Digital infrastructure to support automated driving at transition areas

First Advisory Board Meeting
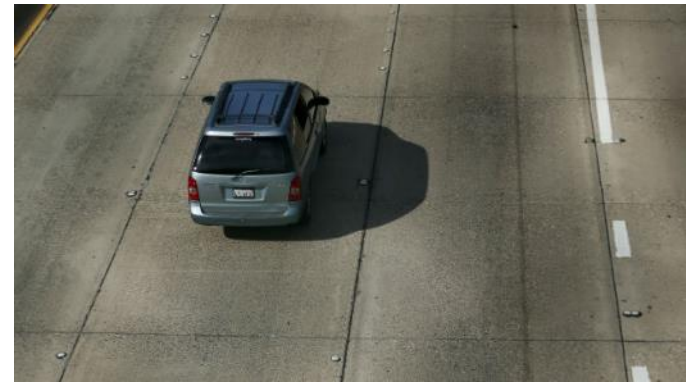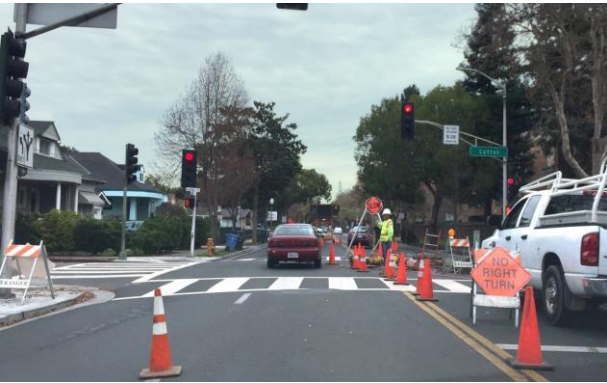
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What if…

- …your CAV is not able to solve the situation ahead?

Situation not understood (e.g. irregular or complexity)

Required action not allowed (e.g. rules)

Required action not possible (e.g. safety margin)

Hardware or software limitation or failure (e.g. not mapped, sensor input, poor localisation)

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What if…

- …your automated vehicle is not able to solve the situation ahead?

- …this happens not to single vehicles only, but to several?

- …it always happens on the same location?

- …in mixed traffic fleets?

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Assumptions

- These are all assumptions and there are many unknowns...

- Thus, first define the factors of relevance for unintended ToC situations

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Defining ToC Factors

1. Environment
   – Static, dynamic, semi-static
2. Autonomous driving functions
   – AD parameters,
     MRM implementation
3. transition of Control process
   – Duration of ToC,
     phased vs. instantaneous
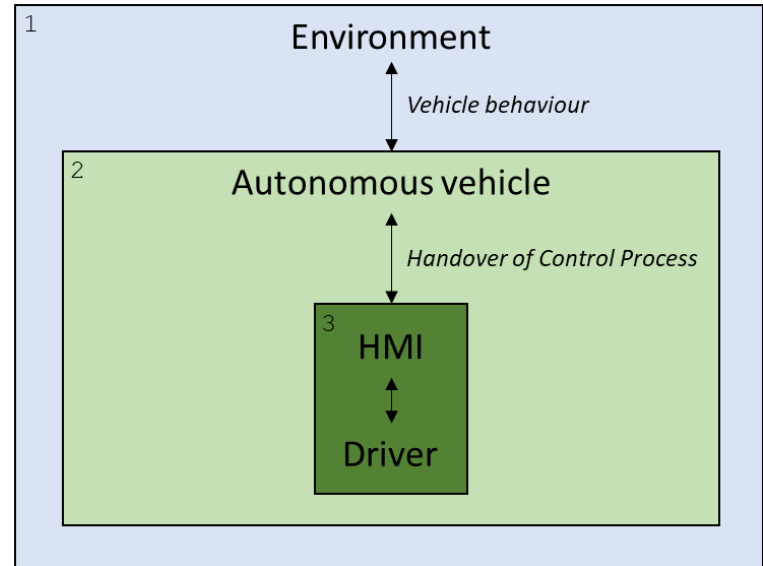
- The combination of these factors determine if unintended ToC will occur, but which?

