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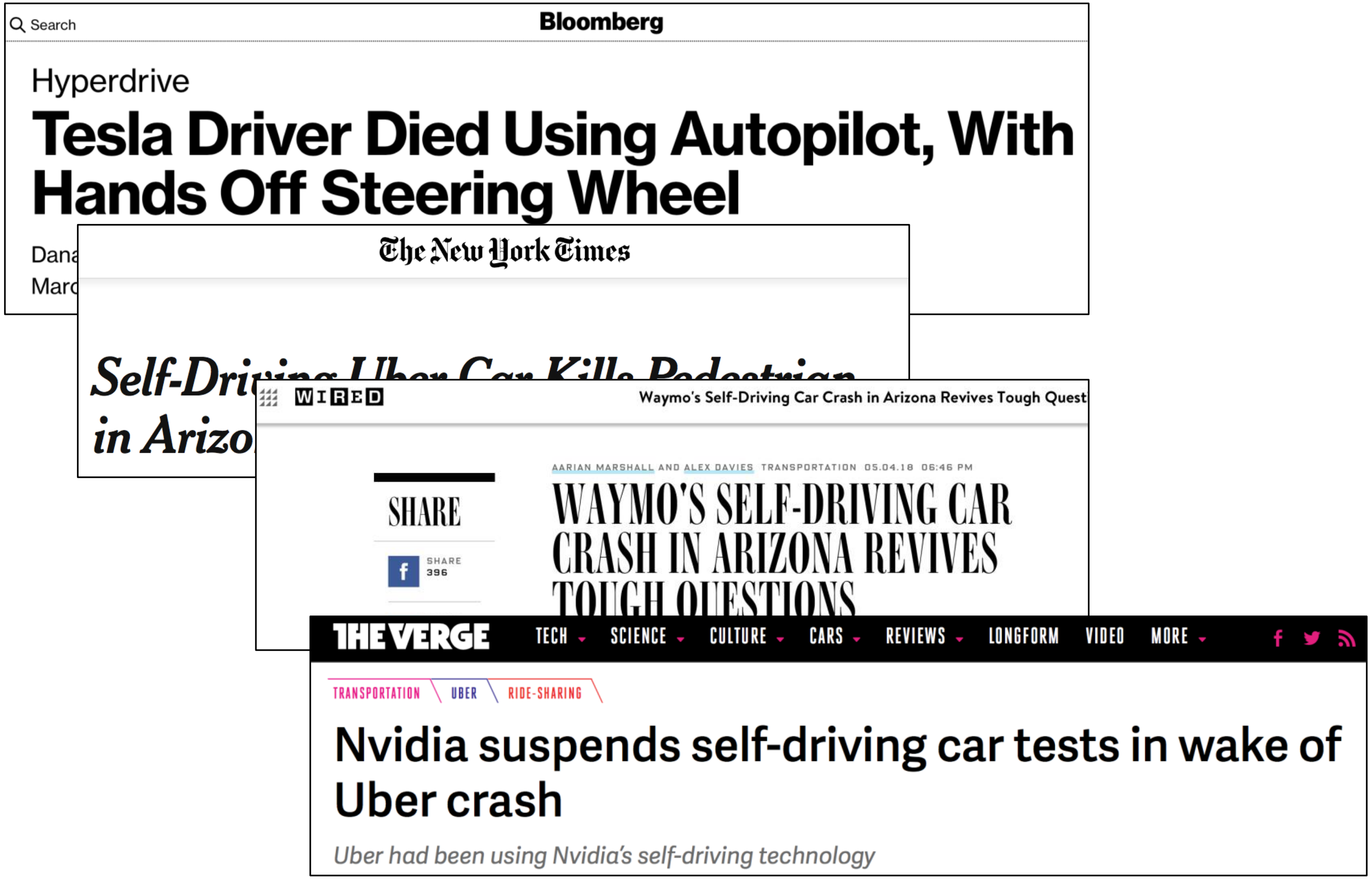
Hands Off the Wheel in Autonomous Vehicles?

