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Human-Machine Collaborations for Sensible Automated Driving

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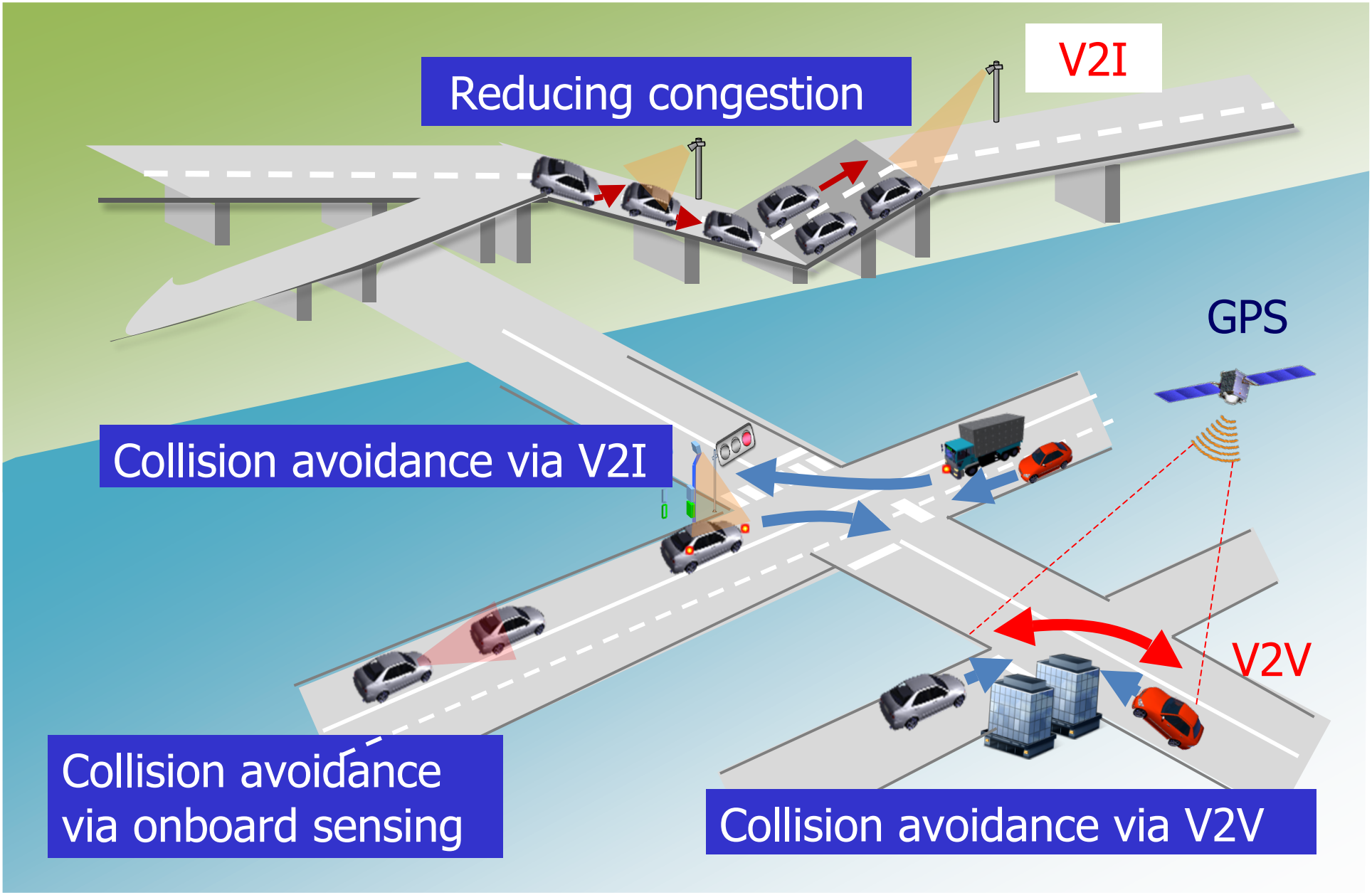
Why automated driving?



Wide variety of automated driving

Photo: BMV

Photo: Volvo

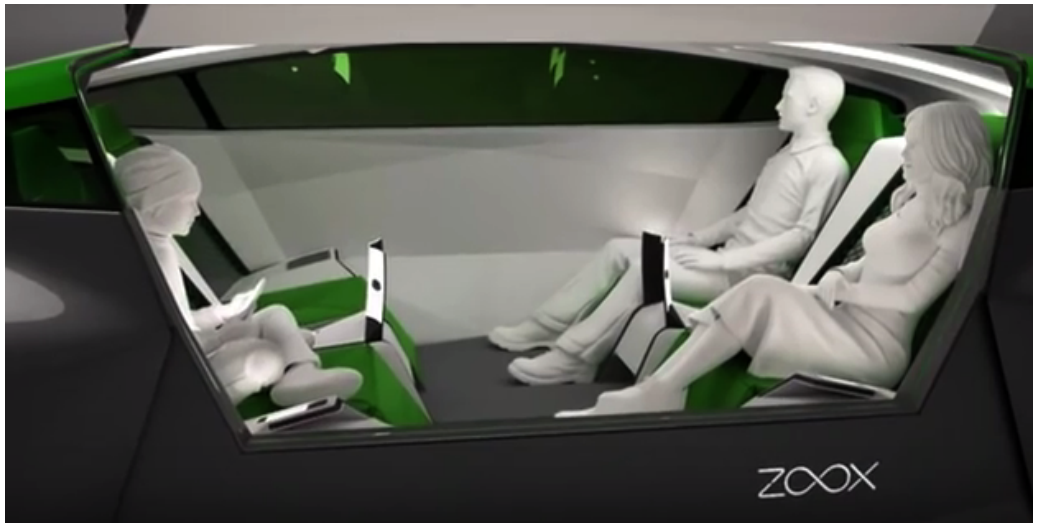


Photo: Zoox

Level 1 automated driving

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

System: longitudinal control by using ACC

Driver: lateral control

Level 2 automated driving

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

Photo: BMV

System: longitudinal and lateral control by using ACC, LCS, ESC, etc.

Driver: human supervisory control

1) plan 2) teach
3) monitor 4) intervene
5) learn (Sheridan 1992)

Human supervisory control

- Monitoring is boring:
  - Highly reliable system seldom fails.
  - Human has to be prepared in case of system failure.
- Intervention is hard:
  - Decisions must be made with insufficient information.
  - No delay is allowed.