Change perspective…

- To perform the driving task, the steps are:
  - Decide what to do, set a goal (what).
  - You need to see around you, sense the environment.
  - Determine action(s) to reach that goal (how and when).
  - Perform the action(s).

Change perspective…

- Each step can go wrong:

  - **Reasoning disturbance**: the vehicle does not know what to do.
    emergency vehicle approaches -> how to give way, unknown/new infrastructure -> go left or right? Take exit? Which lane to choose?, etc.

  - **Environmental disturbance**: the vehicle knows what to do, but is (partially) blind and cannot (sufficiently) sense the environment.
    sensor malfunction, hard to see road works objects/yellow lines, bad markings, snow, sensor interference, etc.

  - **Action determination disturbance**: the vehicle can sense its environment and knows what to do, but not how / which action(s) to take to achieve it.
    enter highway while blocked by queue, change lanes before intersection to lane with queue, road is blocked and traffic laws need to be broken, etc.

  - **Execution disturbance**: the vehicle knows which actions to take, but is incapable of executing them or cannot rely on the driver (i.e. the driving system as a whole, vehicle + driver, is defunct).
    ice on road/black ice, malfunction in vehicle (steering, breaking, acceleration)

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…to find generic solutions…

For each step there is a solution:

- **Enhance reasoning** (i.e. provide a goal or decision)
  move to the rightmost lane to give way to emergency vehicle, take the left lane to reach destination X, etc.

- **Provide environmental information**
  digital map, position of other vehicles/objects/vulnerable road users, area to move to, etc.

- **Determine action** (i.e. enable an action or suggest a different action).
  instruct queue to leave a gap, move to end of merging lane (because there is a gap there somehow), cross a continuous line, ignore a red light, etc.

- **Manage the environment**
  Not much can be done for the vehicle or driver itself, but from a traffic management perspective, warnings or actions for the other vehicles can be provided to minimize the impact of the incapacitated vehicle. In addition, traffic lights could be used to manipulate the immediate traffic situation around/ahead of the incapacitated vehicle.

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…which aim to

Add digital infrastructure (I2V support) to even / compensate dynamics in operational design domain:

- Avoid transition (maintain automation level)

