Autonomous Systems
- Challenges and Opportunities for Standardization

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Example Autonomous Systems

Scope of the Talk

- Definition & Framework
- Specifying Functionality and Rules
- Safety-Related Autonomous Systems
- Testing and Incident Reporting
- Ethics
- Conclusions & Questions

Defining ‘Autonomous System’ (1 of 2)

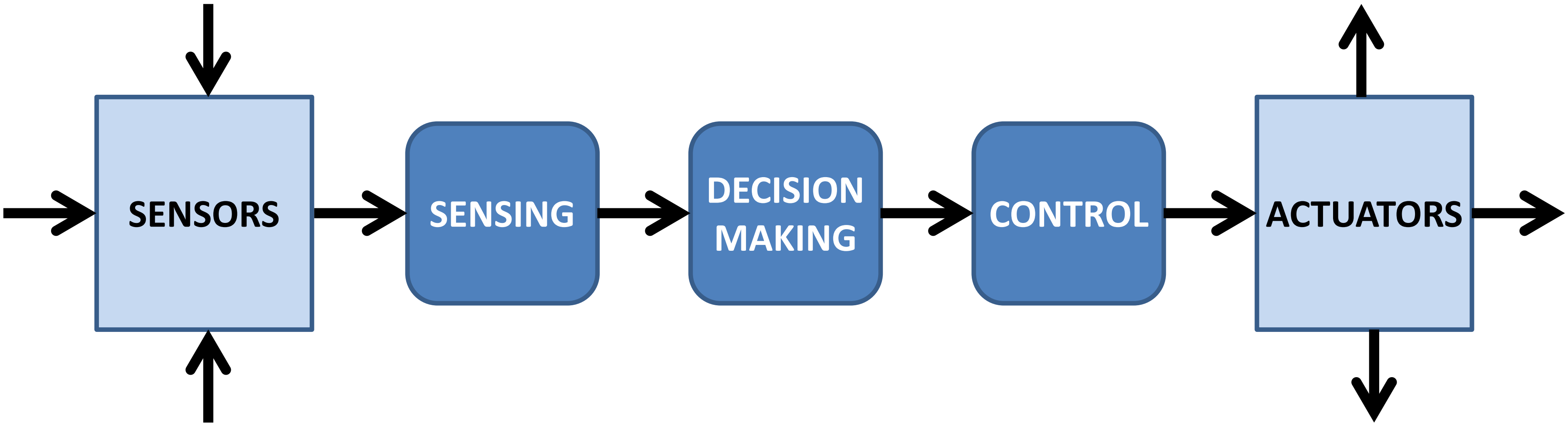
- smart or intelligent system, such as an autonomous vehicle or a smart city, that is aware of, and interacts with, its environment
- ~~‘smart’ or~~ intelligent system~~, such as an autonomous vehicle or a smart city~~, that is aware of, and interacts with, its environment to independently achieve delegated objectives
- intelligent system that is aware of, and interacts with, its environment to ~~independently~~ achieve ~~delegated~~ given objectives without human oversight
- intelligent system that is aware of, and interacts with, its environment to achieve given objectives without human ~~oversight~~ control
- ~~intelligent~~ system that is aware of, and interacts with, its environment and changes its behaviour based on past experience to achieve given objectives without human control
- system that perceives ~~is aware of, and interacts with,~~ its environment and changes its behaviour based on past experience to achieve given objectives without human control

Defining ‘Autonomous System’ (2 of 2)

- system that perceives ~~is aware of, and interacts with,~~ its environment and changes its behaviour based on past experience to achieve given objectives without human control
- system that ~~perceives its environment and~~ changes its behaviour based on past experience and the current situation to achieve given objectives without human control
- system that changes its behaviour based on its experiences ~~on past experience~~ and the current situation to achieve given objectives without human control
- system that ~~changes its behaviour based on its experiences and the current situation to achieve given objectives without~~ works independent of human control
- system that works independent of human control
- system that works for sustained periods independent of human control

Challenge/Opportunity 1:
Definition of autonomous systems

ISO SC7 Generic Functions



Autonomous System Function Options

<table>
<tr><th>ISO SC7</th><th>NIAG</th><th>E & K</th><th>P, S & W</th></tr>
<tr><td rowspan="2">Sensing</td><td>Observe</td><td rowspan="2">Monitoring</td><td>Information Acquisition</td></tr>
<tr><td rowspan="2">Orient</td><td rowspan="3">Information Analysis</td></tr>
<tr><td rowspan="4">Decision-making</td><td rowspan="3">Generating</td></tr>
<tr><td rowspan="3">Decide</td></tr>
<tr><td rowspan="2">Decision and Action Selection</td></tr>
<tr><td>Selecting</td></tr>
<tr><td>Control</td><td>Act</td><td>Implementing</td><td>Action Implementation</td></tr>
</table>

SAE - Levels of Automation for Cars

0 - No automation
1 - Driver assistance (automated steering or acceleration/deceleration)
2 - Partial automation (automated steering and acceleration/deceleration)
3 - Conditional automation (limited driving tasks, driver will intervene)
4 - High automation (limited driving tasks, but no driver intervention)
5 - Full automation (all driving modes, no intervention)

ISO SC7 Levels of Automation (Flexibility)

System Flexibility (later levels may include previous levels)	Example systems	Classification	
		Safety-related	Non-Safety
Fixed rules	Simple thermostat		☑
Fixed rules with feedback	Anti-lock brake system	☑	
Fixed neural network that does not change its behaviour based on its experience	Traffic jam system, e.g. SAE level 3	☑	
	Production-line robot (using ML-based image processing)		☑
System changes its behaviour based on its past experiences	Self-learning thermostat		☑
	Financial dealing system		☑
	Smart building	☑	