In order to pursuit monitoring and intervention appropriately, the driver needs to understand:

- how functions are implemented in automated systems
- functional limitations of automated systems
- possible interaction among automated systems

Dimension of trust

Foundation

conform to natural laws and social order

Performance

consistent, stable, and desirable performance or behaviour can be expected

Process

methods, rule bases, or control algorithms that govern the system behaviour are understandable

Purpose

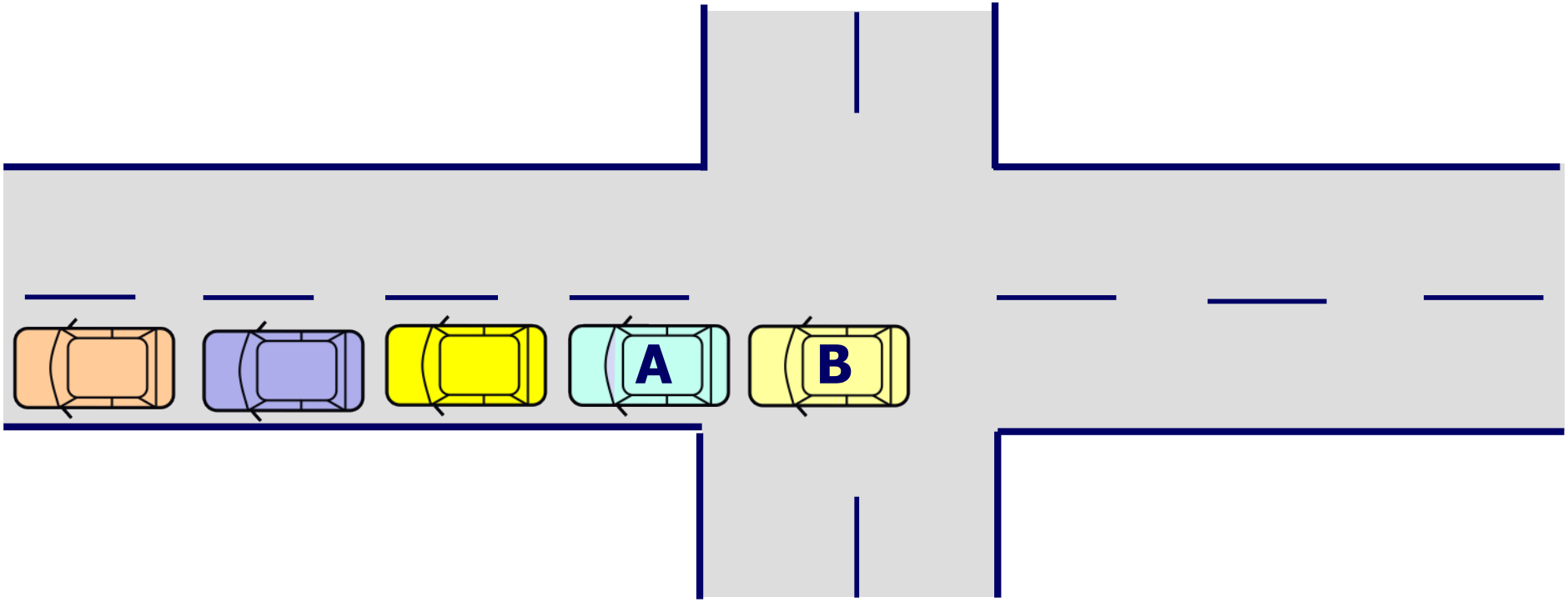
motives or designer's intention is understandable

(Lee & Moray, 1992)

Example: Overrating of foundation

Foundation：conform to natural law and social order

"ACC should be designed to obey traffic rules."



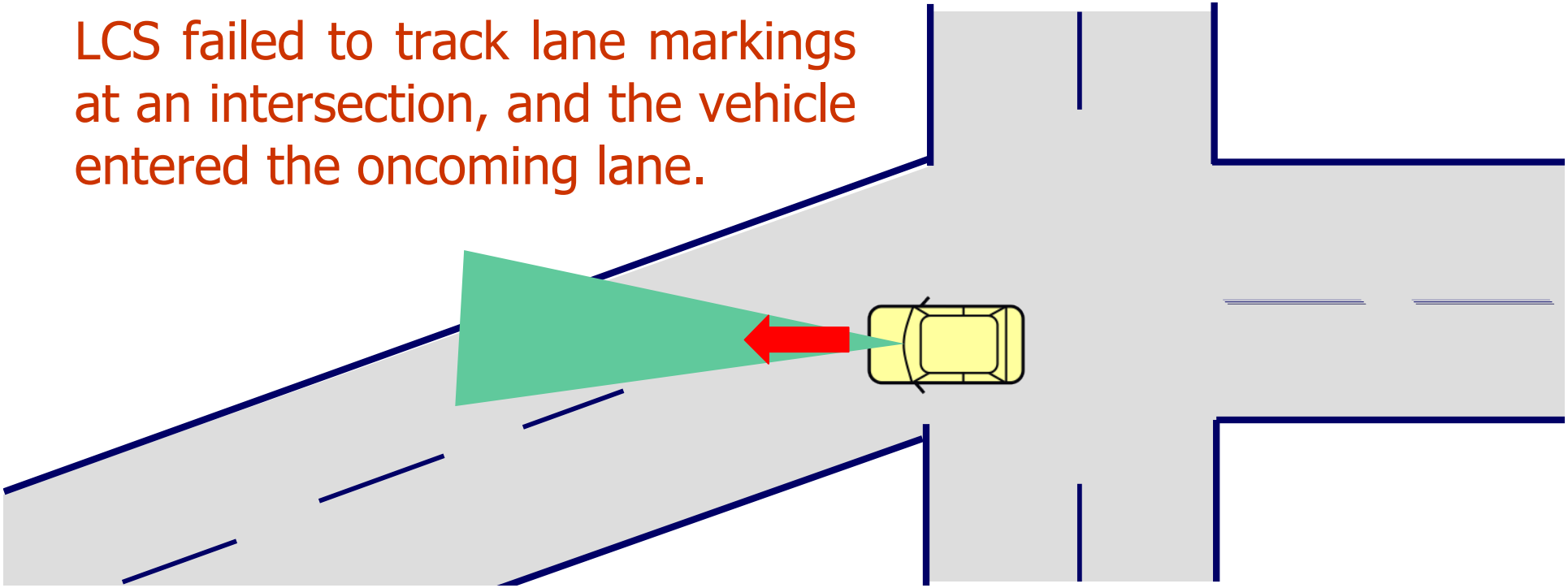
Vehicle B had been driven with ACC enabled, following the lead vehicle A, and was stuck in the middle of an intersection, because of a heavy traffic jam.

Example: Overrating of performance

Performance: consistent, stable, and desirable behaviour can be expected

"LCS has been working perfectly so far. Wherever I go, it must perform its function correctly and nicely."

