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IJDS Symposium
Keynote Lecture
14th June, 2017

Role of the Human Driver in Highly Automated Vehicles

Outlook and challenges for the Science of Driving

Tim Gordon, University of Lincoln

Talk Outline

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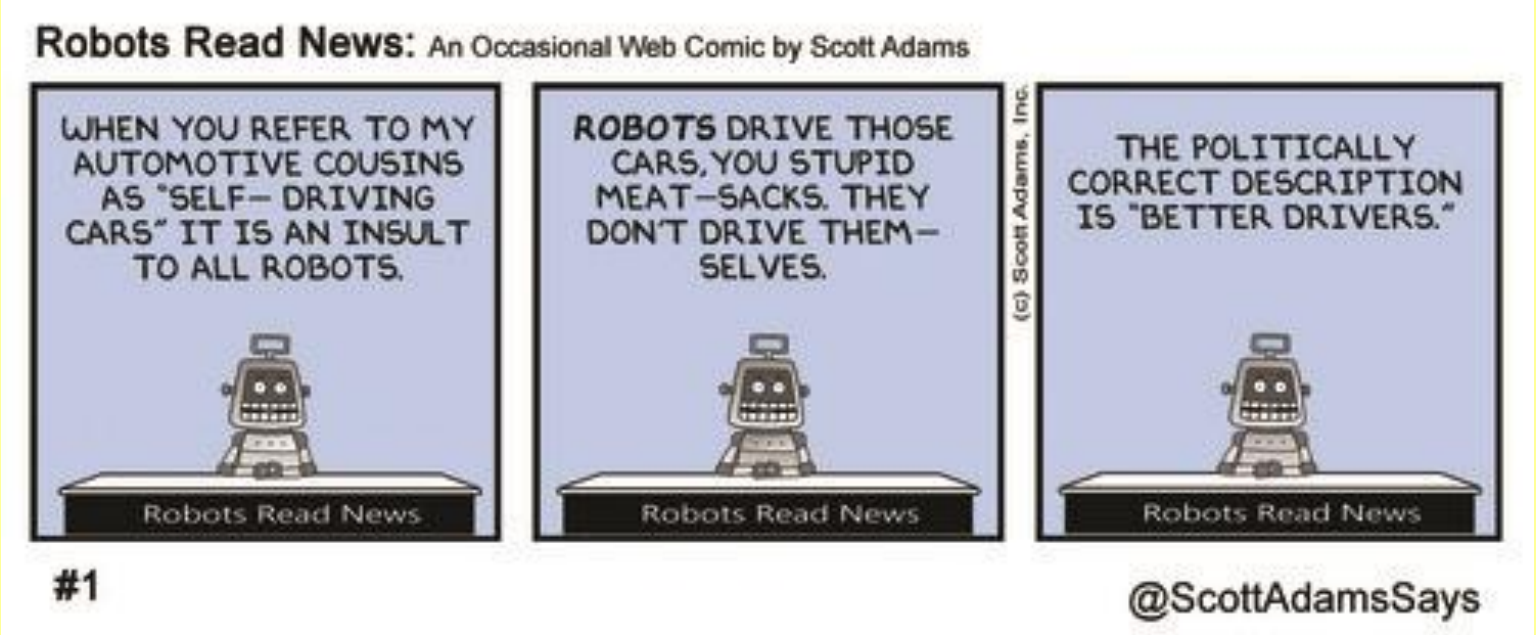
- **Highly automated vehicles**
- The nature of driving
- Human vs. Robot
- Example: Automated Emergency Cornering
- Predictive performance and safety
- The science of driving



A dream from 1956

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Because electricity may be the driver! One day your car may speed along an electric superhighway, its speed and steering automatically controlled by electronic devices embedded in the road. Highways will be made safe—by electricity! No traffic jams, no collisions, no driver fatigue.

Why self-driving?

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- The Motivation
  - **Safety**
  - Convenience
  - Flexibility: ownership, non-drivers
  - Traffic flow in large cities
  - Efficiency: time, energy
  - Fashionable “cool” technology
  - Consumer choice
  - Trend for computerization and automation

“over 90 % of highway accidents occur due to driver-related human errors”

DRIVING AUTOMATION – SAE J3016

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- Many researchers and practitioners subscribe to a **one dimensional model** of the intelligent vehicle evolution

  - Level 0: no visible automation
  - **Level 1: driver assistance**
  - **Level 2: partial (driver = supervisor, takeover)**
  - **Level 3: conditional (eyes-off-road in some cases, driver must be available as backup)**
  - **Level 4: high (eyes off road when enabled, driver may be available as backup)**
  - Level 5: full (door to door, no driver at all)

DRIVING AUTOMATION – SAE J3016

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- Useful but blurs the boundaries of …
  - auto-pilot modes
  - protecting against crashes
  - helping the driver
- Hardly addresses infrastructure and the large-scale traffic/transport system