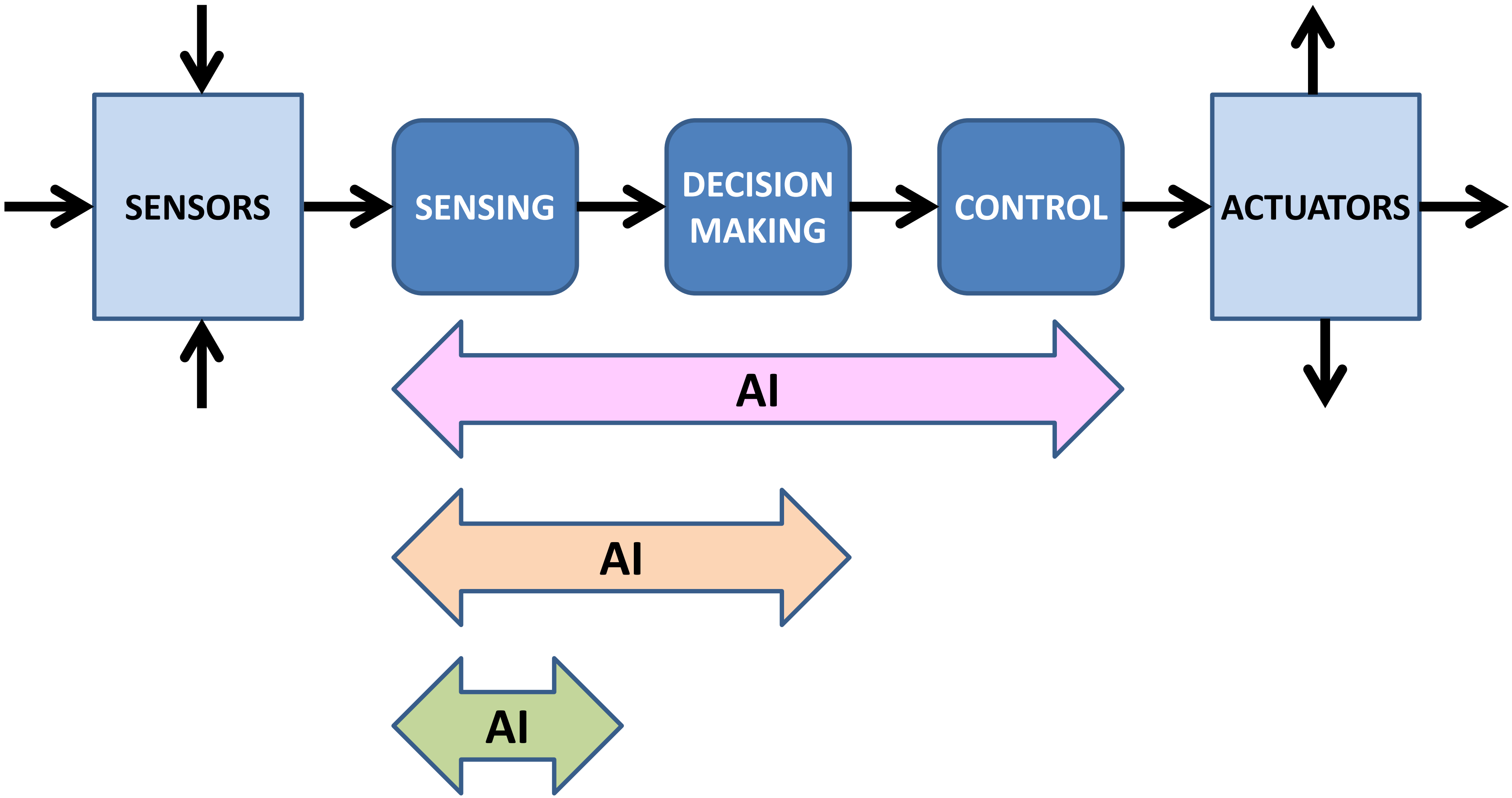
ISO SC7 Framework

System Flexibility		System Functions		
		SENSING	DECISION - MAKING	CONTROL
1	Fixed rules			
2	Fixed rules with feedback (e.g. closed loop control)			
3	Fixed neural network that does not change its behaviour based on its experience			
4	System changes its behaviour based on its past experiences			

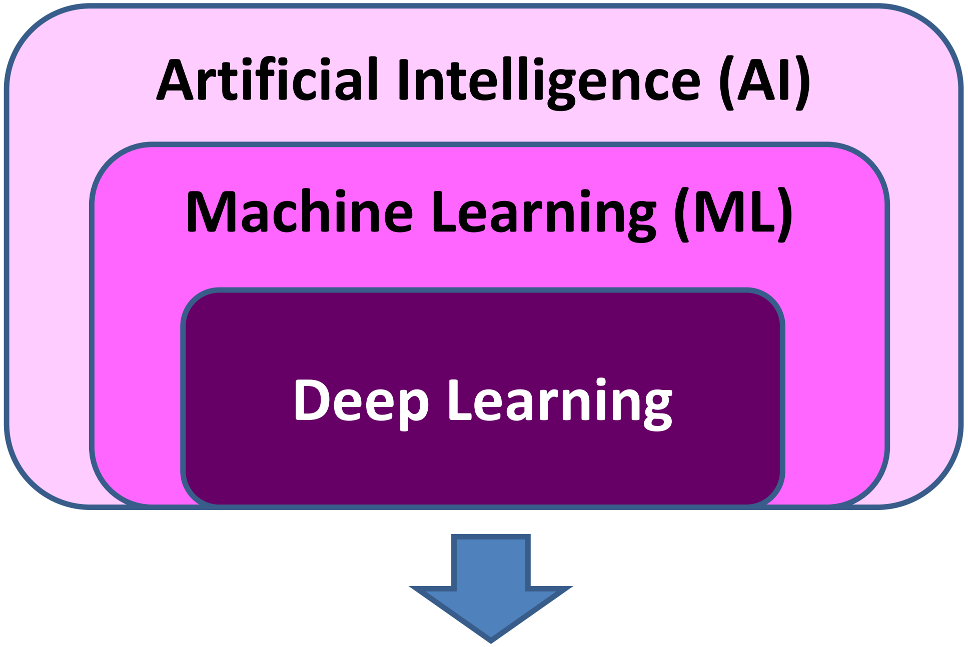
64 possible combinations

Challenge/Opportunity 2:
Definition of a generic framework for autonomous systems

