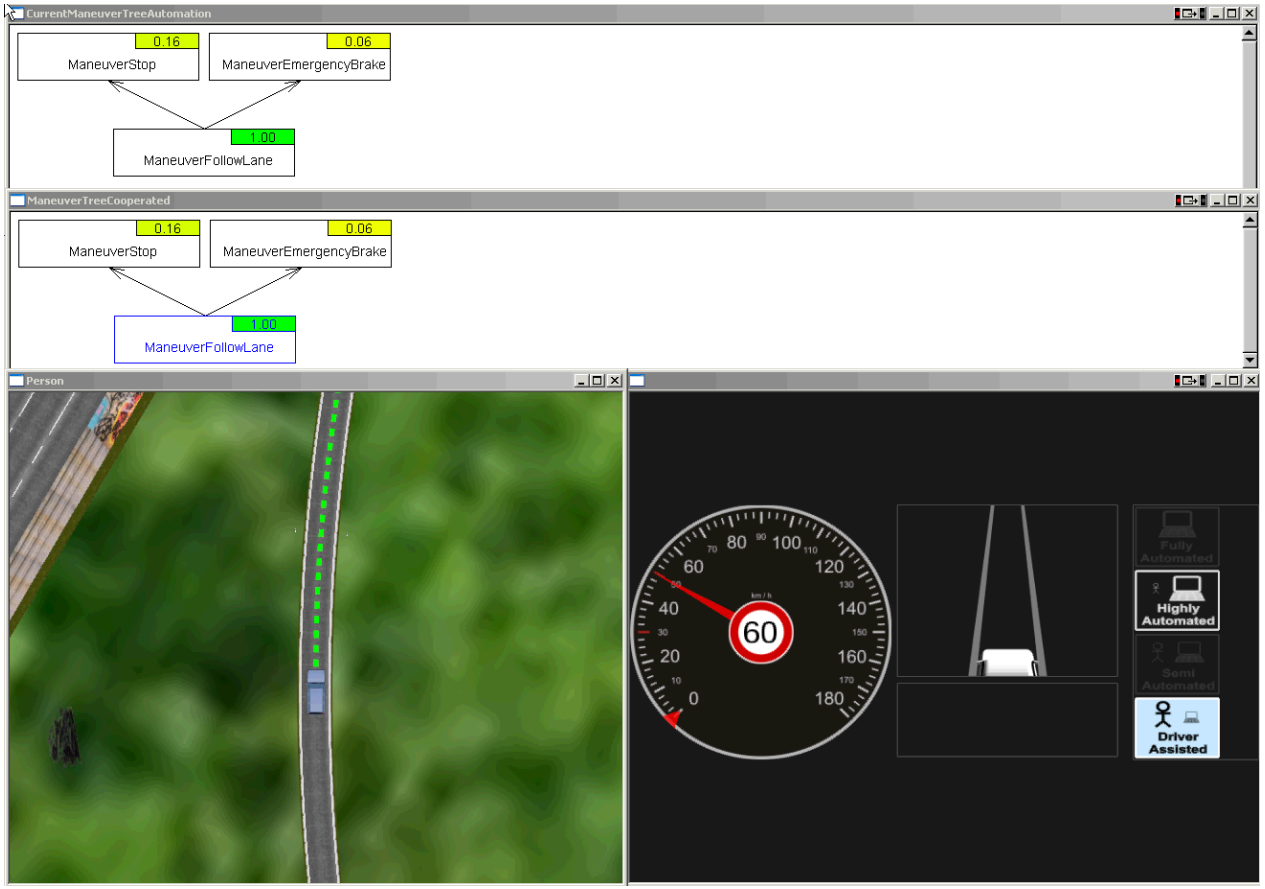




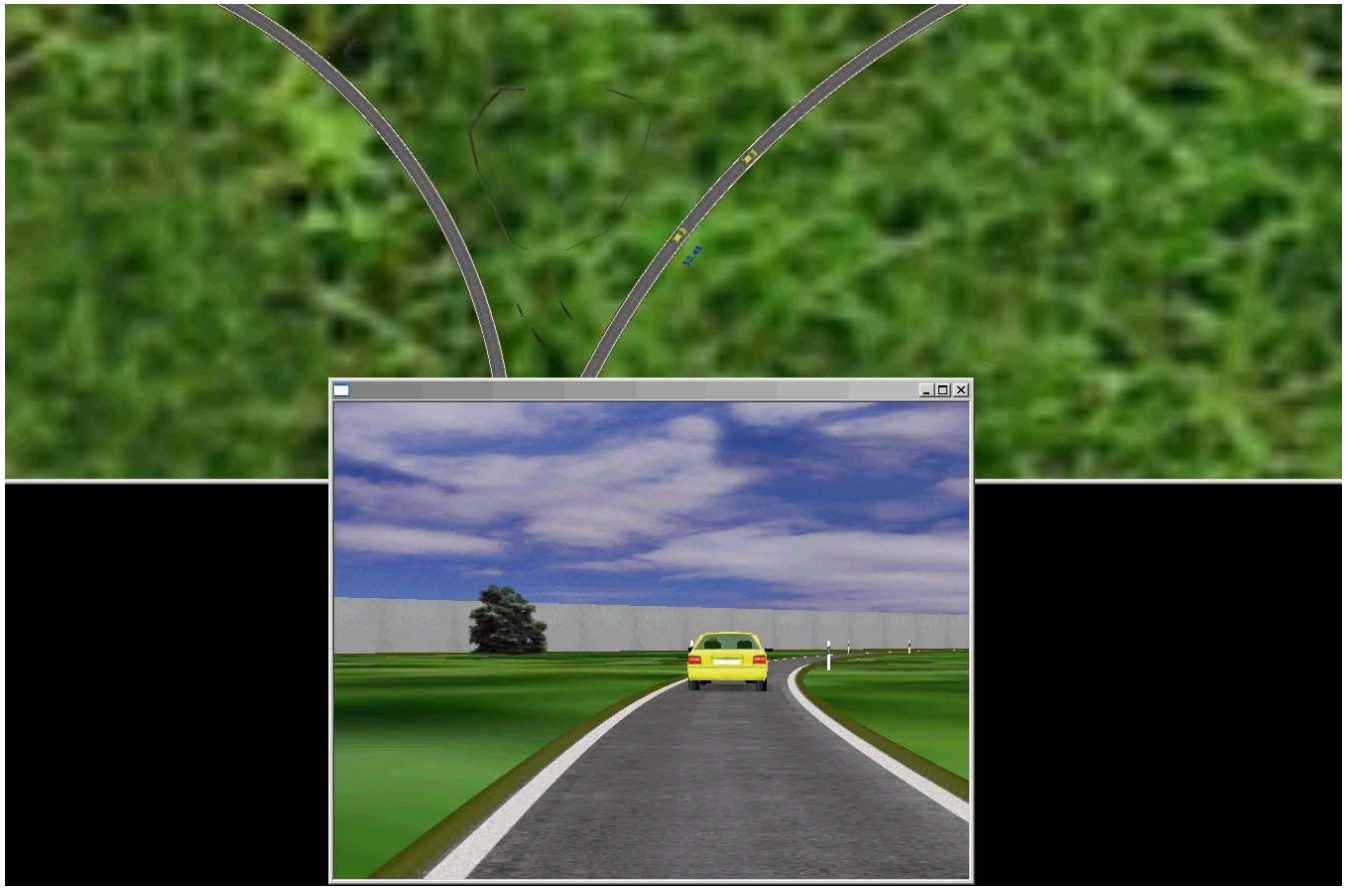


- Explicit communication with driver
- Regard currently driven manoeuvre: Implicit communication
  - Enables common and shared action execution

Application in Project IMoST



Application in Project FAMOS

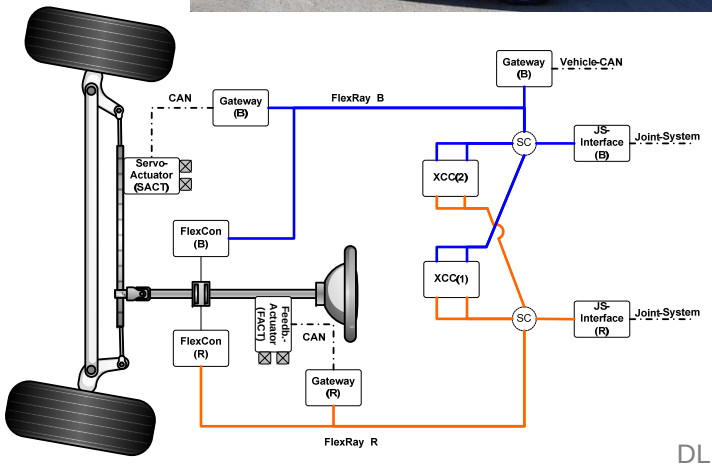


Application in Project FAMOS

Löper, Knake-Langhorst, Schebitz, Schießl and Köster (2011)

Steer-by-wire technology

- **Steer-by-wire driving:**
  - Steering wheel can be used for different purposes
  - Manouevre-based driving
  - Free haptic interaction design (tics, vibrations)
  - Steering wheel parameters adaptable to different levels of automation and different driving situations