- Manage timing of transition
  in time and/or space
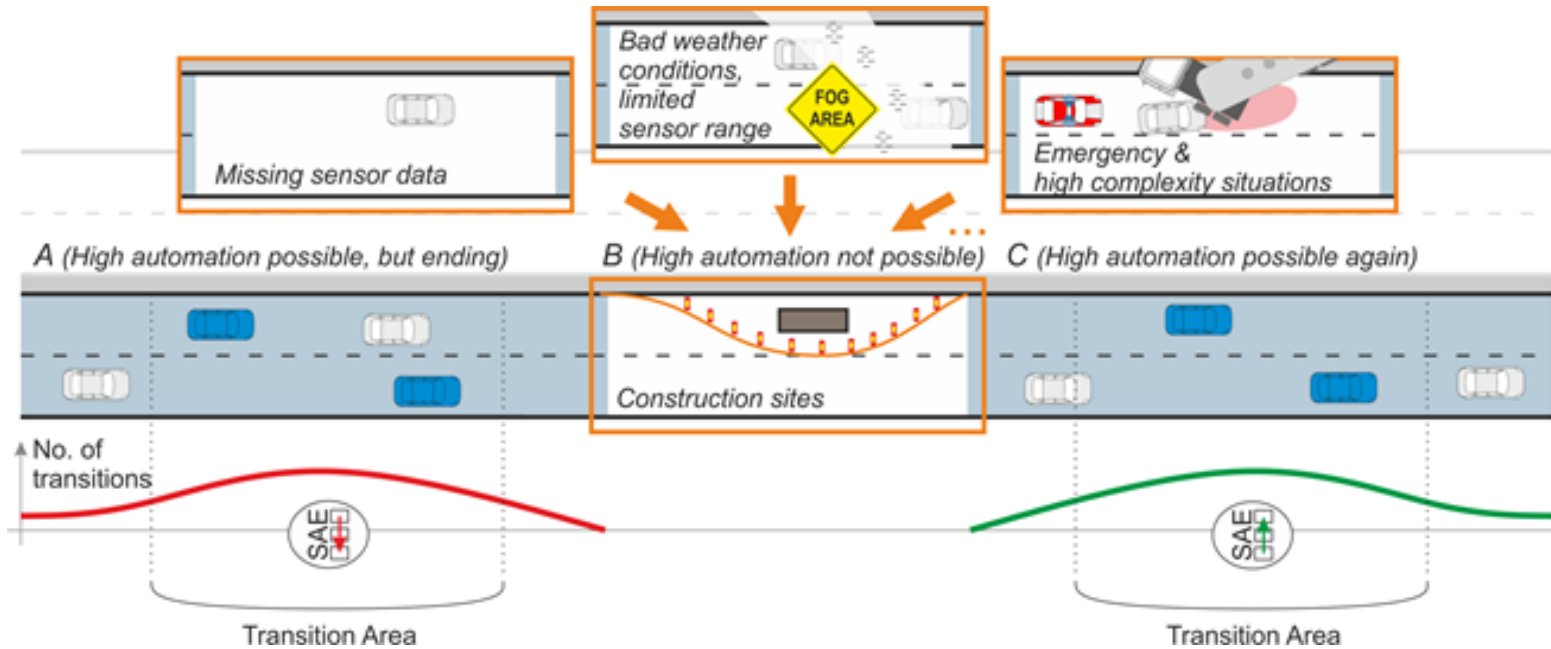
- Enable/support and/or smoothen transition

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Define problems

- Any (unknown) combination of introduced factors can cause a ToC.

- We might know a few and learn more in the future, but for now…

- Define causes through their properties instead of defining them directly.
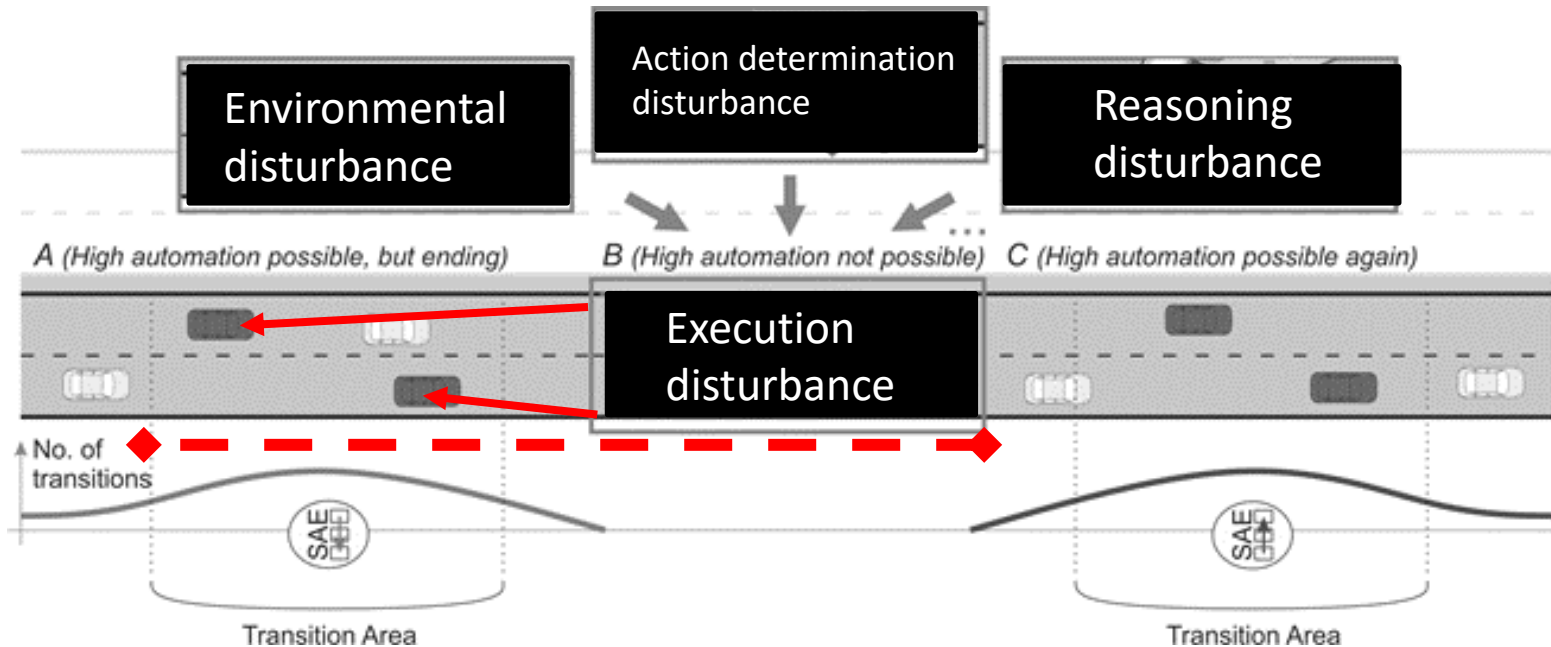
Cause Properties