More than one dimension

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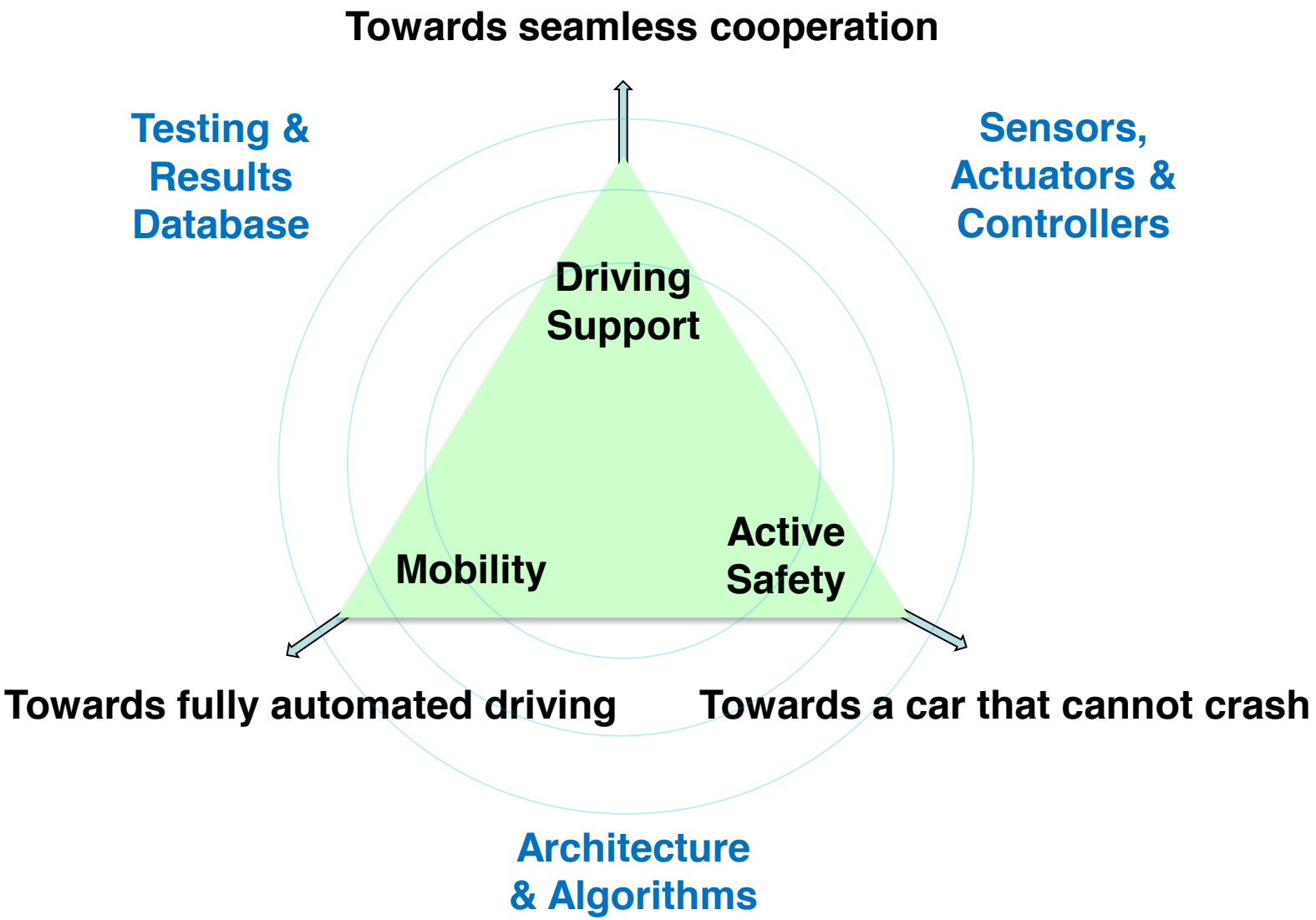