DLR

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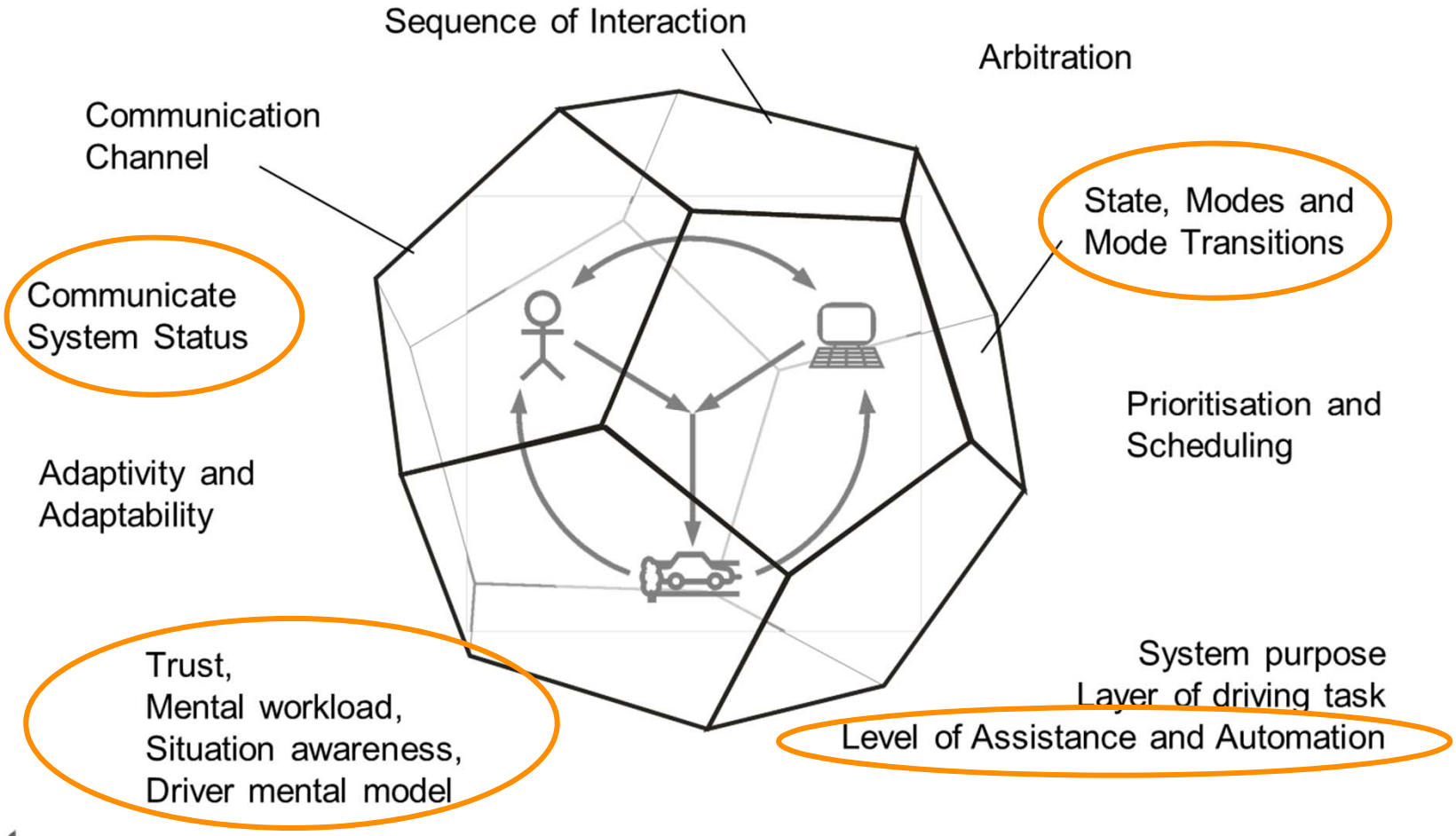
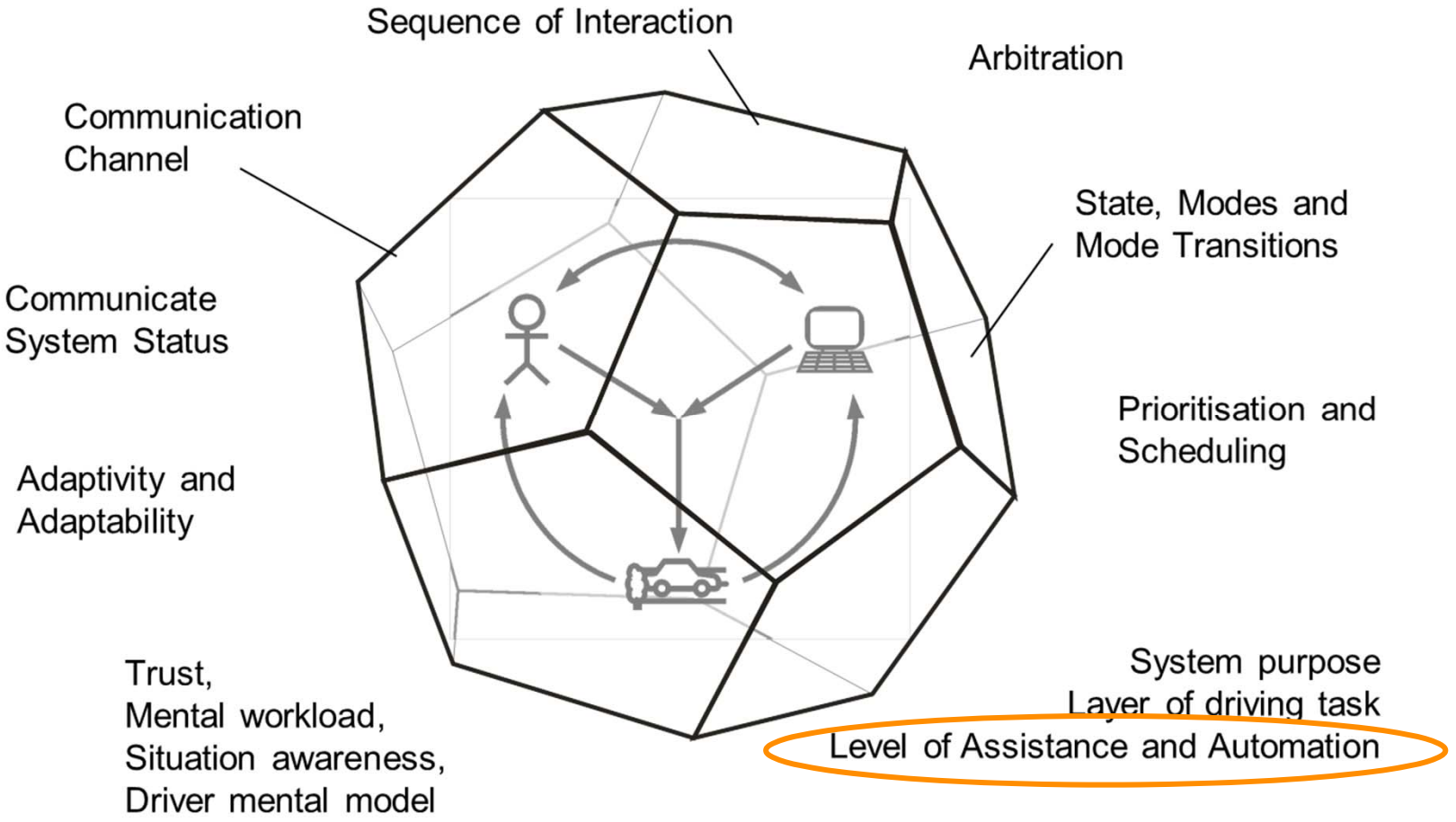
Design aspects of the Human-Machine-Interaction