A Systems Perspective on over a Million Miles of Field Data

Resilience of Autonomous Vehicles

- AVs advertised as transformative – improve congestion, safety, productivity, and comfort.
- Recent media attention on Tesla/Waymo/Uber AVs.
- **Research Gap: Resilience of AV Technology**
  - **Causes – Dynamics – Impacts of failure**



Overview

Data driven analysis of failures in the field during testing of AVs

California Department of Motor Vehicles AV Testing Reports (2014 – 2016)

1,116,605 miles – **144** AVs – **12** Vendors
5328 Disengagements – **42** Accidents

Failure Modes

1 Disengagements

Human Initiated

AV Initiated

Disengagement: A transfer of control from the autonomous system to the human driver in the case of a failure.

Accident: An collision with other vehicles, pedestrians, or property.

Quantified in terms of *disengagements per mile (DPM)* and *accident per mile (APM)*.

2 Accidents

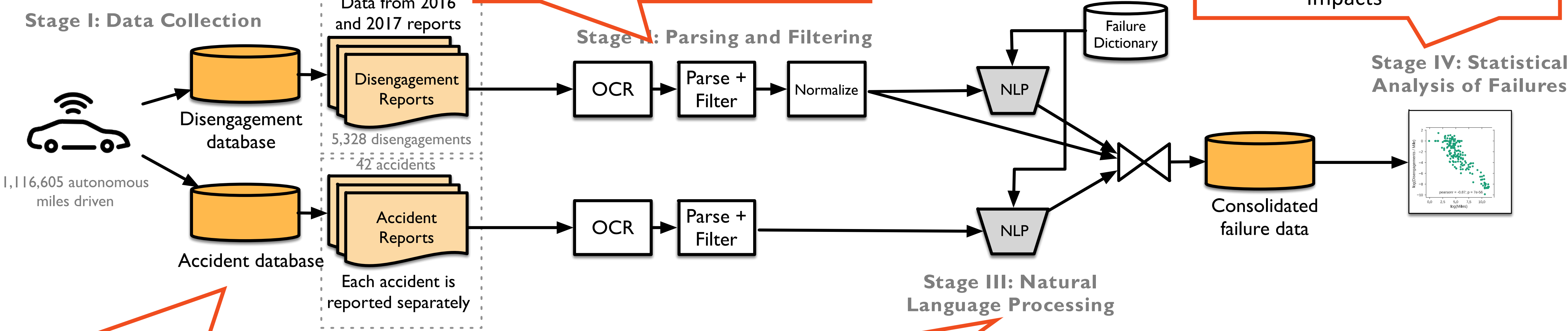
Key Findings

- AVs are **up to 4000× more likely to have an accident** than human drivers.
- DPM, APM strongly negatively correlated with miles driven.
- ML components of AVs responsible for **65% of failure reports**.
- Reliability per mission: AVs are **up to 100× worse** than airplanes.

LogDriver: An End-to-End Workflow for AV Log Data Analysis

- Reports stored as scanned documents.
- Vendor specific parsing & filtering.
- Standardizing data formats across vendors.

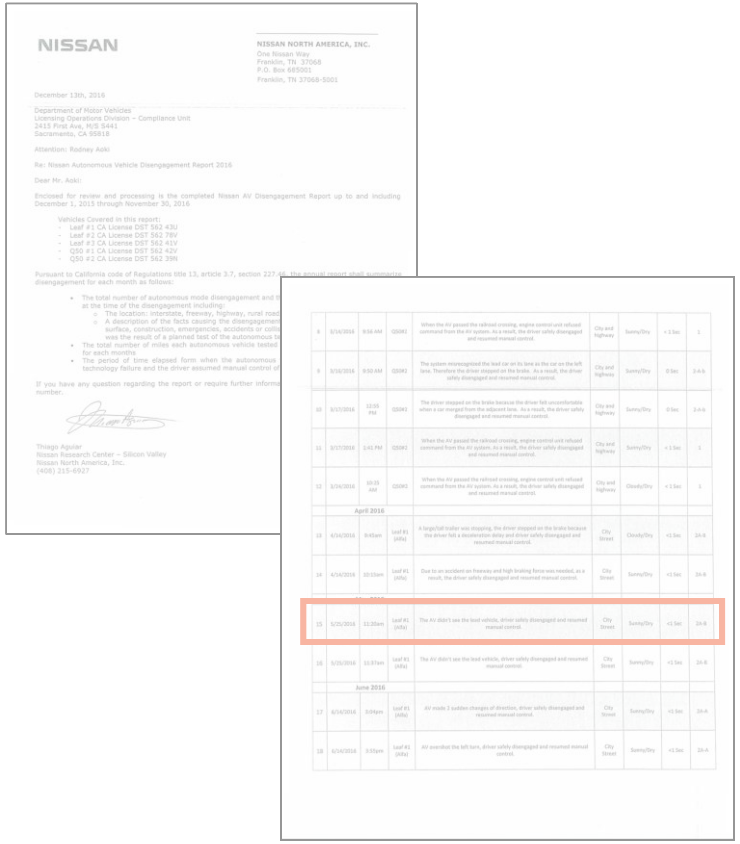
- Analyze failure data to quantify
  - Causes
  - Dynamics
  - Impacts