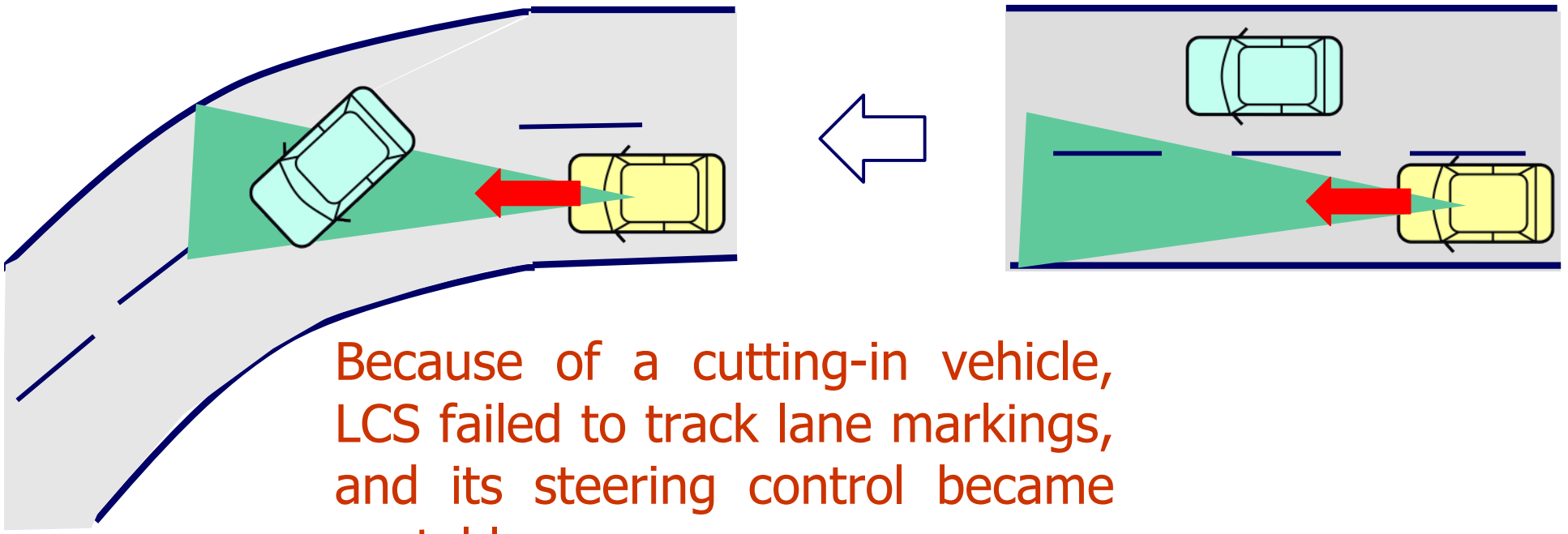
LCS failed to track lane markings at an intersection, and the vehicle entered the oncoming lane.



Example: Overrating of process

Process: methods, rule bases, or control algorithms are understandable

"I do not know how the function is implemented in LCS. I am not informed how the task is carried out. However, it would be quite alright even if I do not know the details."

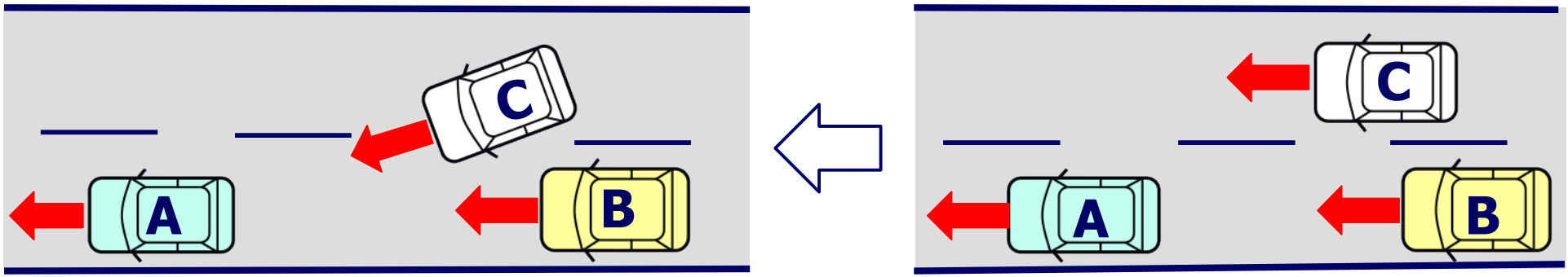


Because of a cutting-in vehicle, LCS failed to track lane markings, and its steering control became unstable.

Example: Overrating of purpose

Purpose：motives or designer's intention is understandable

"I do not understand why ACC is doing such a thing. However, it must be doing what it thinks it necessary and appropriate."



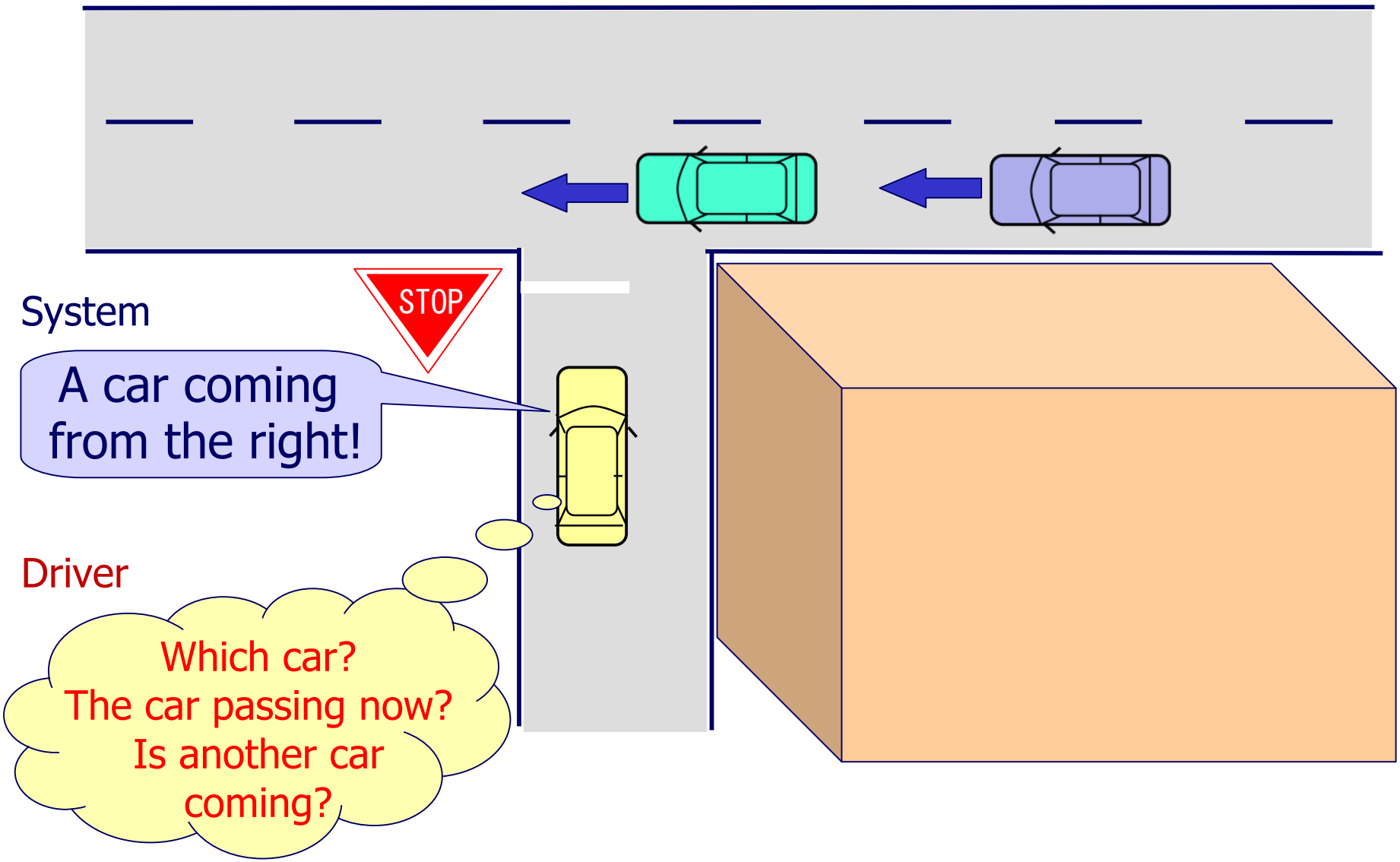
Vehicle B has been driven with ACC enabled, following vehicle A. The ACC shows no intention to decelerate, although vehicle C seems to be cutting in.

