

# Implications of Automated Vehicle Crash Scenarios

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# Topics



- Brief History
- Levels and taxonomy
- How does it all work
- How does it “not” work
- Current regulatory environment
- Q&A

# History of AV



Tsukuba  
1977



ARGO  
1996-2001



DARPA Urban Challenge  
2007



Prometheus  
1987-1995

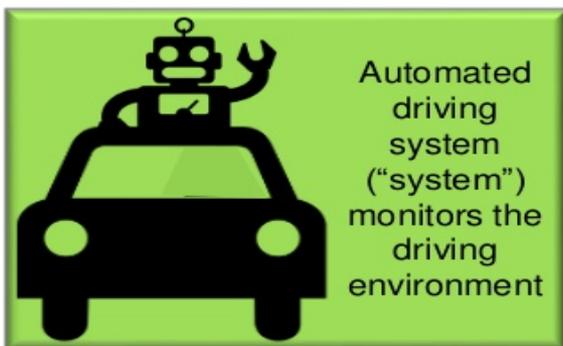


DARPA Grand Challenge  
2004-2005



Google Self-Driving Car  
2010

# SAE Levels

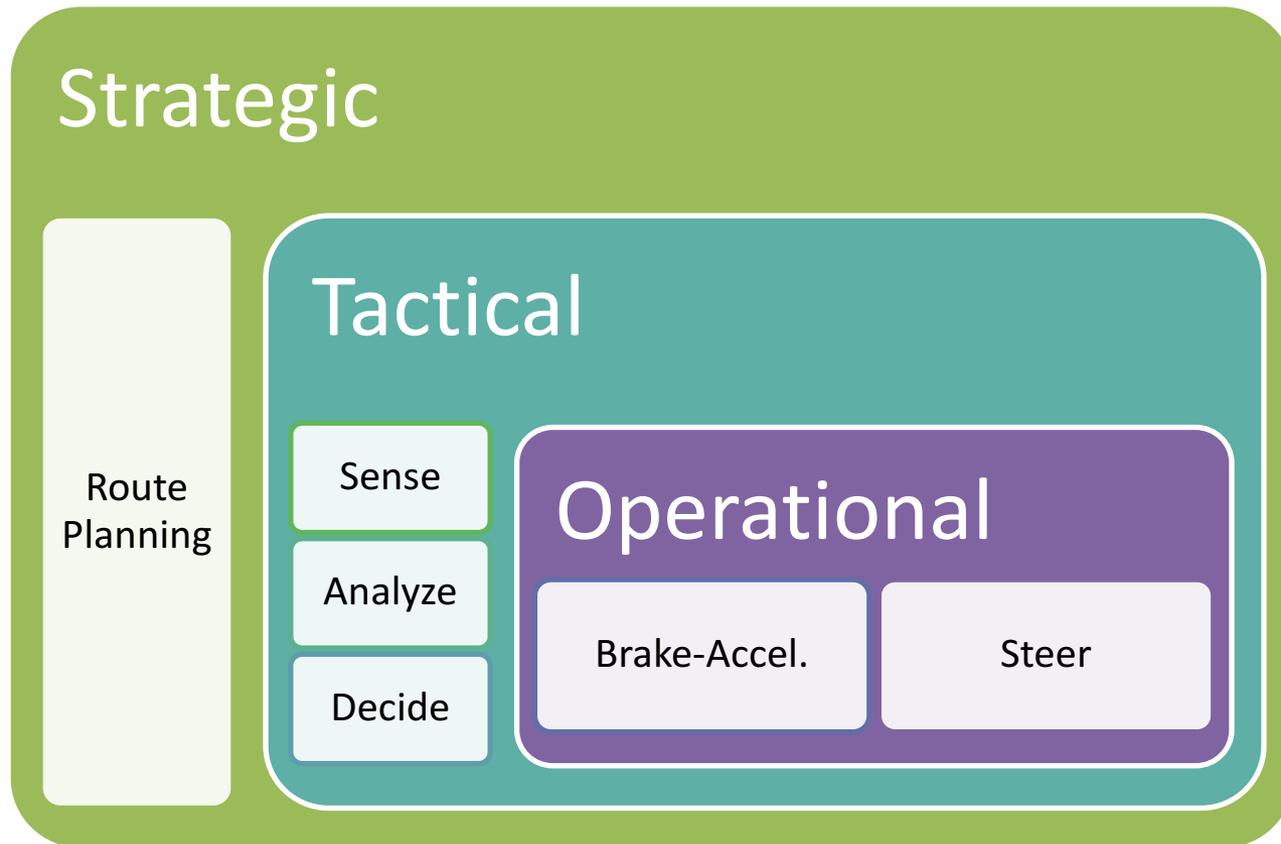


SAE level	Name	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
0	No Automation	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	System	Human driver	Human driver	Some driving modes
3	Conditional Automation	System	System	Human driver	Some driving modes
4	High Automation	System	System	System	Some driving modes
5	Full Automation	System	System	System	All driving modes

# How does it work?



- How does it work?