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Decision making and control

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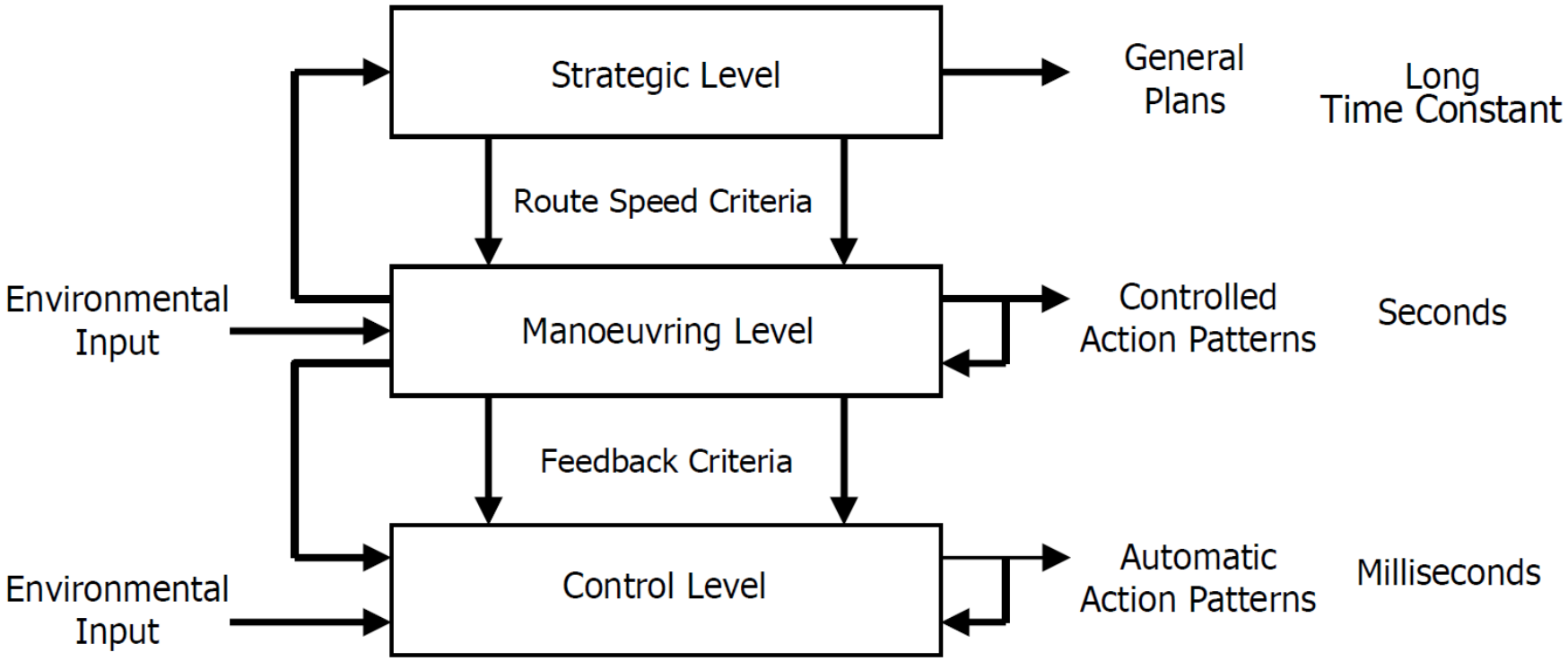
- For all modes, there are **three levels of driving**
- The central level (**tactical** or **maneuvering**) is the most challenging – for an autonomous vehicle this usually includes **path and speed planning** and hence knowledge / prediction of the road and traffic environment



From: John Michon (1984)

The DVET Model

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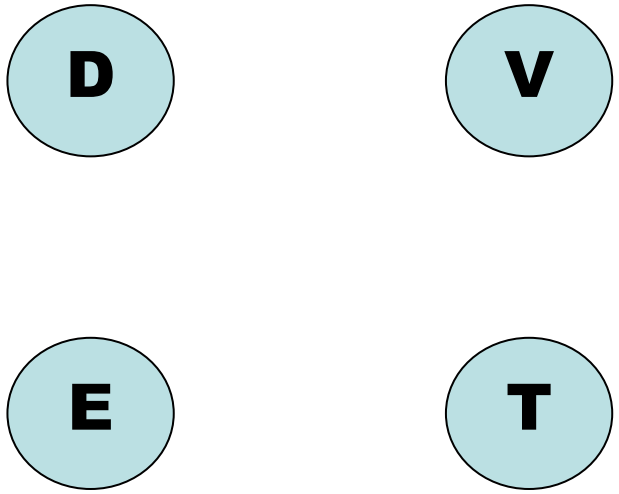
- Driver = human
- Vehicle … base vehicle with control layer support (e.g. ABS)
- Environment – road, traffic, external support



- Technology – driver assistance etc.

The DVET Model

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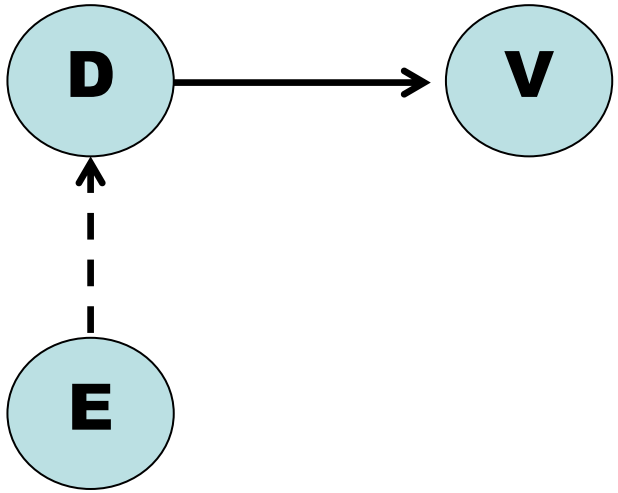
- Level 0



control

information

The DVET Model

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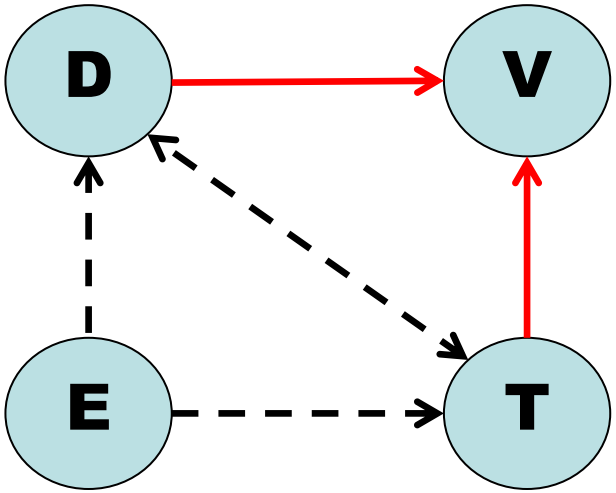
- Level 1 … some level of shared control, e.g. ACC



