University of Tsukuba
筑波大学

Future human-machine collaboration for human-centered automation
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Automated Driving:
Are We Heading Down the Right Path?

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Wide variety of driving automation

Photo: BMV

Photo: Volvo

Photo: Zoox

SAE J3016 (Sep 2016)

SURFACE VEHICLE RECOMMENDED PRACTICE	**J3016™**	**SEP2016**
	Issued 2014-01 Revised 2016-09 Superseding J3016 JAN2014	

(R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

SAE J3016 (Jan 2014)

SURFACE VEHICLE INFORMATION REPORT	**J3016**	**JAN2014**
	Issued 2014-01	

Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems

Levels of driving automation

- SAE J3016 (Sep 2016) -

Level 1	Driver Assistance
Level 2	Partial Driving Automation
Level 3	Conditional Driving Automation
Level 4	High Driving Automation
Level 5	Full Driving Automation

Dynamic Driving Task (DDT)

1. Lateral vehicle motion control
   (via steering)

2. Longitudinal vehicle motion control
   (via acceleration / deceleration)

3. Monitoring the driving environment
   (via object and event detection, recognition, classification, and response preparation)

4. Object and event response execution

5. Maneuver planning

6. Enhancing conspicuity
   (via lighting, signaling and gesturing, etc.)

Level 1 - Driver assistance

The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.

DDT - Dynamic Driving Task

ODD - Operational Design Domain

The specific conditions under which a given *driving automation system* or *feature* thereof is designed to function, including, but not limited to, *driving modes*.

Level 1 - Driver assistance

The driving automation system executes either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.

System: longitudinal control by using ACC

Driver: lateral control

Level 2 - Partial driving automation

The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.

DDT - Dynamic Driving Task

1. Lateral vehicle motion control
2. Longitudinal vehicle motion control
3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation
4. Object and event response execution
5. Maneuver planning
6. Enhancing conspicuity

OEDR

Level 2 - Partial driving automation

The driving automation system executes both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.