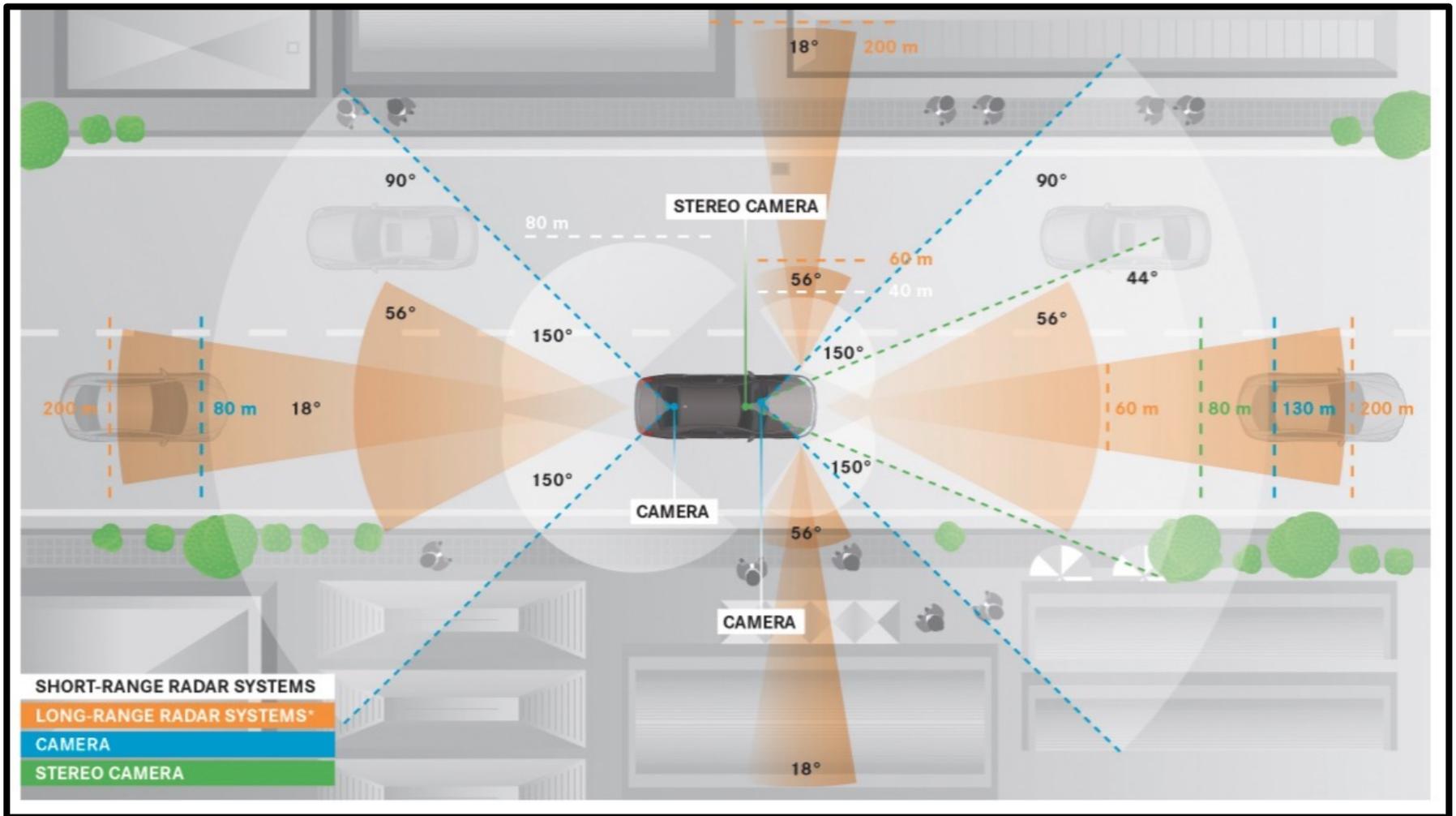
# How does it work?



*We have a brain for one reason and one reason only — and that's to produce adaptable and complex movements*

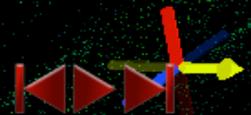
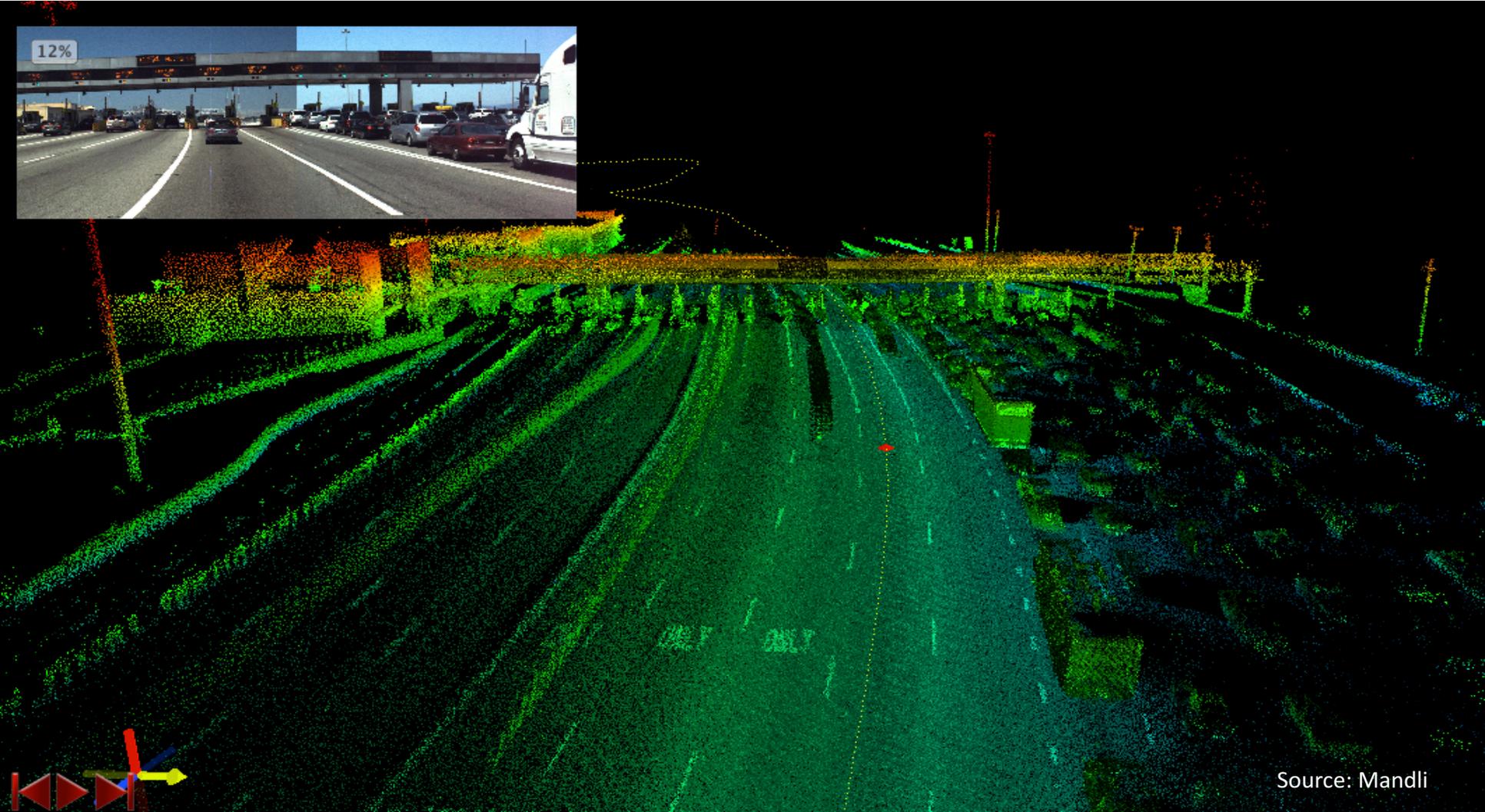
- Daniel Wolpert, Univ. of Cambridge