partial control

The DVET Model

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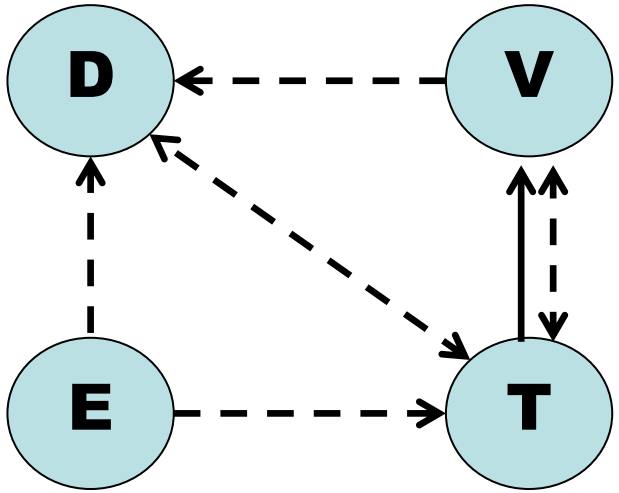
- Level 2: Under normal conditions the technology only needs to know the driver ‘can’ take control
- Technology can independently switch back to lower levels



The DVET Model

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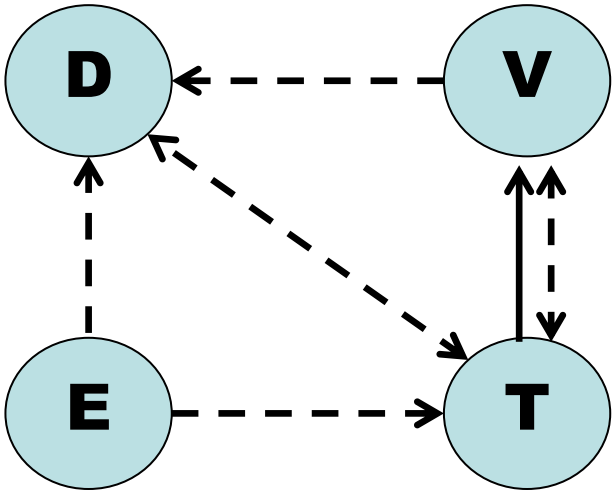
- Level 3: Same as level 2 !!!
- But importantly the technology promises to give the driver due warning of mode switching



- Light on control, **heavy on monitoring**

The DVET Model

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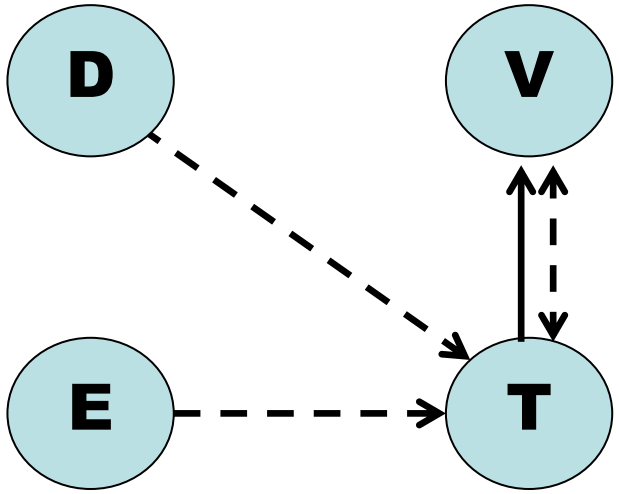
- Level 4: Now the driver does not need to monitor the vehicle or the environment.
- There is no functional requirement for the driver to receive information from the vehicle controller



- Part-time, operating only under certain driving conditions

The DVET Model

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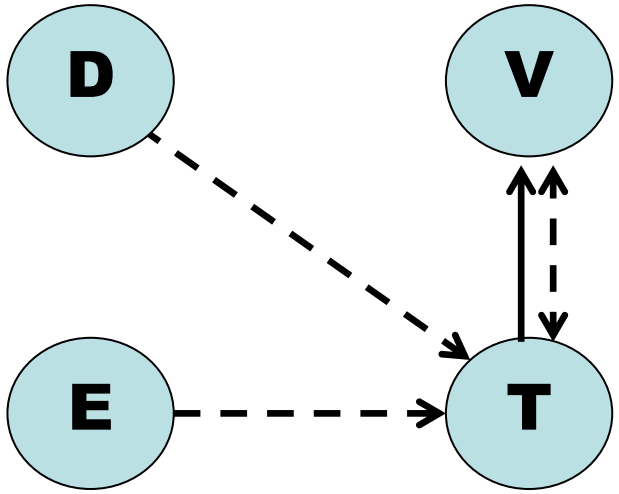
- Level 5: Same as level 4, but for **all** driving conditions



Level 4 High Automation

- SARTRE
  - Safe Road Trains for the Environment
- Mother duck/baby duck scenario
- Lead vehicle is a heavy truck with human driver
- Following vehicles ”connect” to lead vehicle
  - Allows drivers to have eyes-off-the-road time
- Novel approach dealing with normal traffic complexity, reducing the challenge of tactical driving.