Photo: BMV

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

Driver: supervisory control

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

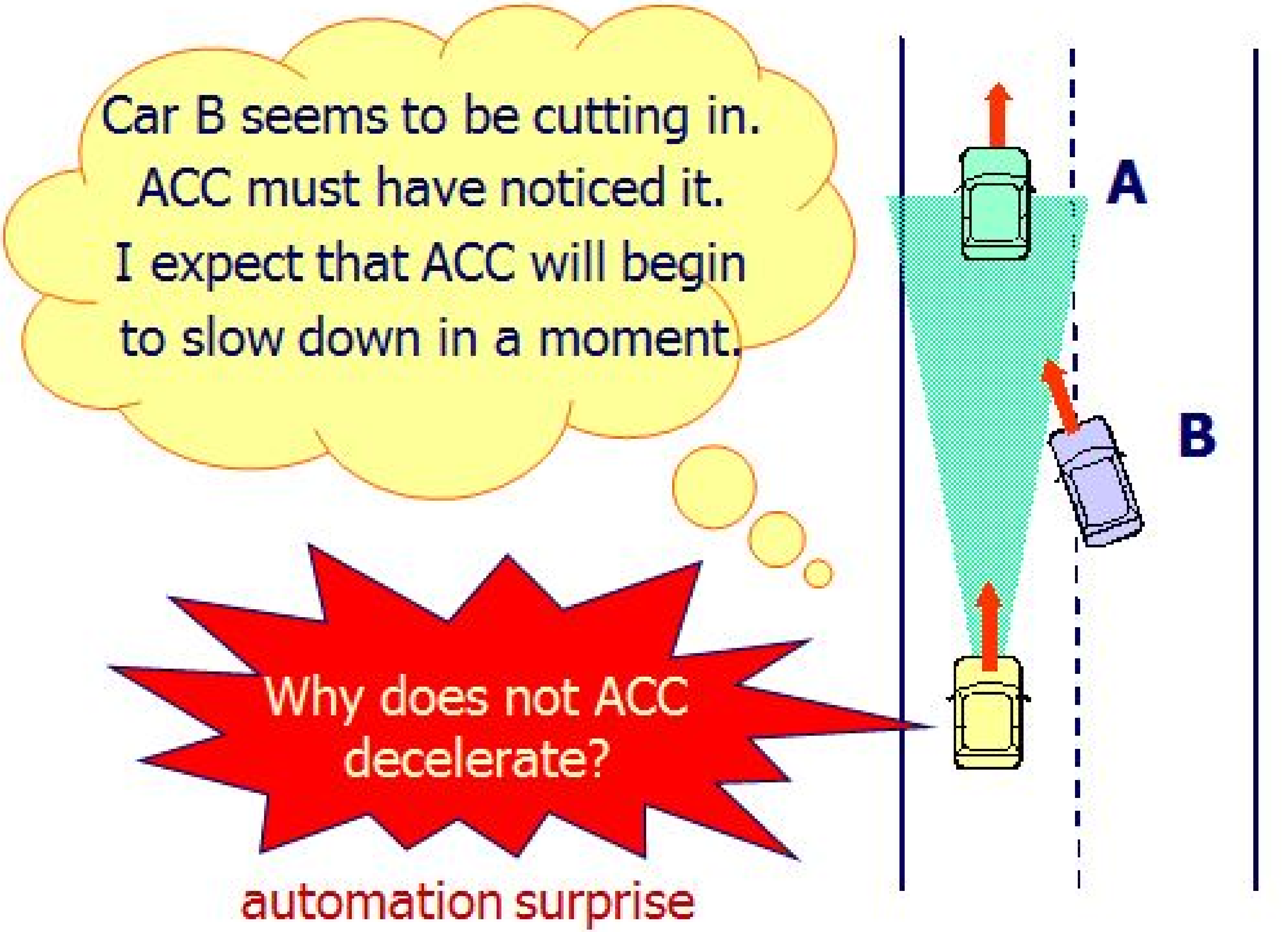
Supervisory control is not human-friendly

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