# How does it work?

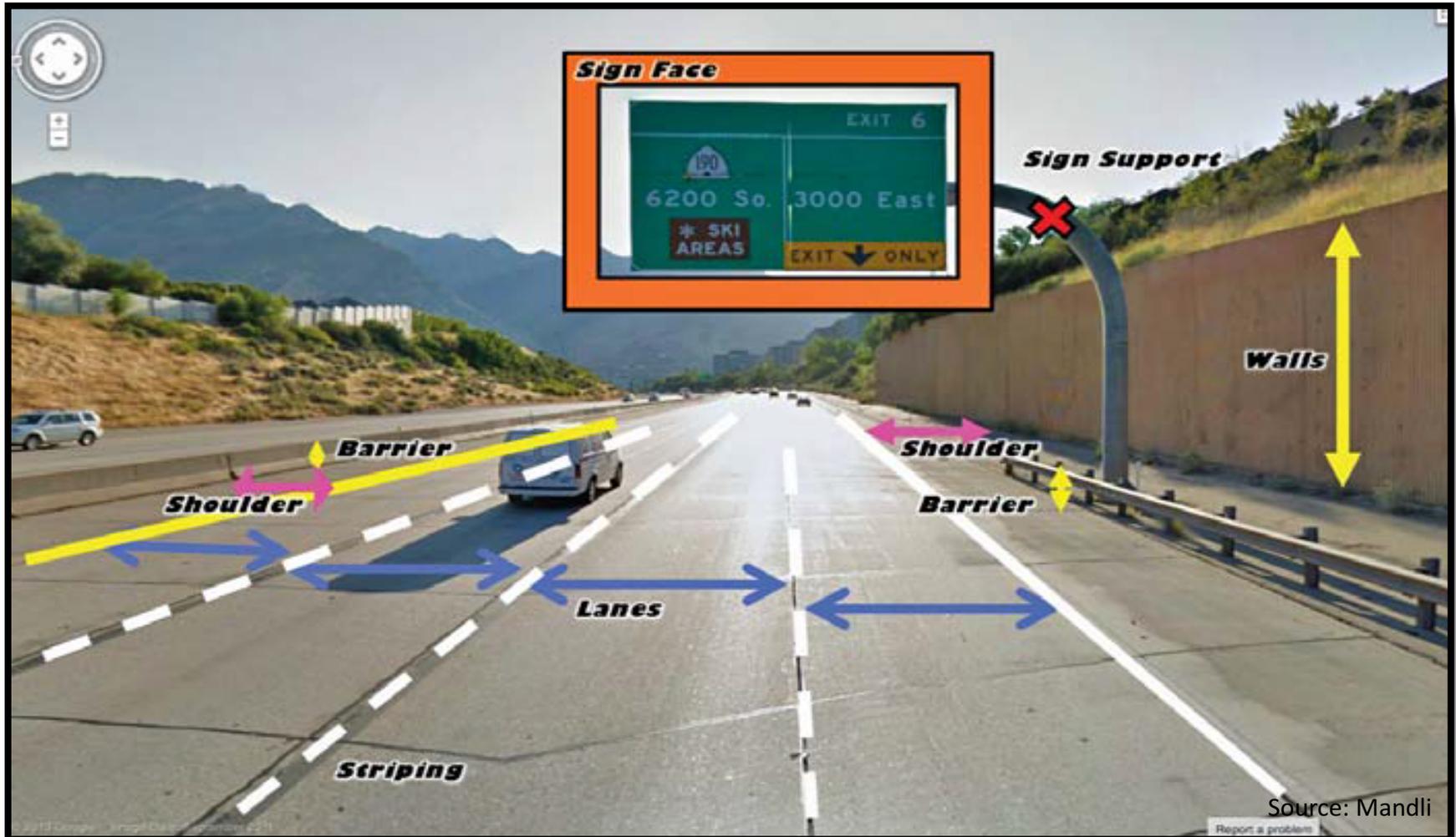


# How does it work?



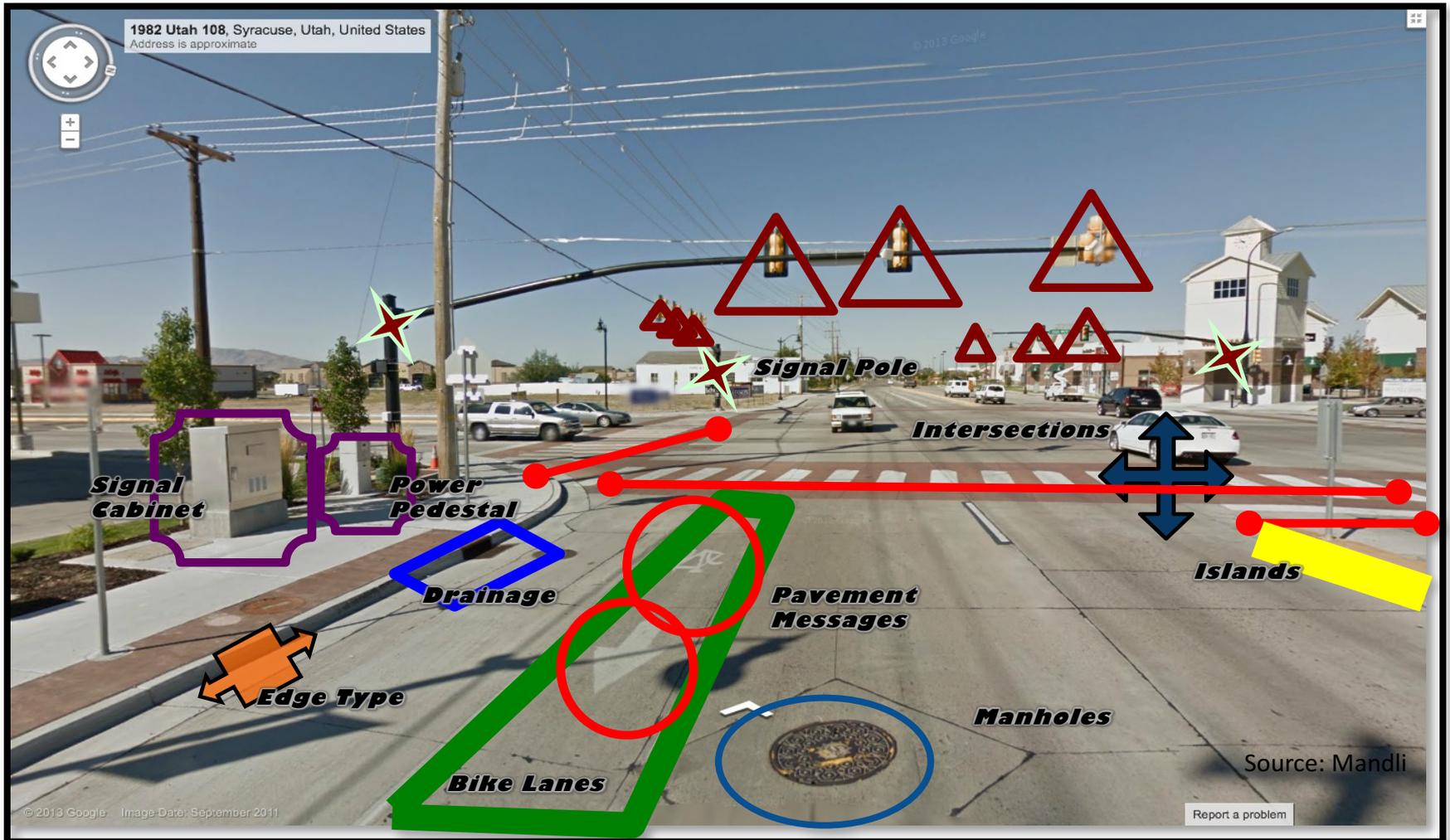


# How does it work?



Source: Mandli

# How does it work?



Source: Mandli

