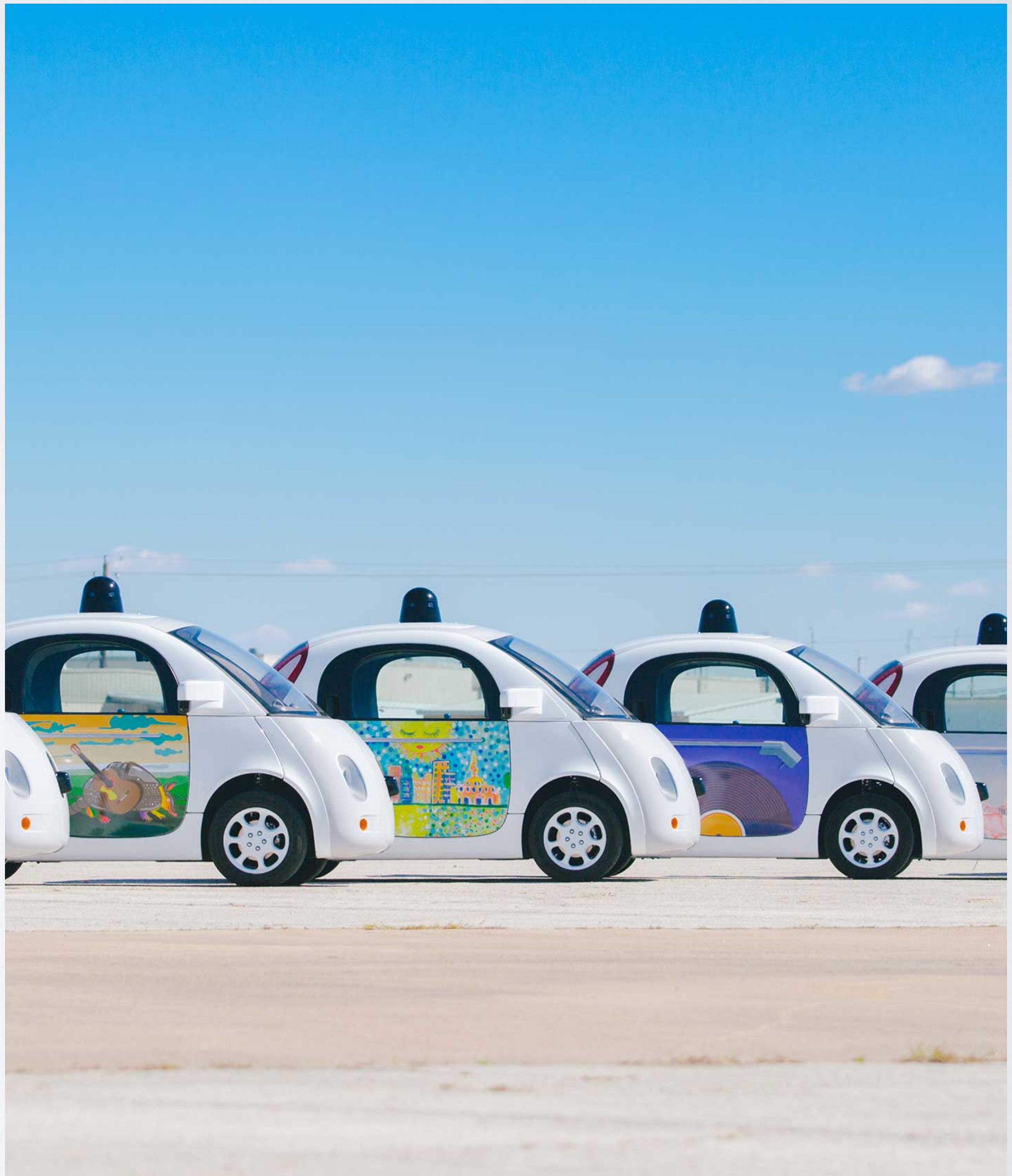
"Does your car have any idea why my car pulled it over?"

DRIVERS ED FOR AVS

Leilani H Gilpin (MIT), Matias Aranguiz (SJTU)

MOTIVATION



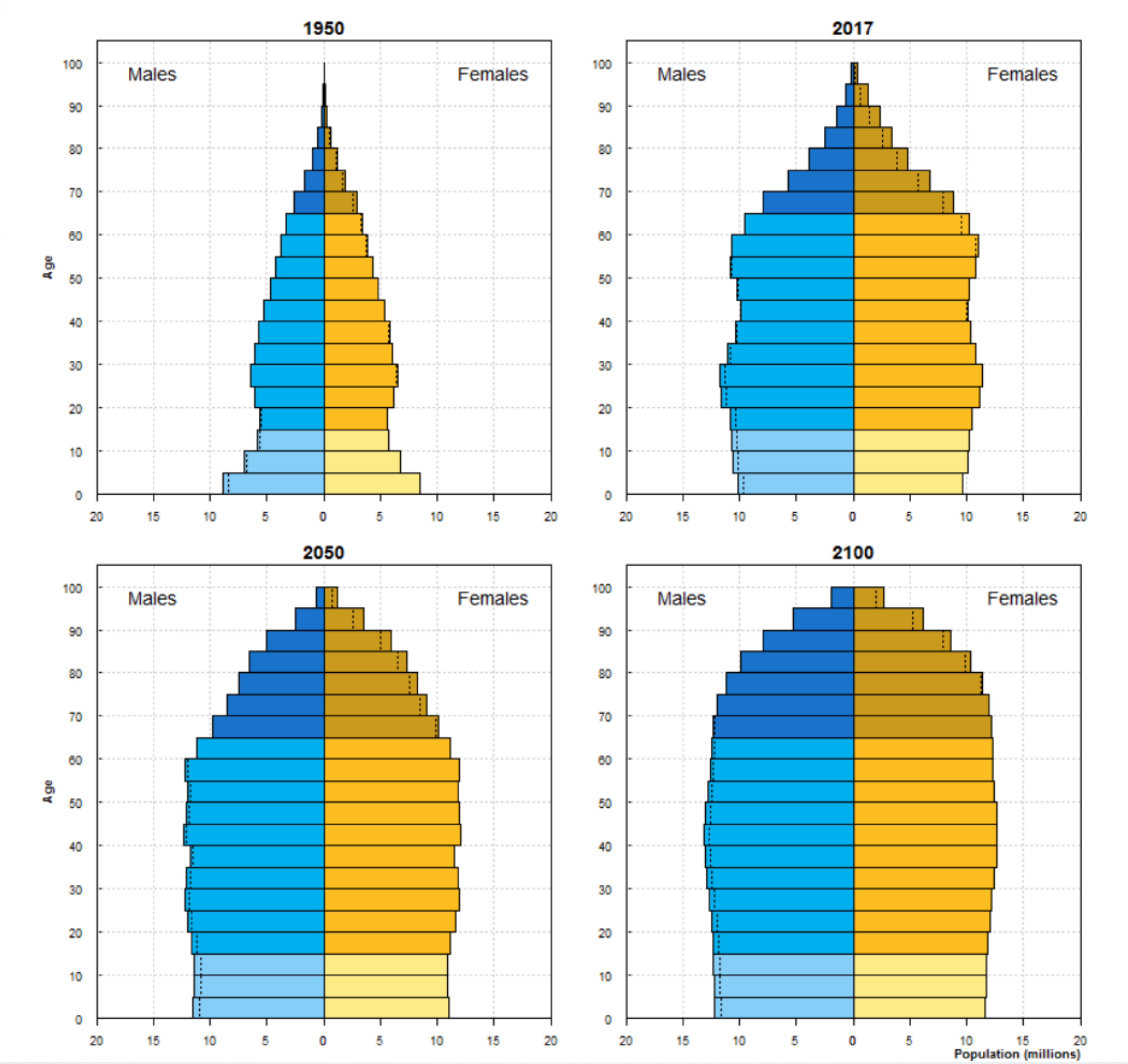
MOTIVATION - TECHNOLOGY

Triggered by
- Regulation/urban design
- Technology/business model
- Consumer preferences

Trend	Current and future enabling forces
Electrification	Desirable products
	Battery technology/cost (<USD 200/kWh, 2020)
	Charging stations (1,200% global increase, 2014-20)
	Emission/efficiency regulation (EU 95 g_{CO2}/km, 2021; US 54.5 mpg, 2025, CA 15% ZEV 2025)
Connectivity	Connected lifestyle extending to the car
	Vehicle safety communication mandate (US vehicle-to-vehicle, expected by 2020)
	Communication network growing (5G, 2020)
	Tech giants and start-ups discover the remaining piece in connected world
Autonomous driving	Sensor and processing solutions
	Communication/legal infrastructure (currently 4 states in the US, more expected)
	Public demonstrations of autonomous driving show benefit
	Tech giants and start-ups discover automated cars "interesting playground"
Diverse mobility	Consumers prefer access over ownership (600% global car sharing revenue increase, 2013-20)
	Smartphone makes scheduling convenient
	Incentives for corporations and consumers
	Urban congestion (30% of traffic for parking)
	Shared mobility providers offer trendy products

Source: McKinsey Auto 2030 report January 2016

MOTIVATION



Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision.