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

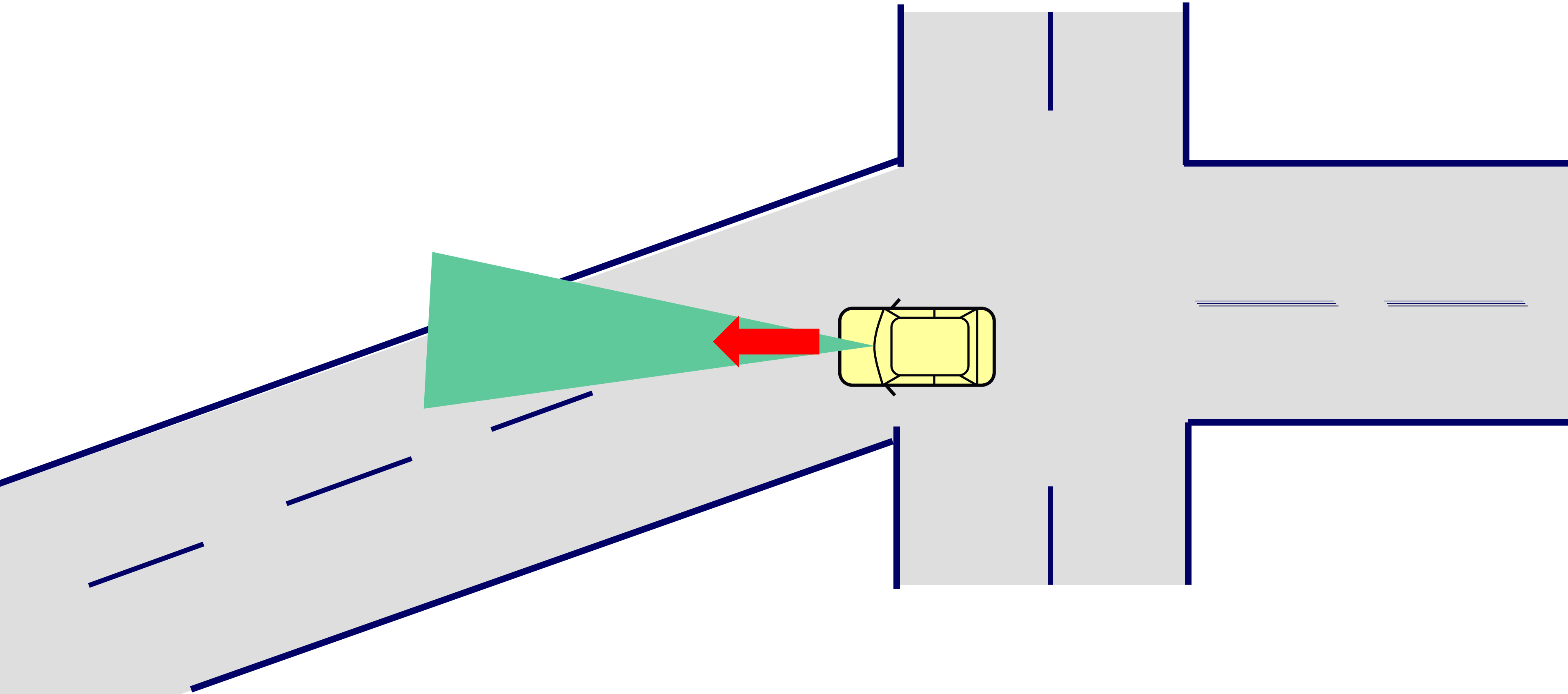
- how functions are implemented in automated systems
- functional limitations of automated systems
- possible interaction among automated systems