# How does it work?



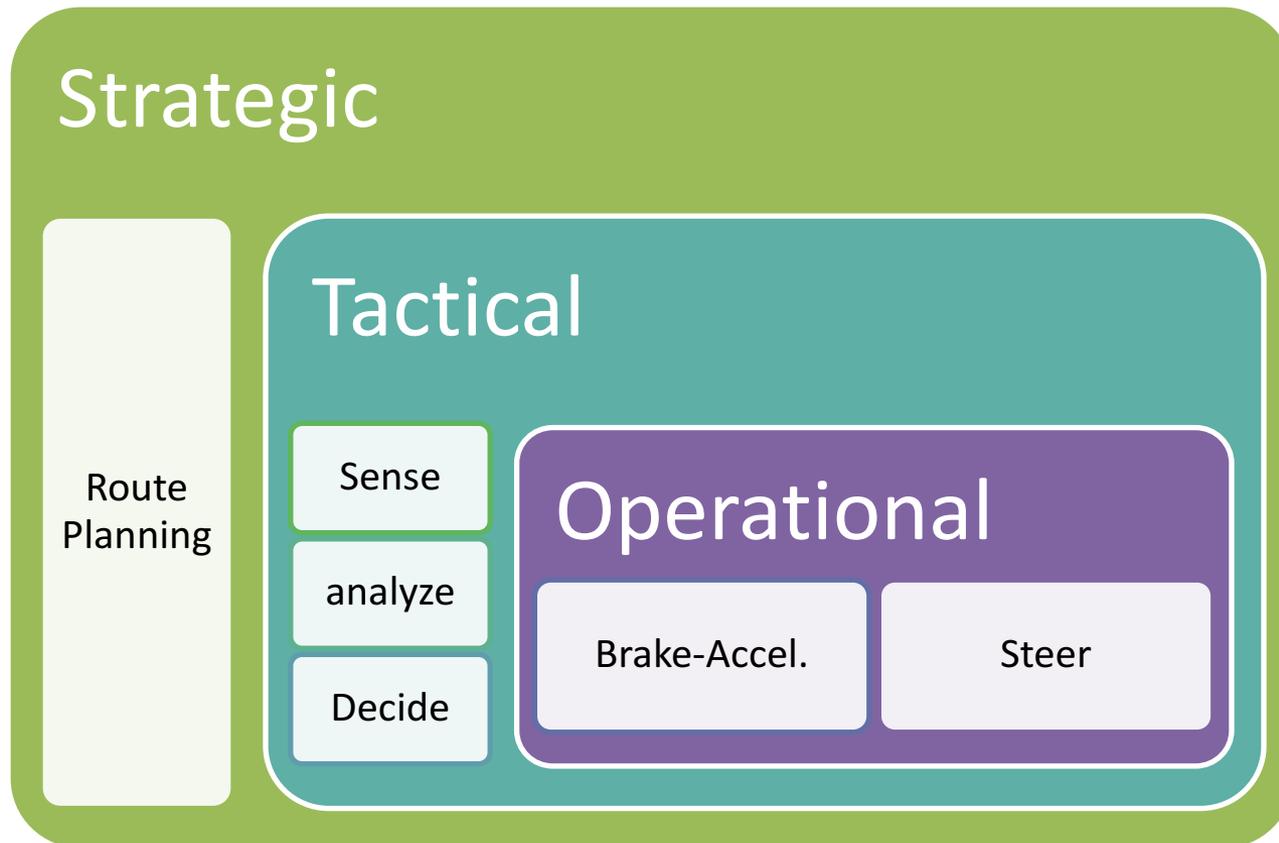
Fused data / mile

	# of Features	Size
Raw Data	-	110GB
Map after feature extraction	~6m	4.7GB
Map after tracking and VocabID	~400k	18MB
Map after Subsampling	~180k	12MB