Well-designed HMI is vital for Level 2 automated driving

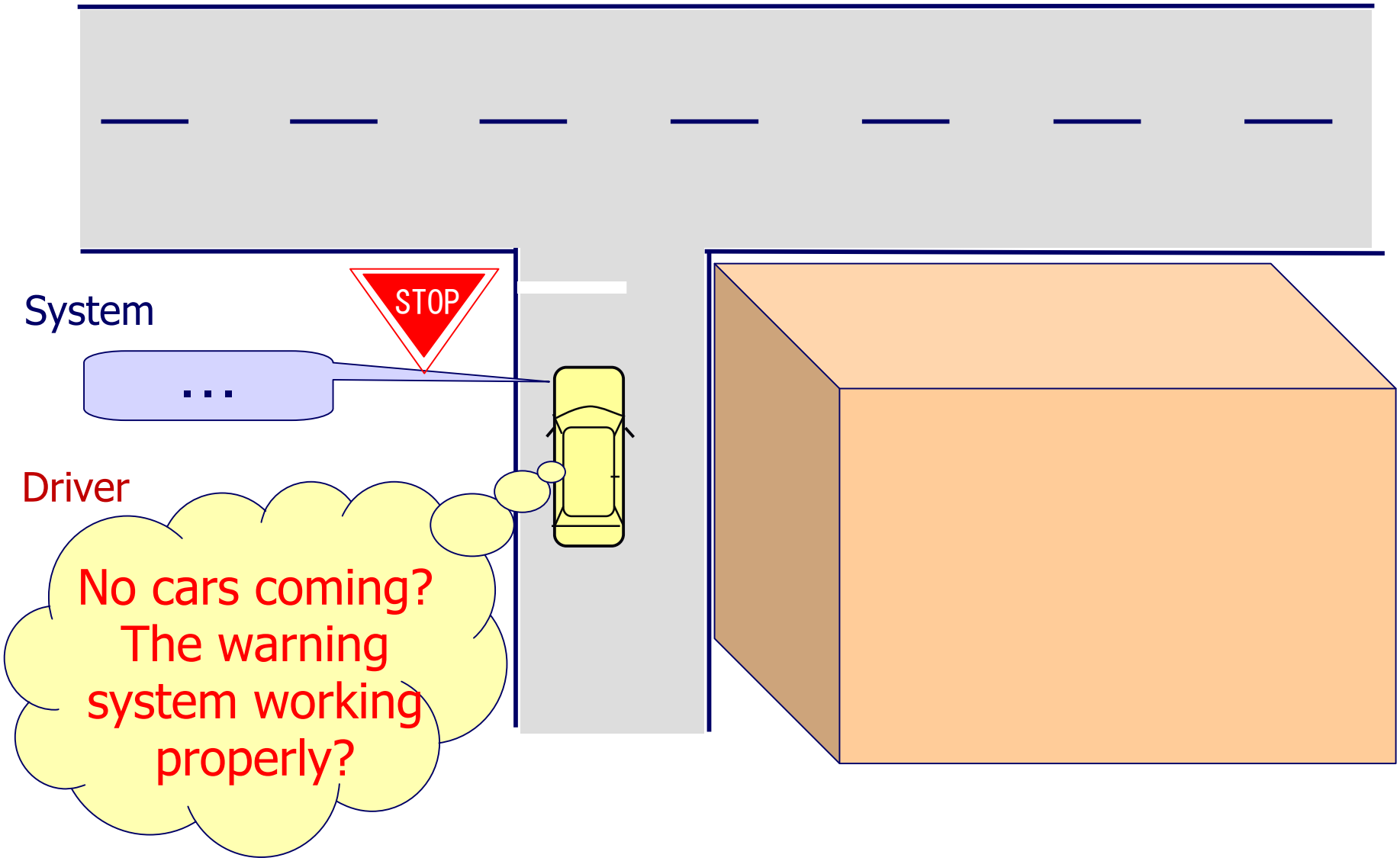
- HMI should provide cues for the human to:
  - share situation awareness with machines
  - understand the rationale of machine's judgement
  - understand machine's intention
  - grasp machine's limitations
  - identify machine's operating condition

- HMI with these characteristics would be useful to:
  - Reduce distrust / overtrust
  - Reduce overreliance
  - Reduce loss of mode awareness / automation surprises