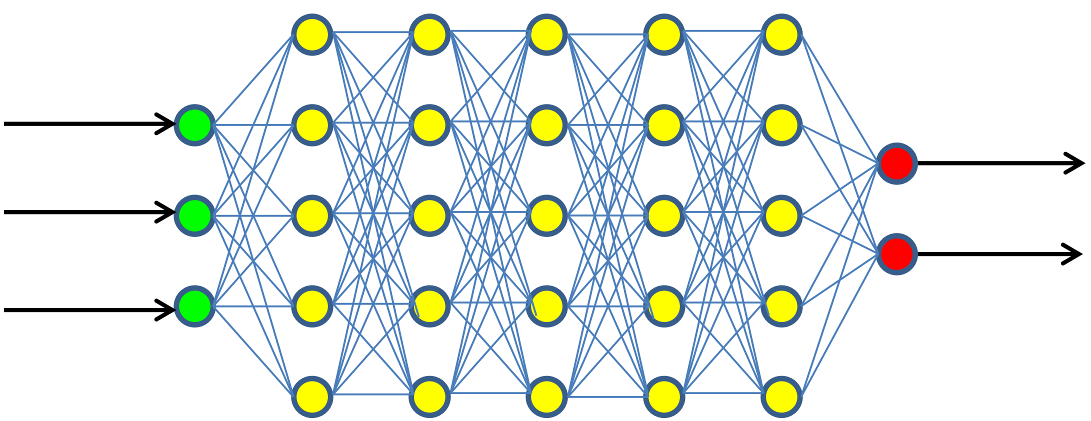
Basic Autonomous System Framework



Deep Learning Systems

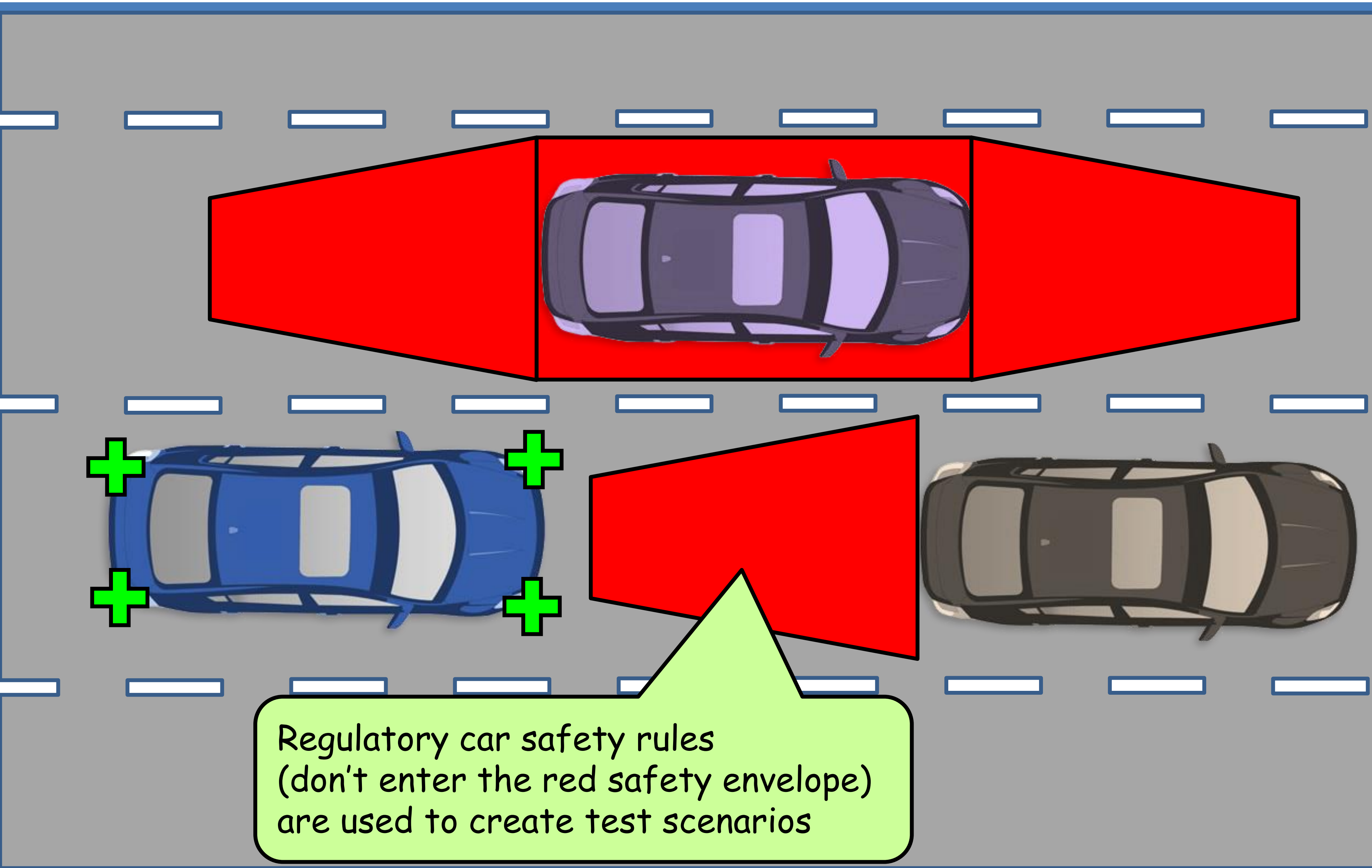


AI already covered by ISO/IEC JTC 1/SC 42.

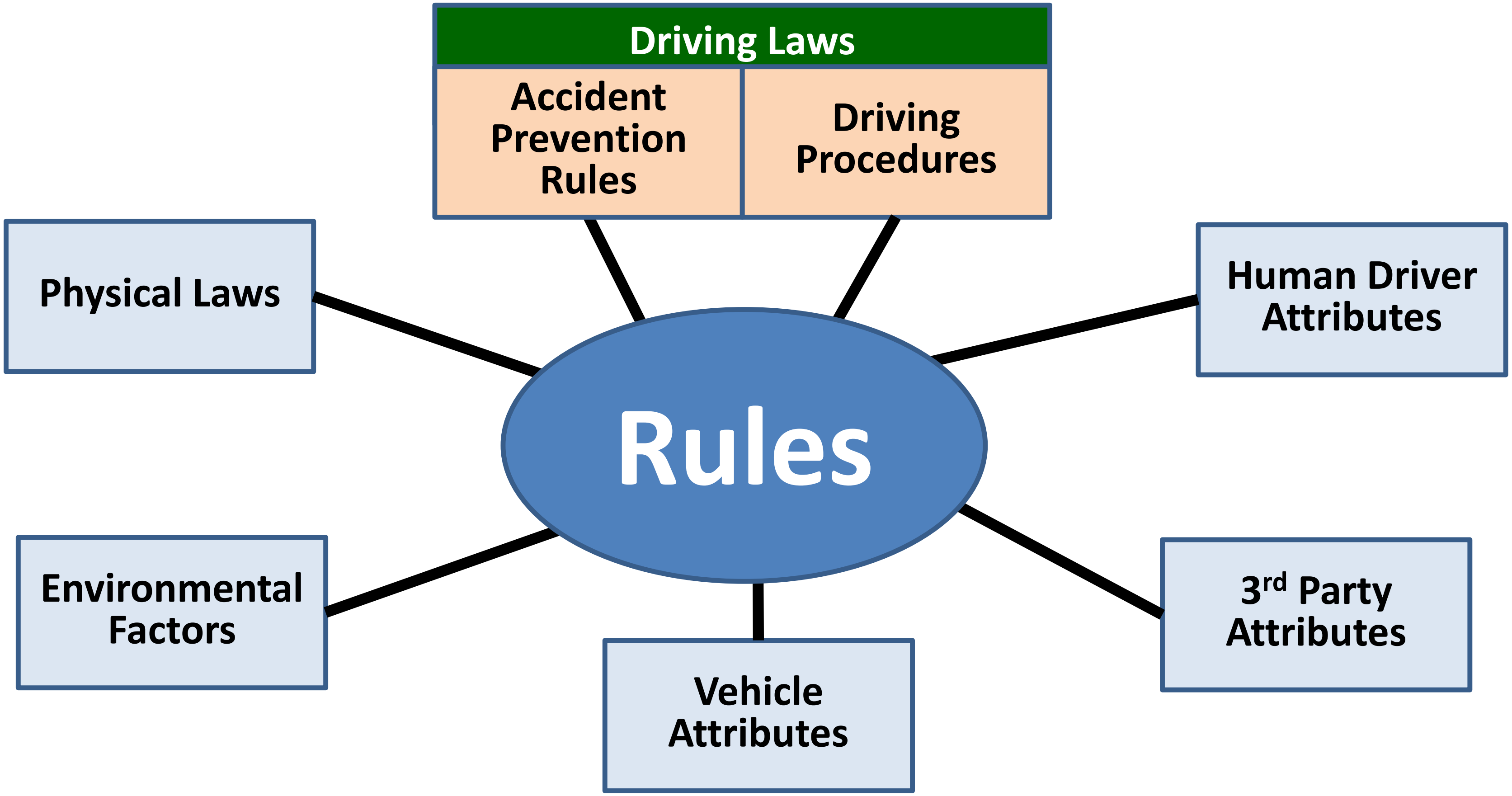


Deep Neural Network

Example – Autonomous Car Safety Rule



Autonomous System Safety Rules



Challenge/Opportunity 3:
Define a format for specifying Safety Rules for autonomous systems.

Defining Autonomous Functions

- **Autonomous car safety rules should cover both:**
  - functions provided by the system
  - context in which the functions must work
- **Several government agencies, research projects, and commercial vendors have their own autonomous car 'rules', e.g.**
  - the EU AdaptiVe project defines 33 separate functional classes for autonomous car systems from SAE levels 1 to 5
  - Waymo (formerly Google's self-driving car project)
  - the US NHTSA

US NHTSA Autonomous Car Functions

1 Detect and Respond to Speed Limit Changes and Speed Advisories

2 Perform High-Speed Merge (e.g., Freeway)

3 Perform Low-Speed Merge

4 Move Out of the Travel Lane and Park (e.g., to the Shoulder for Minimal Risk)

5 Detect and Respond to Encroaching Oncoming Vehicles

6 Detect Passing and No Passing Zones and Perform Passing Manoeuvres

7 Perform Car Following (Including Stop and Go)

8 Detect and Respond to Stopped Vehicles

9 Detect and Respond to Lane Changes

10 Detect and Respond to Static Obstacles in the Path of the Vehicle

11 Detect Traffic Signals and Stop/Yield Signs

12 Respond to Traffic Signals and Stop/Yield Signs

13 Navigate Intersections and Perform Turns

14 Navigate Roundabouts

15 Navigate a Parking Lot and Locate Spaces

16 Detect an
Way, No Turn

17 Detect and Respond to Work Zones and People Directing Traffic in Unplanned or Planned Events

18 Make Appropriate Right-of-Way Decisions

19 Follow Local and State Driving Laws

20 Follow Police/First Responder Controlling Traffic (Overriding or Acting as Traffic Control Device)

21 Follow Construction Zone Workers Controlling Traffic Patterns (Slow/Stop Sign Holders)

22 Respond to Citizens Directing Traffic After a Crash

23 Detect and Respond to Temporary Traffic Control Devices

24 Detect and Respond to Emergency Vehicles

25 Yield for Law Enforcement, EMT, Fire, and Other Emergency Vehicles at Intersections, Junctions, and Other Traffic Controlled Situations

26 Yield to Pedestrians and Bicyclists at Intersections and Crosswalks

27 Provide Safe Distance From Vehicles, Pedestrians, Bicyclists on Side of the Road

28 Detect/Respond to Detours and/or Other Temporary Changes in Traffic Patterns

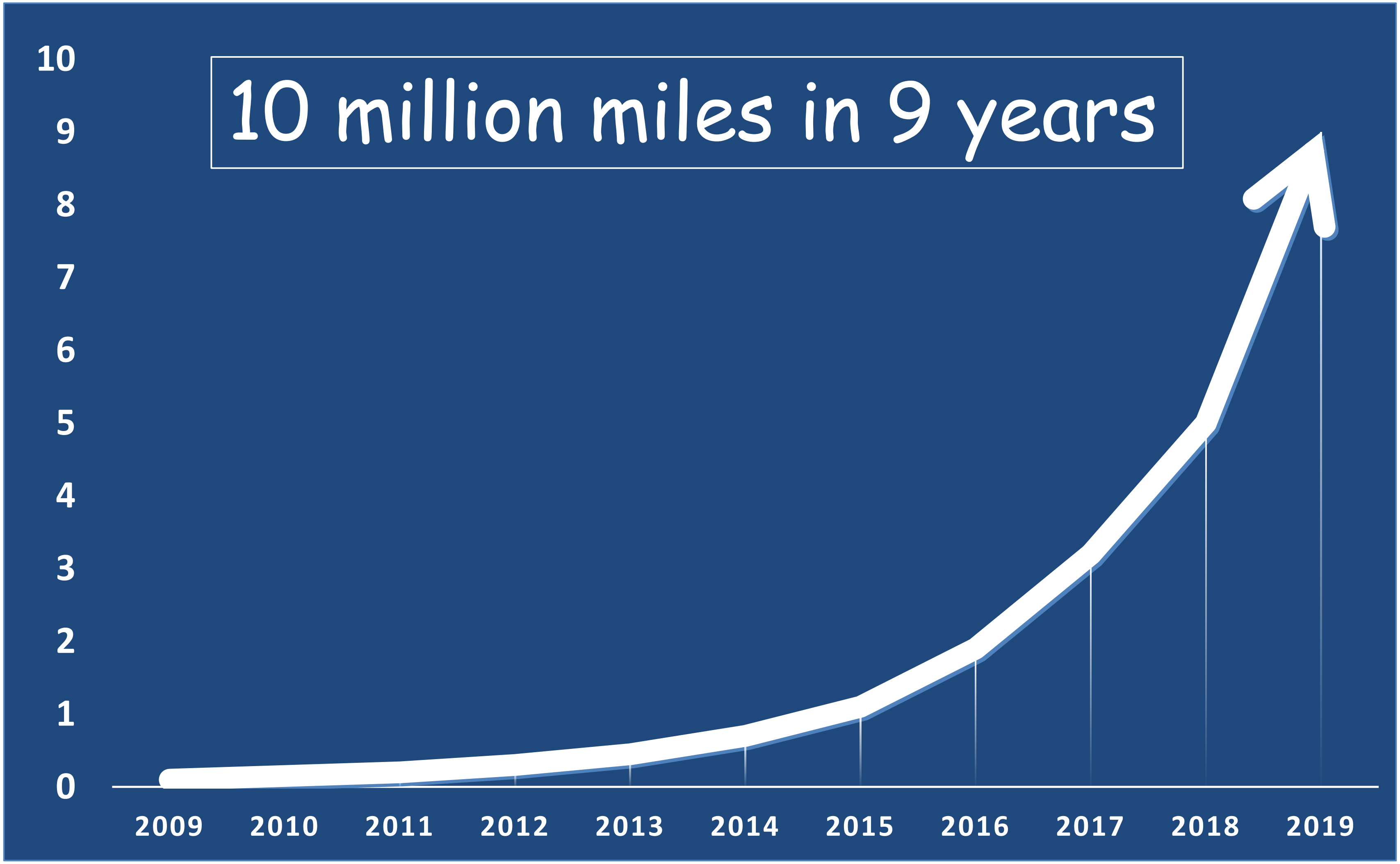
Challenge/Opportunity 4:
Define a format for specifying Generic Functions for autonomous systems.

Defining Operational Scenarios

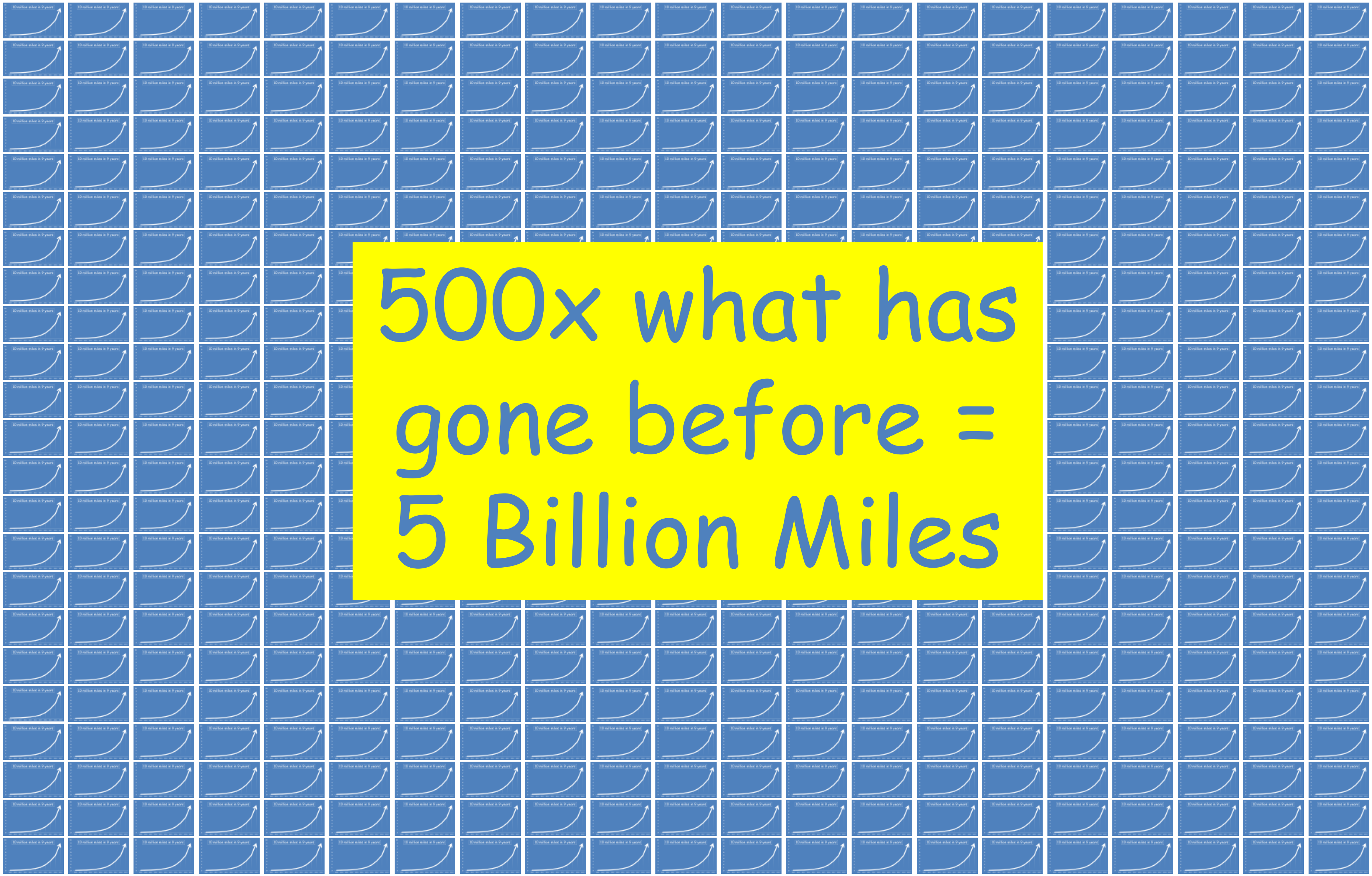
- **Defines each autonomous function's capability limits, e.g.**
  - Roadway types (expressway, local, etc.) on which the function is intended to operate safely;
  - Geographic area (city, mountain, desert, etc.);
  - Speed range;
  - Environmental conditions in which the function will operate (weather, daytime/night-time, etc.); etc.
- **Example**
  - US NHTSA 'Federal Automated Vehicles Policy', published in 2016, defines the 'Operational Design Domain (ODD)' for autonomous cars

Challenge/Opportunity 5:
Define a format for specifying Operational Scenarios for autonomous systems.

Waymo On-Road Test Miles (millions)



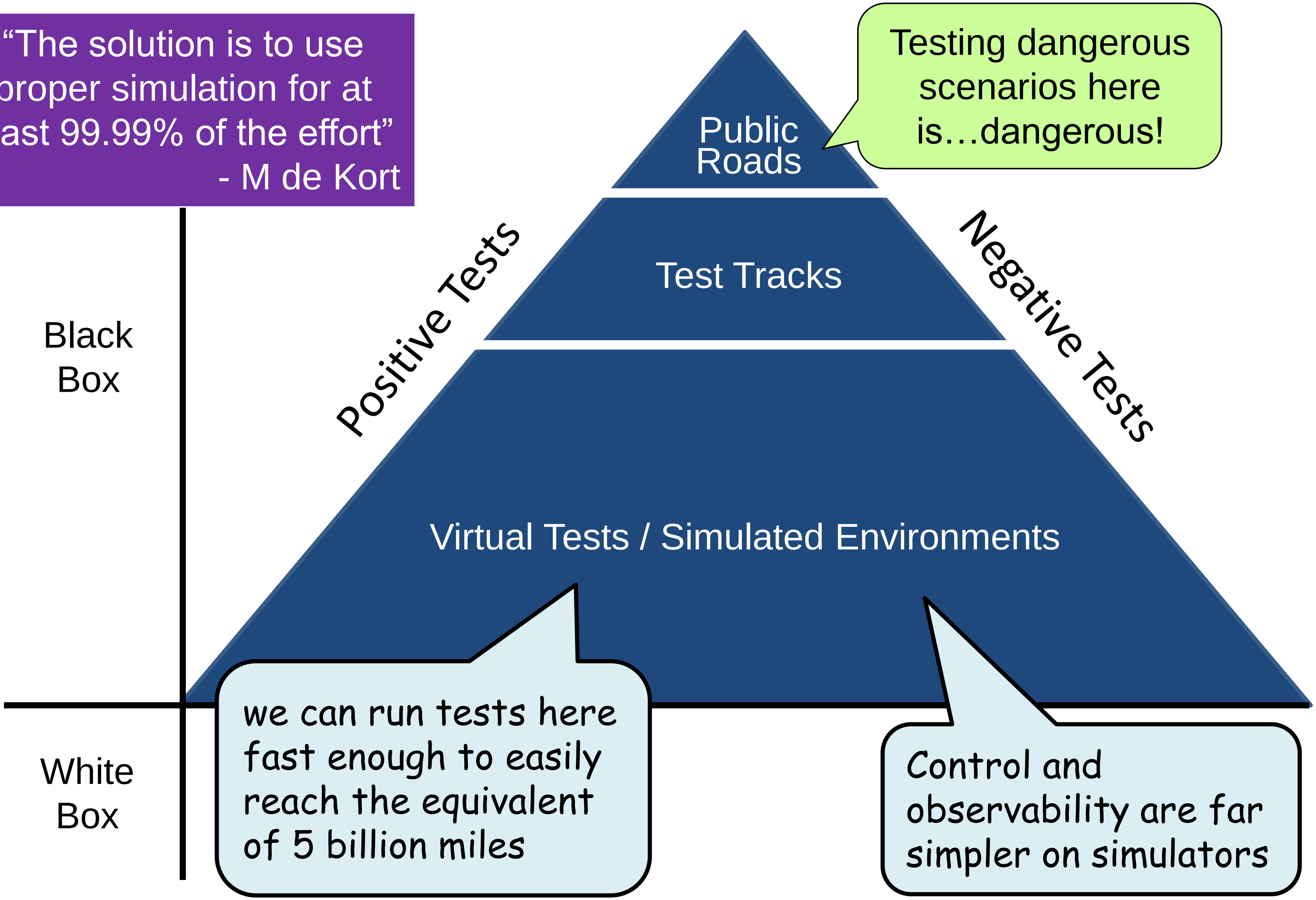
20% Better (than human drivers)



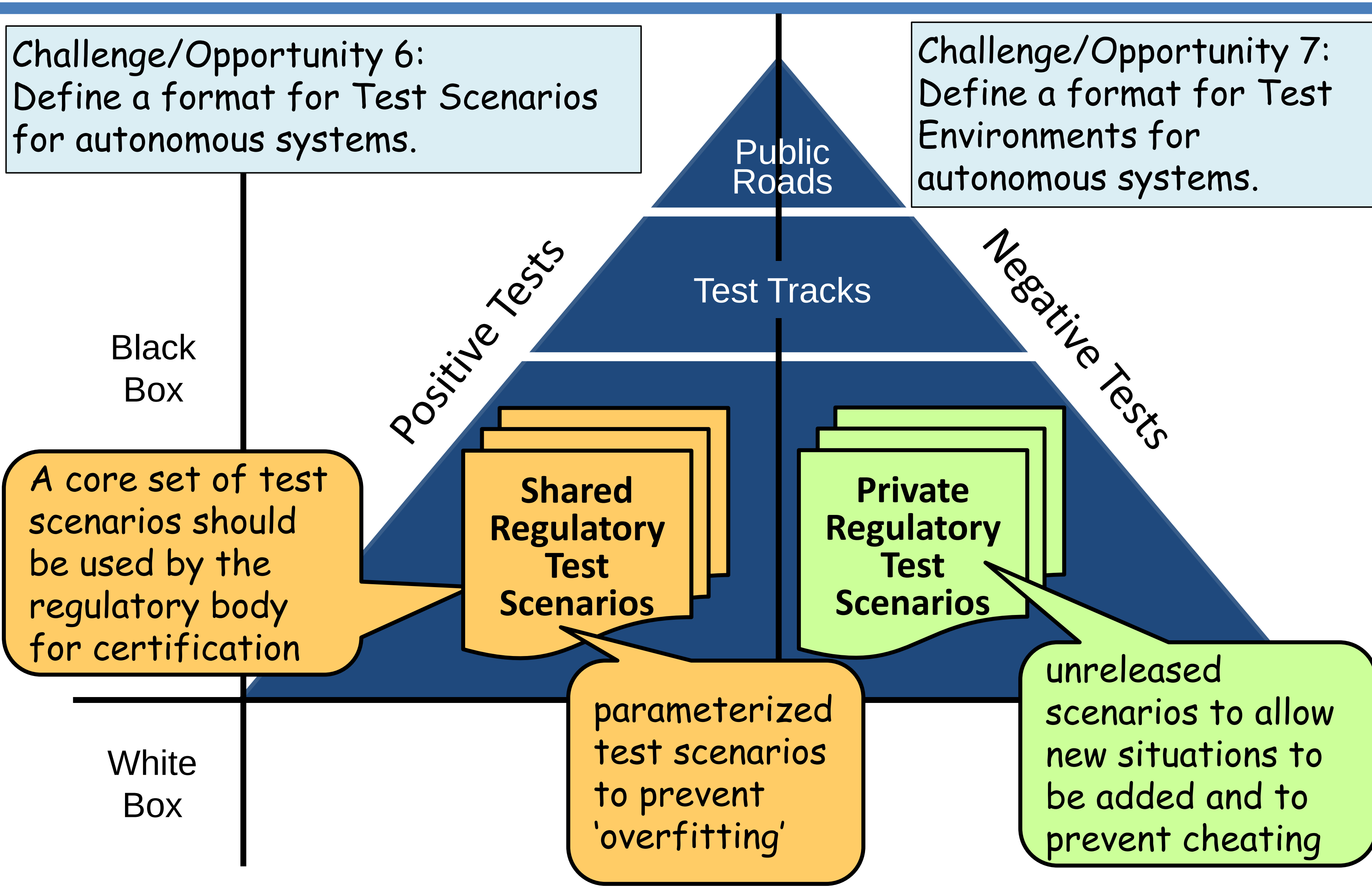
500x what has gone before = 5 Billion Miles