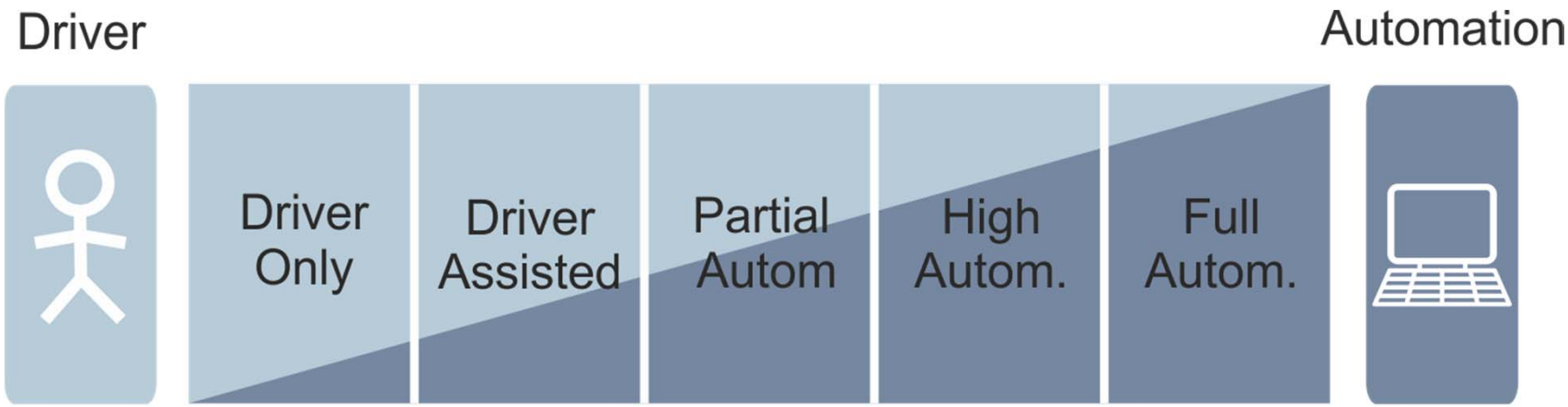


Design aspects of the Human-Machine-Interaction

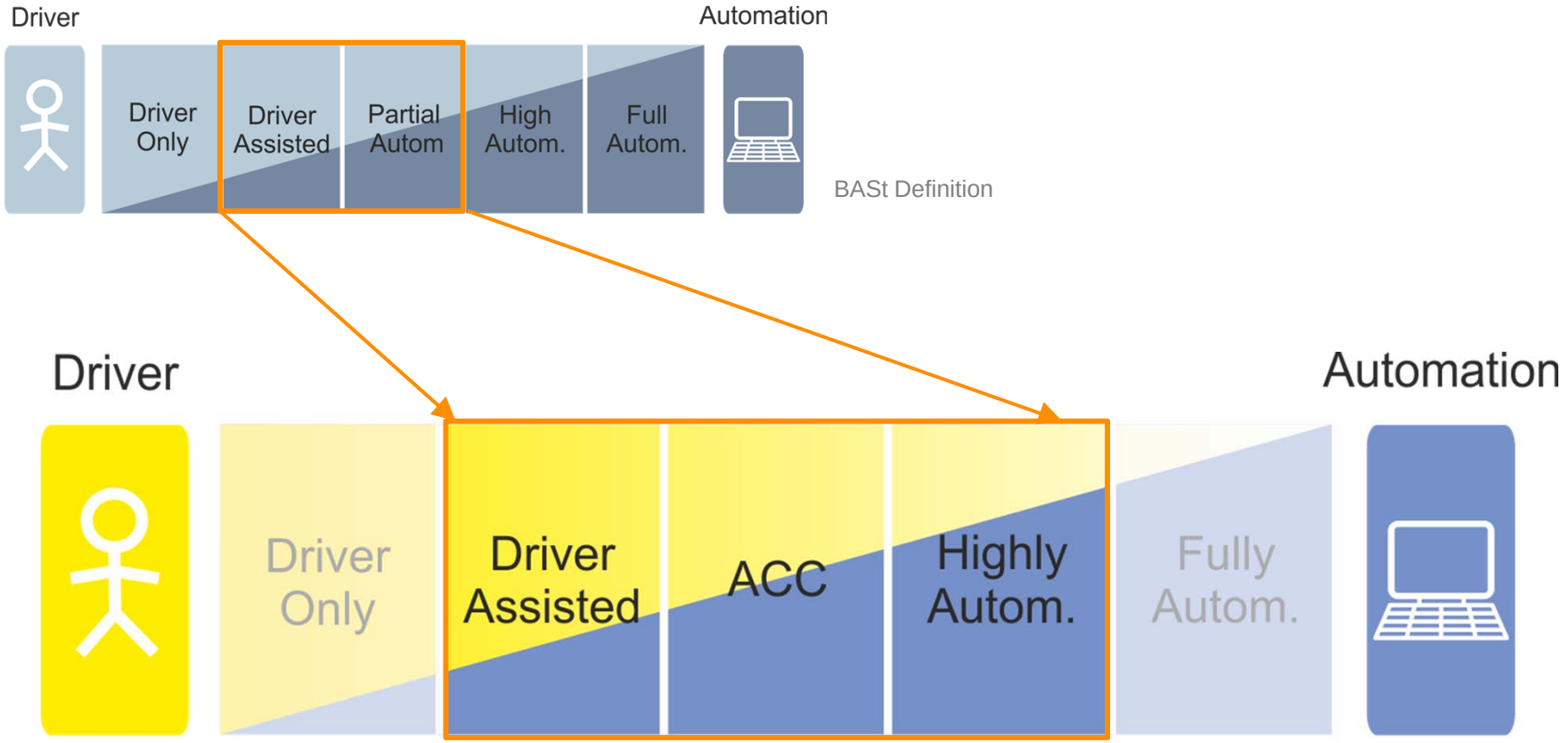


Levels of assistance and automation

- Define how many different levels of automation are suitable
- Choose clearly distinguishable levels of automation