Approx. 4m miles of roads in US

12MB/mile = ~82TB

# How does it “not” work?



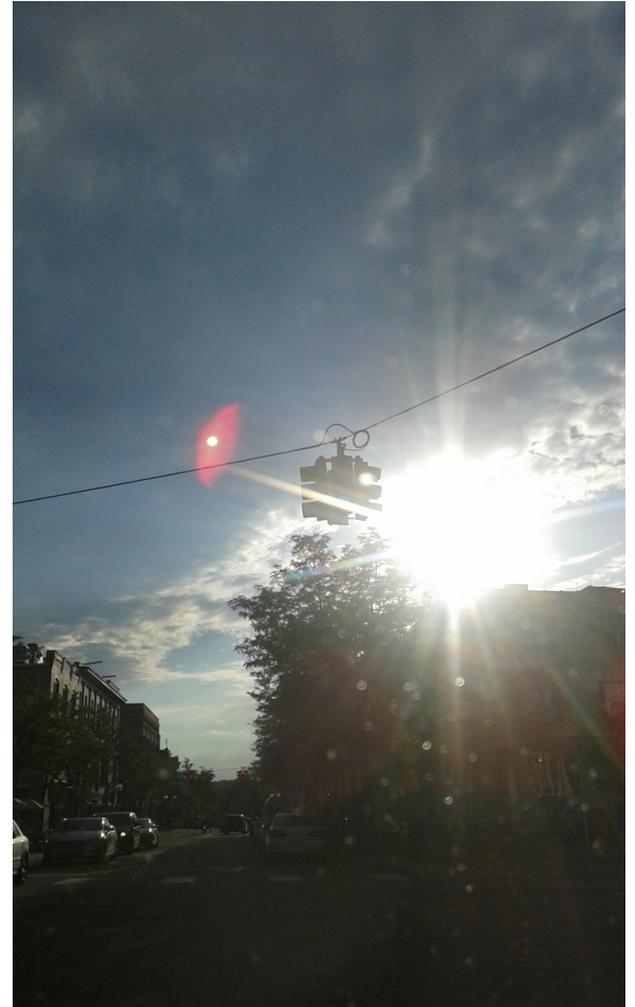
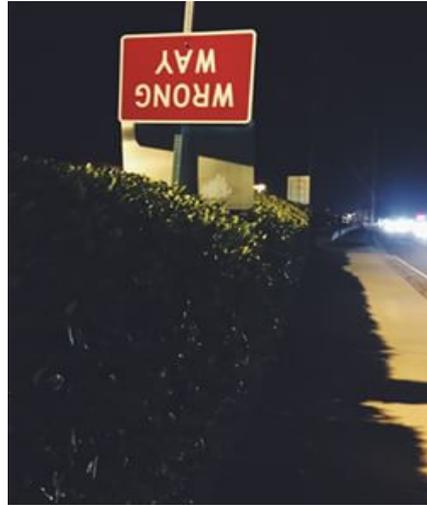
# How does it “not” work?



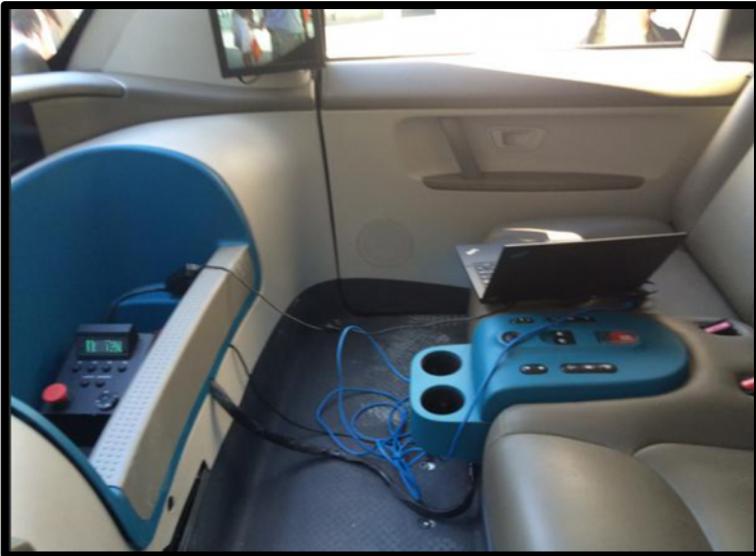
- Possible Failure Modes:

1. Ghost objects
- 2. Electro/mechanical components failure**
3. wrong information
- 4. Unexpected events**
- 5. False driver input/action**
6. ....