GOALS

- Big technical *weaknesses* : physicality of the car
  - Machine perception
  - Communication (security)
  - Ethics (the trolley problem)
- Implementation
  - Regulation
  - The "people"

5 LEVELS OF AUTONOMY

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

THE PROBLEMS WITH MACHINE VISION

Source: XKCD

THE PROBLEMS WITH MACHINE VISION

alt text: "Crowdsourced steering" doesn't sound quite as appealing as self-driving.

Source: XKCD

VEHICLE SIGHT

- LIDAR - light based radar
  - Car can see how far it is from the object or person.
- Standard cameras
- “Seeing through walls”

SO WHAT DOES THIS LOOK LIKE?

Source: Ranft and Stiller : *The Role of Machine Vision for Intelligent Vehicles*

SOME RISKS

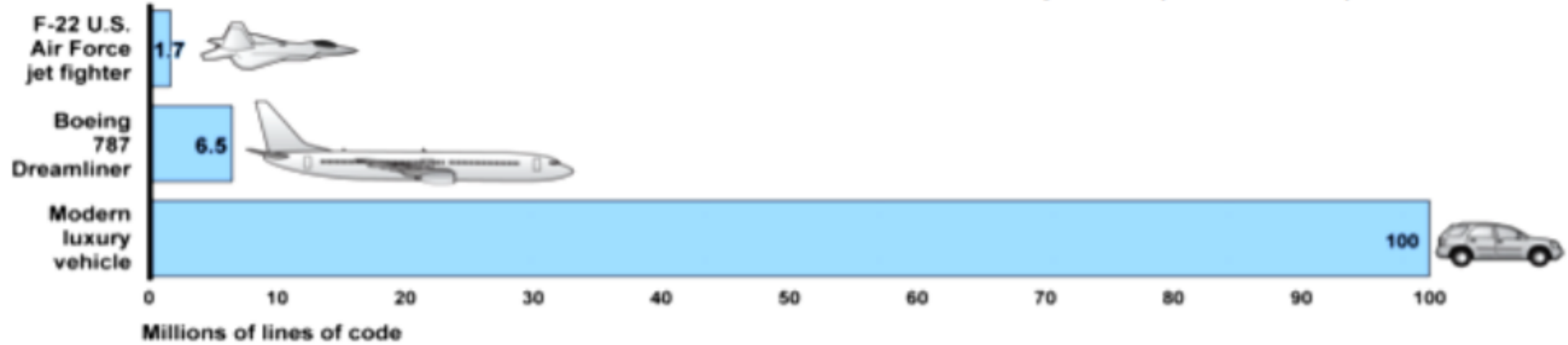
- Training data matters
- Changing cities
- How to engage the human?

Volvo's self-driving cars are thrown off by kangaroos

Their hopping confuses the cars' detection system.

SOME RISKS

Exhibit 12 **Aircraft and Automobile Software Code Compared** (GAO 2016)



Vehicles have more complex computer systems than aircraft, due to complex roadway interactions.

AV SECURITY

WHY IS THE MODERN VEHICLE NOT SECURE?

- The modern car contains two (newer) units
  - Electronic Control Unit
  - Controller Area Network (CAN)
- The CAN network can contain over 80 ECUs and 100 sensors.
- Projected sensors could double in the next year.

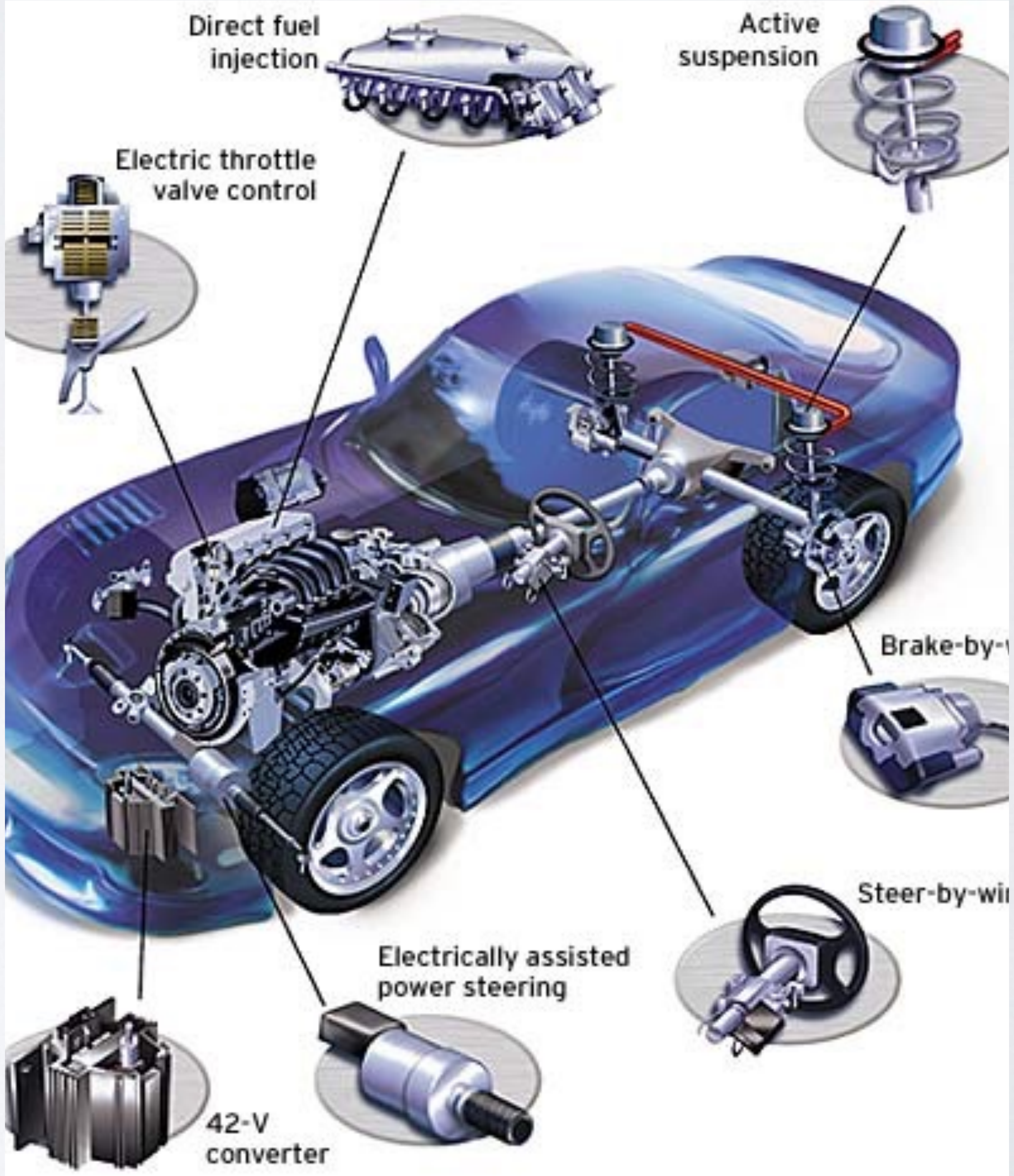
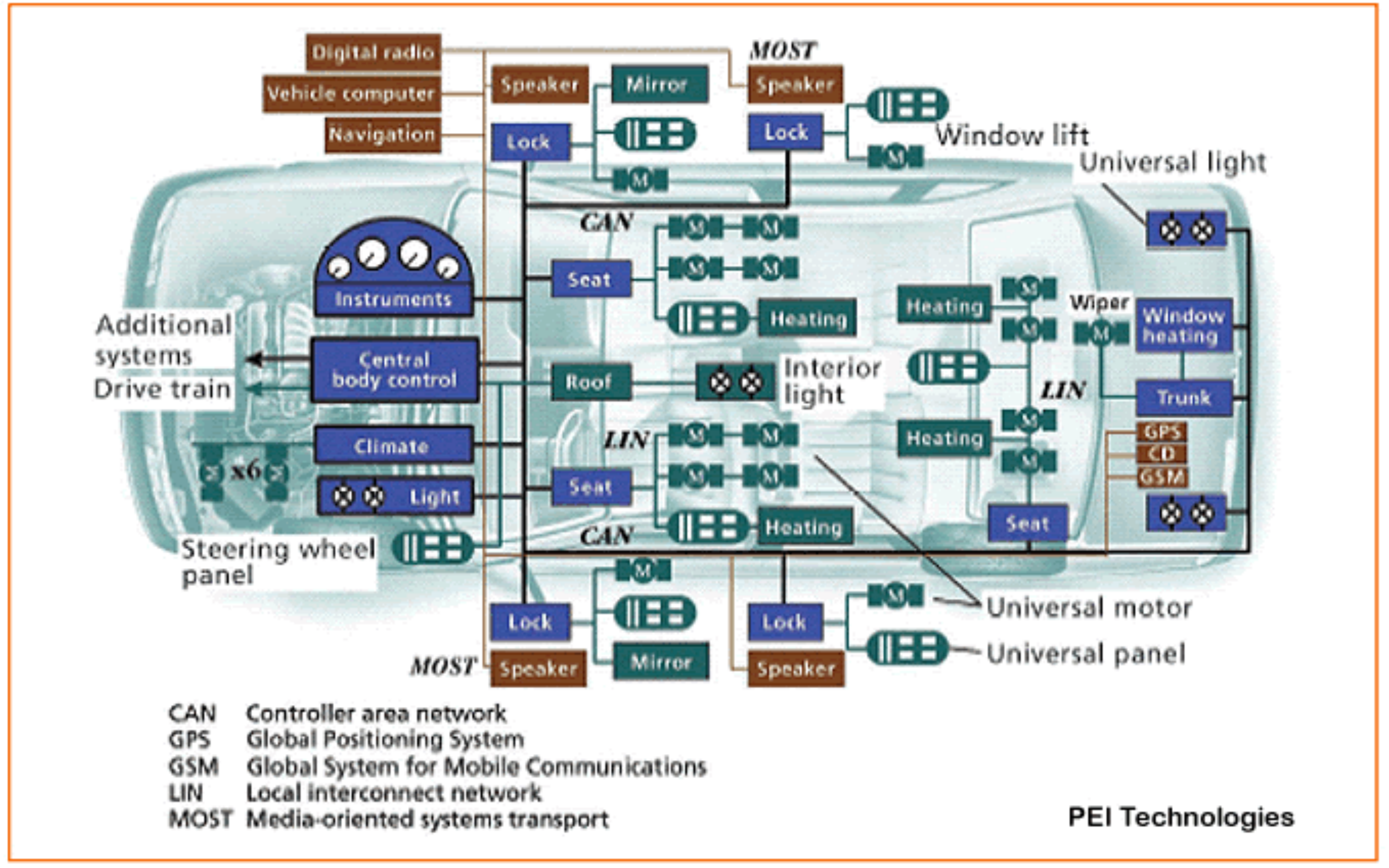


Image courtesy of Toyota Costa Rica



CAR LAYOUT

(C) PEI TECHNOLOGIES

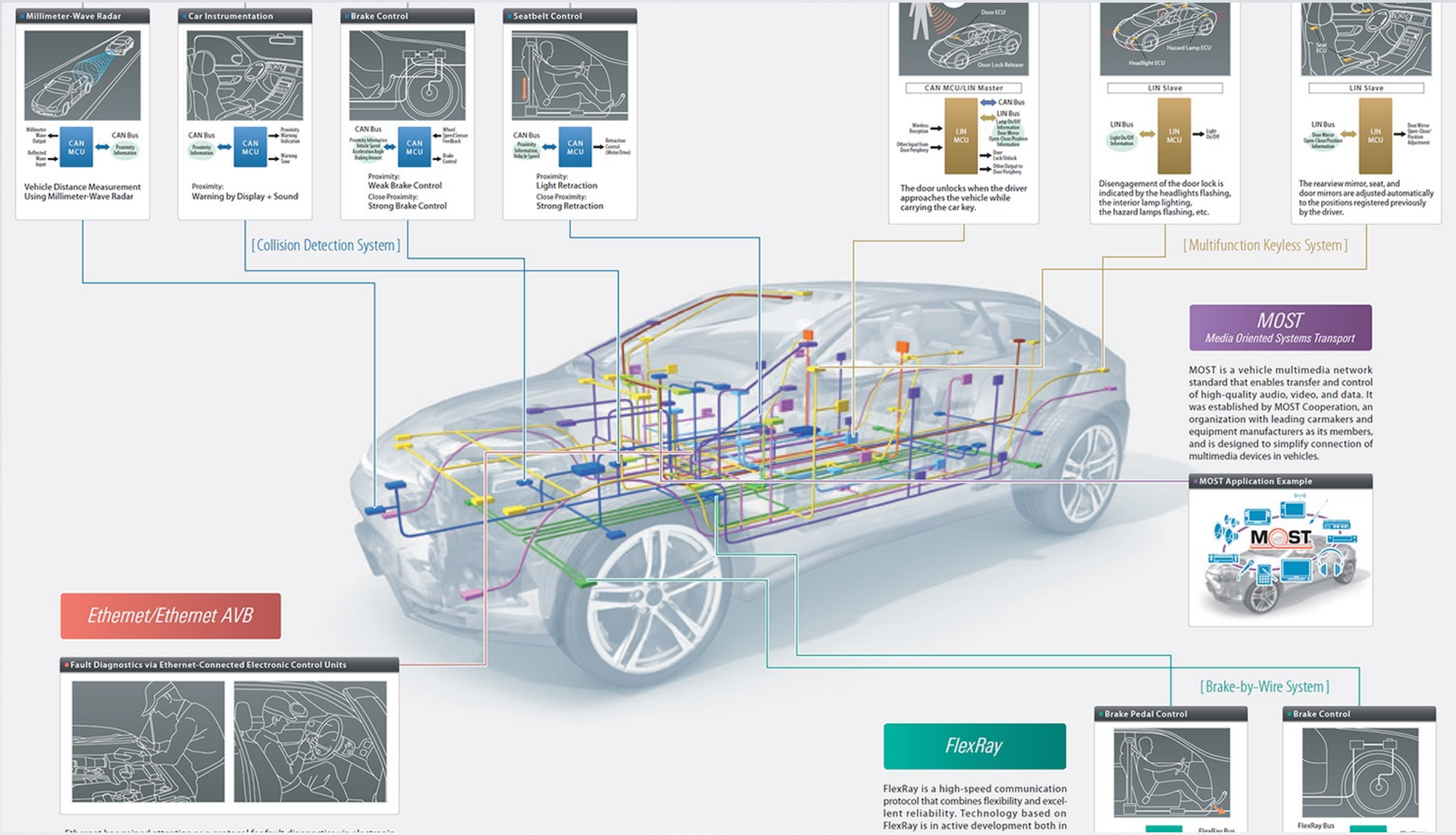
ACCESSING THE CAN

- The early CANs were wired (considered a closed network)
- Could "hack" into these CAN buses by plugging in a device to the car's **federally mandated** universal OBD-II diagnostics port
- Messages are
  - Unencrypted
  - Not authenticated
  - All messages are broadcast to the entire system
- Now, more recent CANs contain wireless components which have massive security implications

WIRELESS CAN ACCESS

- On the freeway, two “hackers” were able to control radio, windshield wipers, air conditioner and accelerator
  - They can track GPS coordinates, measure speed, and even drop pins on a map
- Read the article, “Hackers Remote Kill a Jeep on the Freeway—With Me in It” - Wired

copyright Andy Greenberg-Wired



CAR NETWORKING

(C) DIGIKEY.COM

SO WHY THE CAN BUS?