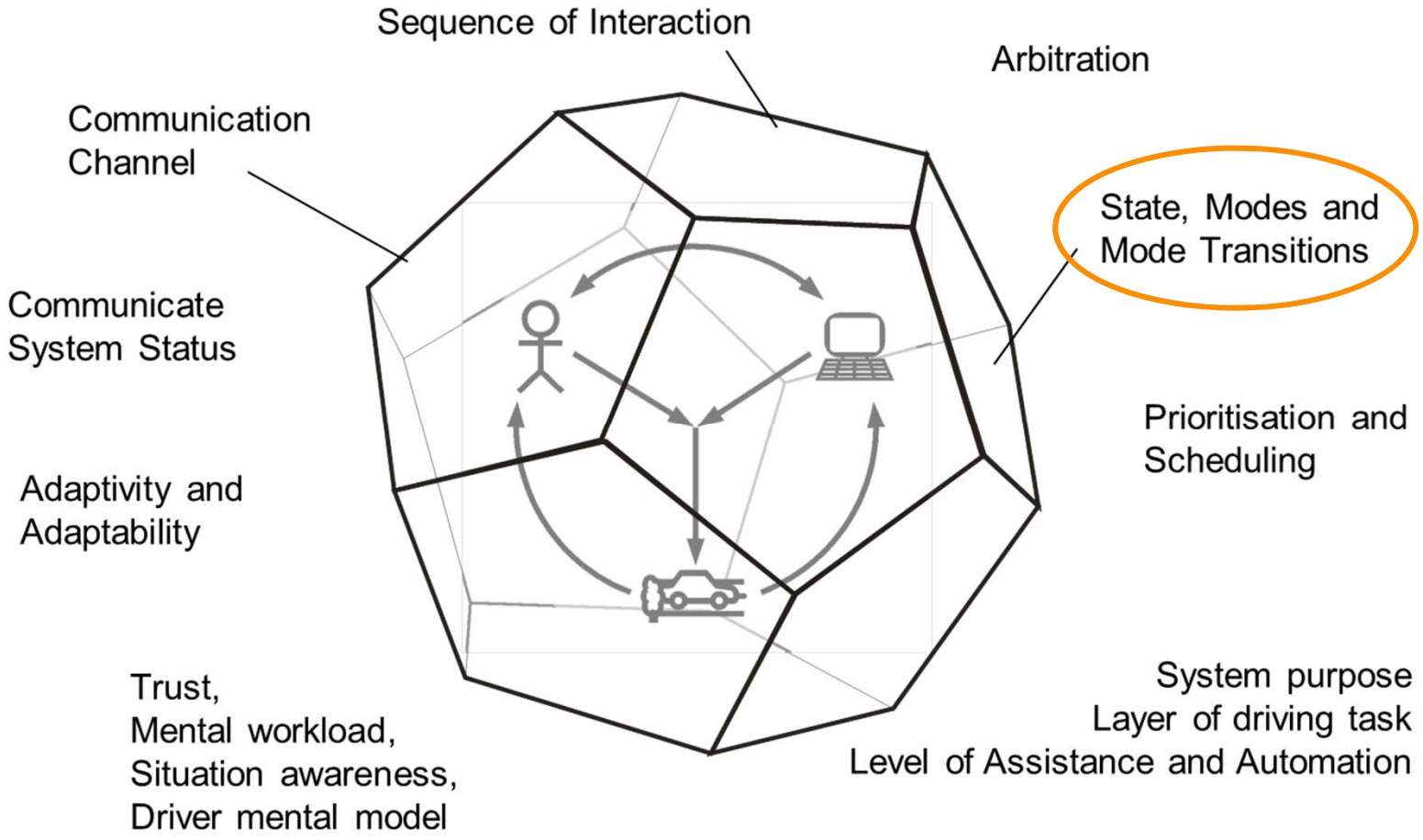


Levels of automation in HAVEit



HAVEit D 33.2

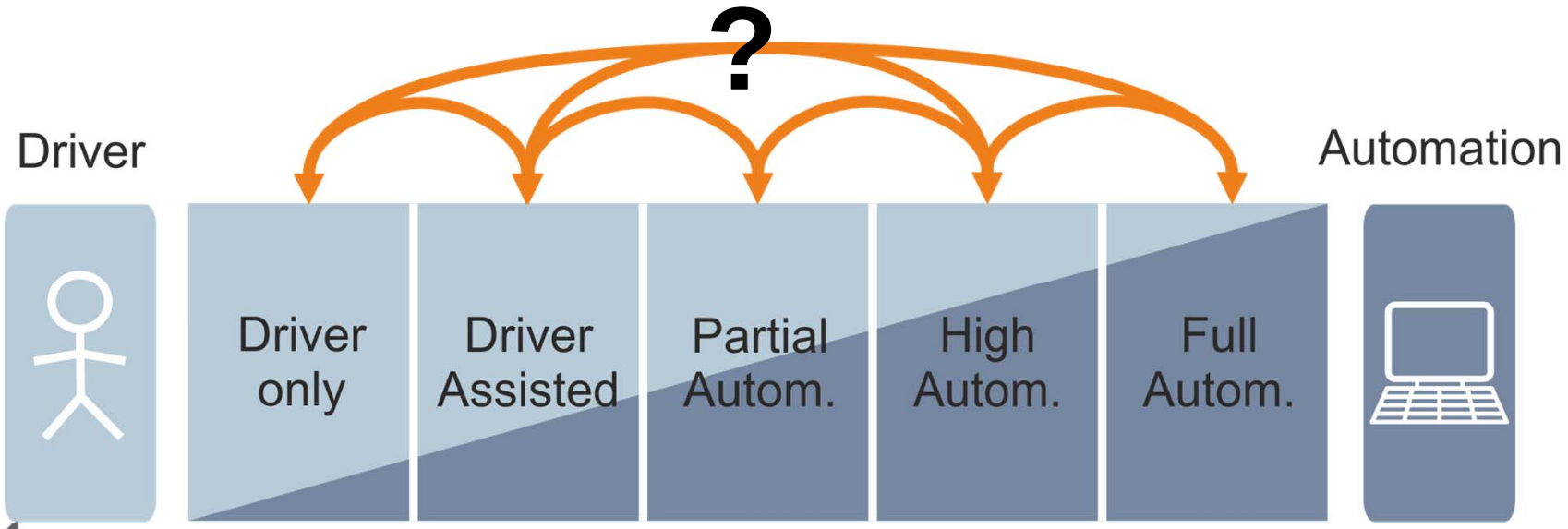
Design aspects of the Human-Machine-Interaction



Transitions between levels of automation

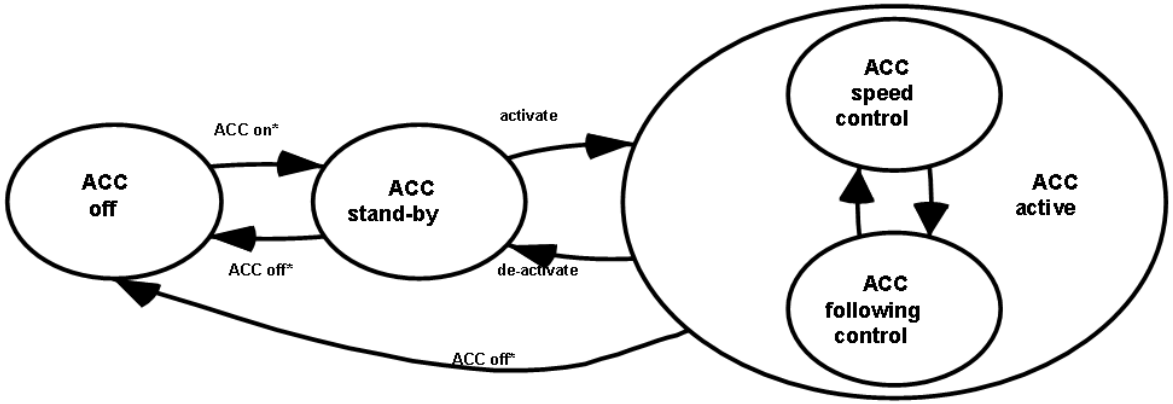
- Define which transitions should be allowed

- Driver initiated transition vs. Automation intiated transitions
- Normal transitions vs. transitions at system limits



Transitions between levels of automation

- From existing to future levels of automation:
  - Driver needs to build up a correct mental model
  - **Integrated and consistent concepts** for the transitions
  - Include already existing standards for systems like ACC (ISO 15622)



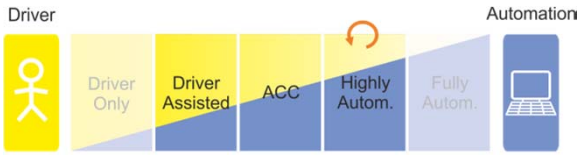
* manual and/or automatically after self test

= system state

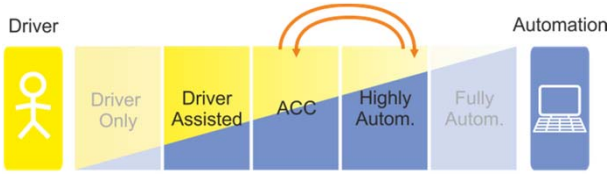
ISO 15622

HAVEit: Example of transition design

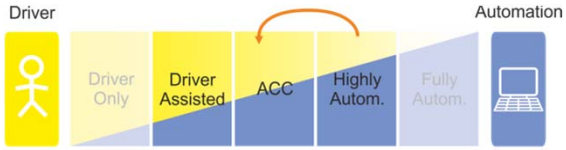
Prototype A



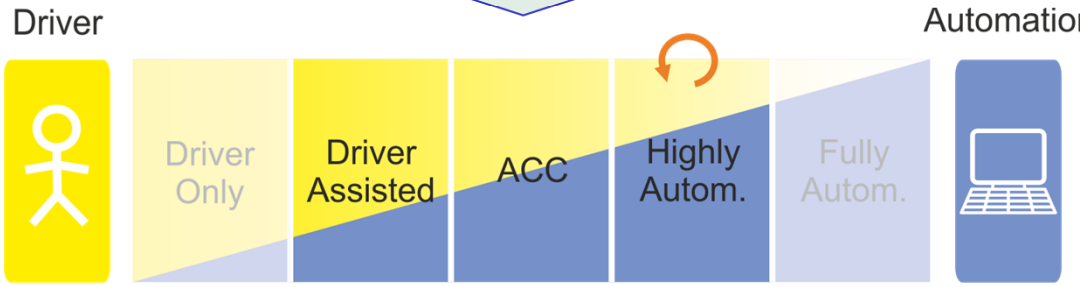
Prototype B



Prototype C

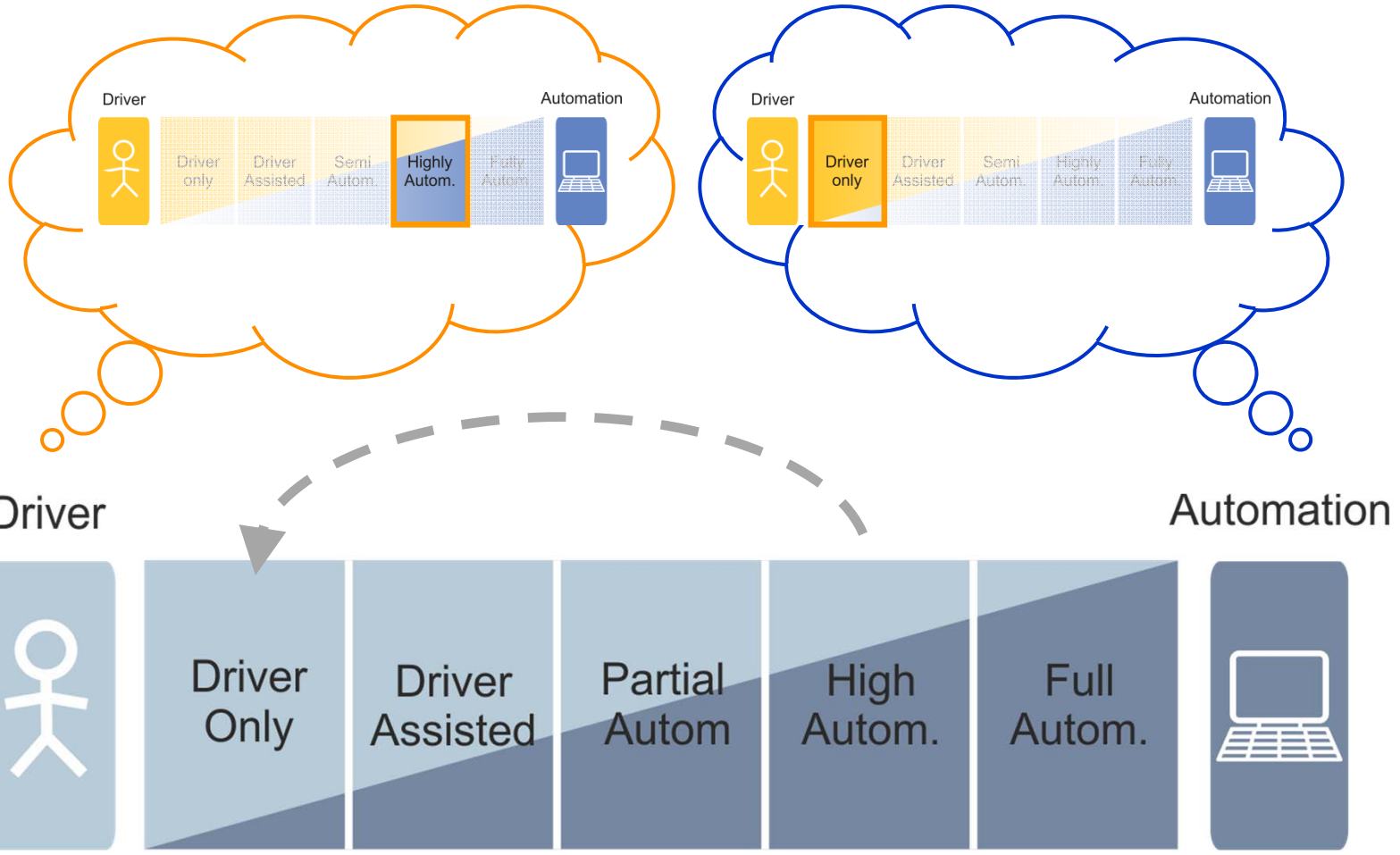


HMI Workshops
Simulator studies
Standardisation



Schieben et al. (2011)