# How does it “not” work?

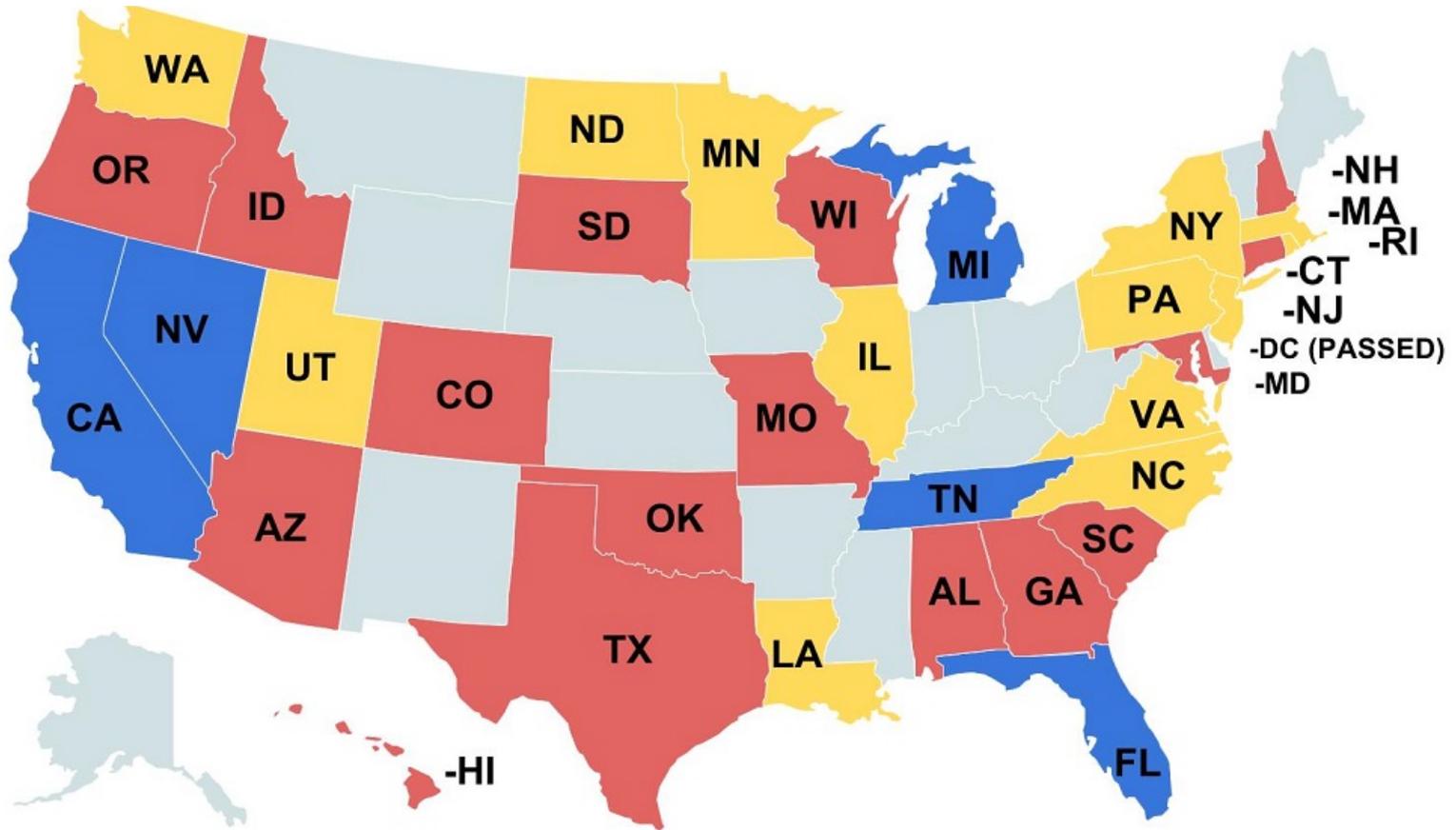


# How does it “not” work?



Source: Washington Post

# Current Regulatory Environment



Current Status

 Passed

 Under Consideration

 Failed

Source: Stanford Univ.

# Current Regulatory Environment: NV



For purposes of this chapter, unless the context otherwise requires, a person shall be deemed the “**operator**” of an autonomous vehicle which is operated in autonomous mode when the person causes the autonomous vehicle to engage, regardless of whether the person is physically present in the vehicle while it is engaged.

“**Autonomous technology**” means technology which is installed on a motor vehicle and which has the capability to drive the motor vehicle without the active control or monitoring of a human operator. The term does not include an active safety system or a system for driver assistance, including, without limitation, a system to provide electronic blind spot detection, crash avoidance, emergency braking, parking assistance, adaptive cruise control, lane keeping assistance, lane departure warning, or traffic jam and queuing assistance, unless any such system, alone or in combination with any other system, enables the vehicle on which the system is installed to be driven without the active control or monitoring of a human operator.

“**Autonomous vehicle**” means a motor vehicle that is equipped with autonomous technology.

# Current Regulatory Environment: CA



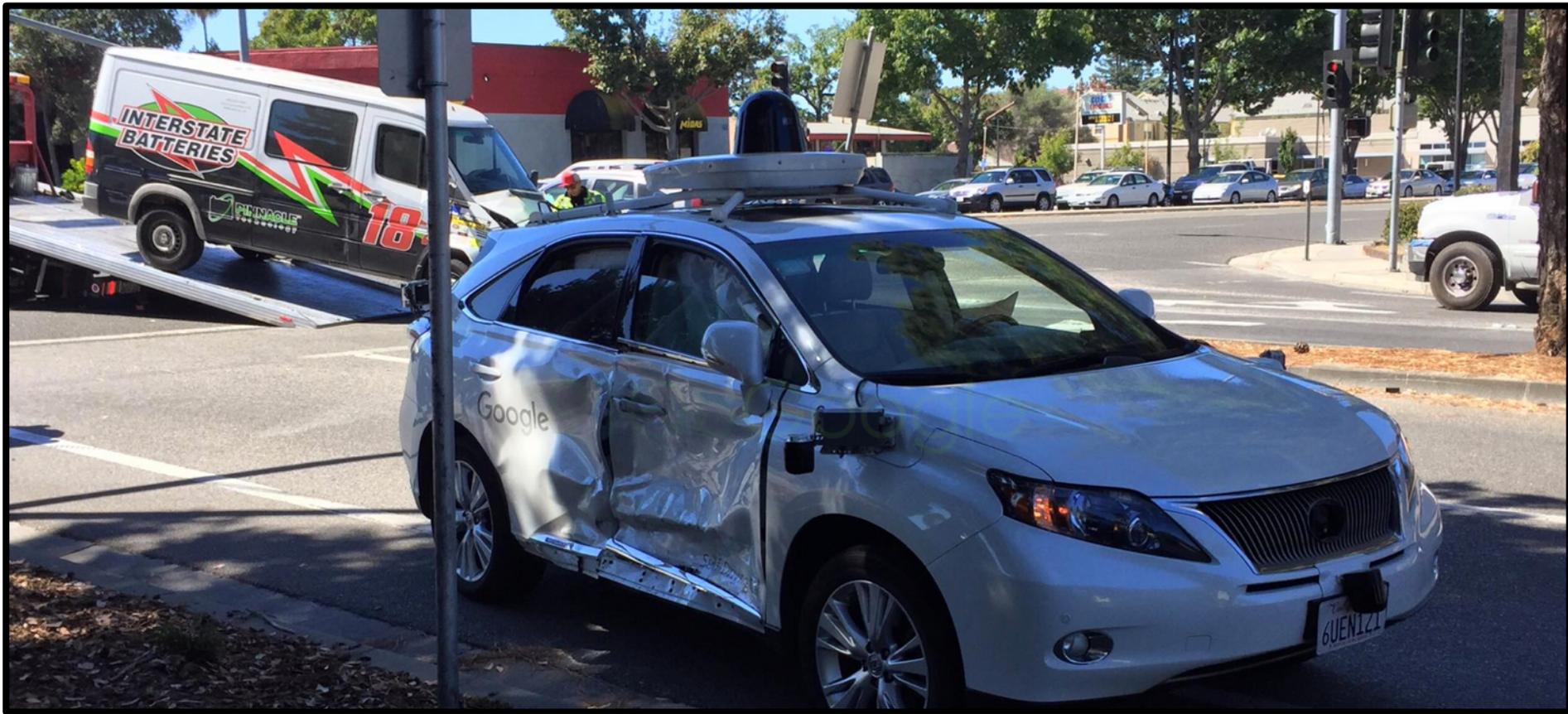
An “**operator**” of an autonomous vehicle is the person who is seated in the driver’s seat, or if there is no person in the driver’s seat, causes the autonomous technology to engage.