Example 1


Car B seems to be cutting in.
ACC must have noticed it.
I expect that ACC will begin
to slow down in a moment.
Why does not ACC
decelerate?
automation surprise
A
B

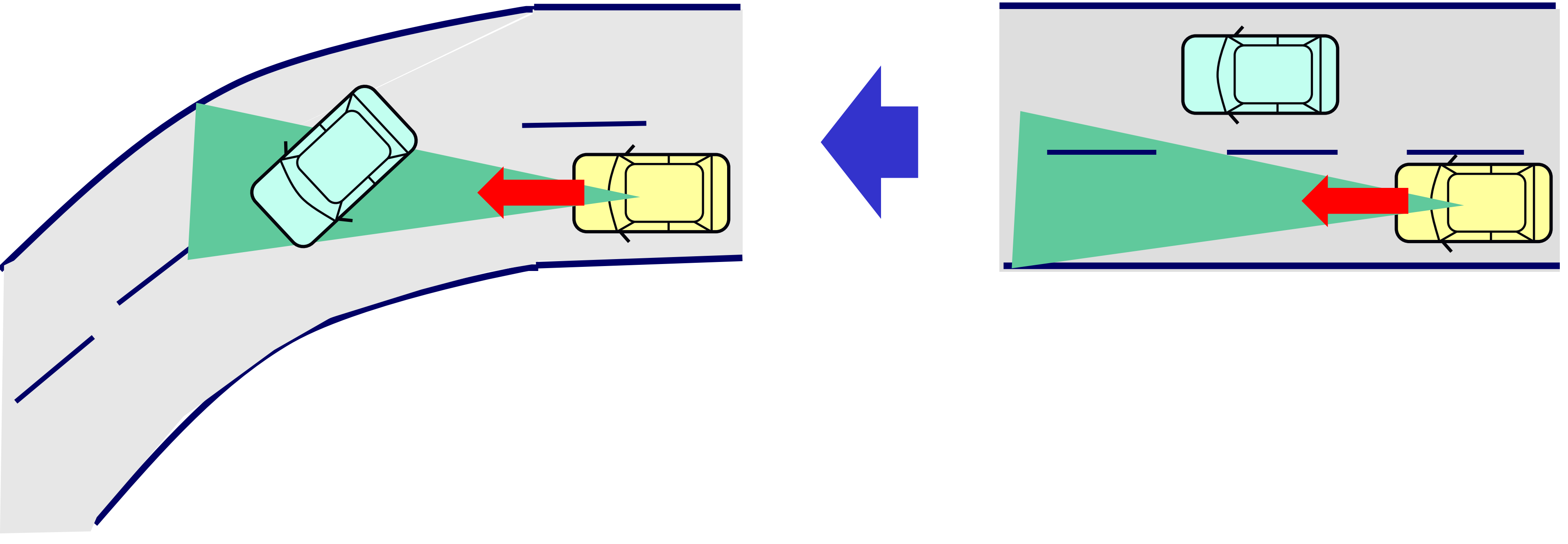
Example 2

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



Example 3

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



Driver monitoring

The driver is assumed in Level 2 driving automation to:

- perform the remainder of the DDT not performed by the driving automation system
- supervise the driving automation system and intervene as necessary to maintain safe operation of the vehicle

Question 1: Is it possible to design a HMI that can monitor the driver in a natural manner?

Question 2: What the system should do when it determined that the driver may not be supervising the system properly?

DDT Fallback

The response by the user or by an automated driving system to either perform the DDT or achieve a *minimal risk condition* after occurrence of a DDT performance-relevant system failure(s) or upon *ODD* exit.

ODD - Operational Design Domain

Minimal Risk Condition

A condition to which a user or an ADS may bring a vehicle after performing the DDT fallback in order to reduce the risk of a crash when a given trip cannot or should not be completed.

Level 3 - conditional driving automation

<u>The sustained and ODD-specific performance</u> by an automated driving system of the entire DDT with the expectation that the DDT fallback-ready user is receptive to system-issued requests to intervene, <u>as well as to DDT performance-relevant system failures in other vehicle systems</u>, and will respond appropriately.

ODD - Operational Design Domain
DDT - Dynamic Driving Task

DDT fallback-ready user

The user (of a vehicle with an level 3 automated driving *feature)* who is able to operate the vehicle and is receptive to system-issued requests to intervene. ~~compelling him/her to perform the DDT fallback.~~

Level 3 - conditional driving automation

The automated driving system performs the entire DDT with the expectation that the DDT fallback-ready user is receptive to system-issued requests to intervene and will respond appropriately.

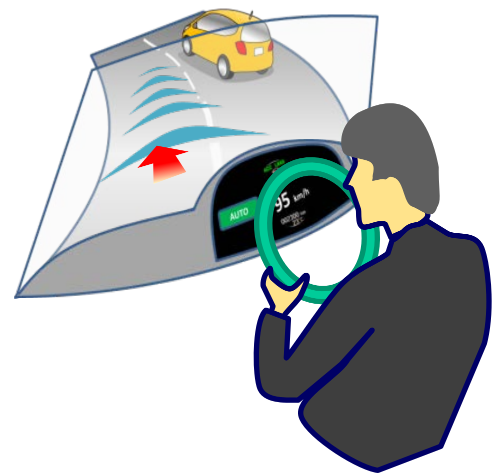
Question 3: Is it reasonable to assume that a DDT fallback-ready user is receptive at all times to system-issued requests to intervene and will respond appropriately?

Level 3 - conditional driving automation

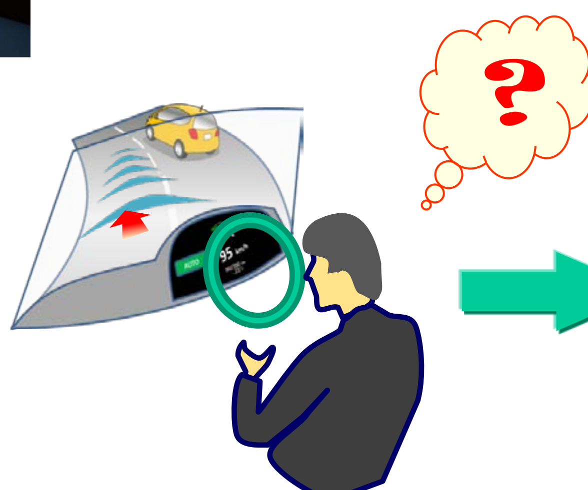
The automated driving system performs the entire *DDT* with the expectation that the *DDT fallback-ready user* is *receptive* to system-issued requests to intervene and will respond appropriately.