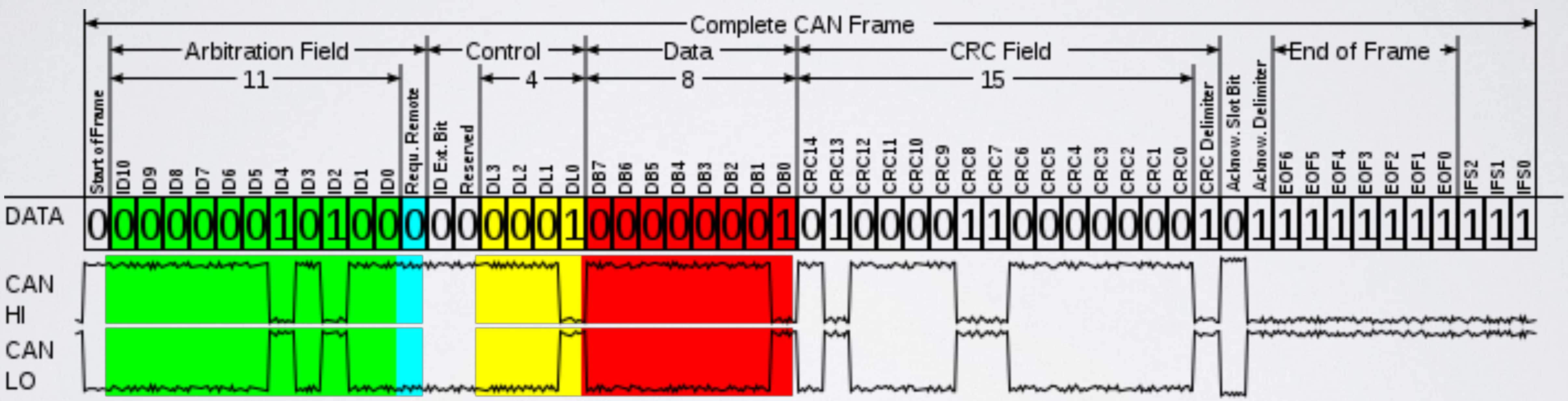
- Adopted early
- Works well when exchanging data because it's reliable and works well in noisy, environment.
- (Also scary : CAN bus is used in a lot of aerospace automation)
- How can we help?

CAN BUS : EASY TO EMULATE

- Easy to hack
    - simple schema
    - schema: time stamp, CAN bus code, extra information
    - connects to all aspects of a car
- Car manufacturers are unwilling to change the standard
- How do we stop it?

```
93.79 B3 -24.94 1.15
93.79 120 13 04 50
93.79 244 0.00
93.795 22 0.00
93.795 23 -0.80
93.795 25 0.00
93.795 30 0.00
93.795 B1 81.83 -5.69
93.795 B3 24.24 -56.52
93.795 120 13 04 50
93.795 244 0.00
93.8 22 0.00
93.8 23 0.89
93.8 25 0.00
93.8 30 0.00
93.8 B1 -46.06 -88.97
93.8 B3 21.87 6.62
93.8 120 13 04 50
93.8 244 0.00
93.805 22 0.00
93.805 23 -0.08
93.805 25 0.00
93.805 30 0.00
93.805 B1 -77.20 -5.41
93.805 B3 18.62 -19.38
93.805 120 13 04 50
93.805 244 0.00
93.81 22 0.00
93.81 23 0.21
```

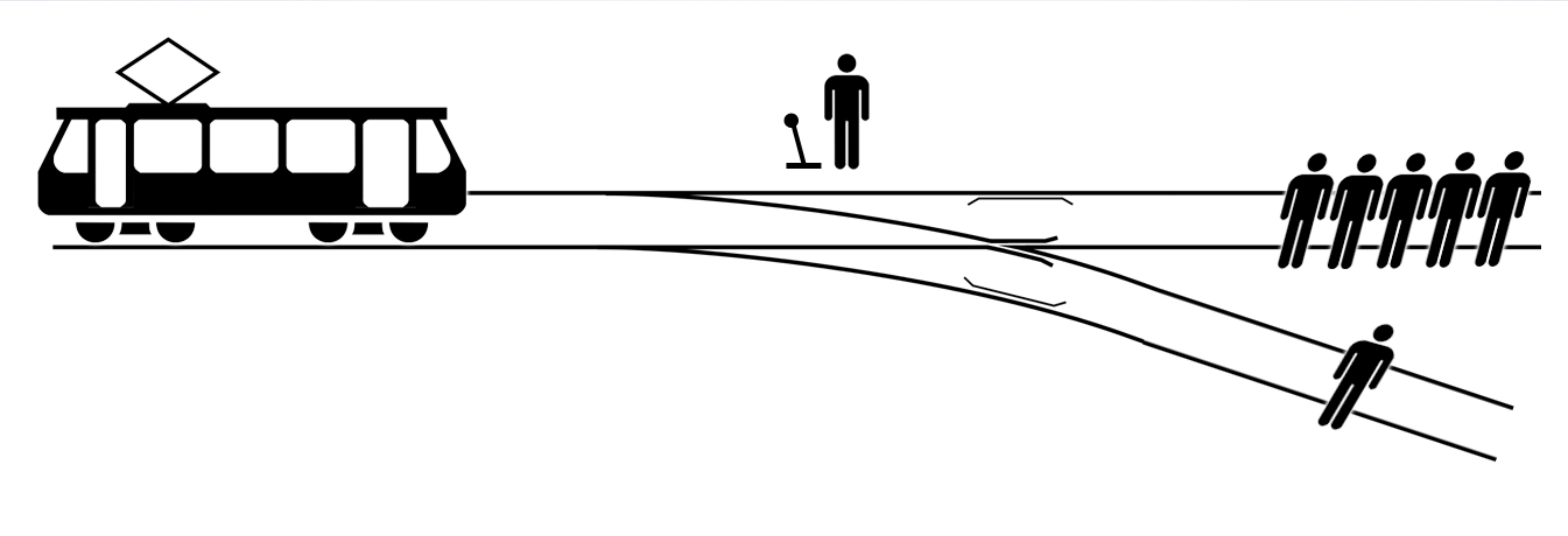
CAN MESSAGE FORMAT



THE TROLLEY PROBLEM

for Autonomous Vehicles

WHAT IS THE TROLLEY PROBLEM?



RESULTS

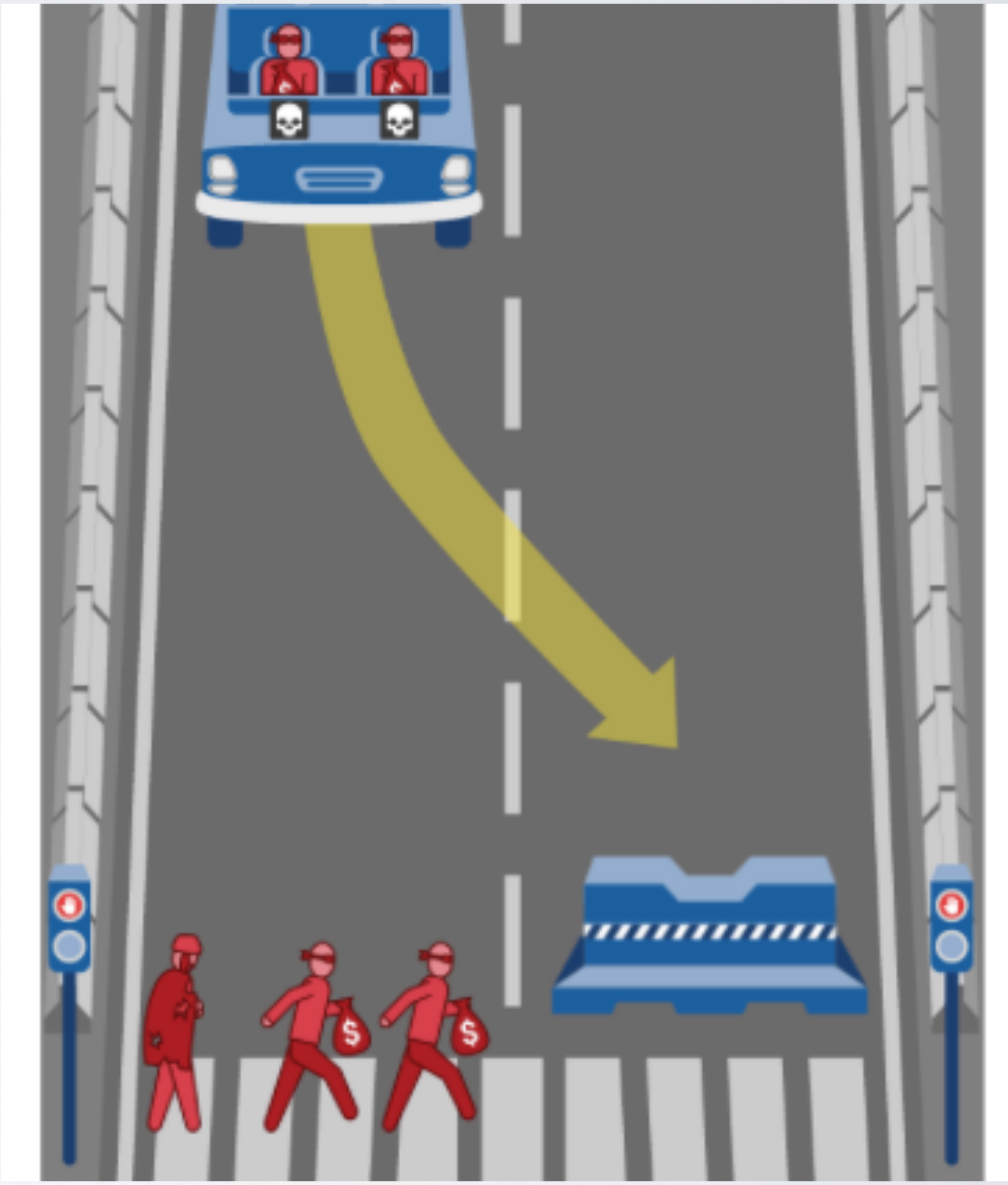
- Approximately 90% choose to kill one and save the five.
- Situation greatly differs if one of the 5 is a relative or a romantic partner.