“**Autonomous technology**” means technology that has the capability to drive a vehicle without the active physical control or monitoring by a human operator.

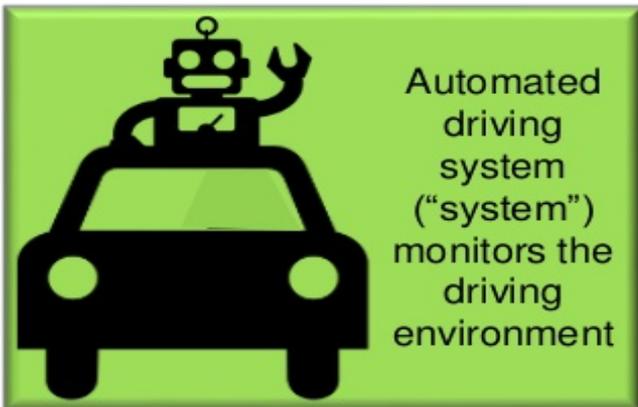
“**Autonomous vehicle**” means any vehicle equipped with autonomous technology that has been integrated into that vehicle.

- An autonomous vehicle does not include a vehicle that is equipped with one or more collision avoidance systems, including, but not limited to, electronic blind spot assistance, automated emergency braking systems, park assist, adaptive cruise control, lane keep assist, lane departure warning, traffic jam and queuing assist, or other similar systems that enhance safety or provide driver assistance, but are not capable, collectively or singularly, of driving t

# Crash Scenarios



Source: 9to5Google



SAE level	Name	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
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# Crash Scenario-1

## Operator in the loop



- Driver/operator is in the control loop is expected to take over of the driving task, if prompted. (SAE Levels 2 and 3)
- An accident is caused due to:
  1. Operators failure to monitor the driving environment and taking proper actions
  2. Operator fails to take over the driving task
  3. **Operator fails to properly engage the system and unable to provide correcting countermeasures**
  4. **System fails to accurately monitor and detect events in surrounding environment**
  5. System fails to act upon the information received.

# Crash Scenario-1

## Operator in the loop



- Level-3 examples ([link](#))

Audi's autonomous cruise control - traffic jam assist

The video player displays four scenes: top-left shows two men in a car with 'FULLY CHARGED Traffic Jam Assist' text; top-right shows a car with red sensor beams; bottom-left shows two cars in a test facility; bottom-right shows a driver's hands on the steering wheel. The player interface includes a progress bar at 3:43 / 3:43, a volume icon, a settings gear, the YouTube logo, and a full-screen icon.

# Crash Scenario-1

## Operator in the loop



Operator fails to properly engage the system and unable to provide correcting countermeasures [\(link\)](#)

Volvo auto brake system fail

The video player interface displays two side-by-side video frames. The left frame shows a man in a black shirt and cap leaning over the hood of a silver Volvo car on a road. The right frame shows a man in a blue shirt standing next to a black Volvo car, with a bridge structure in the background. The video player includes a red progress bar, a refresh icon, a volume icon, a timestamp of 0:32 / 0:32, a settings gear icon, the YouTube logo, and a full-screen icon.

# Crash Scenario-1

## Operator in the loop



System fails to accurately monitor and detect events in surrounding environment

[\(link\)](#)

Volvo S60 Pedestrian Detection System Test

VOLVO V60 VS HUMAN CRASH TEST DUMMIES

2:33 / 2:33

YouTube

The video player displays two side-by-side images. The left image shows a white Volvo V60 with a crash test dummy in the foreground. The right image shows a dark Volvo S60 with several blue crash test dummies in the foreground. The video player interface includes a red progress bar, a play button, a volume icon, a settings gear, and the YouTube logo.