- Location type
  - Fixed
    - Predictable
    - Unpredictable
  - Random
    - One-off/incidental, short term (i.e. seconds)
    - Stationary for long term (i.e. minutes, hours)

- Affection range
  e.g. one spot, trajectory, area

- Cause duration
  e.g. seconds, minutes, hours, days, longer than days…

- ToC urgency
  e.g. several minutes for ToC, … anything in between…, ToC now!

- Share of vehicles impacted by the cause per SAE level
  e.g. 75% level 2 vehicles impacted and 25% level 3 vehicles.

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Instead of:

Do this:

Action determination disturbance

Environmental disturbance

Reasoning disturbance

A (High automation possible, but ending)   B (High automation not possible)   C (High automation possible again)

Execution disturbance

No. of transitions

SAE

Transition Area

SAE

Transition Area

Category: Environmental disturbance
Location: Fixed, predictable
Duration: hours – days
ToC Urgency: seconds - minutes

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Combining it all

1. Main goal
   e.g. create a gap in a queue
   a. Background (rationale behind the goal)
2. Actors (i.e. involved entities)
3. Measures
   e.g. vehicles in queue slow down/stop, upstream vehicles in queue keep moving, approaching CAV slows down and moves to the soon to be gap
4. Implementation of measures (C-ITS messages, VMS messages, V2V display, traffic laws, road signs, etc.).
5. Problems (i.e. causes)
   a. Location type
      i. Fixed
         1. Predictable
         2. Unpredictable
      ii. Random
         1. One-off/incidental, short term (i.e. seconds)
         2. Stationary for long term (i.e. minutes, hours)
   b. Affection range
      e.g. one spot, trajectory, area
   c. Cause duration
      e.g. seconds, minutes, hours, days, longer than days…
   d. HoC urgency
      e.g. several minutes for HoC, … anything in between…, HoC now!
   e. Share of vehicles impacted by the cause per SAE level
      e.g. 75% level 2 vehicles impacted and 25% level 3 vehicles.

6. Scenario variables
   a. Environment (see par. 3.1.1)
      i. Static
         road network
      ii. Dynamic
         traffic composition and condition
      iii. Semi-static
         presence of road works, closed lanes, accidents, damaged road surface, etc.
   b. Autonomous driving functions (see par. 3.1.2)
      i. AD functions
         parameters of autonomous driving like headway, acceleration, etc.
      ii. MRM implementation
   c. Handover of control process (see par. 3.1.3)
      i. Duration of HoC process
      ii. Type
         phased vs. instantaneous
      iii. Vehicle behaviour during HoC
         lateral movement variation, speed variation, etc.
7. Expected impact without measures.
8. Expected impact with measures.

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