- Vendors are required to collect data as per CA laws.
- CA DMV curates databases of vendor reports.
- No standardized reporting formats.

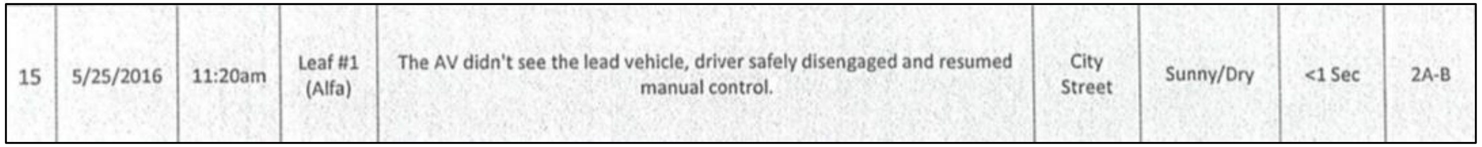
- Parse natural language text relating to failure causes.
- Localize failures in abstract system model.

LogDriver: Nissan Case Study



1 Nissan Disengagement Reports from the CA DMV

2 Individual Report



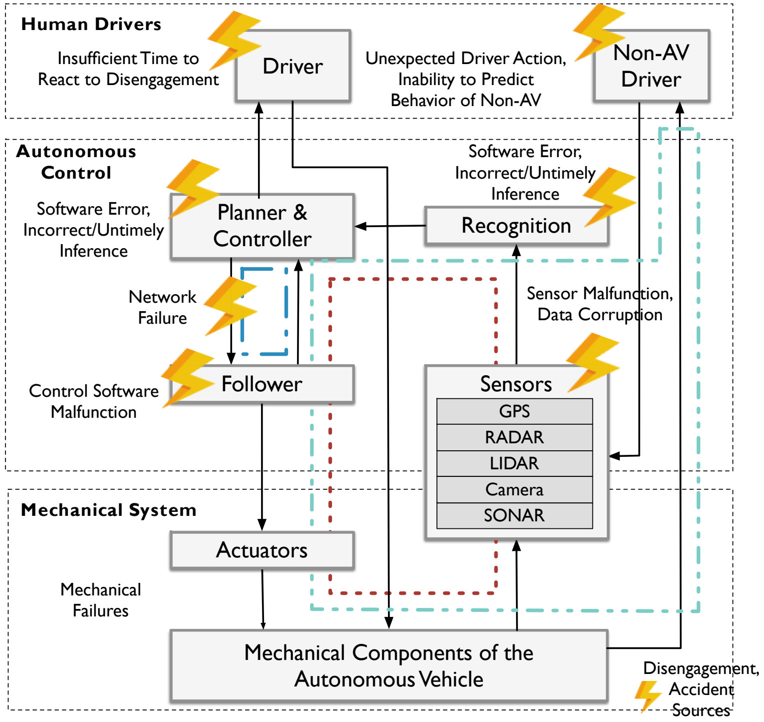
15	5/25/2016	11:20am	Leaf #1 (Alfa)	The AV didn't see the lead vehicle, driver safely disengaged and resumed manual control.	City Street	Sunny/Dry	<1 Sec	2A-B