# Crash Scenario-2

## Operator NOT in the loop



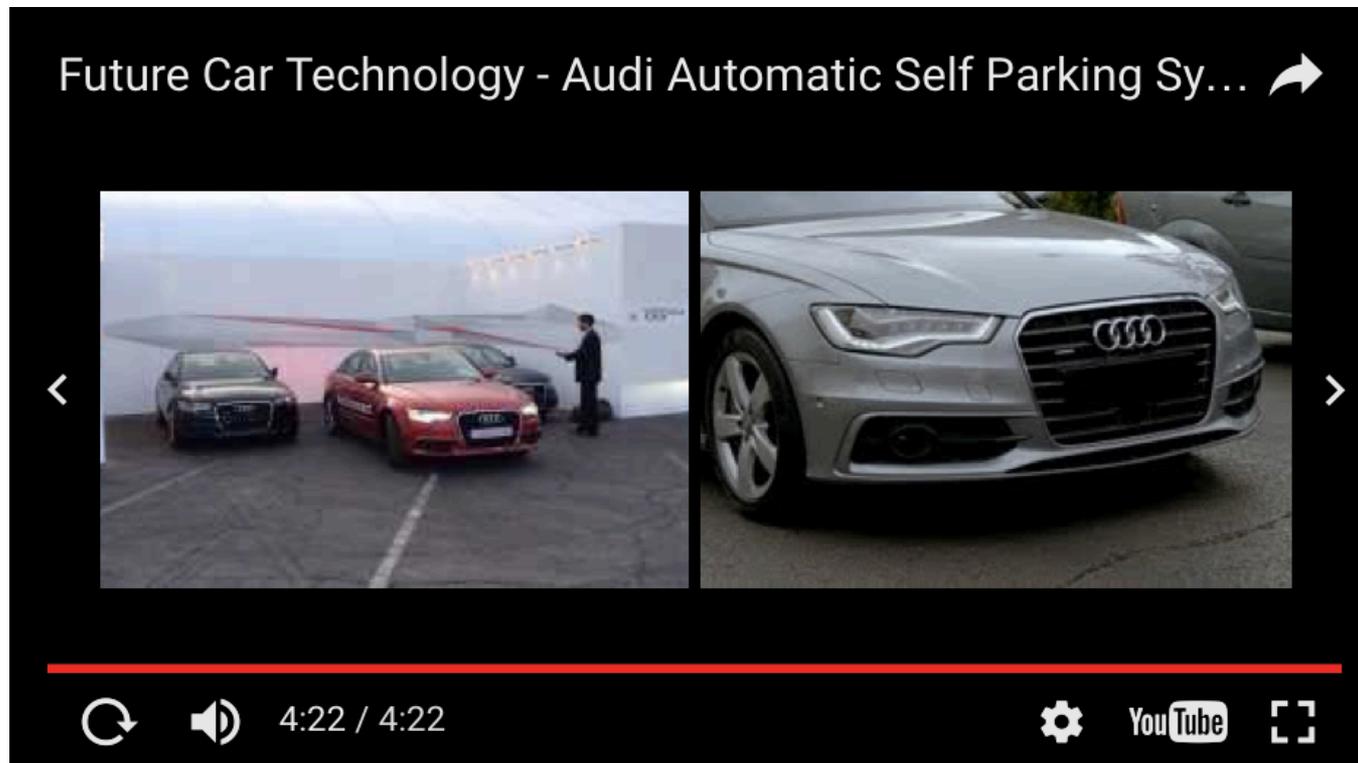
- Driver/operator is NOT in the control loop and the system is expected to perform all tasks related to driving task. (SAE Levels 4 and 5)
- An accident is caused due to:
  1. System fails to accurately monitor and detect events in surrounding environment
  2. System fails to act upon the information received.

# Crash Scenario-2

## Operator NOT in the loop



- Level – 4 example ([link](#))



# Crash Scenario-2

## Operator NOT in the loop



- Level – 5 example ([link](#))

NAVLY : Première desserte de transport public par véhi... 



< >

  1:28 / 1:28  YouTube 

# Crash Scenario-2

## Operator NOT in the loop



System fails to accurately monitor and detect events in surrounding environment





```
int use_track = 0, use_rects = 1;  
//     if (t->vmag > 4)  
//         use_rects = 0;
```

```
if (t->vmag > 3.0 && t->maturity > 8)
```

```
    use_track = 1;
```

```
double MAX_DIM = 10;
```

```
if (t->box.size[0] > MAX_DIM || t->box.size[1]  
> MAX_DIM)
```

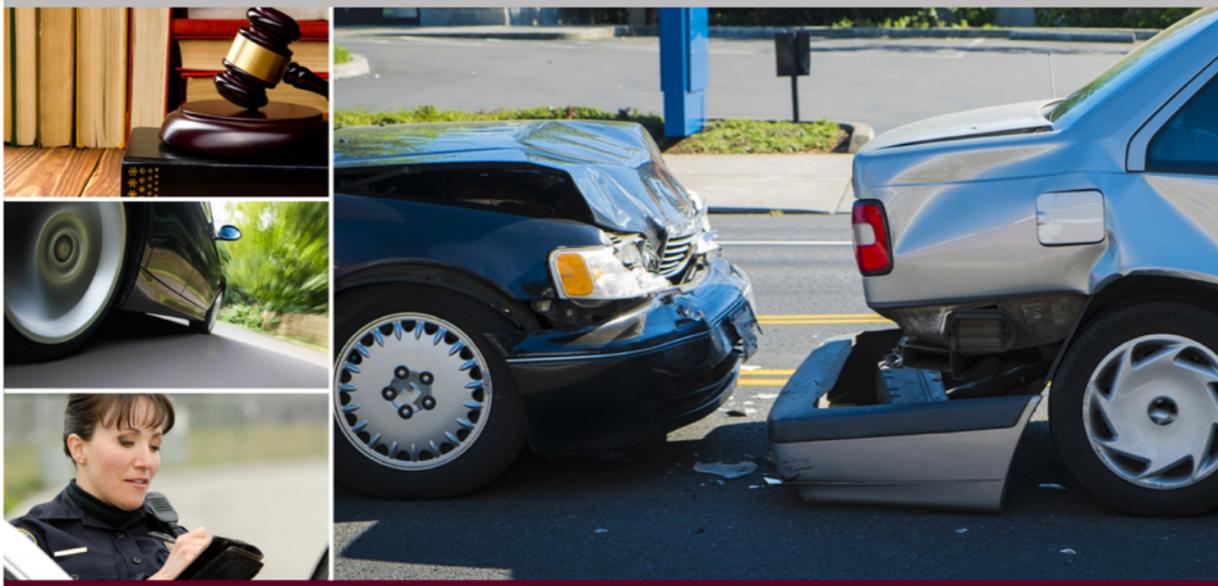
```
    use_track = 0;
```

# Available Data



- Google car rear-ended ([link](#))

# Resources



## Revolutionizing Our Roadways Implications of Automated Vehicle Crash Scenarios

- <http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/PRC-15-46-F.pdf>

# Resources



## Federal Automated Vehicles Policy

*Accelerating the Next Revolution  
In Roadway Safety*



September 2016

<https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf>