

Safety and Trust in Autonomous Driving

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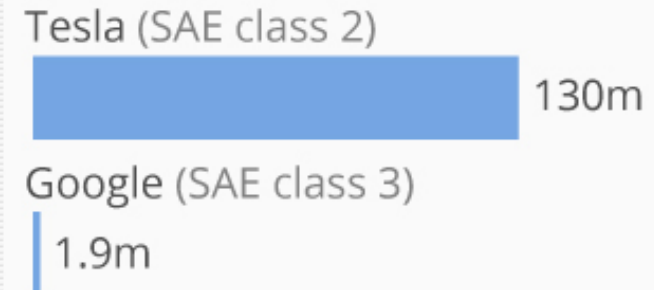
Workshop on Robots, Morality, and Trust through the Verification Lens

FLoC 2018, Oxford

Self-driving cars are on their way



Total autonomous test miles driven so far**



275m miles

are required to prove a self-driving vehicle is at least as safe as a human



* Levels 1 and 2 are assistance systems only. From level 3, the vehicle constantly monitors traffic. From level 4, driver intervention is not required even in an emergency

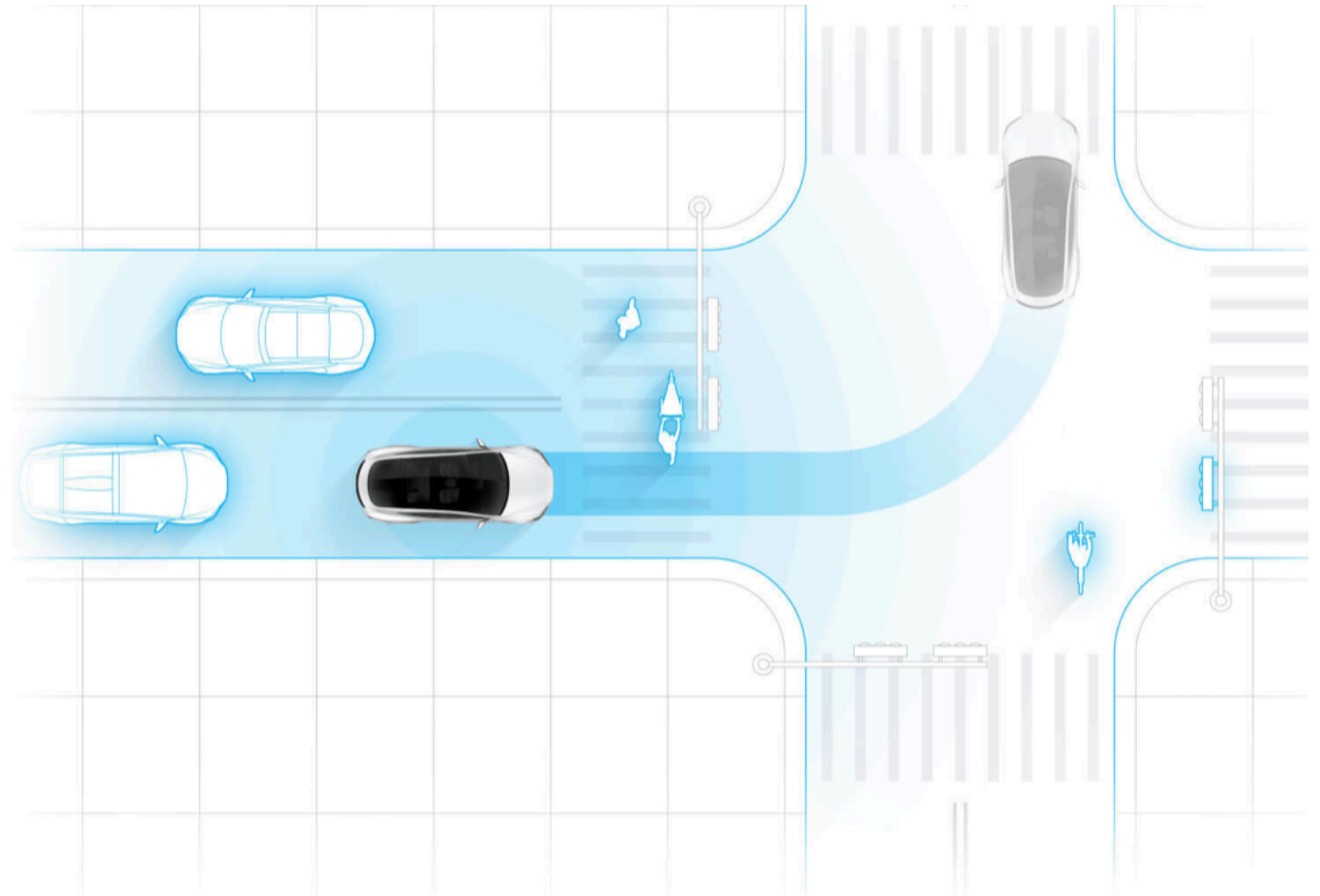
** To June (Tesla)/August 2016 (Google)

Sources: LSP Digital research, manufacturer information, SAE, RAND

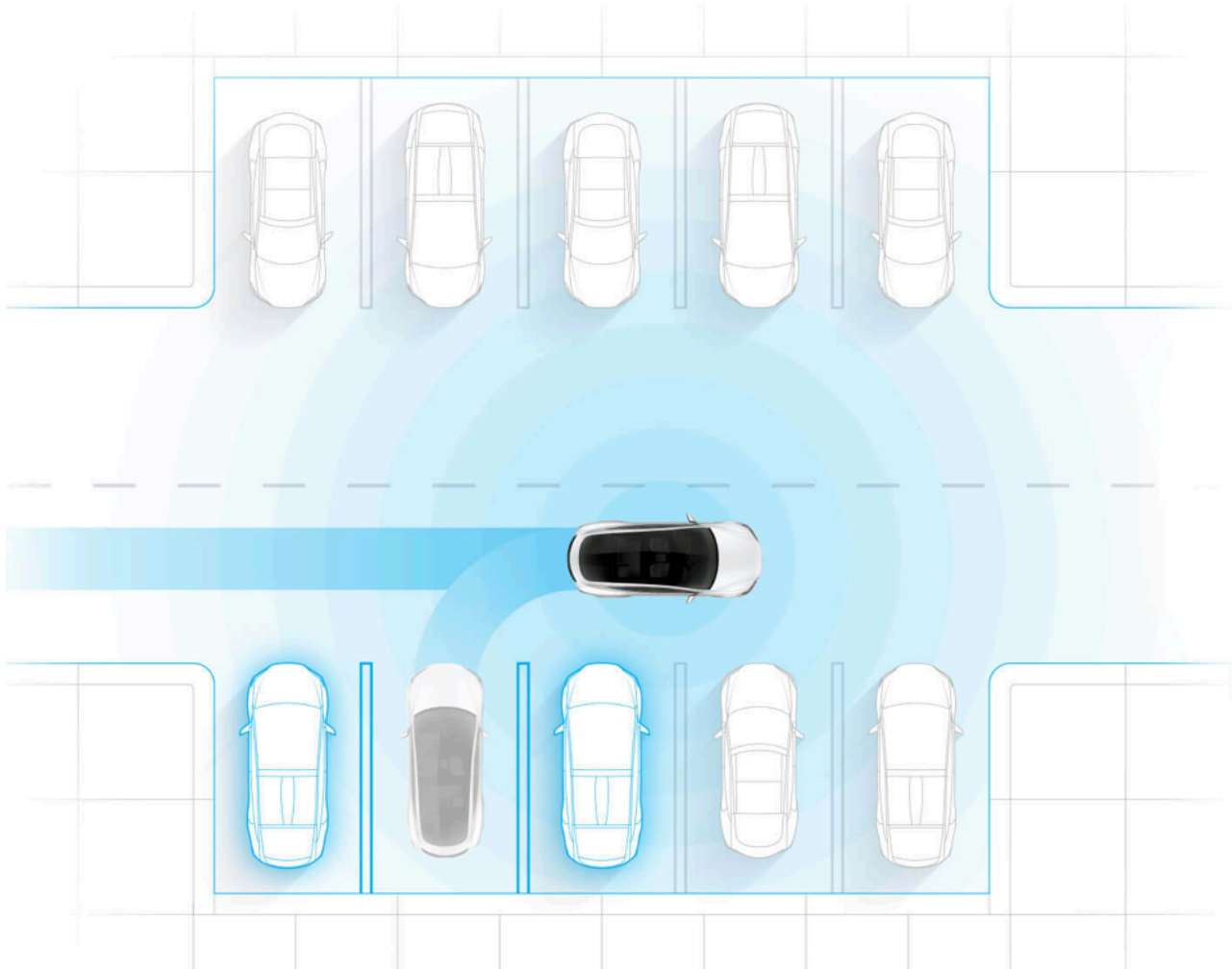
Tesla: “Full Self-Driving Capability”

From Home

All you will need to do is get in and tell your car where to go. If you don't say anything, your car will look at your calendar and take you there as the assumed destination. Your Tesla will figure out the optimal route, navigating urban streets, complex intersections and freeways.



Tesla: “Full Self-Driving Capability”



To your Destination

When you arrive at your destination, simply step out at the entrance and your car will enter park seek mode, automatically search for a spot and park itself. A tap on your phone summons it back to you.

Tesla: “Full Self-Driving Capability”

Please note that Self-Driving functionality is dependent upon extensive software validation and regulatory approval, which may vary widely by jurisdiction. It is not possible to know exactly when each element of the functionality described above will be available, as this is highly dependent on local regulatory approval. Please note also that using a self-driving Tesla for car sharing and ride hailing for friends and family is fine, but doing so for revenue purposes will only be permissible on the Tesla Network, details of which will be released next year.

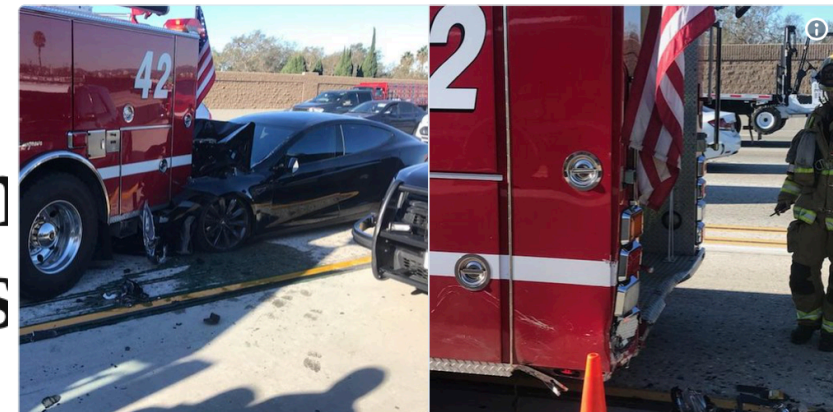
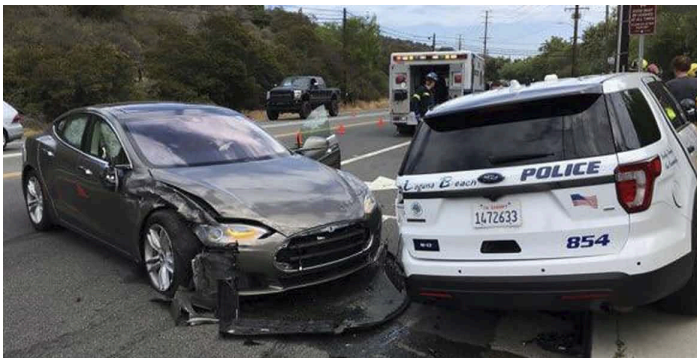
May 2016

Tesla driver dies in first fatal crash while using autopilot mode

March 2018

Self-driving Uber kills Arizona woman in first fatal crash involving pedestrian

Tesla that crashed into police car was in 'autopilot' mode, California official says



Culver City Firefighters
@CC_Firefighters



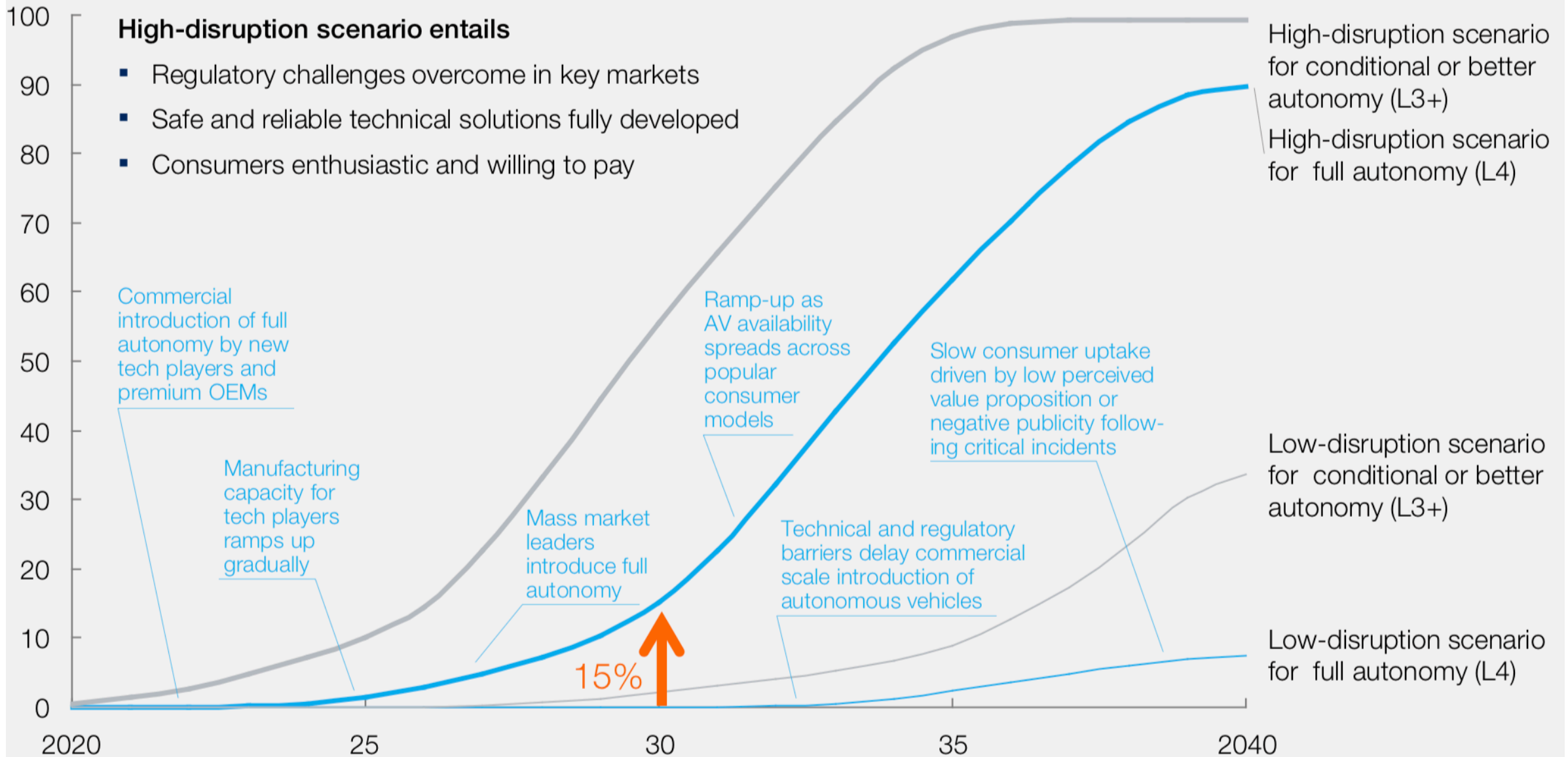
While working a freeway accident this morning, Engine 42 was struck by a [#Tesla](#) traveling at 65 mph. The driver reports the vehicle was on autopilot. Amazingly there were no injuries! Please stay alert while driving! [#abc7eyewitness](#) [#ktla](#) [#CulverCity](#) [#distracteddriving](#)

8:57 PM - Jan 22, 2018 · Irvine, CA

♡ 343 💬 478 people are talking about this

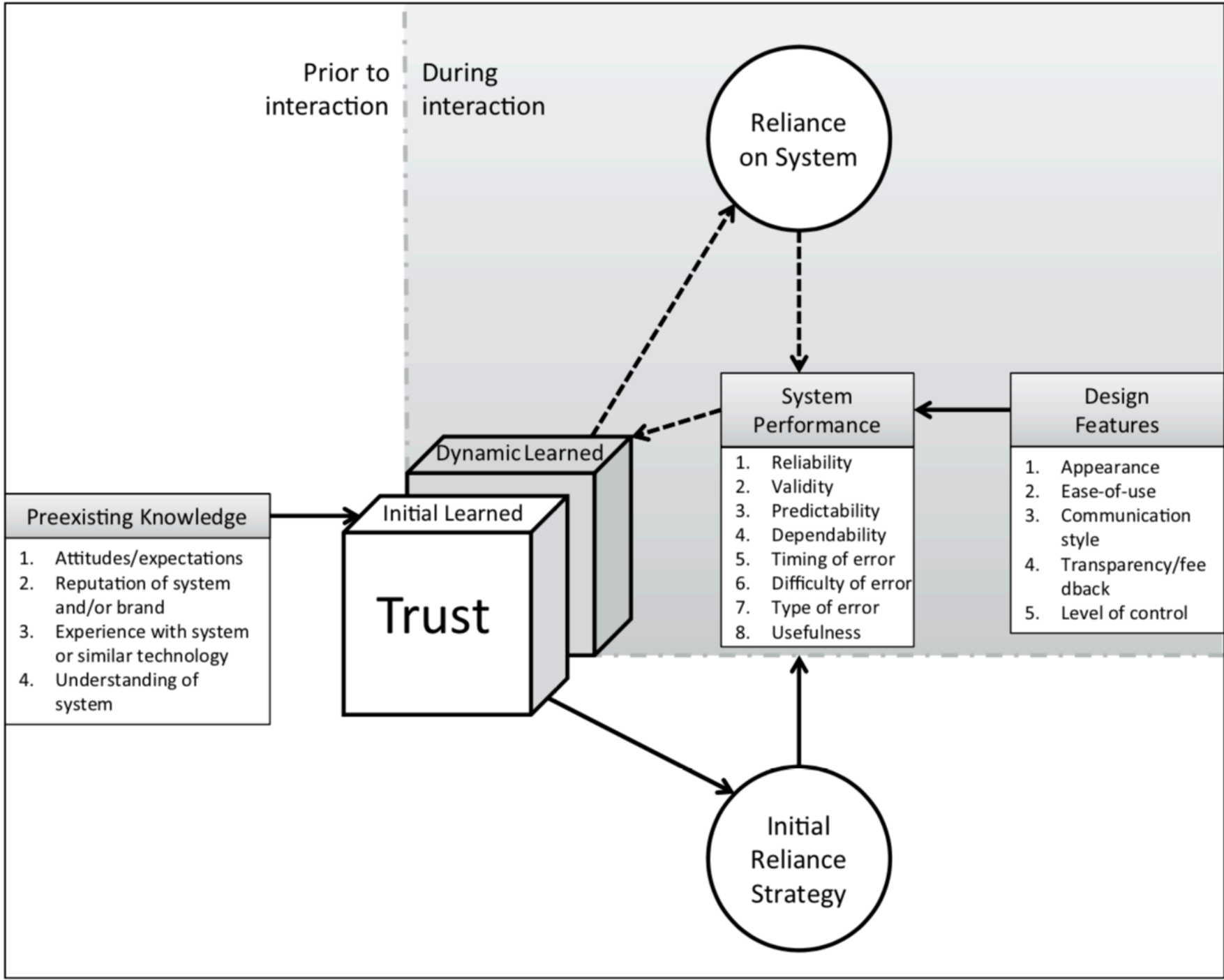
New vehicle market share of fully autonomous vehicles

Percent

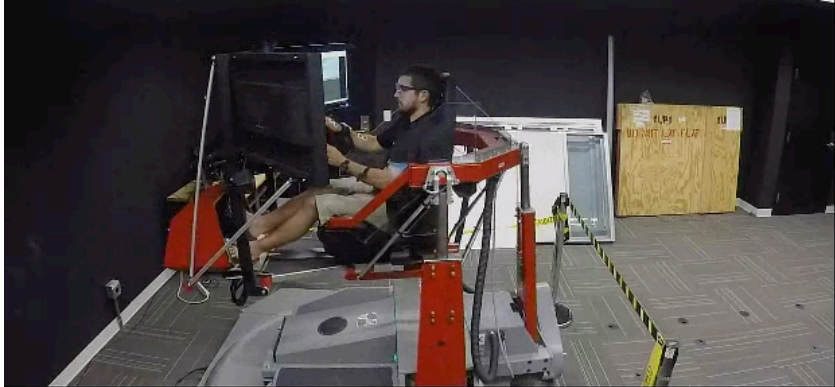




Trust in your self-driving car?



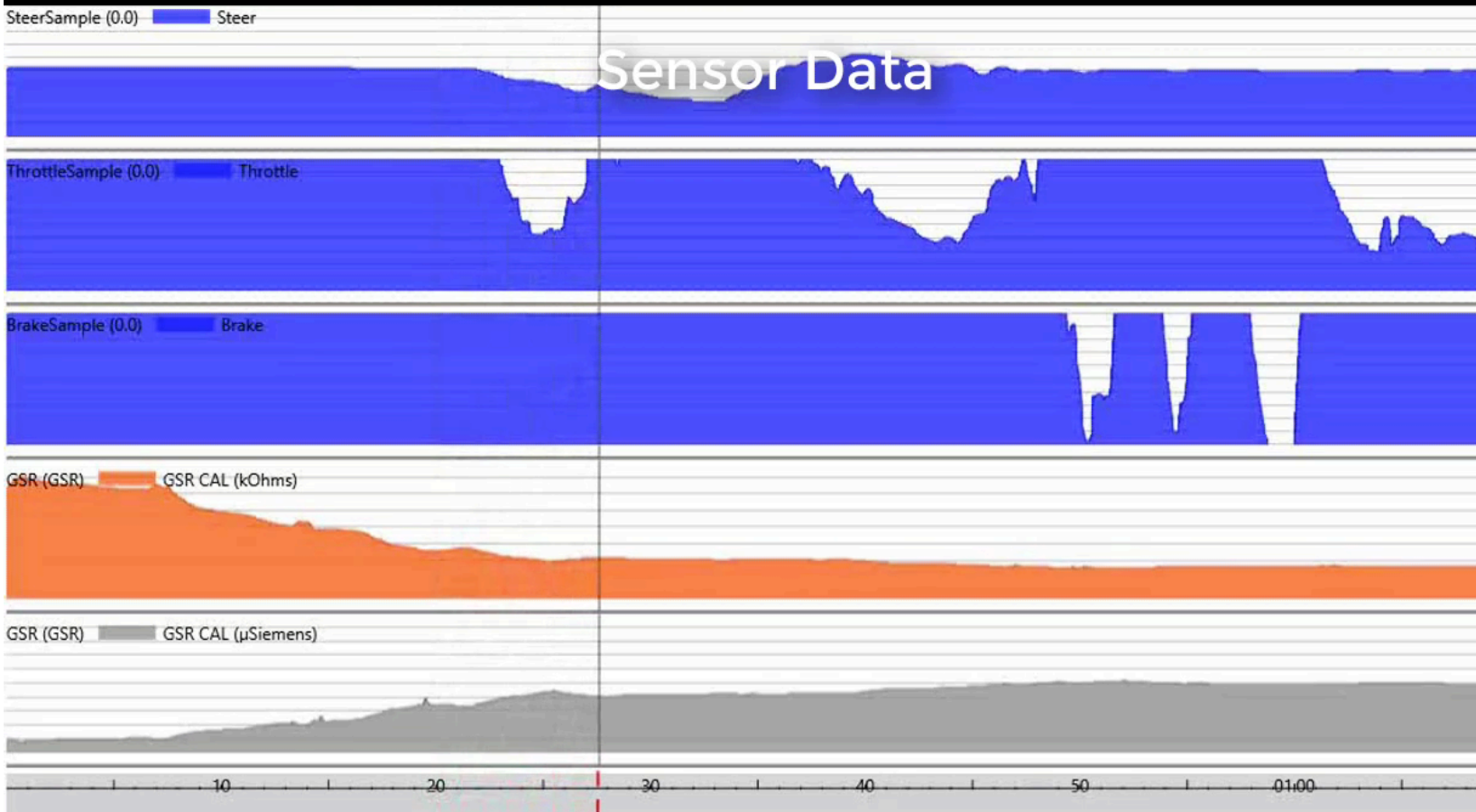
Environmental Camera



Eye-Tracker



Respondent



Stimulus: Tobii Glasses 2 Scene

Exposure time: 02:03



Forums

Does Autopilot get to close to semi trucks when passing?

Submitted by **Dofpic** on April 22, 2016

I have noticed when I am passing a semi on either side while on Auto pilot my MS gets awfully close to the semi trailer. I do not notice this with other vehicles. But with Semis my MS almost moves closer to the trailer. One could almost reach out of the window and touch the trailer. Has anyone else noticed this? Otherwise it works great in just about every other situation.

AIMc | April 22, 2016

This has been a *slight* issue from some. It appears to be in bright sunlight when the TT casts a shadow on the lane lines. That has been mine, and others, experience.

TaoJones | April 22, 2016

It's been a significant issue for me. I prefer to drift left when passing semis and to drift right when oncoming traffic approaches. Both movements of maybe a foot or so increase the margin of safety

REGISTER

LOGIN

BACK TO TESLA MODEL S

JANUARY 2, 2017

Tesla's new Autopilot update detected and displayed stop signs, but it didn't act on them

Fred Lambert - Jan. 2nd 2017 7:35 pm ET [@FredericLambert](#)



Scenario: passing trucks



Scenario: stop sign



Scenario: passing bicyclists



Scenario: wall



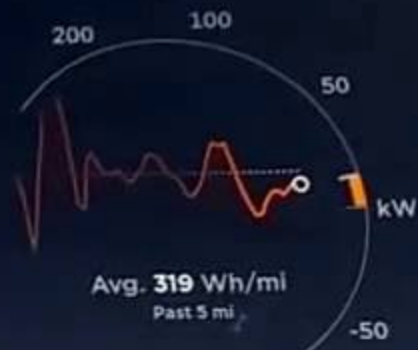


MAX
75

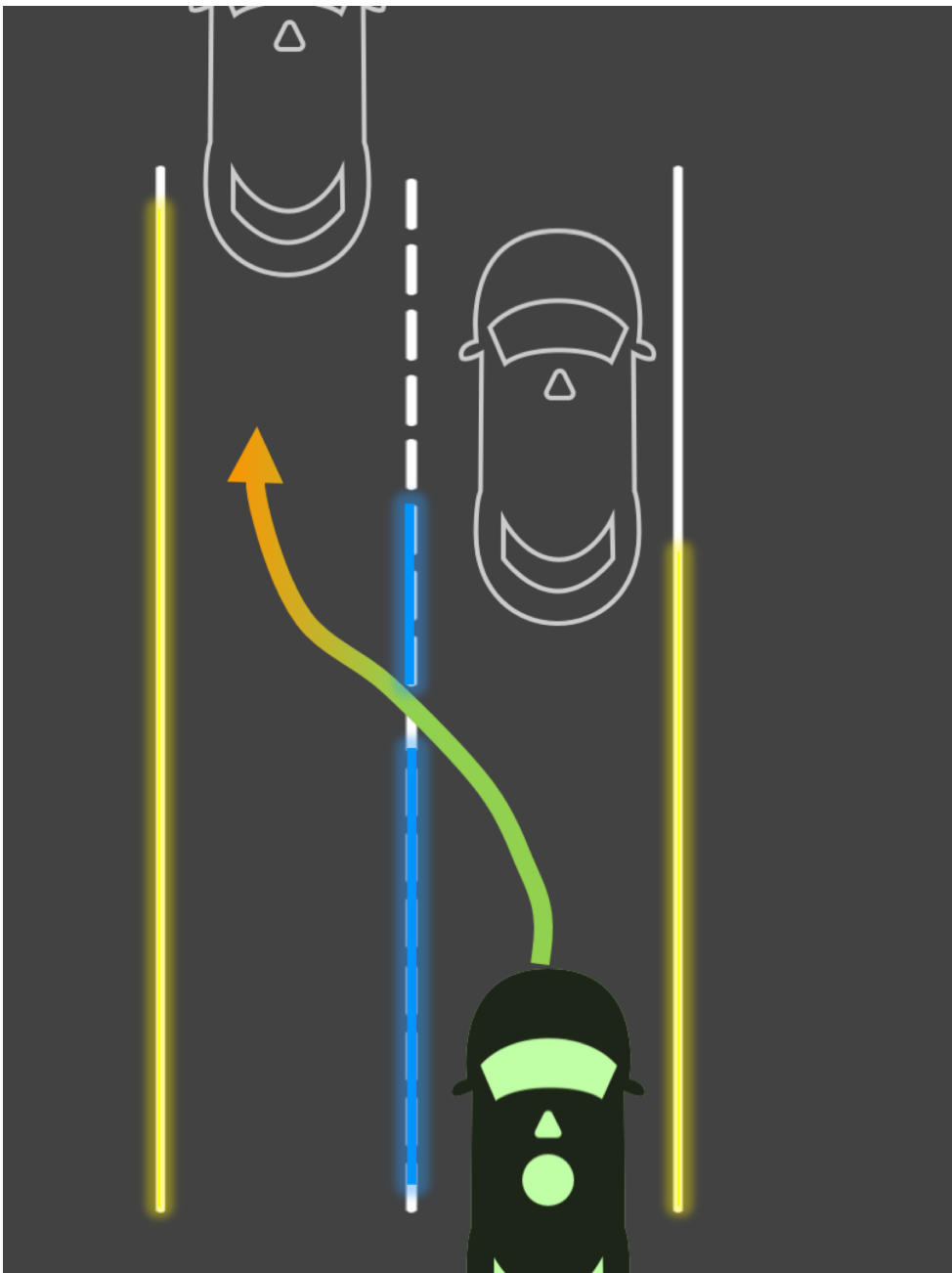
61
mph



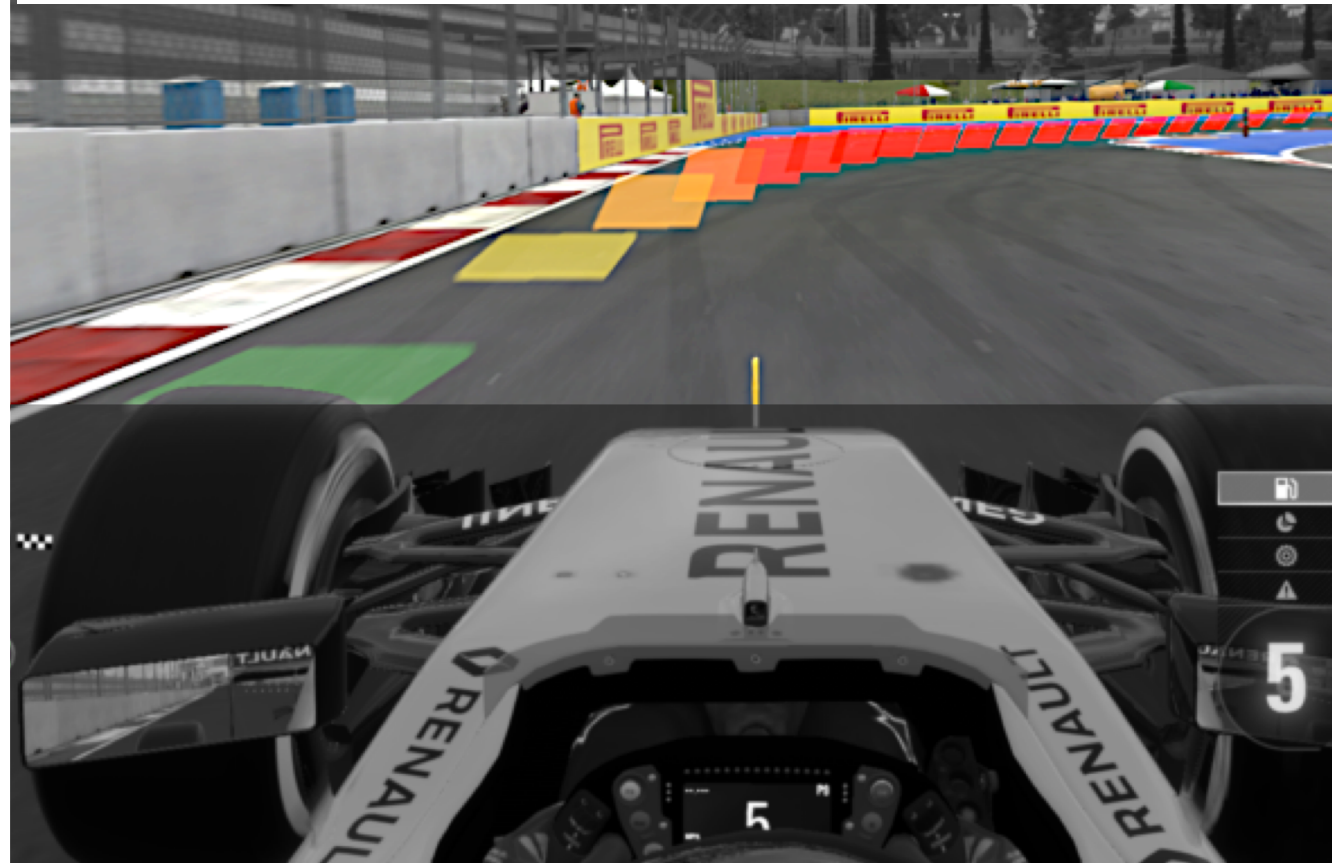
SPEED
LIMIT
70

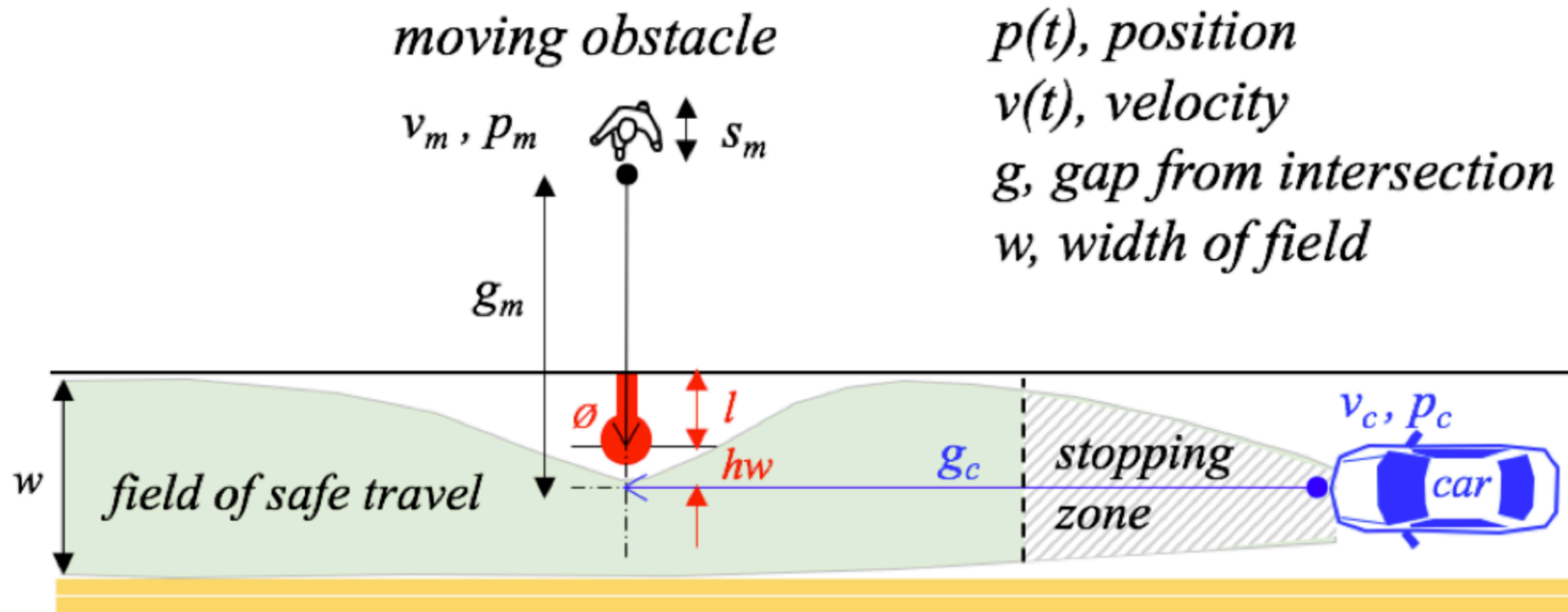


8:13 AM P R N D



Inspired from gaming design. **On the right**, the optimal race line is projected in front of the car to assist the user when to accelerate and brake. **On the left**, we invert this process and **project the desired trajectory of the car and color code it to show the intended actions of the autonomous vehicle**





“Driving is predominantly a perceptual task...and the analysis has to be carried out on a perceptual level...The **Field of Safe Travel** consists of the field of possible paths which the car may take unimpeded” (Gibson & Crooks, 1938)

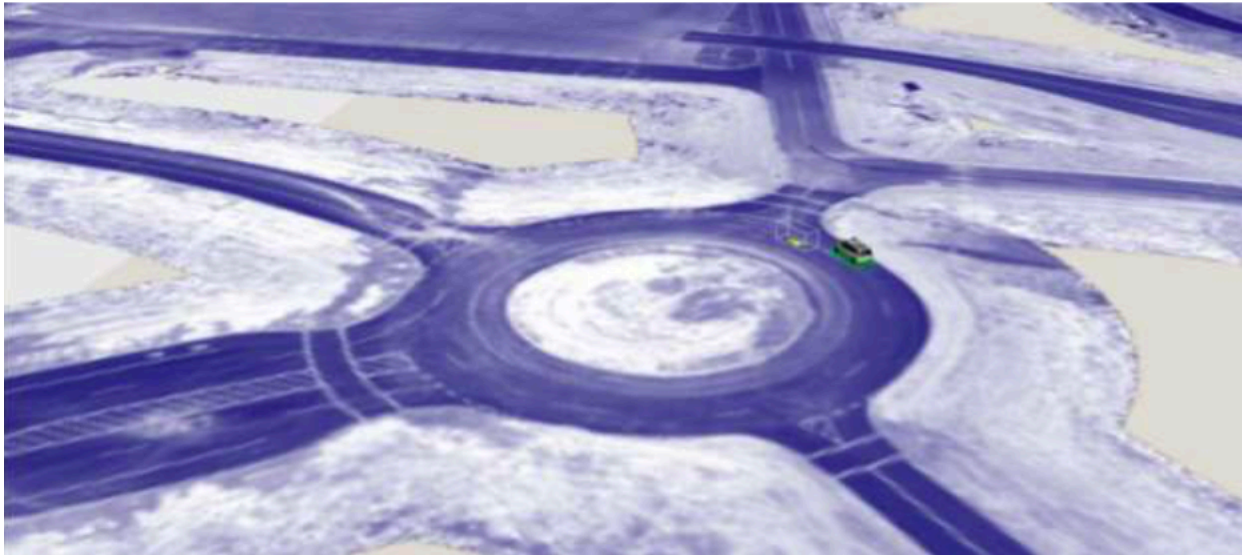
Waymo might *simulate* driving down a particularly *tricky road* hundreds of thousands of times in a single day.

They now drive *8 million miles per day* in the virtual world. In 2016, they logged *2.5 billion virtual miles versus a little over 3 million miles* by Google's self-driving cars that run on public roads.

'Carcraft' is Waymo's virtual world for autonomous vehicle testing

Yup, it's named after 'World of Warcraft.'

* Carcraft, Waymo's simulation building software



* Source: The Atlantic, *Inside Waymo's Secret World for Training Self-Driving Cars* (2017 Aug)

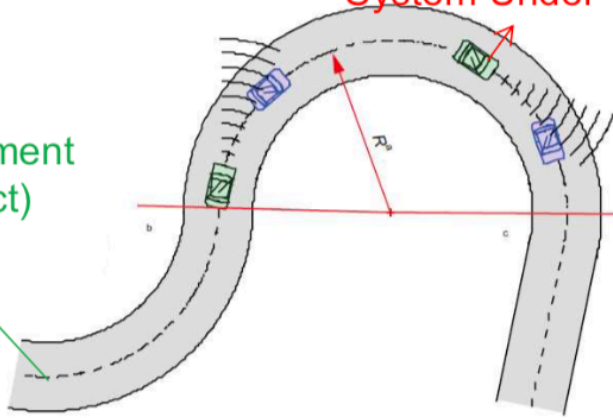
Characteristics of the Road Environment

Geometric aspects

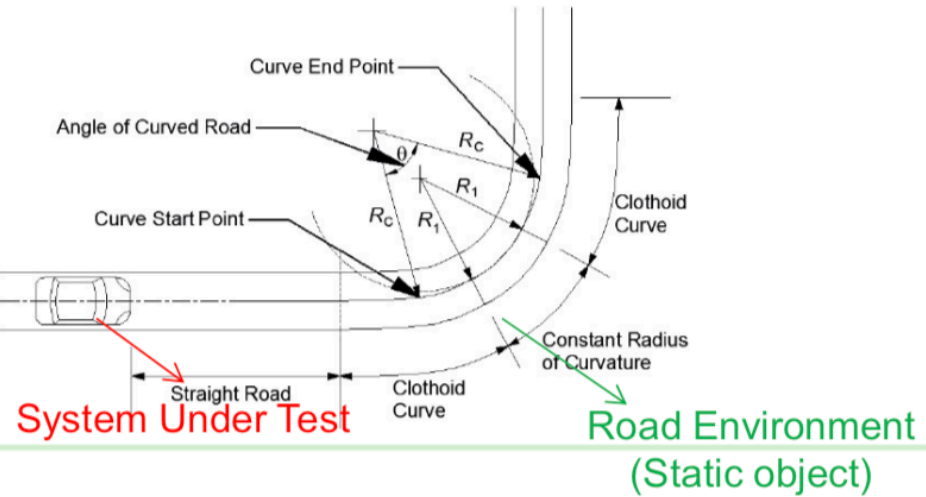
ISO 15622 Adaptive cruise control systems

System Under Test

Road Environment
(Static object)



ISO 11067 Curve speed warning systems

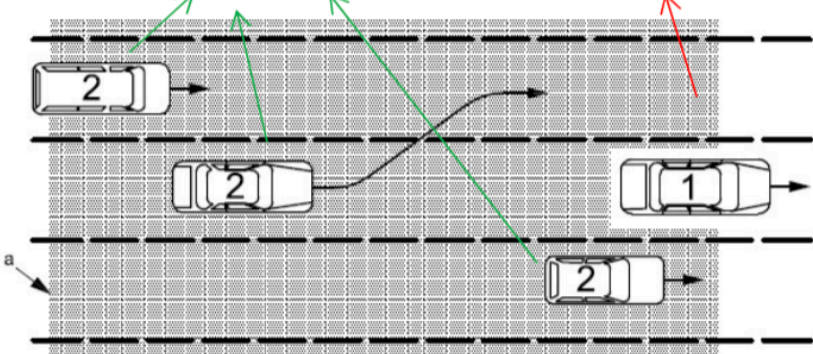


Behavioral aspects

ISO 17387 Lane change decision aid systems

Road Environment
(Dynamic object)

System Under Test



EURO NCAP Test

Road Environment
(Dynamic Object)

System Under Test



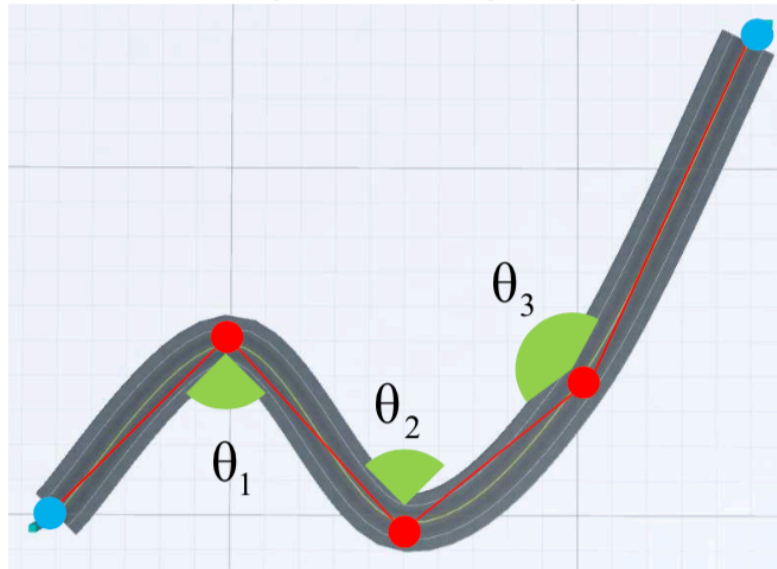
A Path Specification

Definition: A Path Specification

A path specification S^p is a tuple of $\langle A, N, T, D \rangle$

- A : the area where an object may stay
- N : the min/max number of directional changes of an object
- T : the min/max degree of each directional change
- D : the min/max distance of any successive directional change

Example: Curvy Road
(Static Object)



A path
specification S^p

$$N = [2, 5]$$

$$T = [45^\circ, 170^\circ]$$

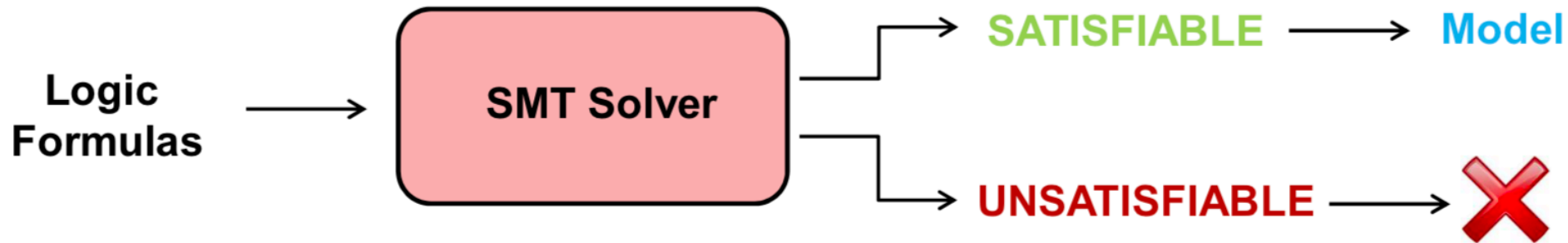
$$D = [50 \text{ m}, 150 \text{ m}]$$

Example: Pedestrians
(Dynamic Object)



Satisfiability Modulo Theories (SMT) Solver

- A formula is **satisfiable** if it has an interpretation that makes it *logically true*
 - The interpretation is a **model**
- A formula is **unsatisfiable** if it does not have any model