VARIATIONS

- The fat man
- The fat villain
- The transplant
- The man in the yard

MORAL MACHINE

- A platform to get a human perspective on moral decisions made by autonomous machines
- Can judge moral dilemmas and can design your own scenarios



WHAT DO YOU THINK?

OTHER PROBLEMS

- Instincts are quick (disagree with the Media Lab)
- Model would need to be fast
- Currently do ex post facto analysis (after the fact)
  - This would need to be able to be run in real time

IMPLEMENTATION ISSUES

EXISTING REGULATIONS

Here and abroad.

IN SUMMARY

- There is not much useful regulation (now).
- Most says if you can have self-driving cars (and insurance)…or not
- Liability is a BIG issue.

WHO?

- In US
  - Department of Transportation (DOT)
  - National Highway Traffic Safety Administration (NHTSA)
  - Currently regulates the manufacturing safety standard of vehicles, where state government regulate the operation of vehicles.

WHAT HAS NHTSA DONE?

- Mandated installation of event data recorders (EDRs) in all new vehicles
  - To help a court determine if the human driver, computer driver, or a particular automated feature of a car caused a crash or traffic incident.
  - Problem: not easy to know the cause
- Federal Motor Vehicle Safety Standards (FMVSSs), which sets performance and testing standards for the safety components of a vehicle.
  - cover crash-avoidance, crashworthiness, and post-crash features of vehicles.
  - prohibit third-party modifications that interfere with safety
  - cannot control owners modifications.

SOME EXISTING STATE RULES

- District of Columbia, Michigan, Florida, and Washington, D.C. all require a driver to be present to manually override the self-driving mode to prevent crashes.
- California, Florida, and Nevada require drivers to submit an insurance instrument, surety bond, or proof of self-insurance in the amount of five million dollars.
- California's and Florida's statutes also include a clause expressly stating that federal law preempts any section where the states' laws are in conflict.
- Nevada and Florida crafted a licensing framework that requires operators of self-driving cars to obtain a certificate of compliance for the vehicle and a driver's license
- California was planning to require a licensed operator to be inside the vehicle. But, Google wants: no steering wheel, pedals, or person required.

TWO CHALLENGES WITH REGULATION

1. Liability rules
2. How to best define insurance (with AVs)

LIABILITY

- (Prob. of an accident) × (average damage) + insurance fee
- If the driver doesn't drive
  - Who is responsible
    - Manufacturer
    - Maintenance
    - Street mapping
    - Infrastructure to vehicle (city or PPP)

LIABILITY (CONTINUED)

- If the driver does not drive….
  - Data event recorders
  - Proof of negligence or causation will need an expert
  - What happens with different traffic regulations?
  - (Lower probability of an accident) x (? damage)

INSURANCE

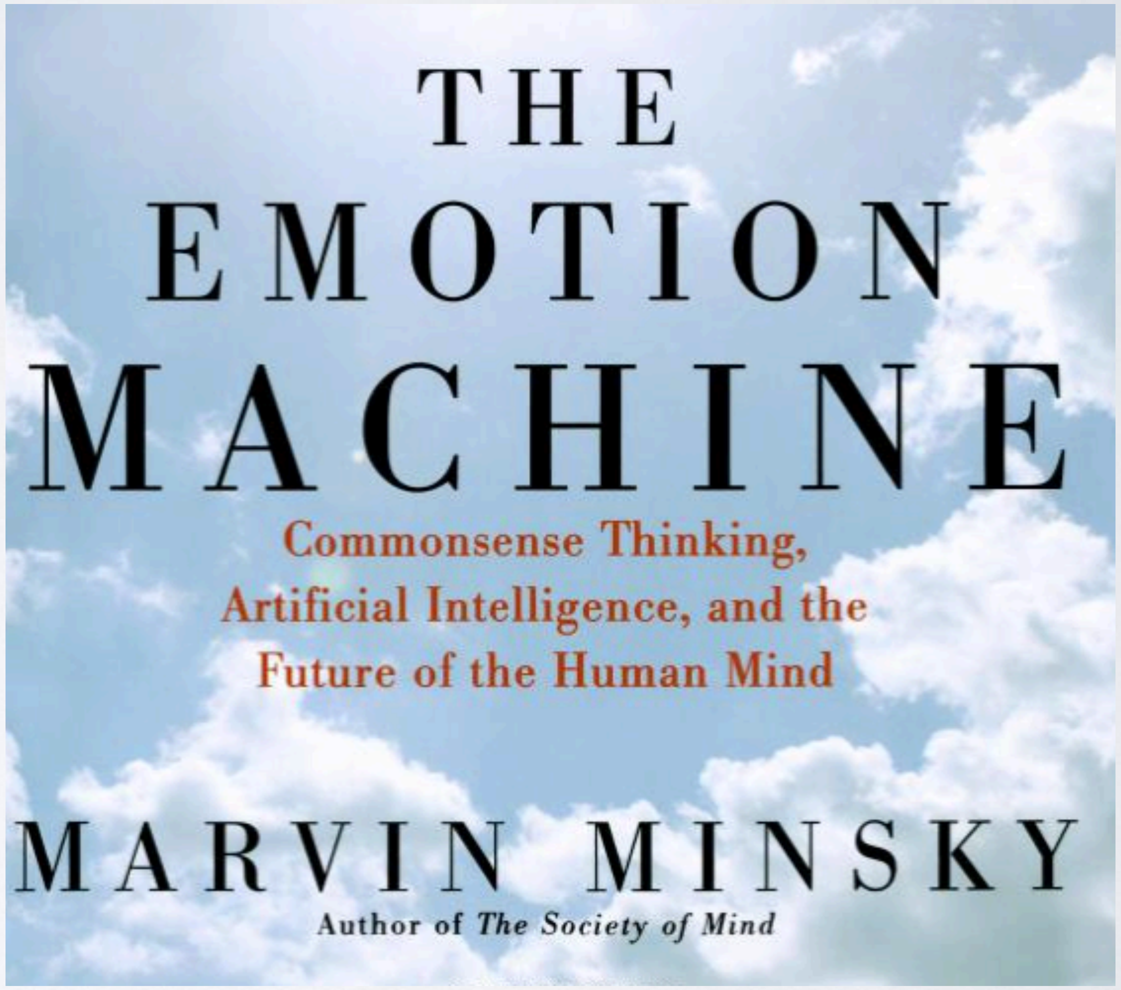
- Insurance premiums will reduce?
- Liability will be transferred to manufacturers
  - Musk said if he do now get insure he will create his own
- Car prices will include the manufacturer expects to spend in insurance premiums.
- Manufacturer's liability makes more likely that the cars will be leased, rather than sold.
- Ridesharing businesses such as Uber or Lyft own the vast majority of autonomous vehicles and provide transportation for private parties on an individual-ride basis

THE BIG PROBLEM WITH SELF-DRIVING CARS

the people

EMOTION MACHINE

Joan is part way across the street on the way to deliver her finished report. While thinking about what to say at the meeting, she hears a sound and turns her head — and sees a quickly oncoming car. Uncertain whether to cross or retreat, but uneasy about arriving late, she decides to sprint across the road. She later remembers her injured knee and reflects upon her impulsive decision. *"If my knee had failed, I could have been killed. Then what would my friends have thought of me?"*



JOAN CROSSING THE STREET

Reaction: Joan reacted quickly to that sound.

Identification: She recognized it as being a sound.

Characterization: She classified it as the sound of a car.

Attention: She noticed certain things rather than others.

Imagining: She envisioned two or more possible futures.

Indecision: She wondered whether to cross or retreat.

Decision: She chose one of several alternative actions.

Recollection: She retrieved descriptions of prior events.

Reconsideration: Later she reconsidered this choice.

Selection: She selected a way to choose among options.

Apprehension: She was uneasy about arriving late.

Planning: She constructed a multi-step action-plan.

Embodiment: She tried to describe her body's condition.

Emotion: She changed major parts of her mental state.