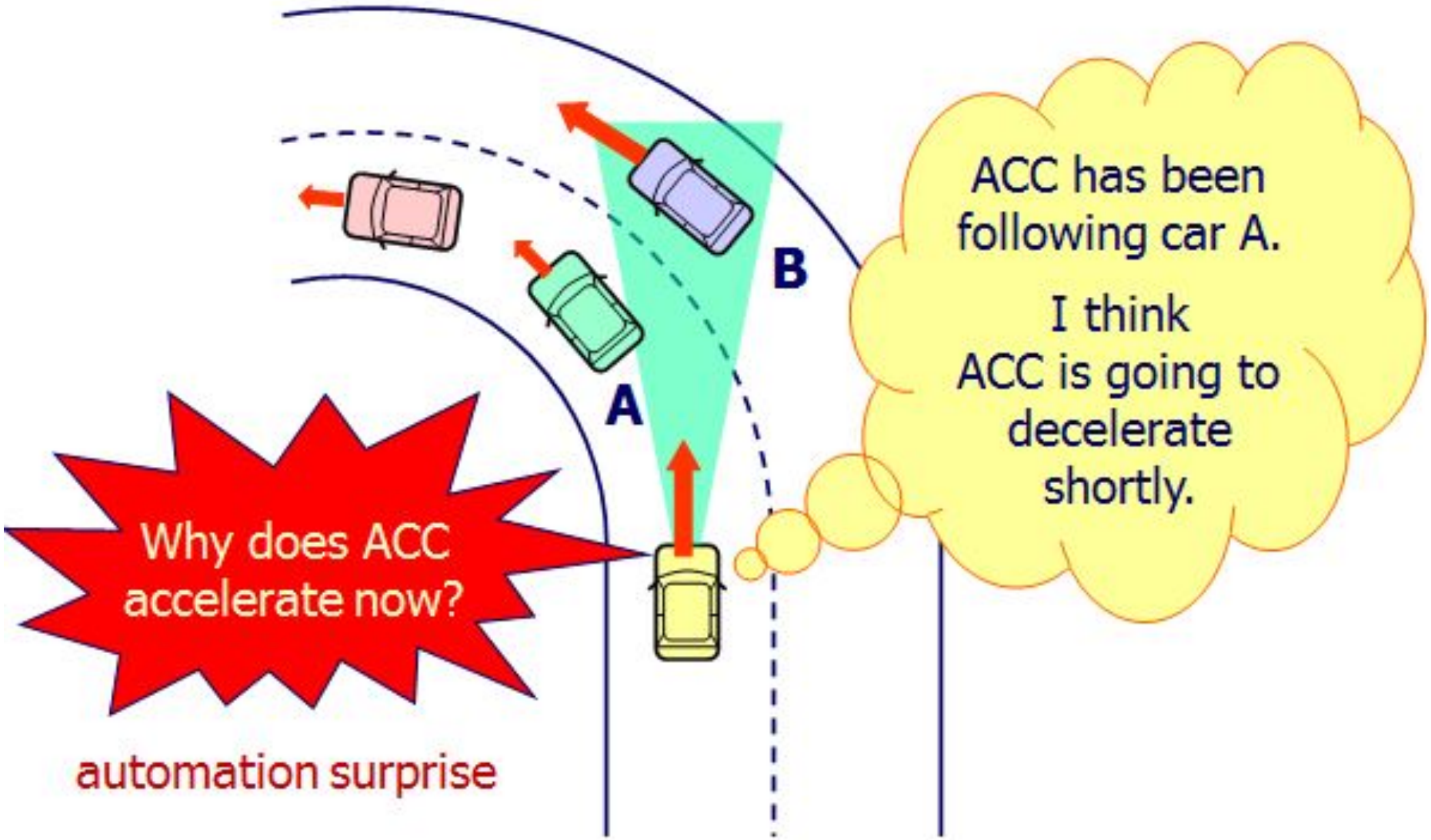
Ambiguity under imprecise information



Is the warning system trustworthy?

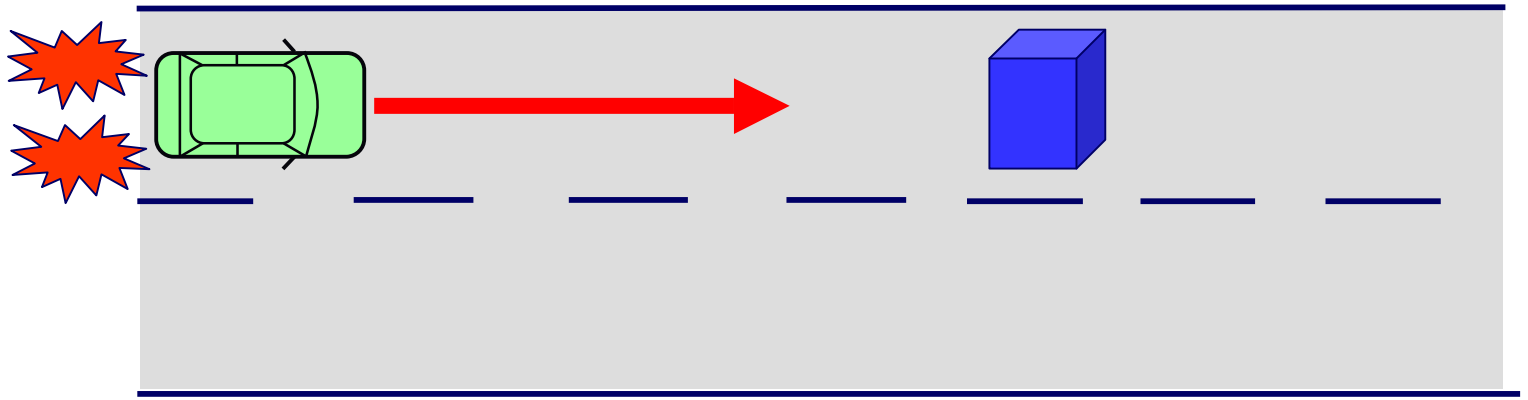


What the driver sees ≠ what the machine sees

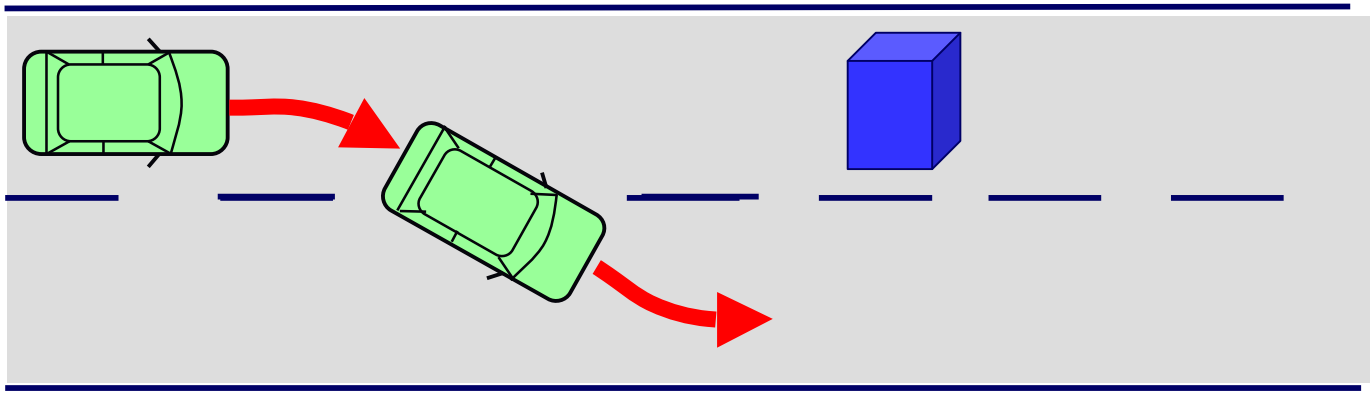


Conflict of intentions can occur even when what the driver sees = what the machine sees