Transitions: Mode Confusion

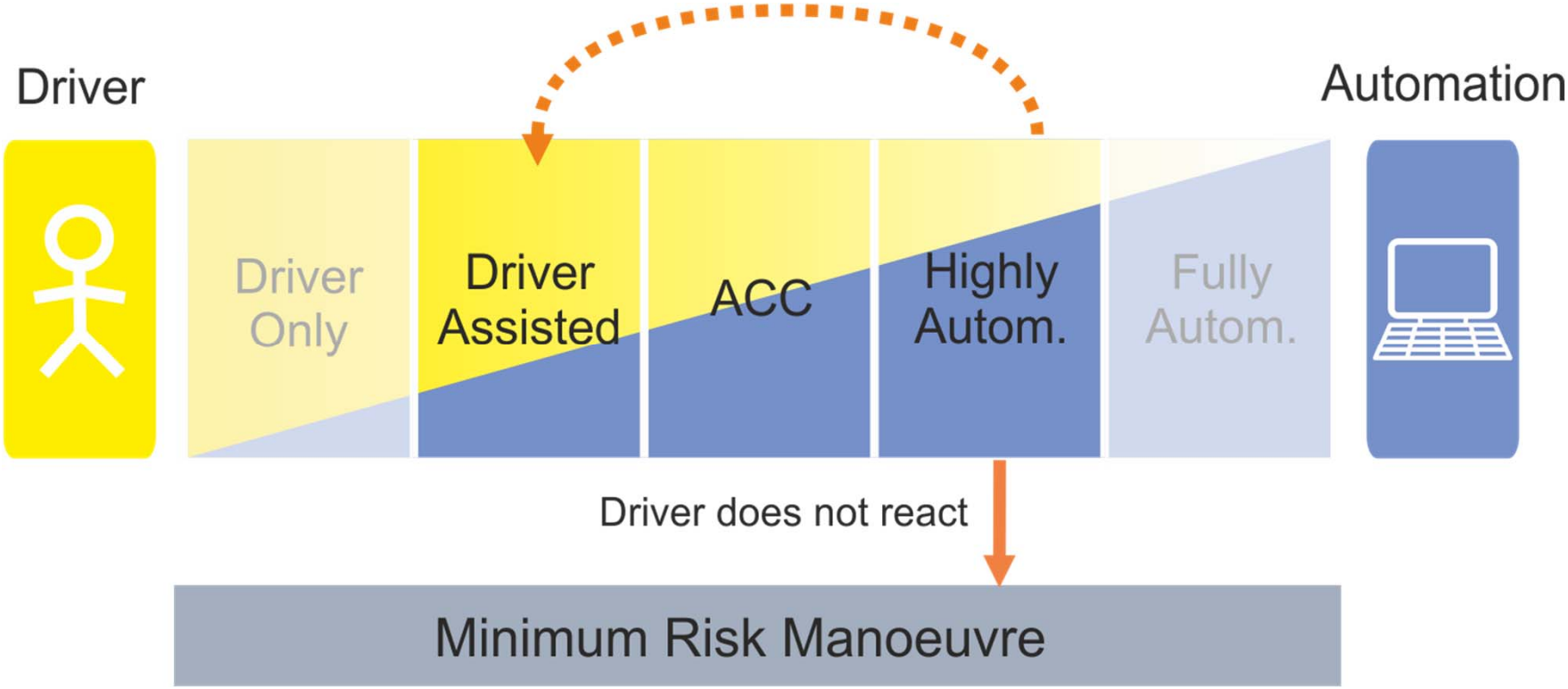


Transitionen: Interlocked Transitions

- Explicit transition design
- Hand-over of control only after confirmation by the other partner („Interlocked Transition“, „Handshake“)

HAVEit D 33.6

Transitions: Concept for take-over requests

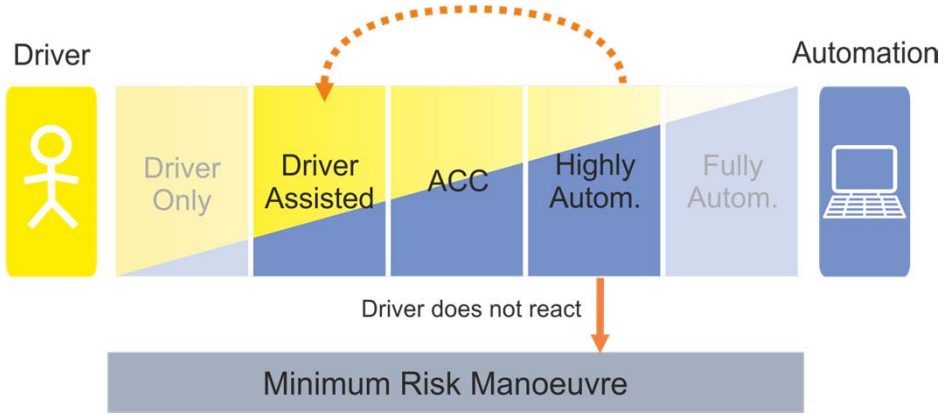


Transitions: Concept for take-over requests

Example: HAVEit take-over request:

- Try to bring the driver back in the loop
  - Acoustic & visual alarms
- Check if driver takes over as intended
  - Hands-on check
  - Attention monitor
- If driver does not react, bring vehicle to a safe stop

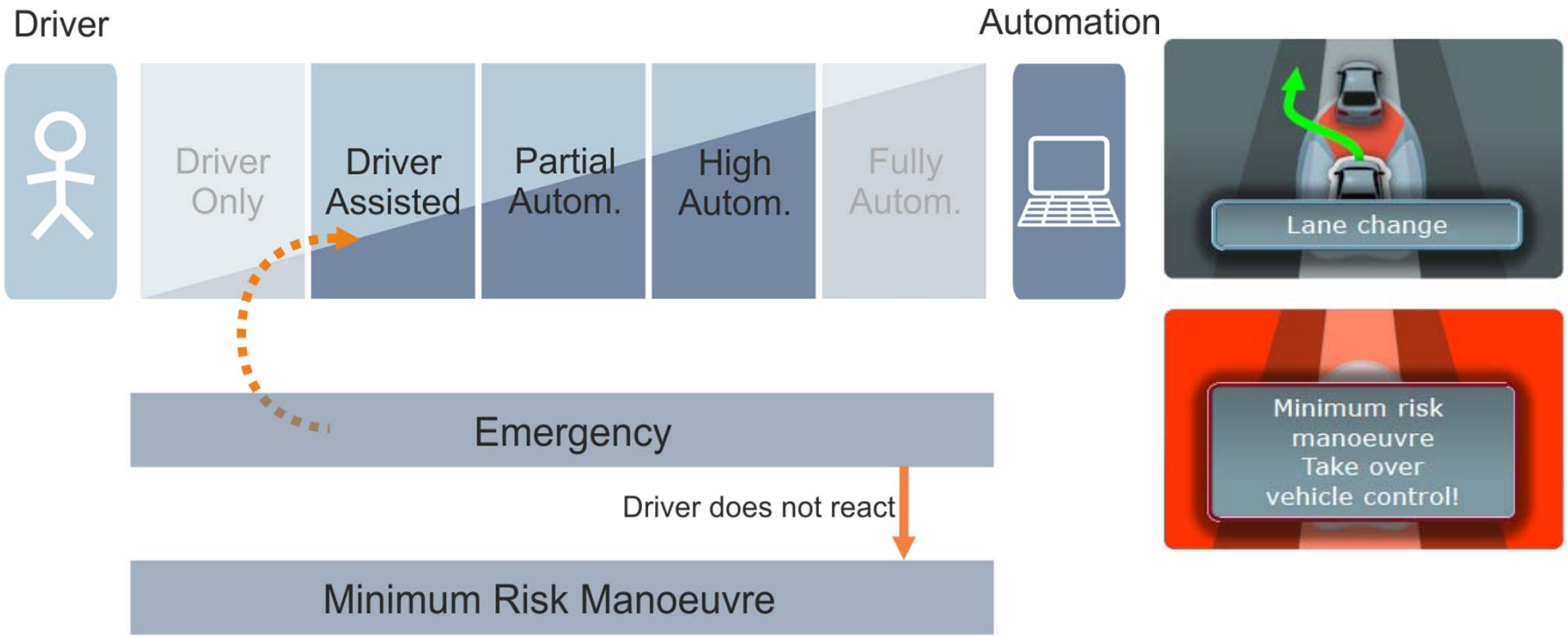
  → Minimum Risk Manoeuvre



HAVEit D 33.2

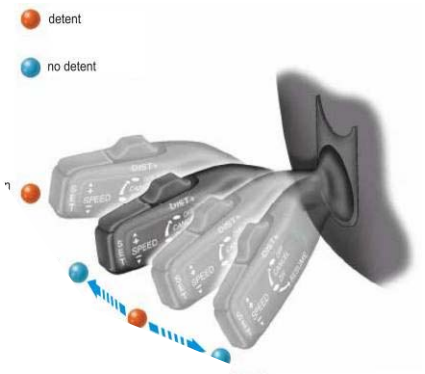
Transitions: Concept for take-over requests