Autonomous Cars – Test Environments

"The solution is to use proper simulation for at least 99.99% of the effort"
- M de Kort

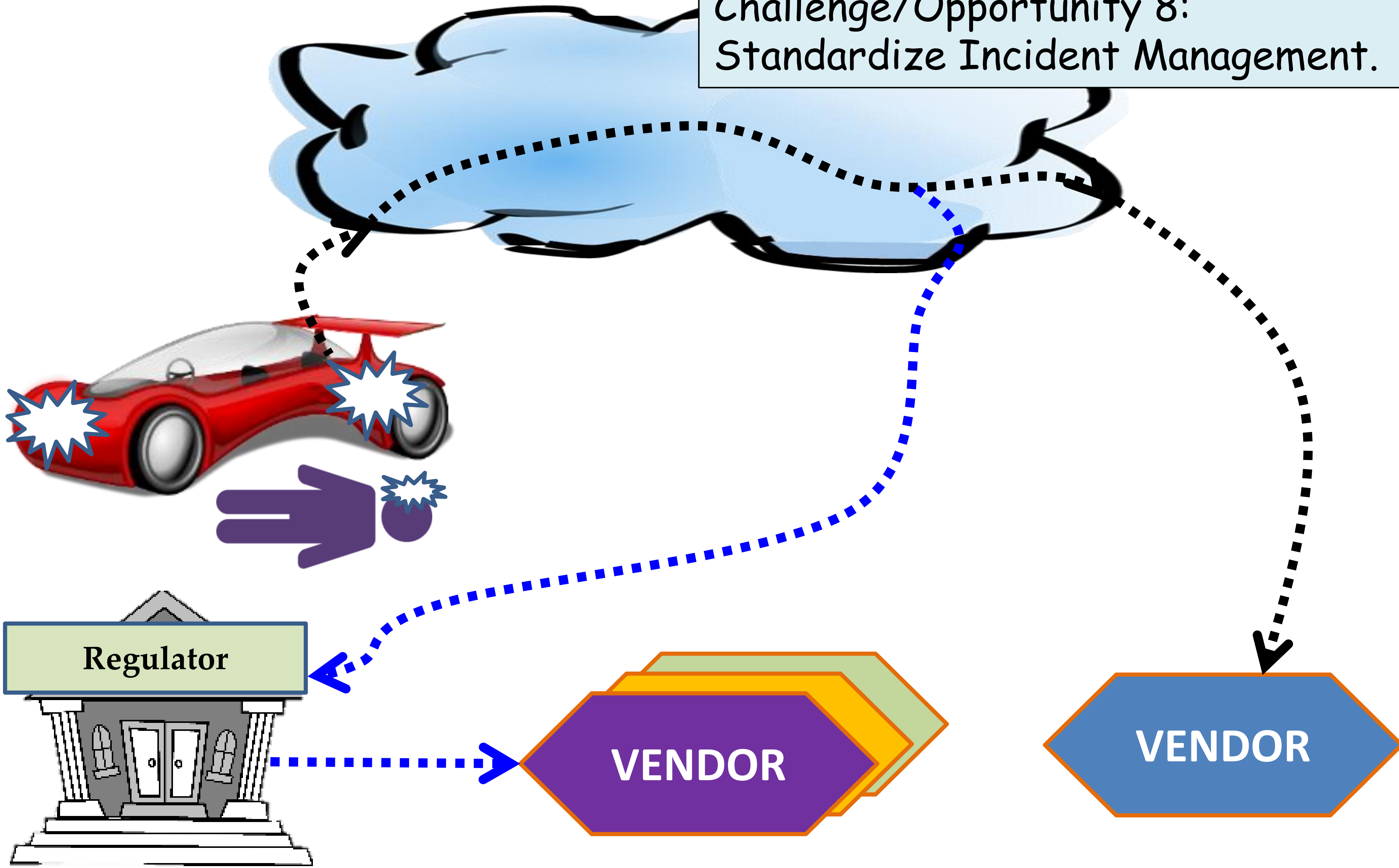


Regulatory Test Scenarios

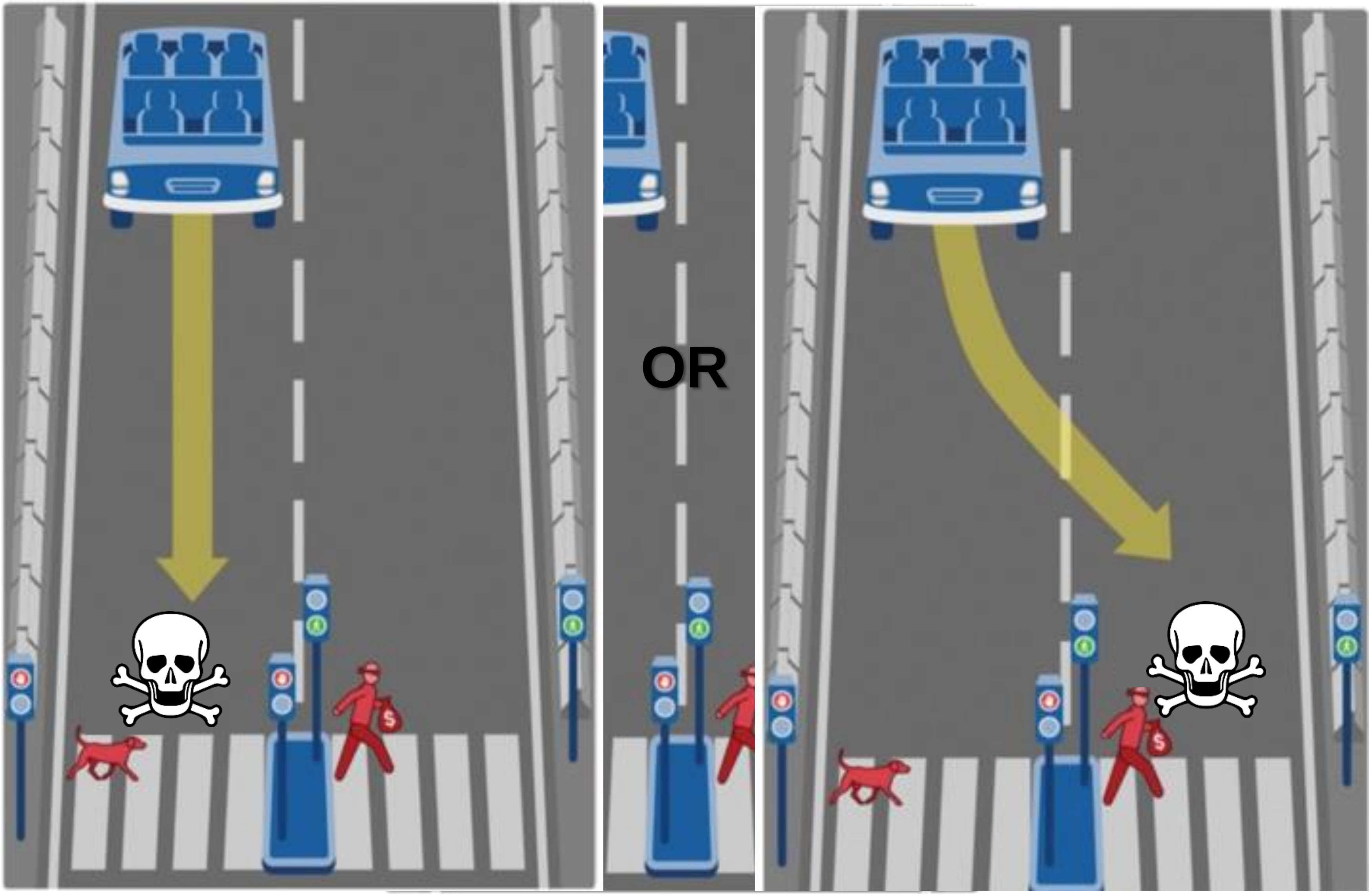


Learning – from Accidents & Attacks

Challenge/Opportunity 8:
Standardize Incident Management.

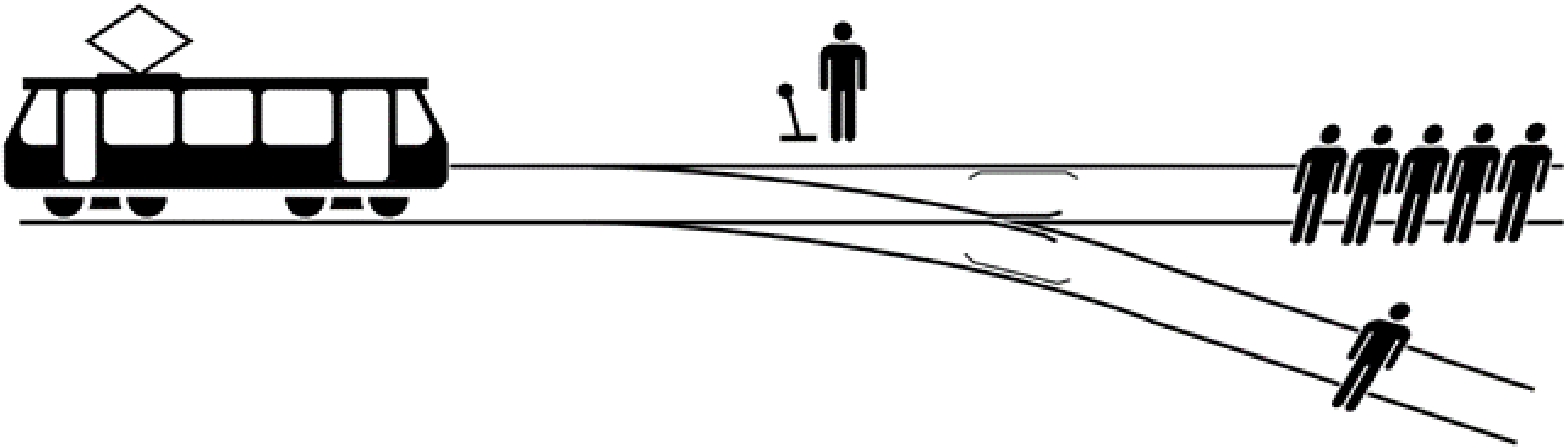


MIT's Moral Machine (moralmachine.mit.edu)



Better than Humans?

Ethics & Autonomous Systems



Challenge/Opportunity 9:
How do we define ethics for autonomous systems?

Conclusions

Conclusions – Standards for Autonomous Systems

- **We are already using (and relying on) autonomous systems**
- **Governments are reticent about standardizing and regulation as they are worried it will disadvantage their industry**
- **Without standards, we will have:**
  - – unsafe systems
  - – systems that are expensive to regulate
- **For standards, we need:**
  - – government commitment
  - – much more research, to understand:
    - the new dangers these systems bring
    - what 'good practices' we should mandate

Thank you for listening

Questions for Panel?