Representation: She interconnected a set of descriptions.

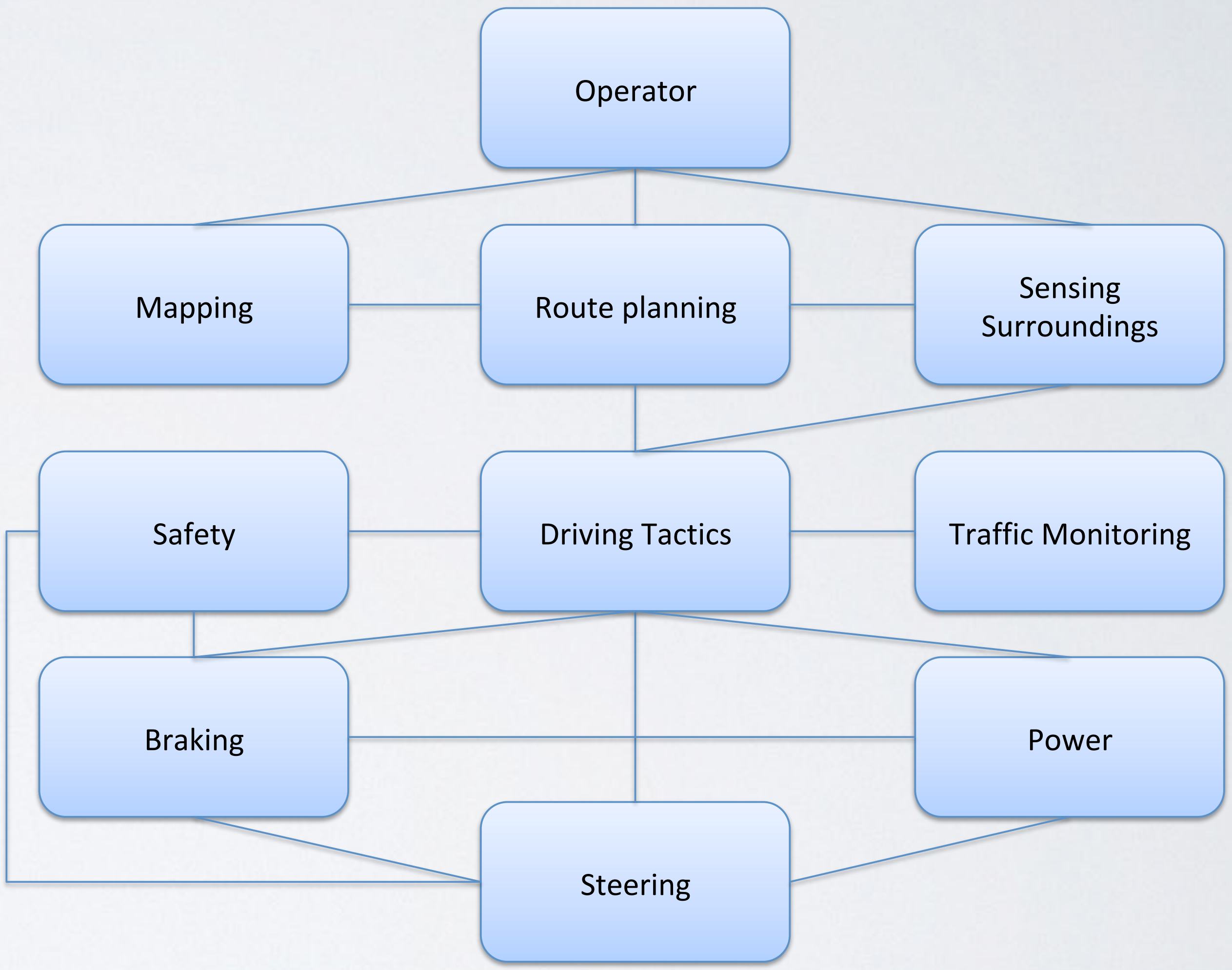
Language: She constructed several verbal expressions.

Narration: She heard them as dialogs in her mind.

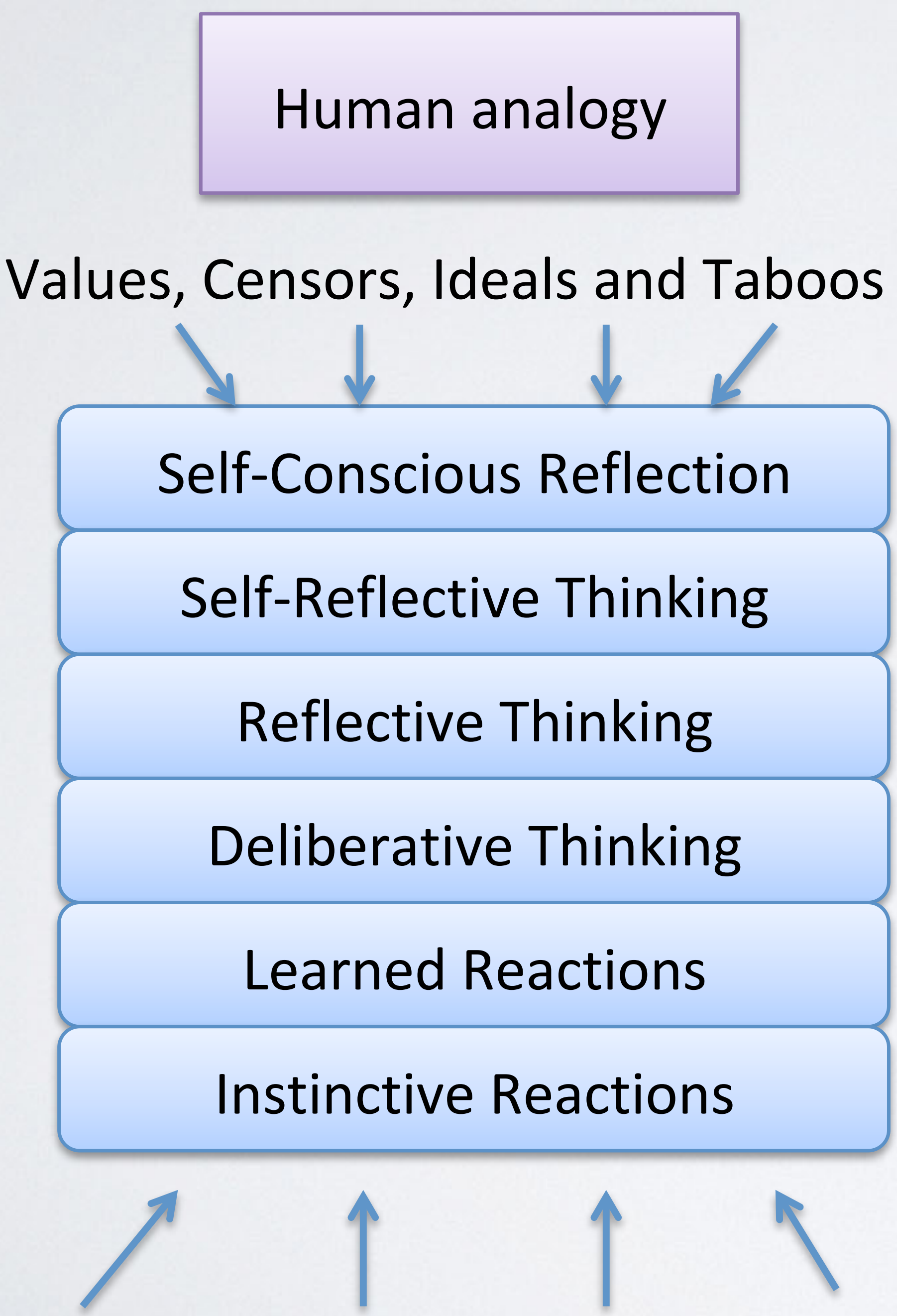
Anticipation: She expected certain future condition.