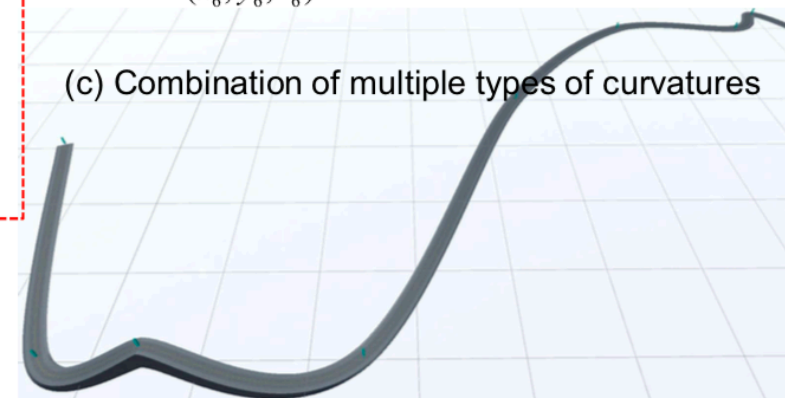
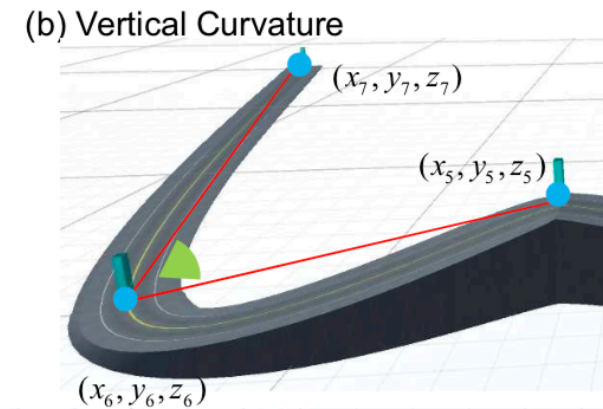
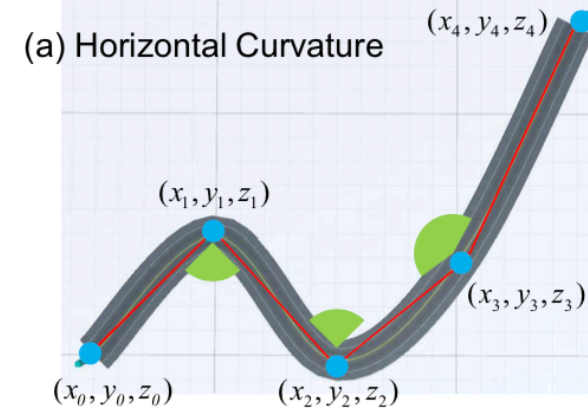
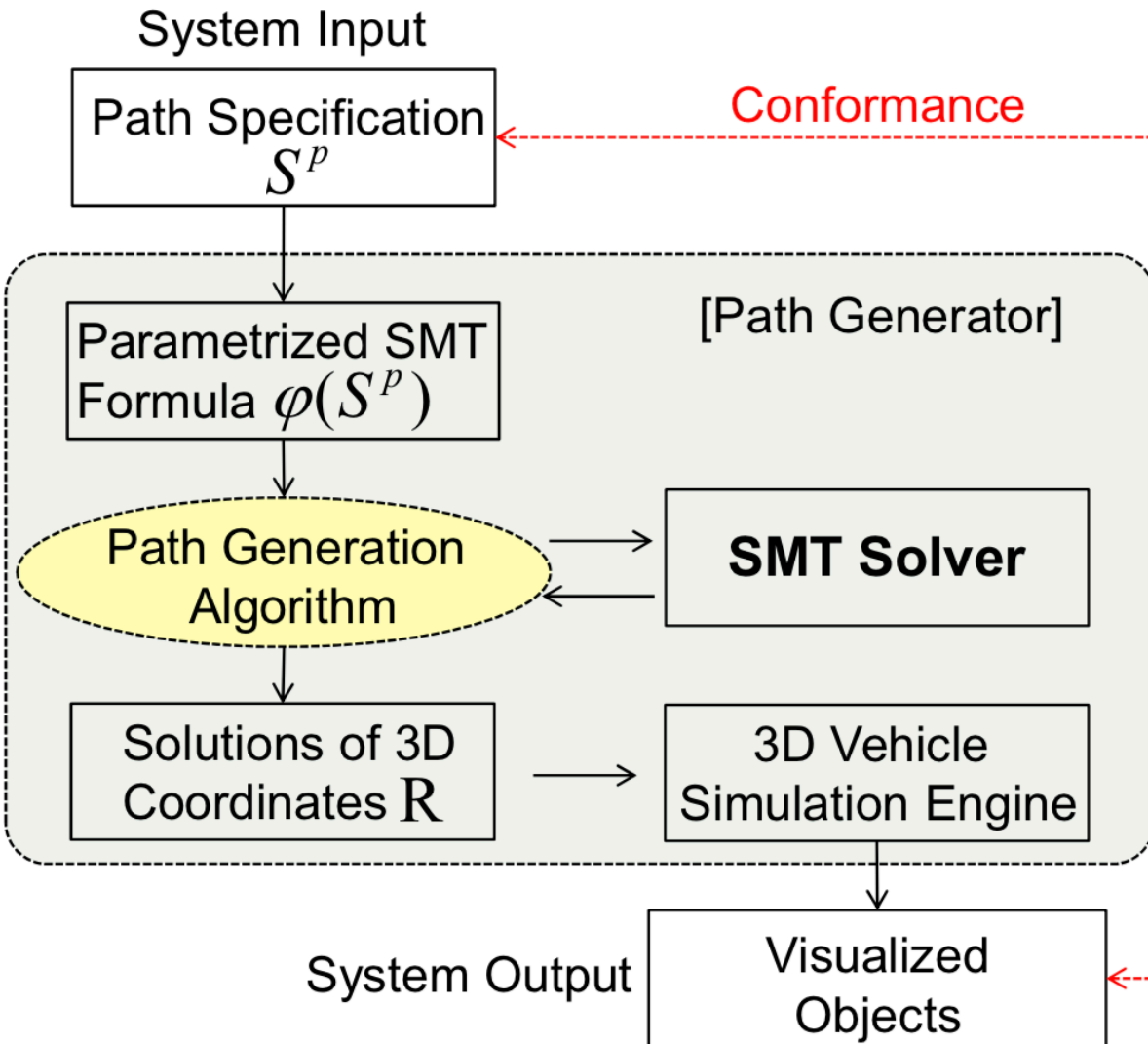
(Example: Propositional Logic)

$x \geq 0 \wedge x \leq 2 \wedge y \geq 1 \wedge y \leq 3 \wedge (y - x) = 3$ \longrightarrow **SATISFIABLE** \longrightarrow **Model** $[x = 0, y = 3]$

$x \geq 0 \wedge x \leq 2 \wedge y \geq 1 \wedge y \leq 3 \wedge (y - x) = 4$ \longrightarrow **UNSATISFIABLE** \longrightarrow **X**

┌
└
Propositional variables

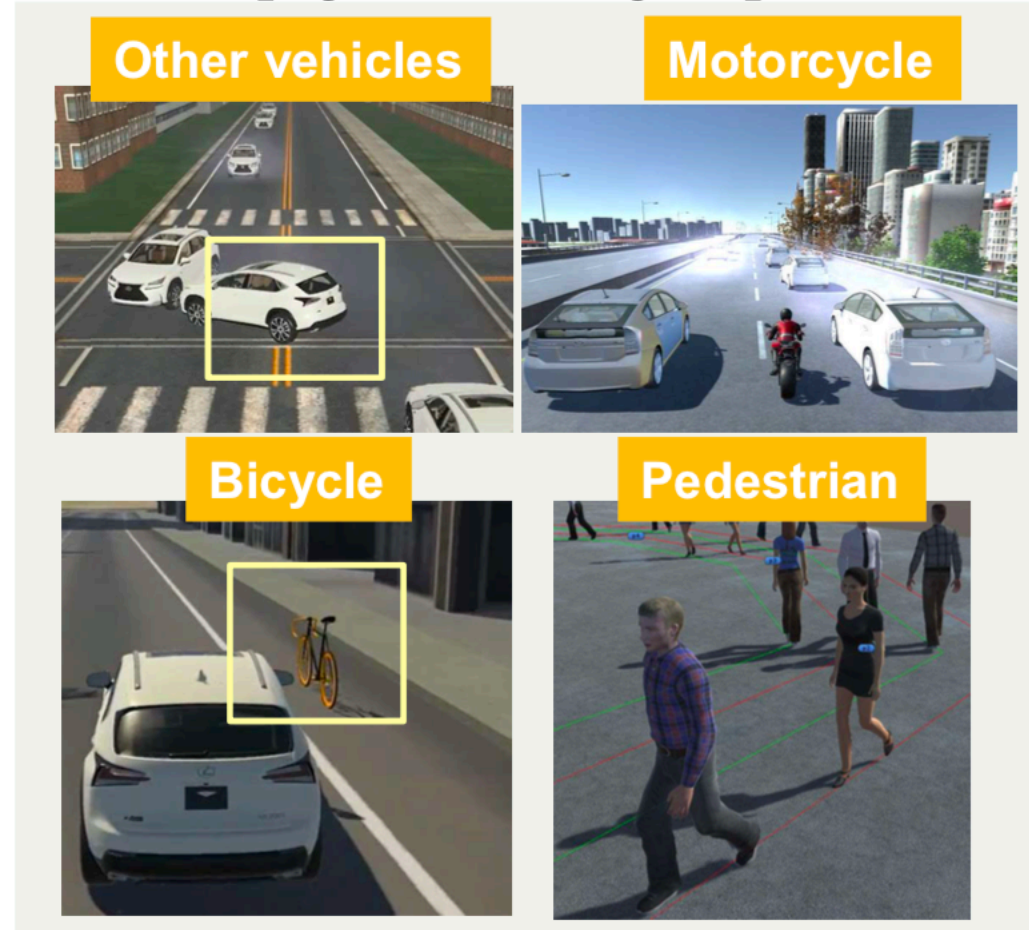
Approach Overview



[Static object]



[Dynamic object]



Challenge: How to characterize the behavior of dynamic objects (e.g., pedestrian)?

Concluding remarks

- New challenges for verification and validation
- Certification for regulatory approval
- Multi-disciplinary research