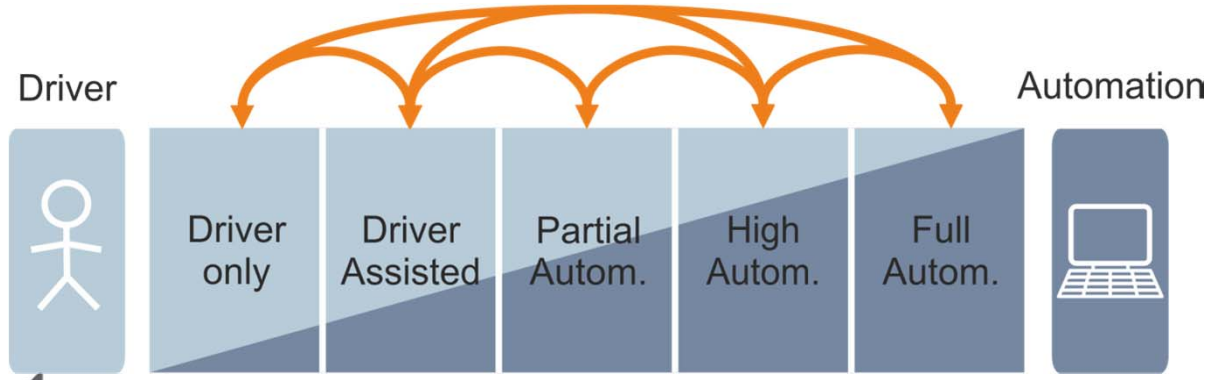
- Also after automatic emergency interventions
  e.g. collision avoidance by steering



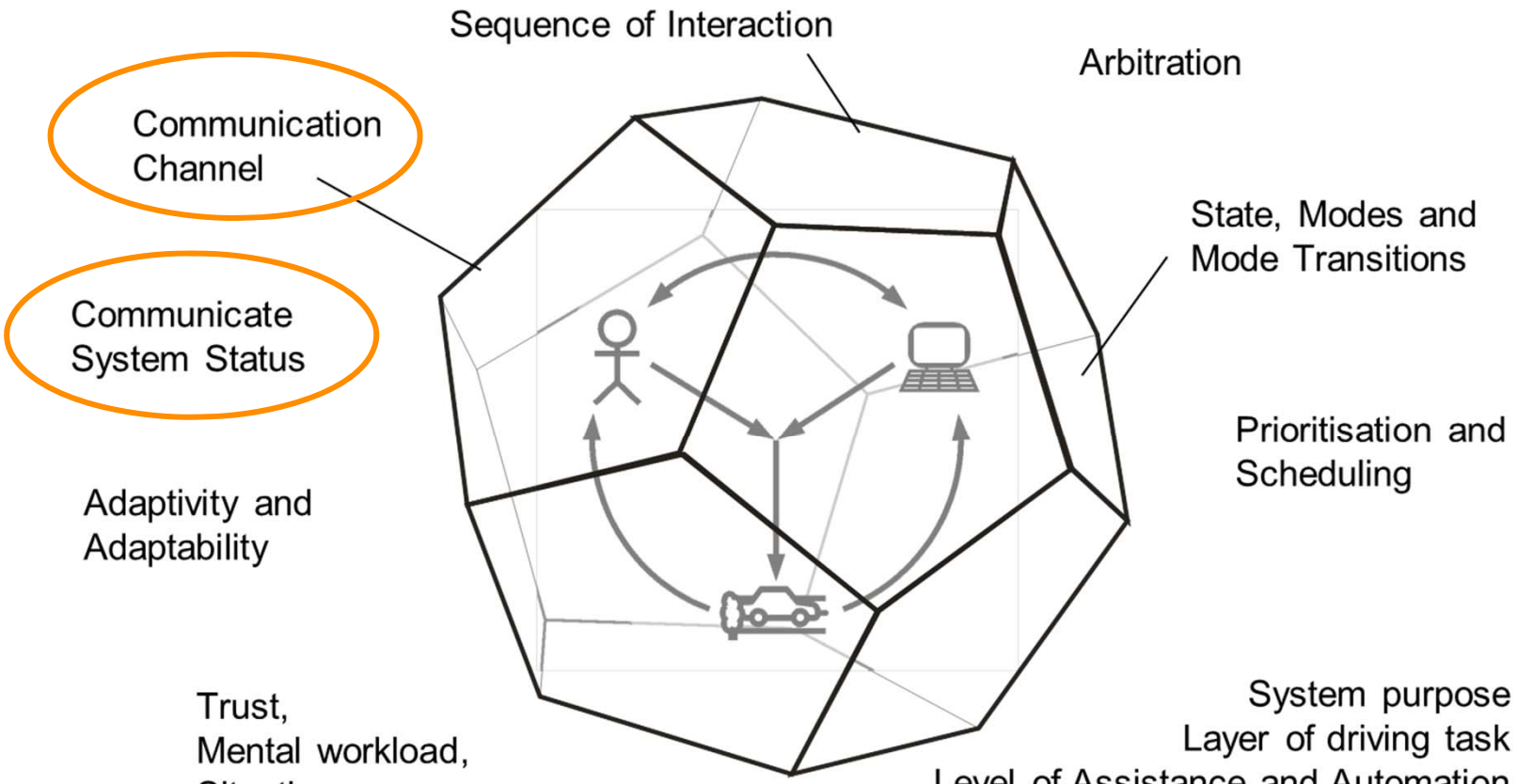
Transitions: Devices and strategies

- Interface for transitions between different levels of automation
  - Common switching devices
  - Smart transition (e.g. hands-off detection on steering wheel)
- Adaptive automation



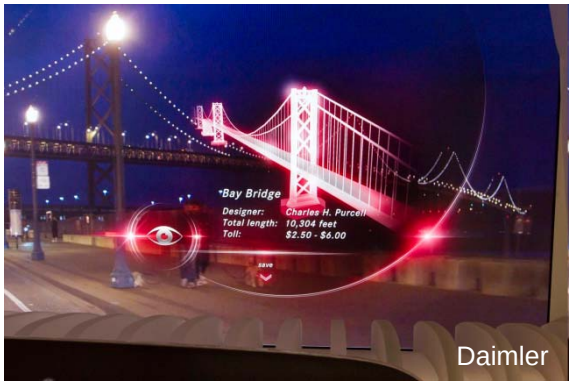


Design aspects of the Human-Machine-Interaction



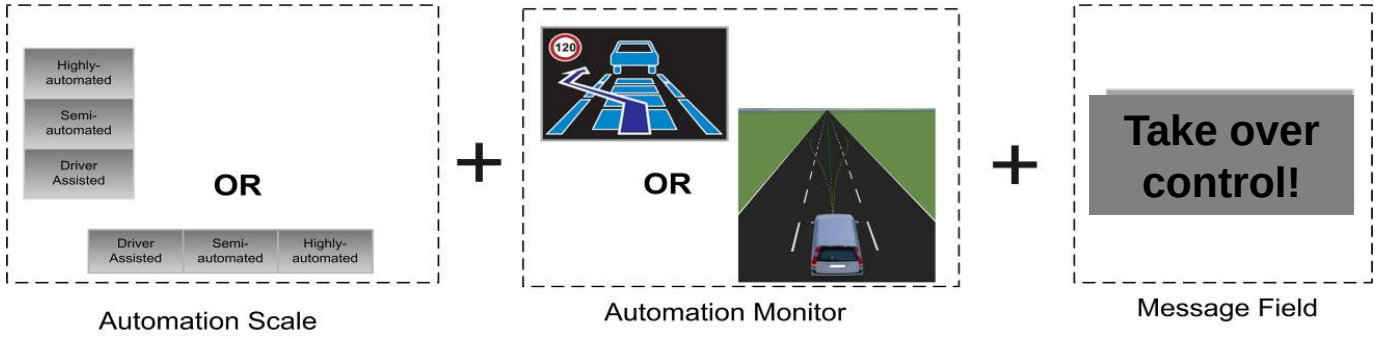
Interaction concepts: Displays

- Provide information and assistance in lower levels of automation
- Raise awareness for the current automation actions
  - Contact analogue displays
  - Head-up-displays