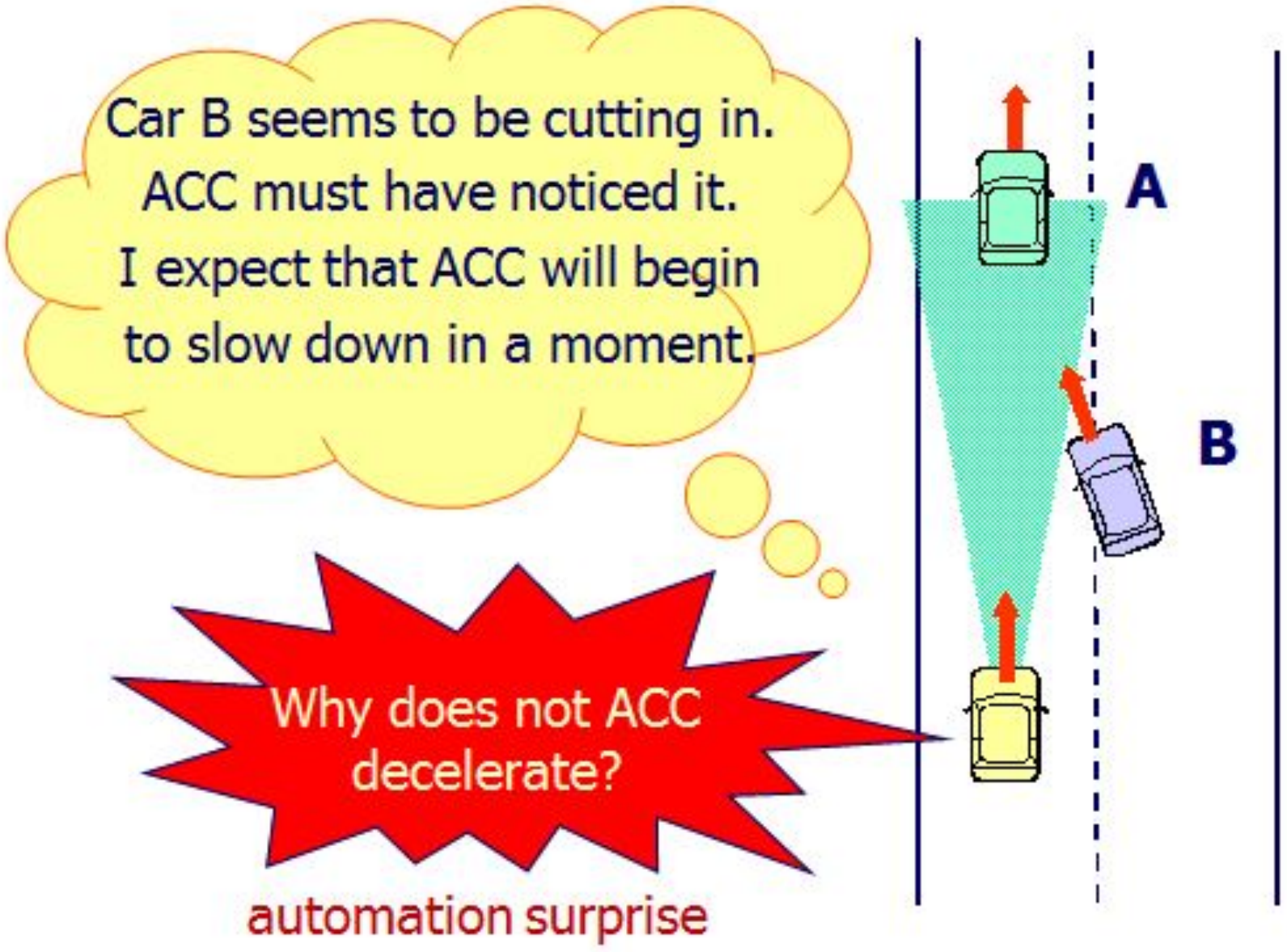
Agent 1 wants to…



Agent 2 wants to…



Failure to recognize limit of capability



Level 3 automated driving

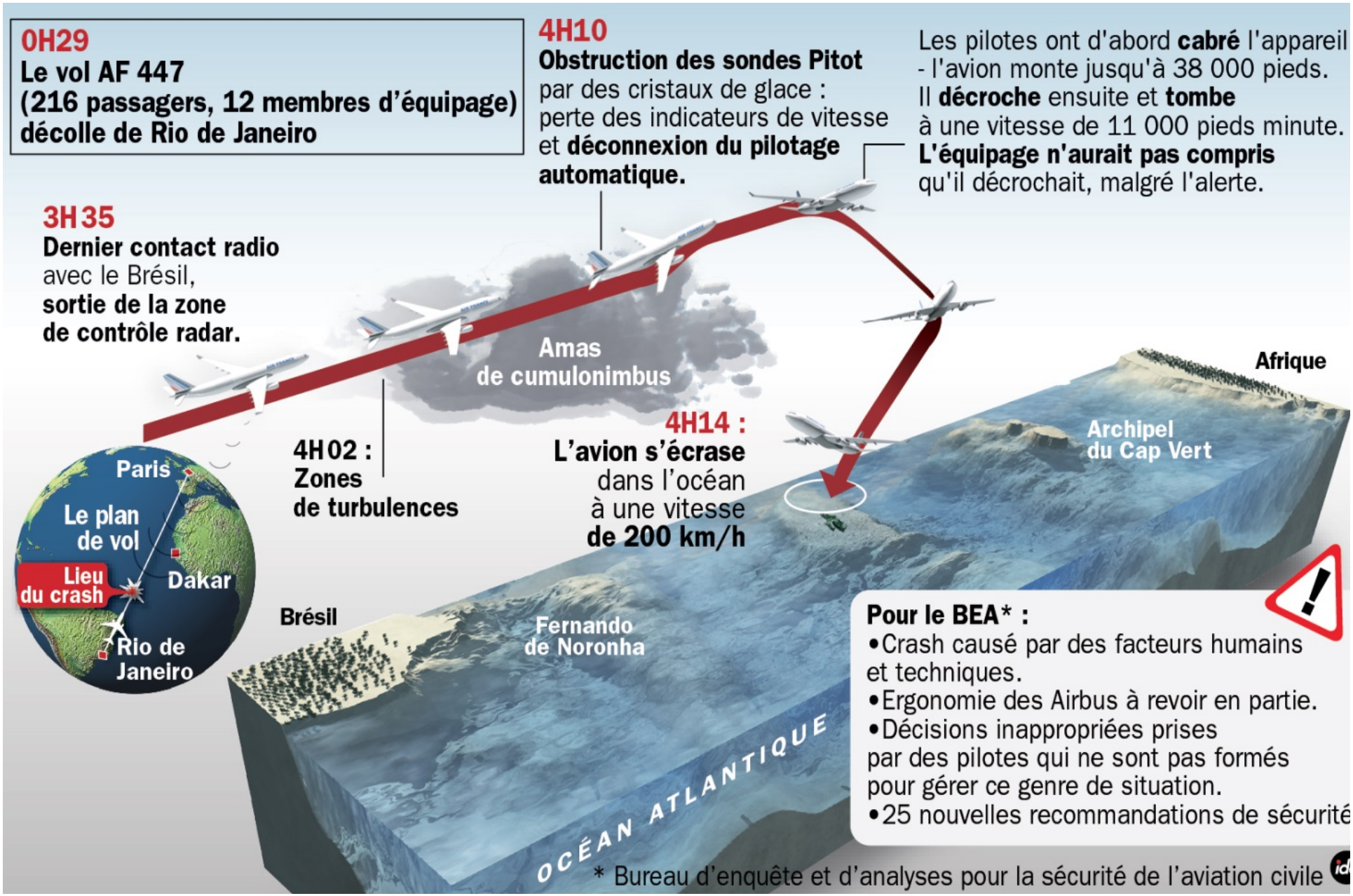
The system takes over longitudinal and lateral control. The driver is no longer required to permanently monitor the system. In case of a take-over request by the system, the driver must take over control with a certain time buffer.