Photo: Volvo

"Could you take over control in 10 sec?"



"Could you take over control in 10 sec?"



What happens if the driver failed to react to the request to intervene?

Level 3 - conditional driving automation

The automated driving system performs the entire DDT with the expectation that the DDT fallback-ready user is receptive to system-issued requests to intervene and will respond appropriately.

Basic model in J3016

The system disengages an appropriate time after issuing a request to intervene.

Question 4: Is it sensible for the system to disengage "an appropriate time after issuing a request to intervene"?

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)

Request to intervene: Design alternatives

Baseline: "Intervene and resume control within 10 sec."

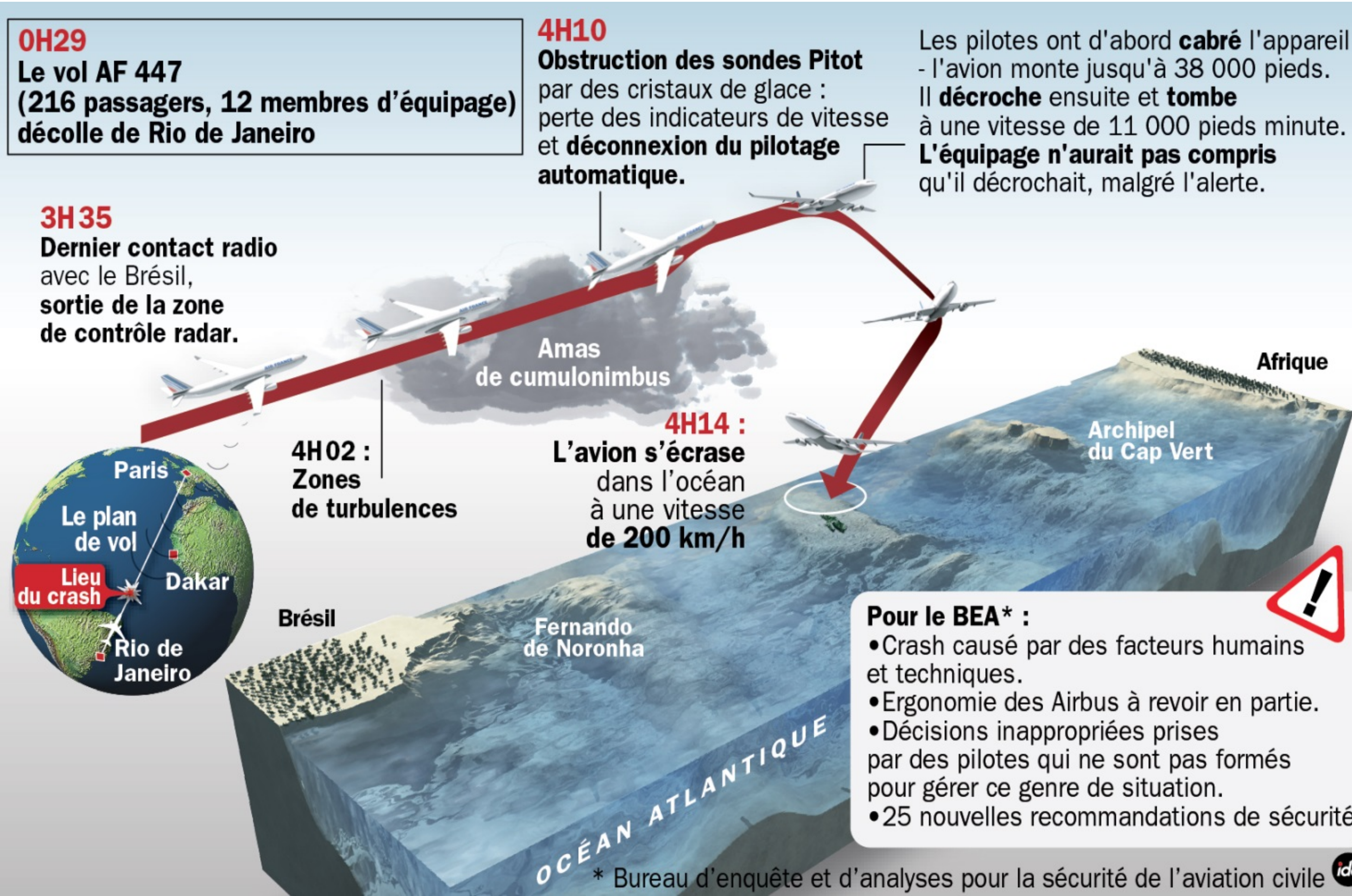
LOA 5: "Intervene and resume control.
The system deactivates after confirming that you resume control."