Level 5 Automation

- PRT: Personal Rapid Transport or podcar
- Small automated vehicles following specially built guide ways
- Since 2011 at Heathrow
  - From terminal to parking area
  - Up to 40 kph
  - Dedicated tracks with fences etc.
  - More like a flexible rail system than general purpose self-driving vehicle
- Highly structured and predictable environment

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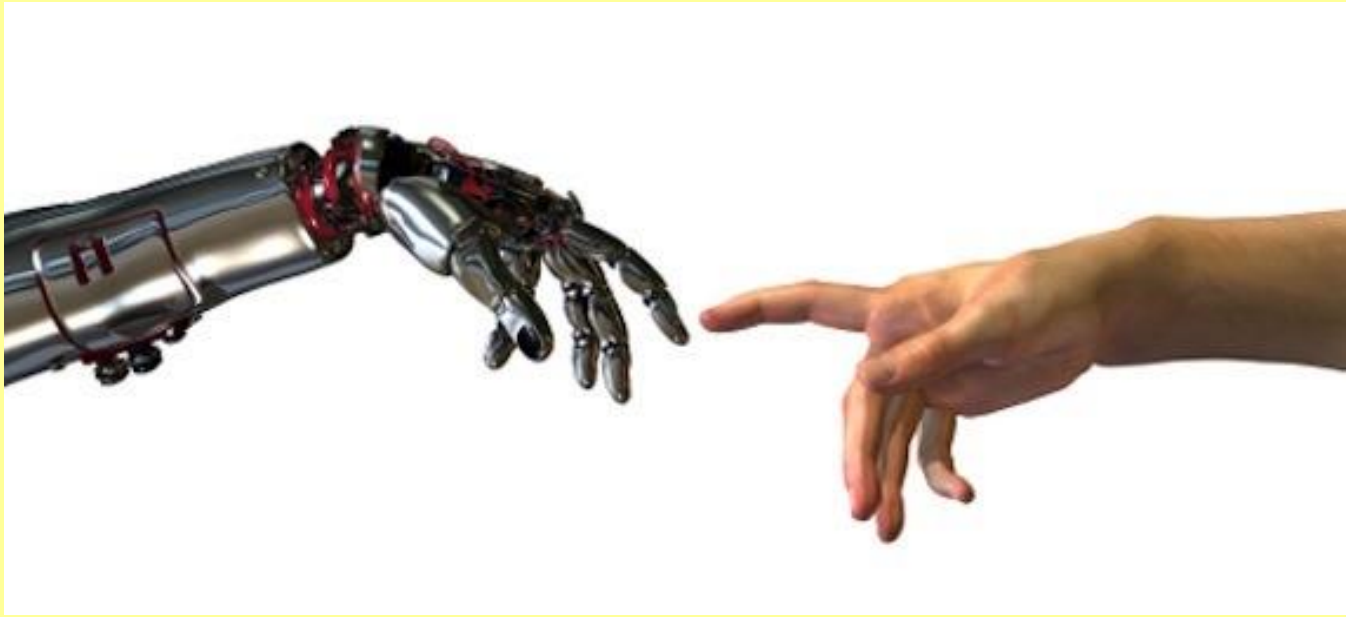

Which is best at what?

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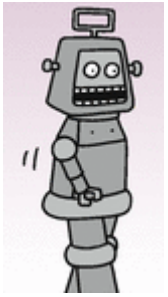
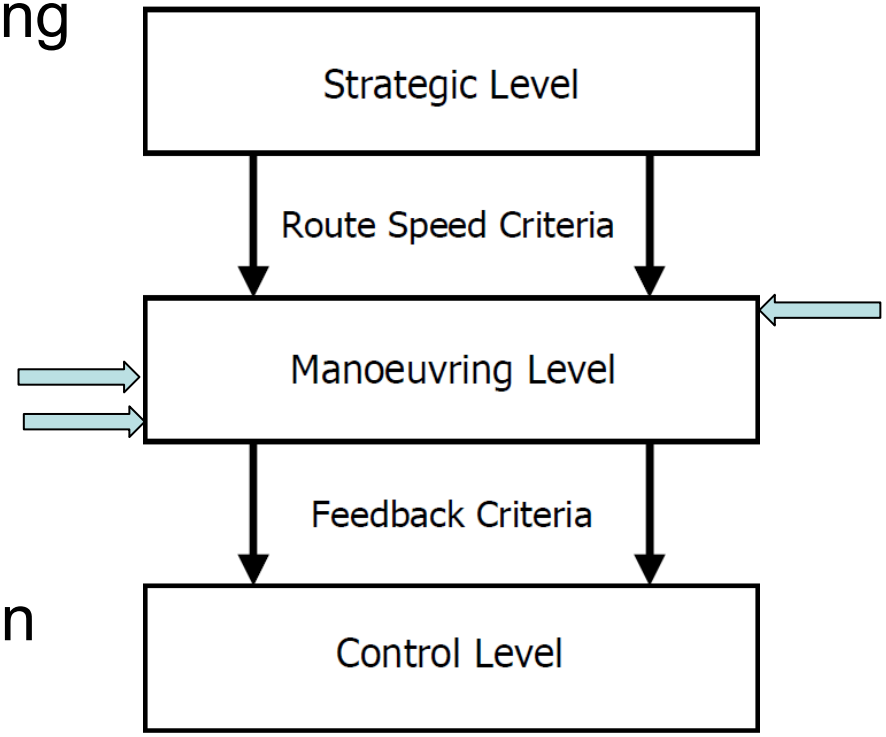
robot