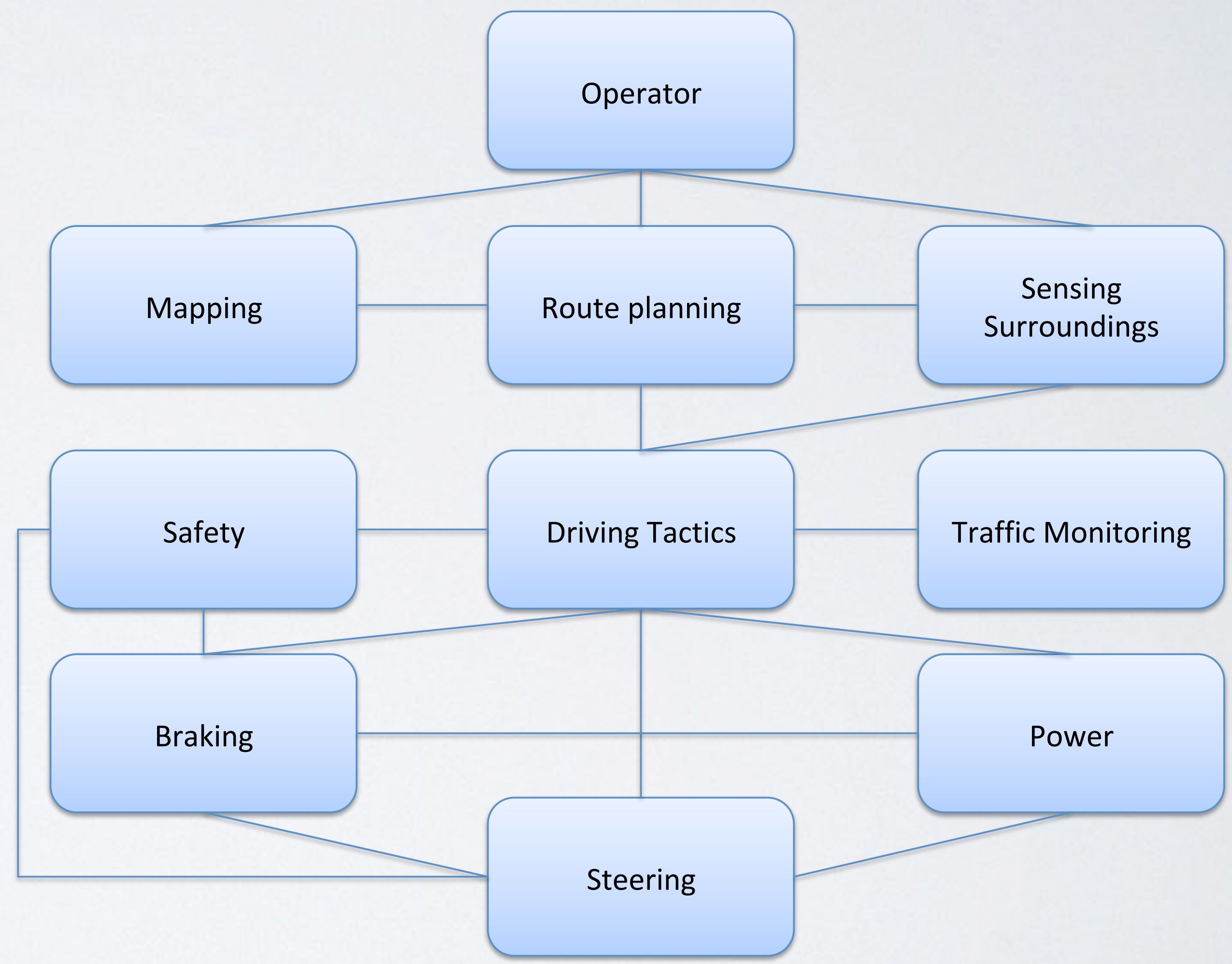
LAYERED SYSTEM OF HUMAN REASONING

- **Inborn, Instinctive Reactions**: Joan hears a sound and turns her head. All animals are born equipped with 'instincts' that help them to survive.
- **Learned Reactions**: She sees a quickly oncoming car. Joan had to learn that conditions like this demand specific ways to react.
- **Deliberative Thinking**: To decide what to say at the meeting, she considers several alternatives, and tries to decide which would be best.
- **Reflective Thinking:** Joan reflects upon what she has done. She reacts, not just to things in things in the world, but also to recent events in her brain.
- **Self-Reflective Thinking:** Being "uneasy about arriving late" requires her to keep track of the plans that she's made for herself.



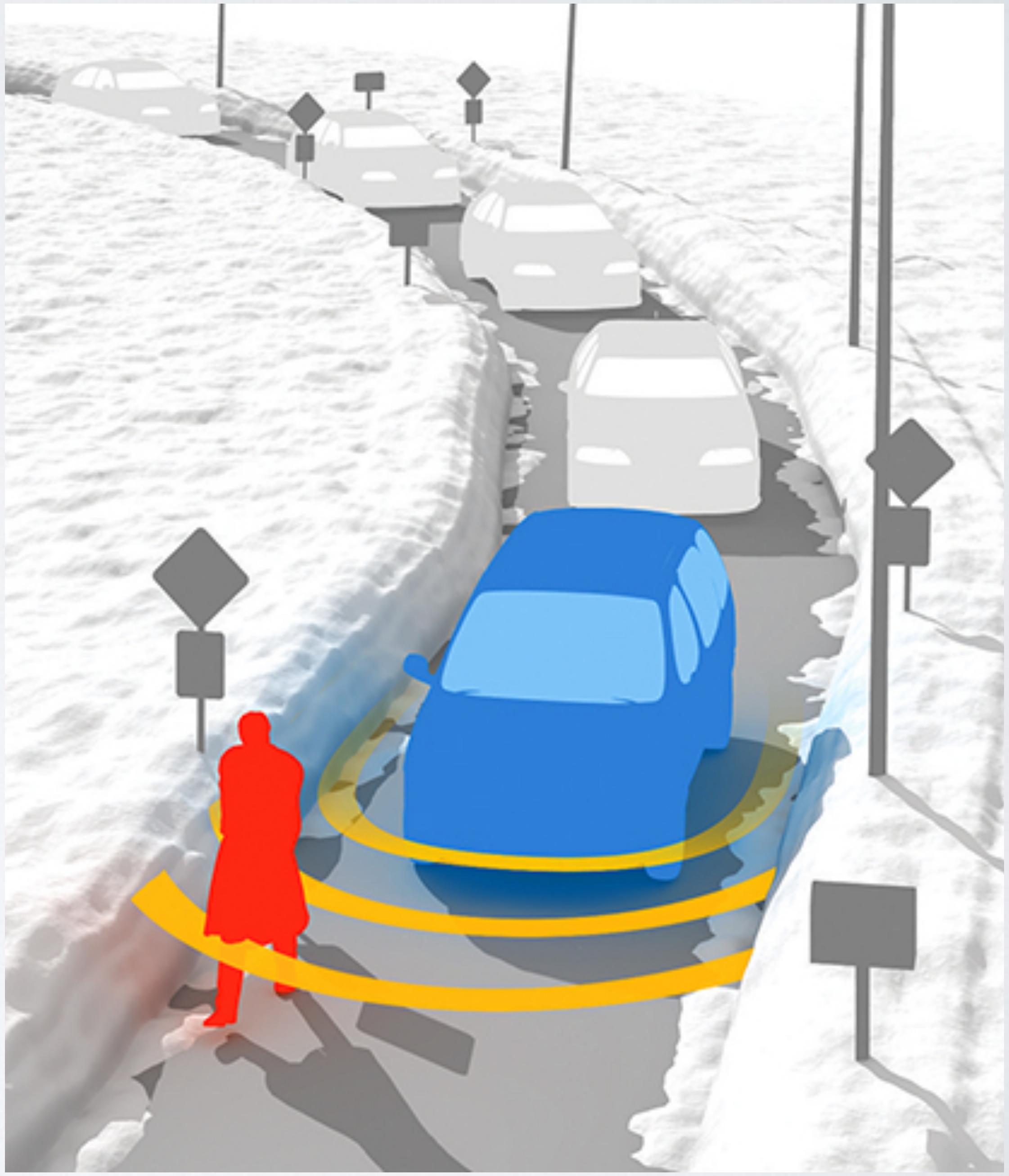
LAYERED SYSTEM OF HUMAN REASONING





NOW, RODNEY BROOKS

- Technology has unintended consequences
- Highlights different problems
  - Dynamics of interaction
    - pedestrian
    - pedestrian to car (even car to car)
  - Bullying