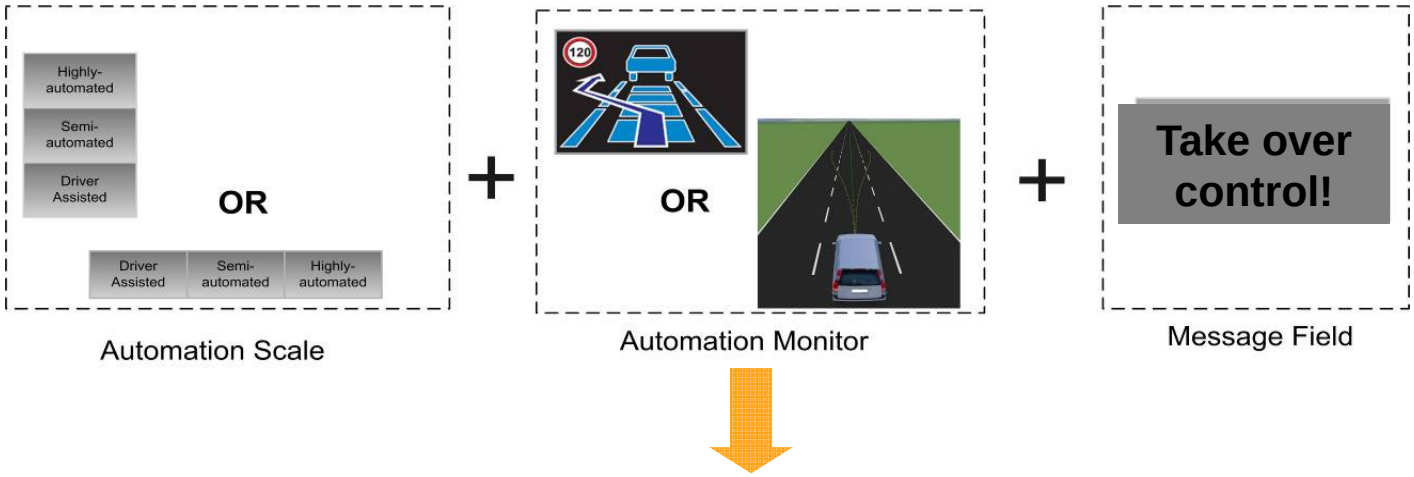
Interaction concepts: Displays

- **Integrated display and interaction concept** for different levels of automation
- Indicate the available and active levels of automation
- Standardized display elements in the cluster instrument

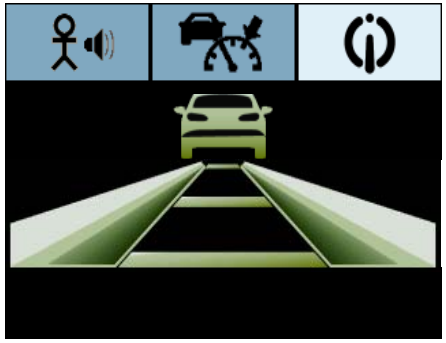


HAVEit D 33.2

Interaction concepts: Displays



Joint System Demonstrator



Conti ARC

VTEC AQuA

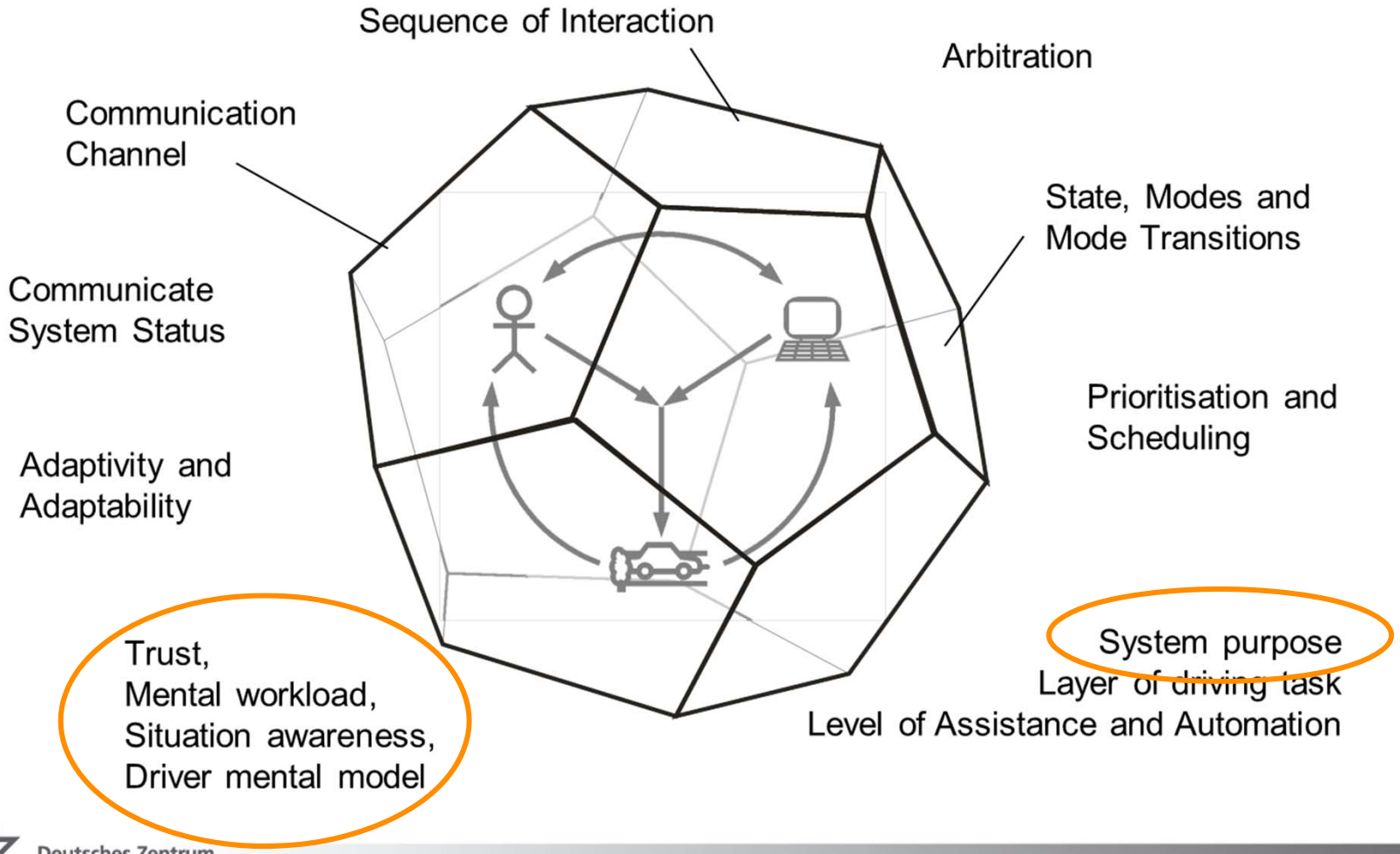
VW TAP

Flemisch, Schieben, Strauss, Lueke & Heyden (2011)

Interaction concepts: Displays

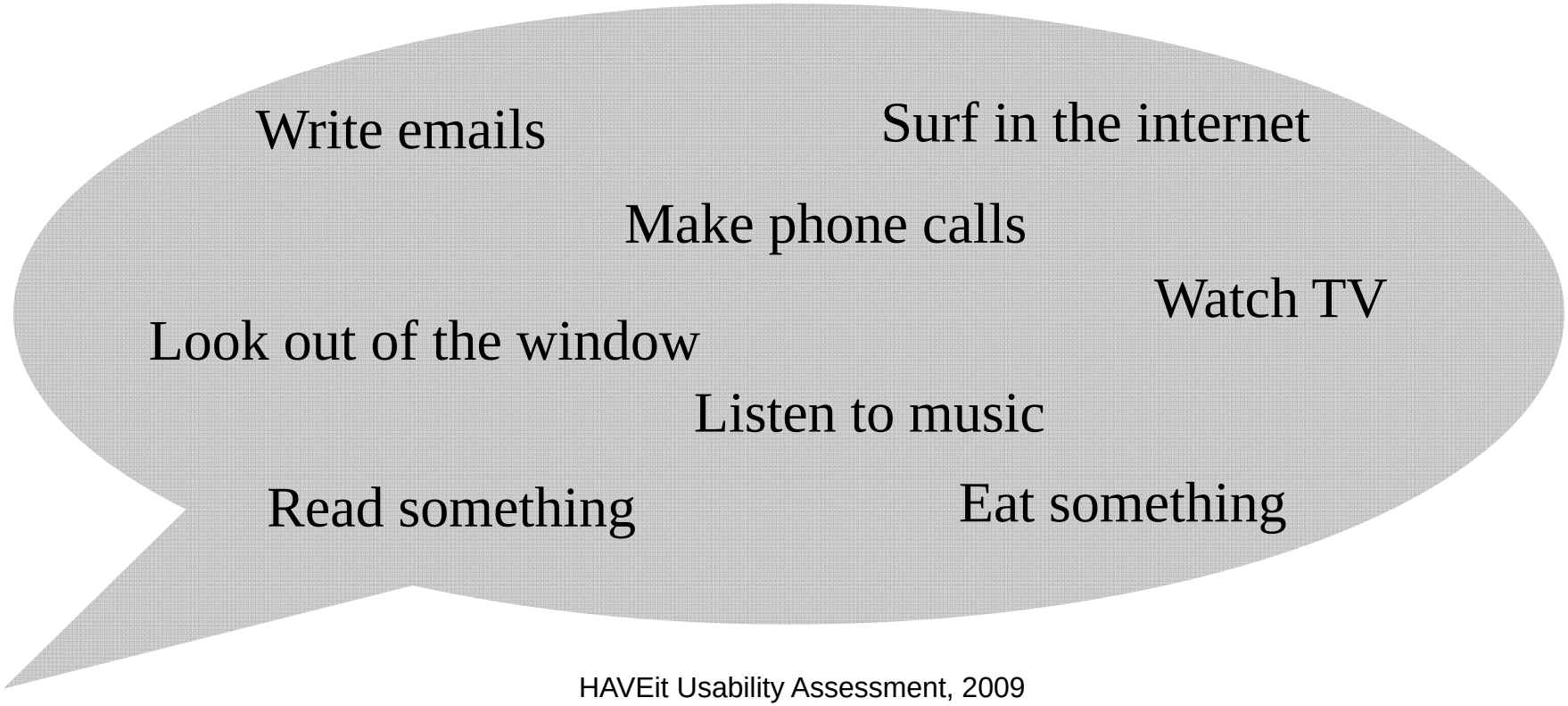
- Integrated display and interaction concepts
- Standardized display elements in the cluster instrument
  - **Automation scale**: available and active level of automation
  - **Safety shield**: available and active protection functions
  - **Message field** (overlay)