human

basic plans

optimal planning
navigation
data fusion



situational awareness

vigilance
path planning
estimation

optimal motion control

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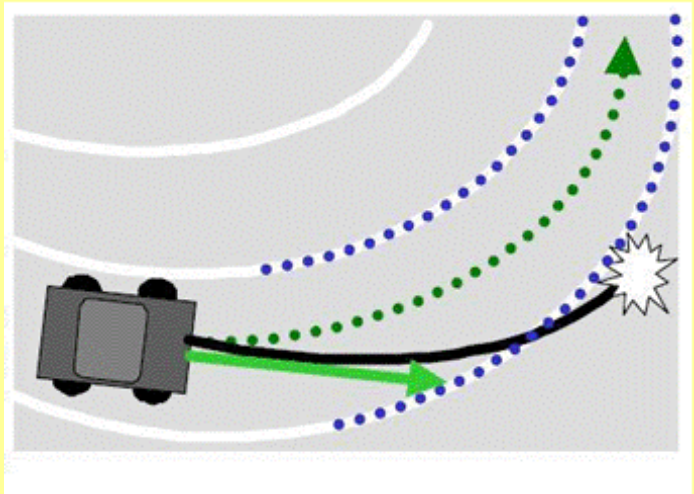

- AEC may use **precise information** about the environment
  - road geometry from a digital map
  - vehicle position to cm accuracy
  - shoulder width and crash barriers
  - friction coefficient

- AEC enjoys **control authority** beyond any human
  - response time ~ 5ms
  - 5 actuators simultaneously
  - optimal use of tyre forces

AEC may operate at several levels

- Fully autonomous control of brakes and steering using enhanced digital maps
- Semi-autonomous, controlling brakes and helping the driver with steering
- Curvature control, blind to the environment but supporting the driver – responding with brakes when the steering demand is too high

AEC may be employed as a **driver aid** for challenging curves, or as a **'last second' intervention** to prevent serious injury.

AEC does not exist …. yet

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AEB is Effective

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- Safety benefits of active safety systems are normally related to crash probability reduction for a given conflict type
- Safety benefits of active safety systems like AEB have proved effective in the field
  - Volvo City Safety
  - collisions reduced by 20 %
  - injuries reduced by 33 %

Level 2 Partial Automation

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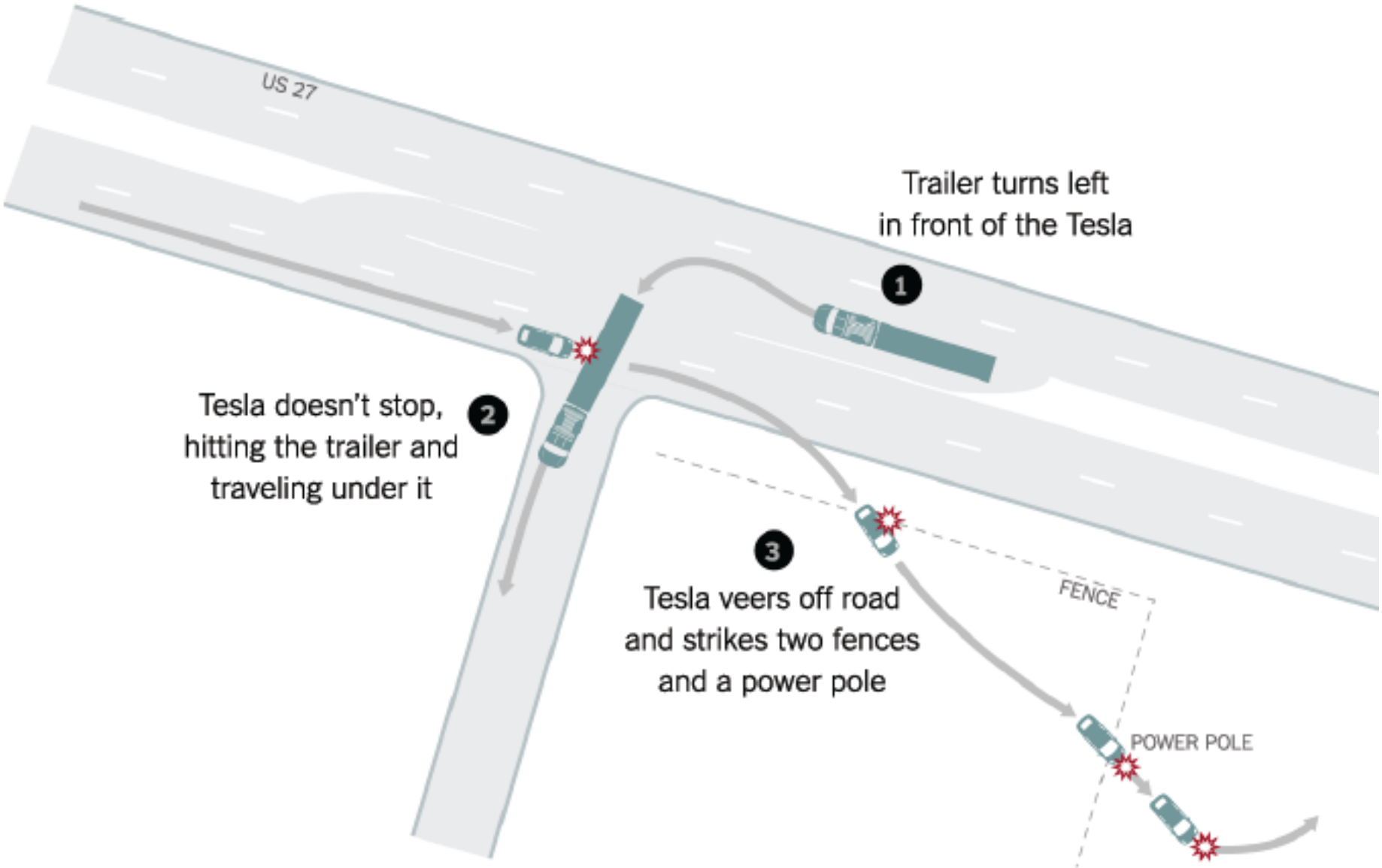