Source: IEEE Spectrum. Illustration by Bryan Christie Design

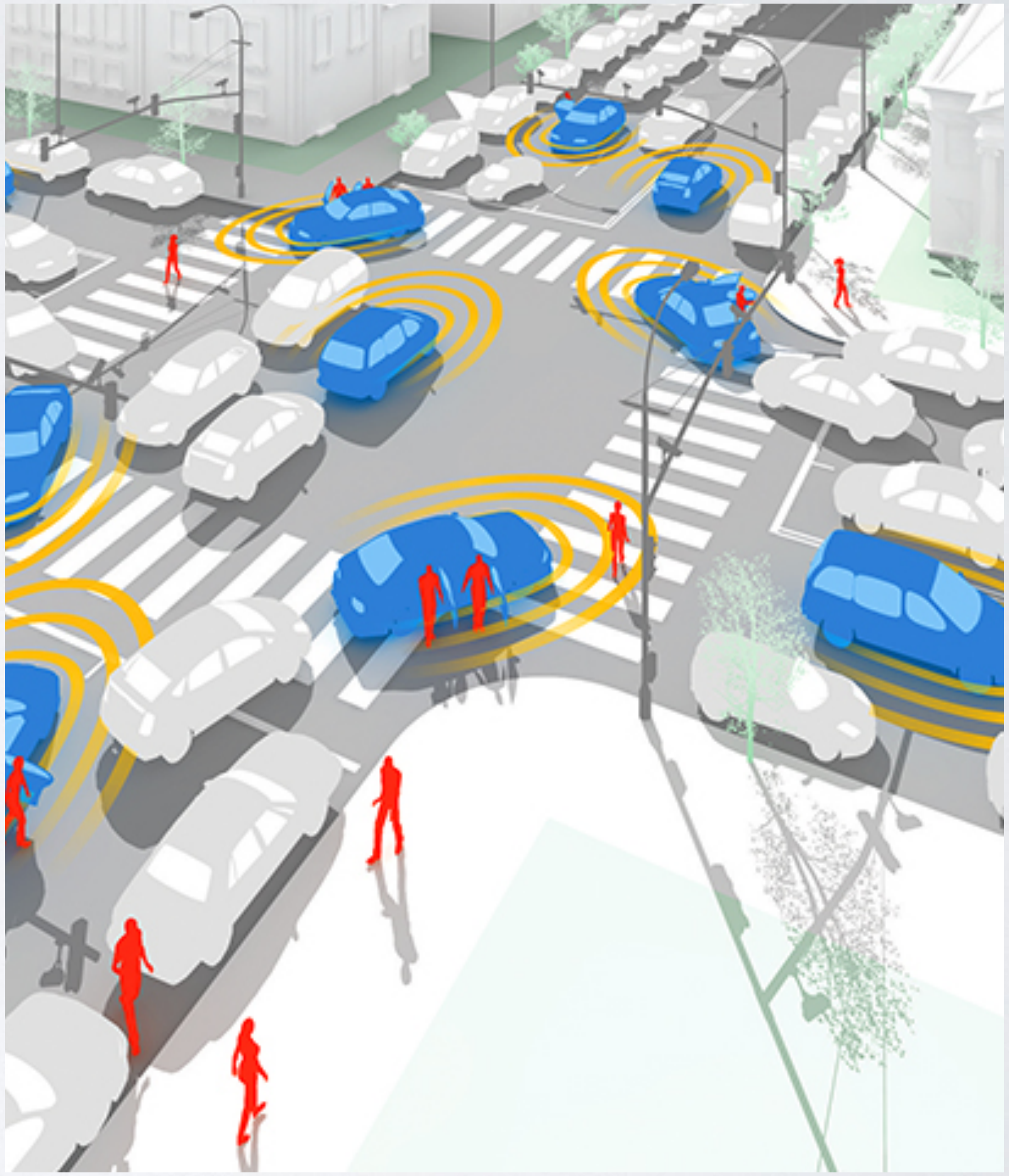
DYNAMICS OF INTERACTION

- Reading body language
- Signifying to the pedestrian
- Interactions with different levels of autonomy

Source: IEEE Spectrum. Illustration by Bryan Christie Design

BULLYING

- Block others with self-driving cars (adding another line).
- Use multiple AVs to wait in line *early.*
- Using AVs early in the market…



Source: IEEE Spectrum. Illustration by Bryan Christie Design

OTHER PROBLEMS

- Infrastructure
- Restricted environments
  - Autonomous subways

Autonomous subway in Copenhagen

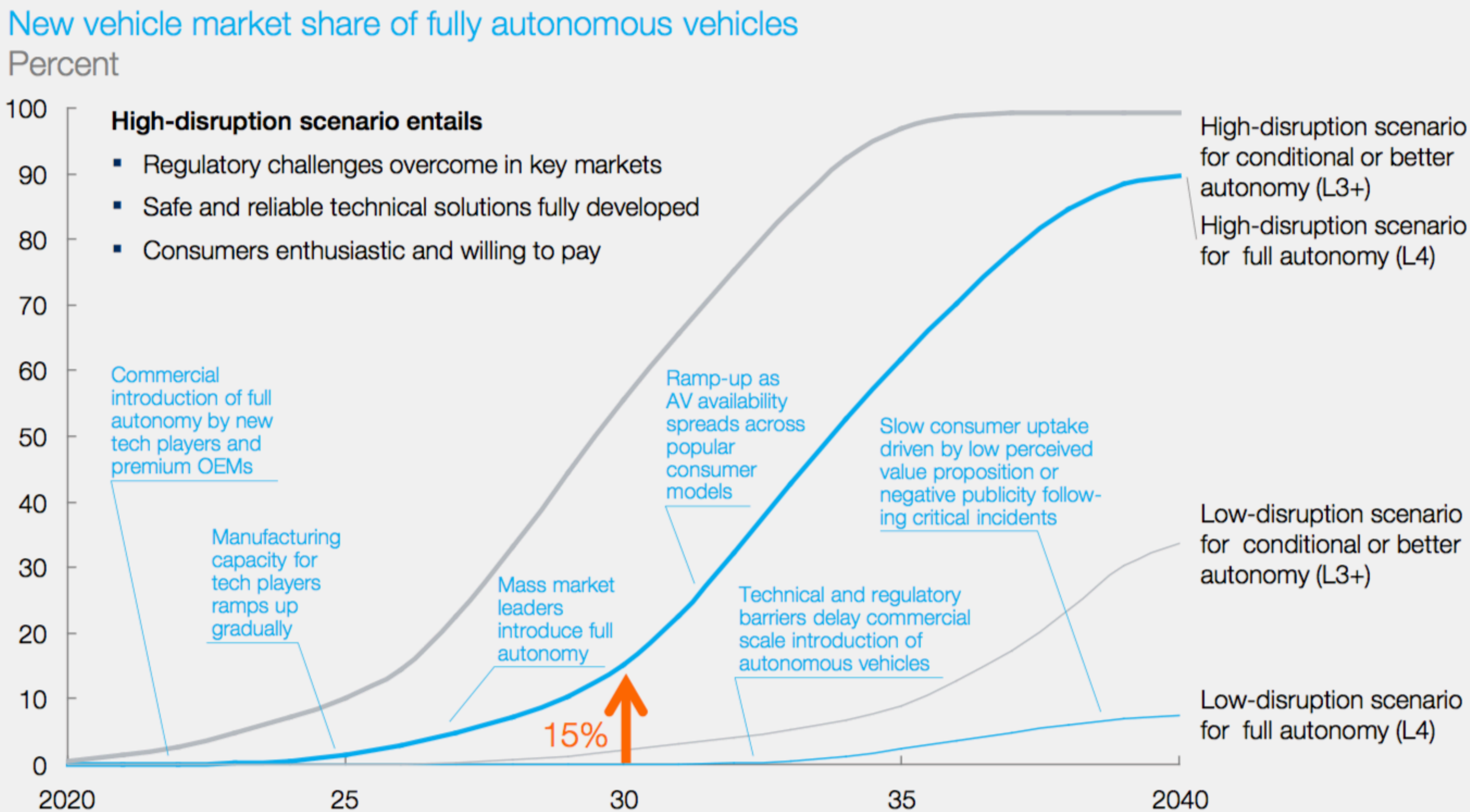
WHAT’S NEXT?

TESTING STILL "BAD"

Company	Autonomous miles	Disengagements	Rate per 1000 miles
Google	635868	124	0.20
Cruise	10015	284	28.36
Nissan	4099	28	6.83
Delphi	3125	178	56.95
Bosch	983	1442	1466.94
Mercedes	673	336	498.95
BMW	638	1	1.57
Ford	590	3	5.08
Tesla	550	182	330.91
Honda	0	0	0.00
VW	0	0	0.00

Source: California DMV. Image - Mark Harris

Subject to progress on the technical, infrastructure, and regulatory challenges, up to 15% of all new vehicles sold in 2030 could be fully autonomous



SOURCE: McKinsey

OEM - original-equipment manufacturers

Exhibit 3

Today consumers use their vehicles for all purposes; in the future, they will choose an optimal mobility solution for each specific purpose

Today:
One vehicle for every trip purpose

Avg. share of annual driving time

2030:
A solution for each specific purpose[1]

1 Only showing automobile based mobility, alternative options like walking, biking, and public transportation are also included in optimal mobility solutions

SOURCE: McKinsey