Design aspects of the Human-Machine-Interaction



Other tasks than driving?

- „What would you like to do while driving highly automated?“



HAVEit Usability Assessment, 2009
8 participants, multiple answers were possible

Interaction concepts: Other tasks than driving?

- If other tasks than driving are allowed:
  - Changes in cockpit design
  - Changes in the interaction between driver and passengers

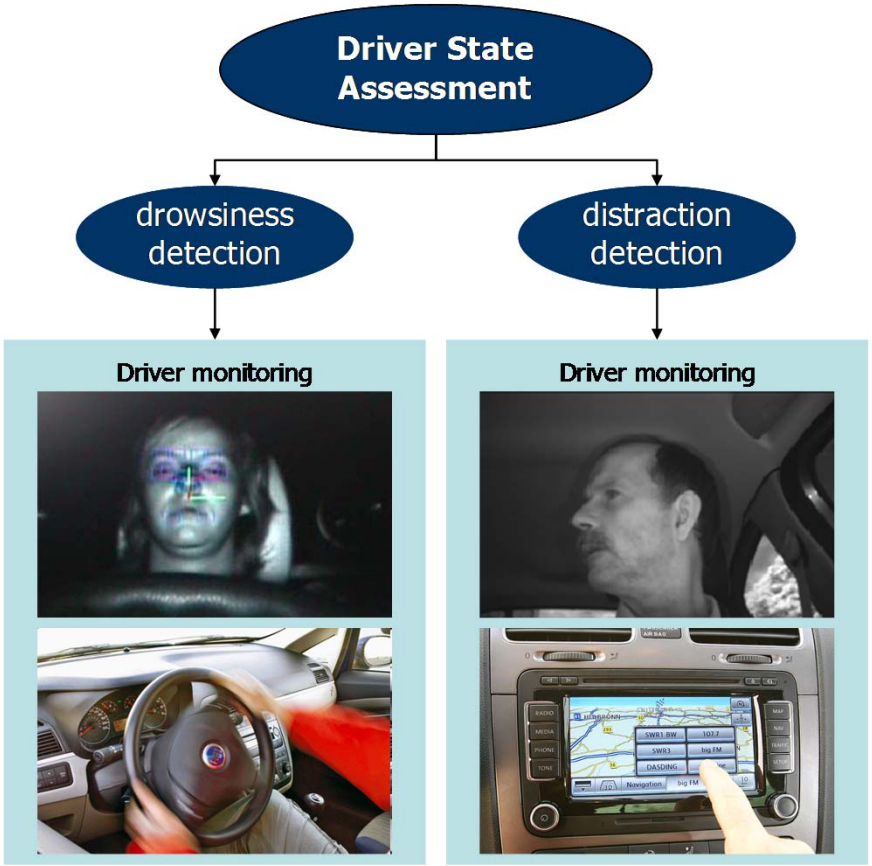
H. Miller, 1957

Audi A2 Concept

VW

Interaction concepts: Other tasks than driving?

- **Driver State Assessment**
  - Check the state of the driver to ensure that he can take over and to avoid misuse
  - Camera
  - Tracking of input
  - Hands-on sensor on steering wheel



HAVEit D32.1

Effects of automation

- Critical effects might occur due to the introduction of automation
  - Mode Confusion
  - Misuse
  - Complacency/Overtrust
  - Loss of skills
- Effects need to be monitored
- Countermeasures need to be introduced if necessary

Agenda

- Different levels of automation in a highly automated vehicle
- **Technical development** for highly automated driving
- Design of the **Human-Machine-Interaction** for highly automated driving
- Summary and Outlook

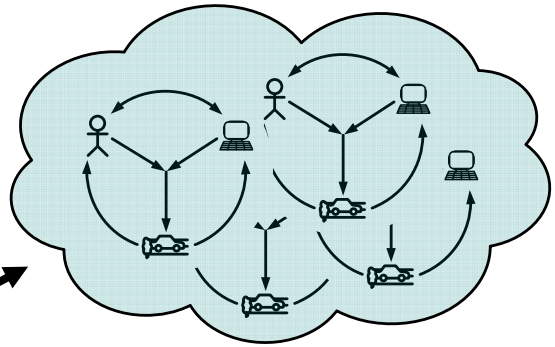
Summary

- Different levels of automation in one vehicle
- **Technical issues:**
  - Appropriate hardware enables additional degrees of freedom
    - X-by-wire, Head-up displays, novel inceptors, etc.
  - Cooperative, user-compatible automation
    - Outer and inner user compatibility
    - Uncertainties
- **Human-Machine-Interaction:**
  - Vehicles with different levels of automation → Challenges in HMI design
    - Transitions
    - Take over requests
  - Secondary tasks and influences on cockpit design

Outlook

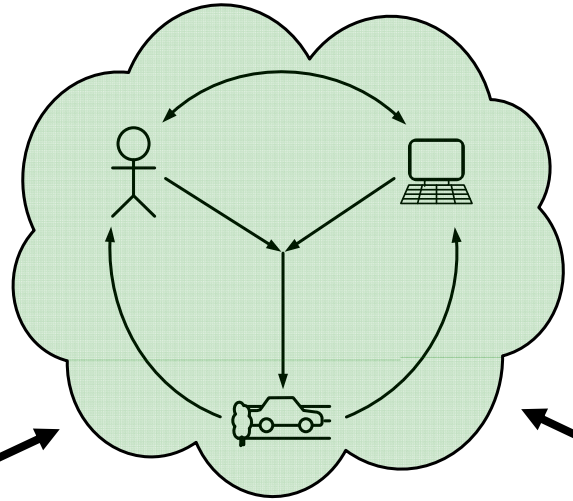
Holistic System Design

- Arbitration & Interaction
- Integration of Functions
- Modes & Transitions
- HMI: visual, acoustic, haptic, kinaesthetic,…



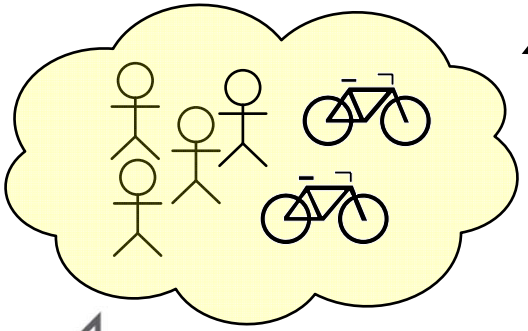
Human Factors Investigations

- Driver Behaviour and Performance
- Situation Awareness
- Mode Confusion
- Overtake Ability
- Controllability



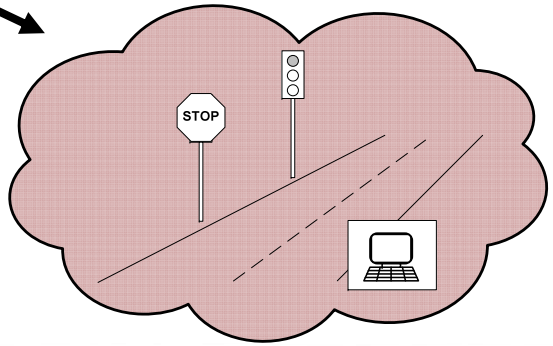
Technical Development

- C2X
- X-by-Wire
- Cooperative Automation
- Sensors
- Inceptors & Interfaces
- Contact-Analogue Displays



Modelling

- Driver Behaviour
- Reaction to Assistance
- Interaction
- Traffic Flow



Thank you for your attention!

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