LOA 6: "Intervene and resume control within 10 sec.
Veto if you do not agree with this idea."

LOA 6.5: "Intervene and resume control at once.
The system is about to deactivate."

LOA 7: "Intervene and resume control at once.
The system has just deactivated."

Machine-initiated authority trading can fail



What if no response to the request?

Baseline: “Intervene and resume control within 10 sec.”

LOA 5: “Intervene and resume control.
The system deactivates after confirming that you resume control.”

LOA 6: “Intervene and resume control within 10 sec.
Veto if you do not agree with this idea.”

LOA 6.5: “Intervene and resume control at once.
The system is about to deactivate.”

LOA 7: “Intervene and resume control at once.
The system has just deactivated.”

What if no response to the request?

Baseline: "Intervene and resume control within 10 sec."

↓ when no response

The system disengages when 10 seconds passed.
Nobody controls the vehicle after that.

LOA 5: "Intervene and resume control.
The system deactivates after confirming that you resume control."

↓ when no response

The system may not disengage, and thus it initiates DDT fallback to achieve a minimum risk condition.

What if no response to the request?

LOA 6: "Intervene and resume control within 10 sec. Veto if you do not agree with this idea."

when vetoed or no response

(1) If vetoed, the system initiates DDT fallback to achieve a minimum risk condition.

(2) When no response or the human's failure to take over control, the system disengages when 10 seconds passed. Nobody controls the vehicle after that.

What if no response to the request?

LOA 6.5: “Intervene and resume control at once.
The system is about to deactivate.”

when no response

The system disengages immediately.
Nobody controls the vehicle after that.

LOA 7: “Intervene and resume control at once.
The system has just deactivated.”

when no response

Nobody controls the vehicle.

Which design alternative is sensible?

Risk (LOA 5) < Risk (LOA 6) < Risk (baseline) < { Risk (LOA 6.5), Risk (LOA 7) }

The human may veto when not being ready to intervene and resume control. The system initiates DDT fallback to achieve a minimal risk condition.

Value of veto

If no response to the request to intervene, the system initiates DDT fallback to achieve a minimal risk condition.

Level 4 driving automation (2014 ver.)

≠ Level 4 driving automation (2016 ver.)

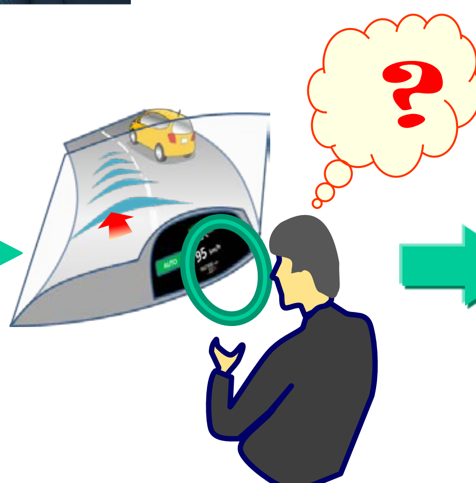
Level 4 - high automation (2014 ver)

The system performs all aspects of the DDT, even if a human fails to respond appropriately to a request to intervene.