The New York Times | Source: Florida traffic crash report

How safe is regular driving?

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- Crude estimation (based on 2012 US National Crash Data)
  - 3 trillion miles of driving,
  - 5.6 million police-reported crashes:
    Mean crash rate = $6 \times 10^6 / 3 \times 10^{12}$
    ~ 2 crashes per million miles of driving
    ~ 1 fatal crash per 100 million miles of driving (0.5%)

- Travel (as driver) roughly 50 x 12,000 miles = 0.6 million miles
  ~ 1 police reportable crash per lifetime
  ~ 1 fatal crash involvement per 200 lifetimes

- No comparable data for automated or partially-automated cars

How safe is automated driving?

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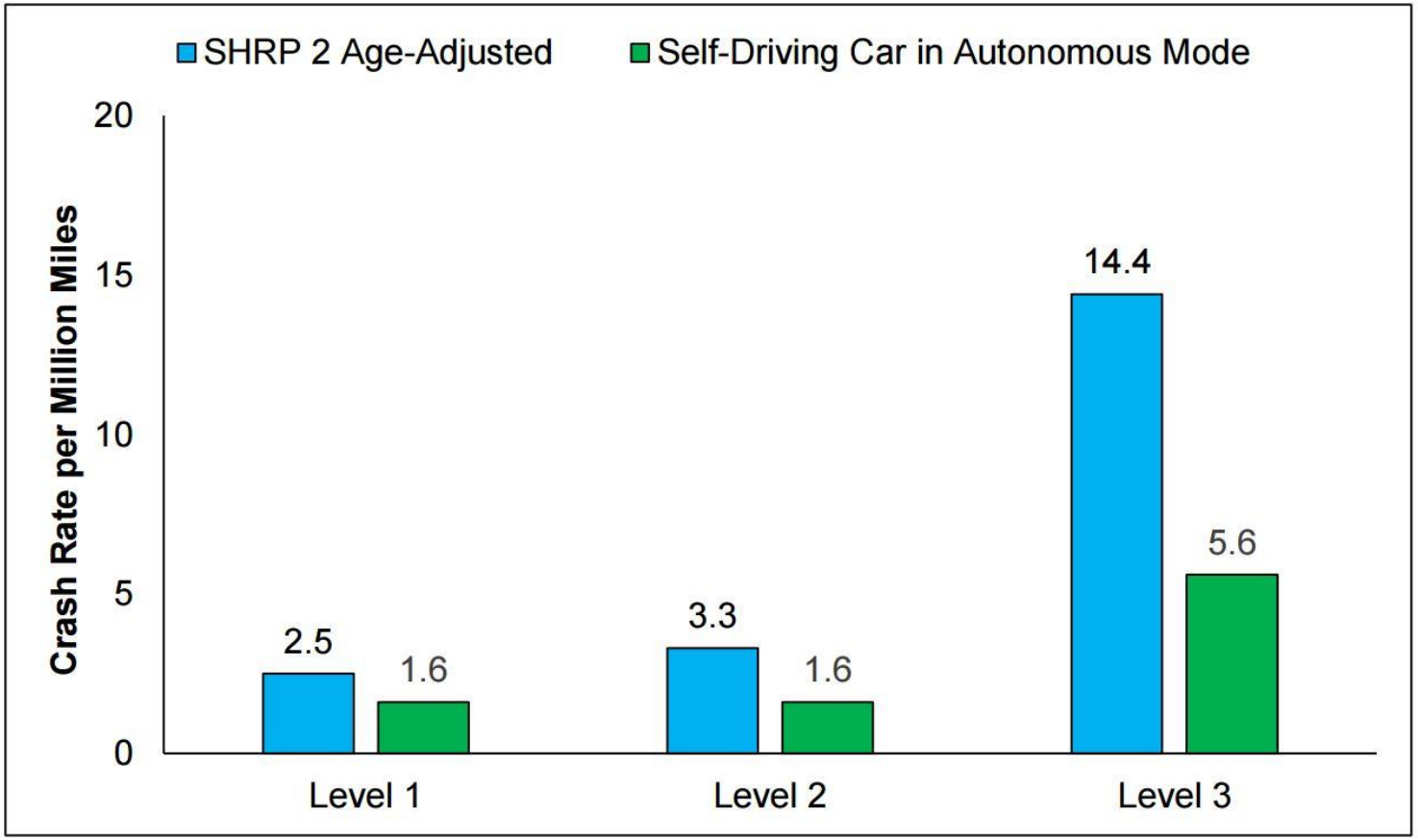
- Study of 1.4 million miles of Google car driving – by Virginia Tech Transportation Institute, January 2016
- Numbers are higher than police-reported