Photo: Volvo

take-over request

Control authority must be traded from machine to human safely and smoothly

Authority trading from machine to human can fail



Levels of automation (LOA) for decision & control

1. The computer offers no assistance; human must do it all.
2. The computer offers a complete set of action alternatives, and
3. narrows the selection down to a few, or
4. suggests one, and
5. executes that suggestion if the human approves, or

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6. allows the human a restricted time to veto before automatic execution, or

6.5 executes automatically after telling the human what it is going to do, or

7. executes automatically, then necessarily informs humans, or
8. informs him after execution only if he asks, or
9. informs him after execution if it, the computer, decides to.
10. The computer decides everything and acts autonomously, ignoring the human.

(Sheridan 1992; Inagaki, Itoh, Moray 1998)

Which take-over request may be sensible?

1. "Design conditions shall no longer be met in 10 sec." (LOA=4)

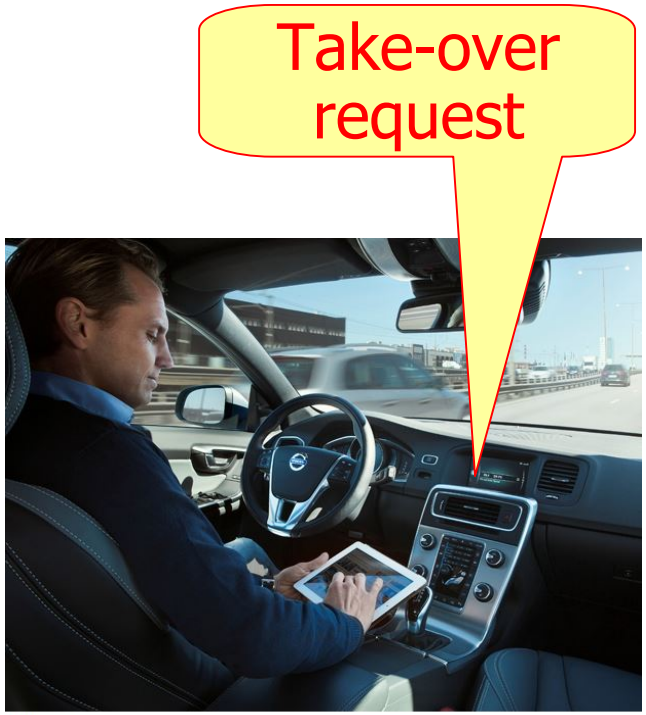
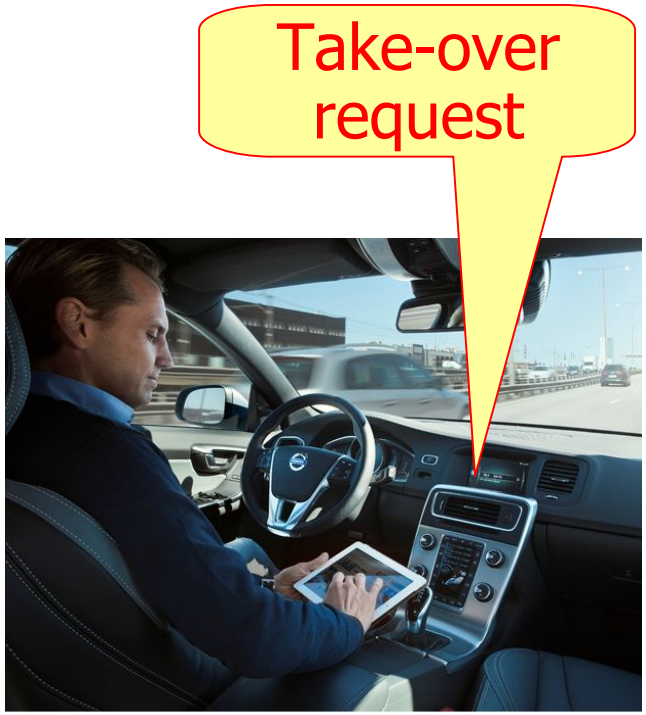


Photo: Volvo

Which take-over request may be sensible?



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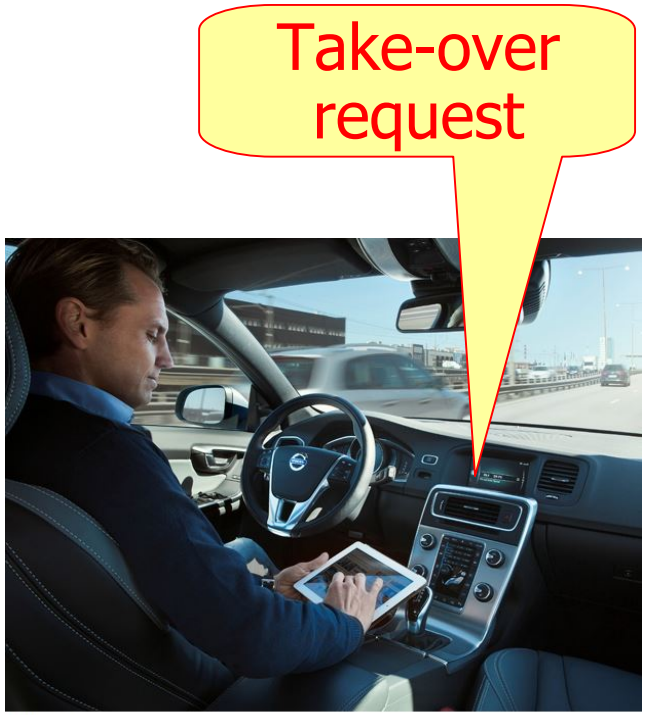
1. "Design conditions shall no longer be met in 10 sec." (LOA=4)
2. "Design conditions shall be no longer met shortly. Could you take over control in 10 sec?" (LOA=5)

Which take-over request may be sensible?



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1. "Design conditions shall no longer be met in 10 sec." (LOA=4)
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3. "Design conditions shall be no longer met in 10 sec. Automation shall be deactivated then." (LOA=6)

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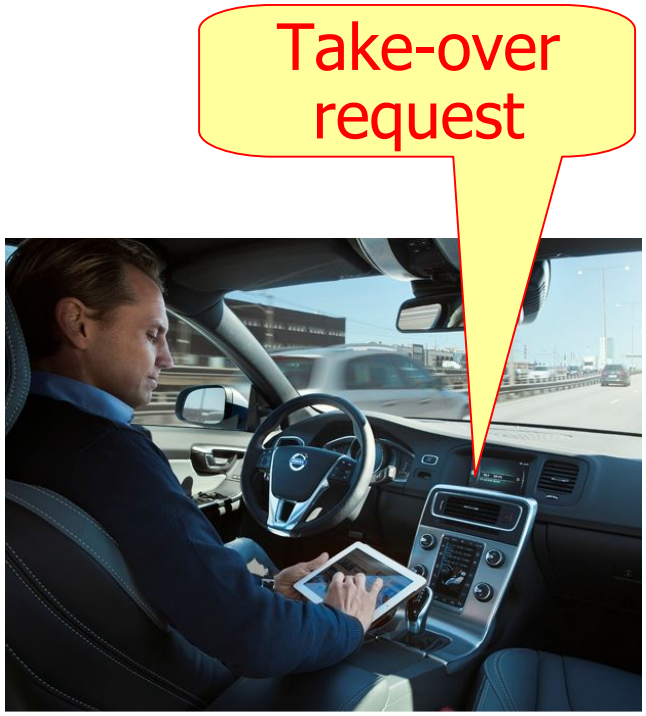

Photo: Volvo

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2. "Design conditions shall be no longer met shortly. Could you take over control in 10 sec?" (LOA=5)
3. "Design conditions shall be no longer met in 10 sec. Automation shall be deactivated then." (LOA=6)
4. A message, "Automation has been deactivated," is given after execution. (LOA=7)

Which take-over request may be sensible?

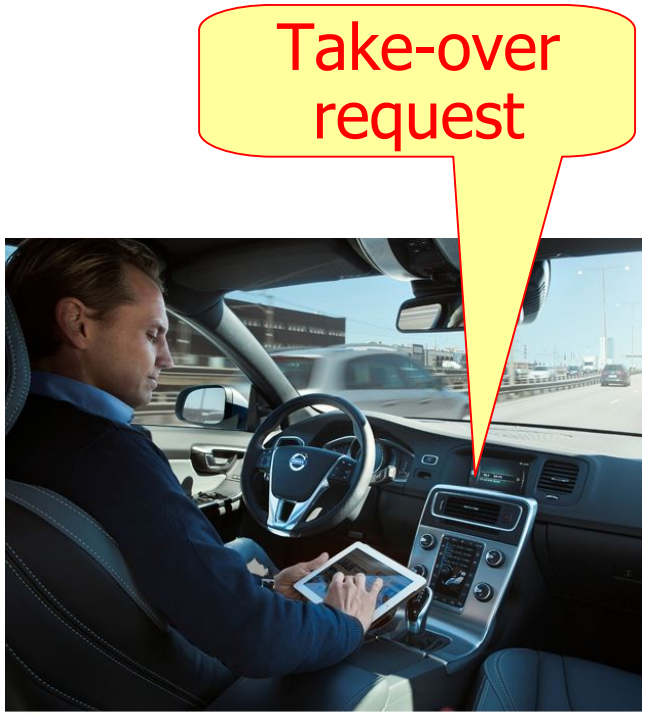


Photo: Volvo

1. "Design conditions shall no longer be met in 10 sec." (LOA=4)
2. "Design conditions shall be no longer met shortly. Could you take over control in 10 sec?" (LOA=5)
3. "Design conditions shall be no longer met in 10 sec. Automation shall be deactivated then." (LOA=6)
4. A message, "Automation has already been deactivated," is given after execution. (LOA=7)
5. No message is given after execution. (LOA=9)

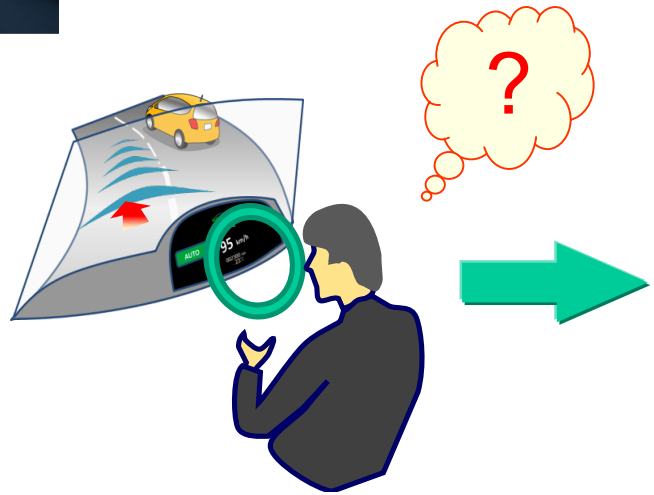
Level 4 automated driving

The system takes over longitudinal and lateral control. The driver is no longer required to permanently monitor the system. If human driver does not take over, the system will return to the minimal risk condition by itself.

Photo: Volvo

"Could you take over control in 10 sec?"

"Could you take over control in 10 sec?"



The system restores the vehicle to the minimal risk condition automatically.

Level 4.5 automated driving

The system takes over longitudinal and lateral control. The driver is no longer required to permanently monitor the system. When it is anticipated that design condition shall not be met a short time later, the system restores the vehicle to the minimal risk condition automatically.

Photo: Volvo

"Control mode is switched to emergency-mode."

After telling that,
system activates emergency
control mode instantly.
(LOA 6.5)

(Inagaki 2016)

Level 5 automated driving

The system performs all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. By design, safe operation rests solely on the automated driving system.

Can we trust in the automated driving system?

Photo: Google

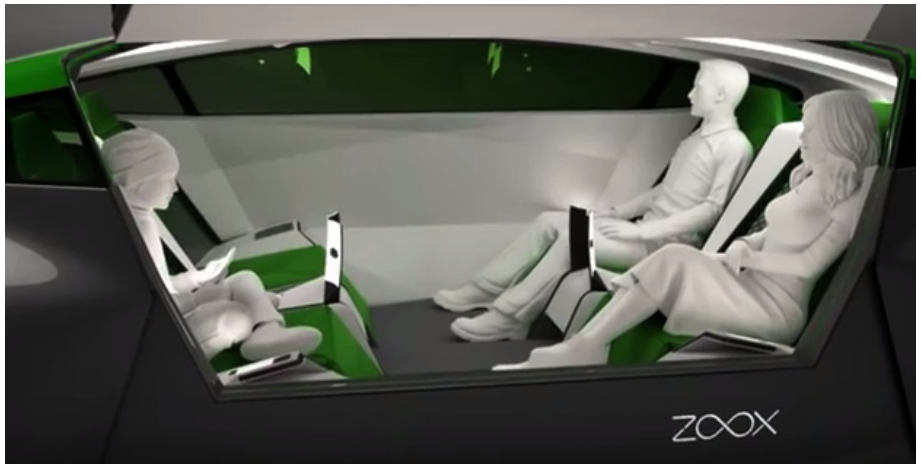


Photo: Zoox