Photo: Volvo

"Could you take over control in 10 sec?"

"Could you take over control in 10 sec?"

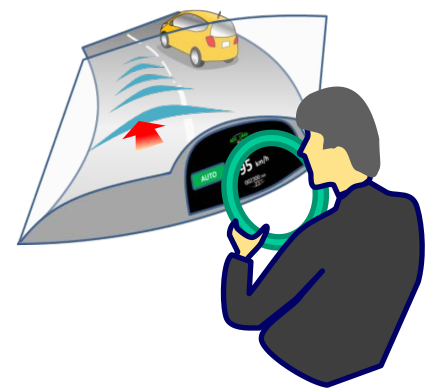


The system deactivates only after the driver takes over. It initiates DDT fallback if the human does not take over control.

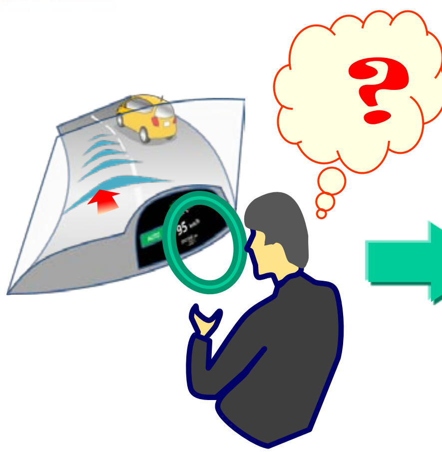
Level 4 - high automation (2014 ver)

Photo: Volvo

"Could you take over control in 10 sec?"



"Could you take over control in 10 sec?"



The system initiates DDT fallback if the human does not take over control.

The system performs no effective control (e.g., for 10 sec) before initiating DDT fallback. **Is this safe enough?**

Message alternatives issued by Level 4 automated driving system (2014 ver)

LOA 5: "Push a button if you want the system to perform the DDT fallback for you."

LOA 6: "The system initiates the DDT fallback within 10 sec. Veto if you do not agree with this."

LOA 6.5: "The system is about to initiate the DDT fallback."

LOA 7: "The system has already started the DDT fallback."

↓

Level 4 automated driving system (2016 ver)

Level 4 - high driving automation (2016 ver)

The automated driving system performs the entire DDT and DDT fallback, without any expectation that a user will respond to a request to intervene.

Question 5: J3016 (2016) says that “the system may issue a request to intervene.” How can the human figure out whether a request will be issued or not in a given situation?

Level 5 - Full driving automation

The automated driving system performs the entire DDT and DDT fallback unconditionally (i.e., not-ODD specifically) without any expectation that a user will respond to a request to intervene.

Photo: Zoox

Question 6: Is there really no need to have a measure to communicate with the automated driving system?

Design for Driving Automation and Legal Systems Conforming to Characteristic Features and Limitations of Cognition and/or Decision Making of Human Drivers

Grant-in-Aid for Scientific Research (S)

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Human Factors Research Aspect

Goals

(1) to identify human factors in driving automation with solutions,

(2) to formulate guidelines for design of human-machine interface, and

(3) to develop training programs for enhancing driver's resilience in cases of unexpected events.

Engineering Design Research Aspect

Goals

(1) to develop systematic methods for finding out ‘missing levels of automated driving’ in the list by SAE, NHTSA, BASt, etc.

(2) to identify an optimal level of automation for performing safe and smooth transfer of control authority from the automated driving system to the human driver when the system requests, and

(3) to develop safety control mechanisms for cases of traffic conditions which the automated driving systems may not be able to cope with.

Authority and Responsibility Research Aspect

Goals

(1) to identify problems of the current legal system when the automated driving systems are put into the real world,

(2) to develop a new legal theory for analyzing negligence liability when using driving automation, and

(3) to propose a new system for driver's license in the age of driving automation.