How safe is an automated vehicle?

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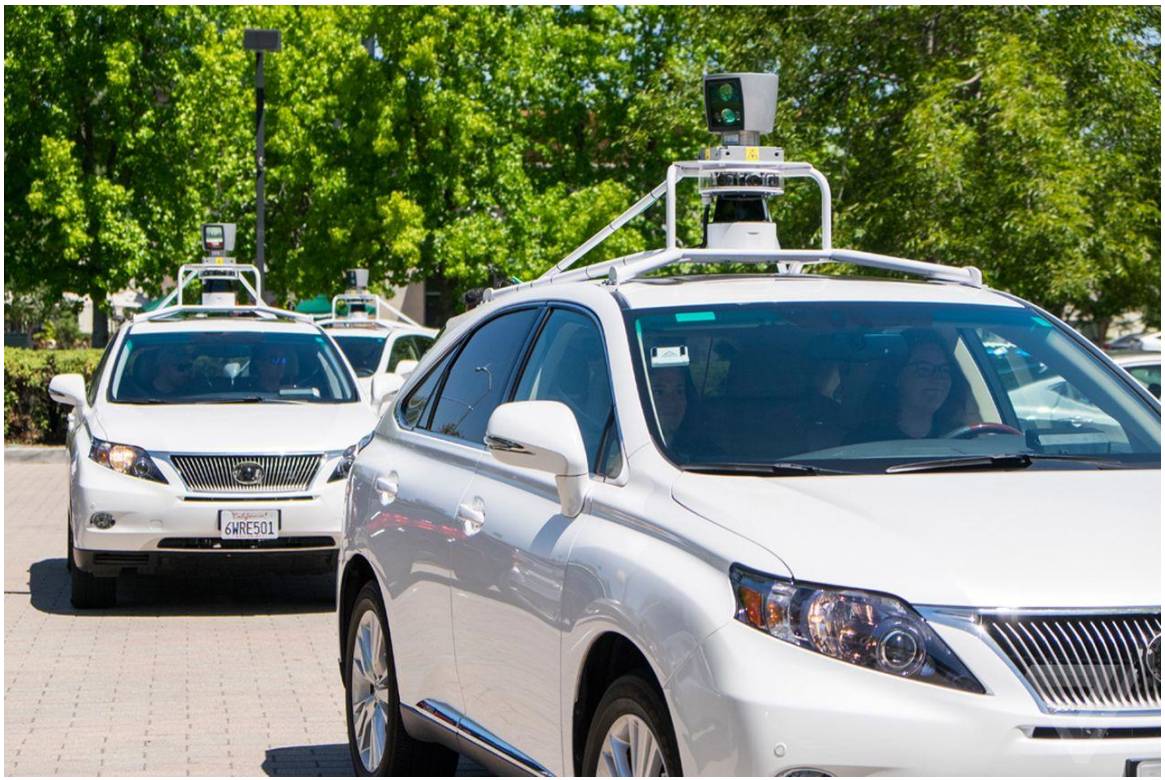
- There is no data to support a predictive analysis
- The Google car caused a slight accident (Feb 2016)
- See YouTube for details!



Predictive Safety Evaluation

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- It remains challenging to **predict** safety benefits from ADAS systems for known crash types
- There is further uncertainly predicting acceptance and adaptation to technology by human drivers
- The possibility of new crash types and unforeseen consequences is so far a completely intractable problem … self-driving deployment presents an '**unknown unknown**'

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DRIVER-VEHICLE SYSTEMS IN ADVANCED ENVIRONMENTS

CONLUSIONS

- In the **automated highway** there is no need of a human driver.
- For the **super-AI robot driver** it is the same.
- But realistically there **will** be a human driver to share control and share the driving

- Predicting and improving active safety is more important than ever
- Simplifying the driving environment is key
- Predicting the next 10 seconds … how do we do that?

- *Thanks to the Engineering Research Division of UMTRI who first came up with the Science of Driving concept … understanding the whole driving process*