3 OCR + Parsing + Cleaning

The AV **didn't see** the lead vehicle… +

Categories: Recognition

4 STPA[1] based ontology model



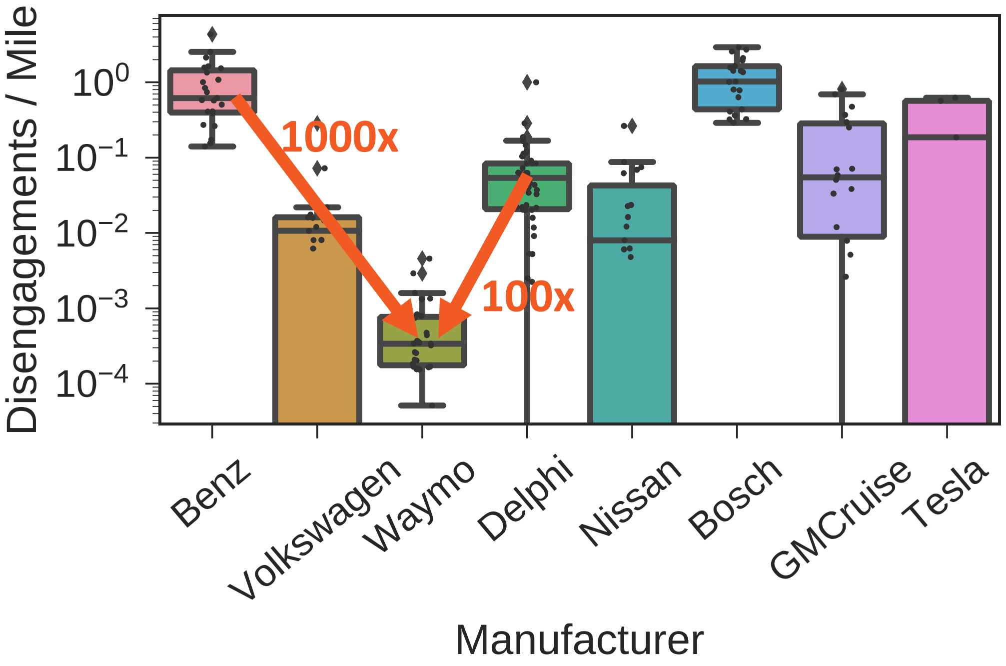
[1] N. Leveson, *Engineering a safer world: Systems thinking applied to safety*. MIT press, 2011.

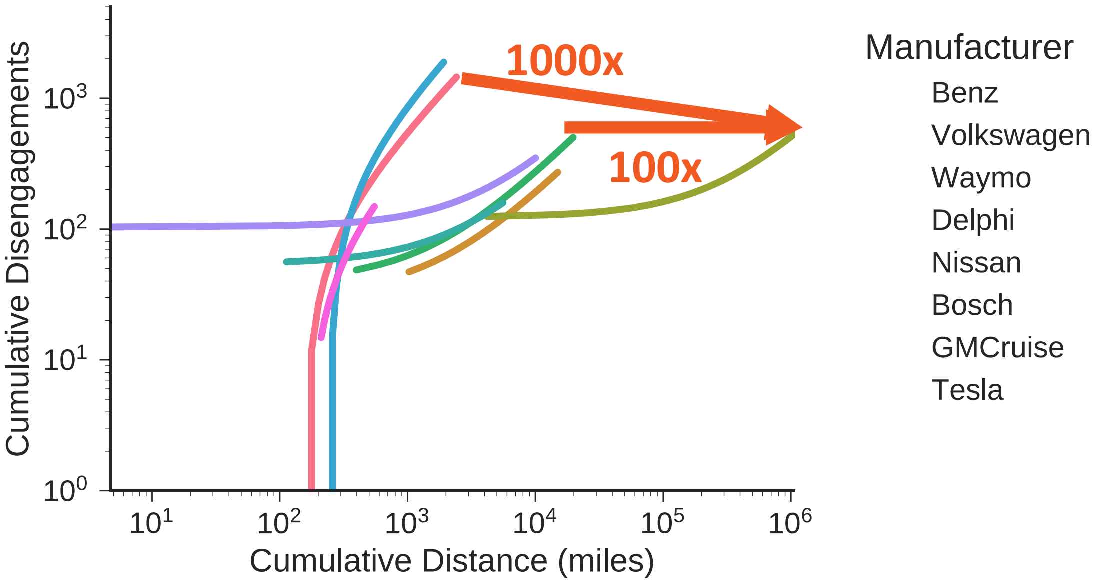
Data Driven Insights

- Maturity of AV Technology
- Causes of Failures
- Improvement in AV Technology over Time
- Hands Off the Wheel?
- Safety: AVs vs Humans

Maturity of AV Technology

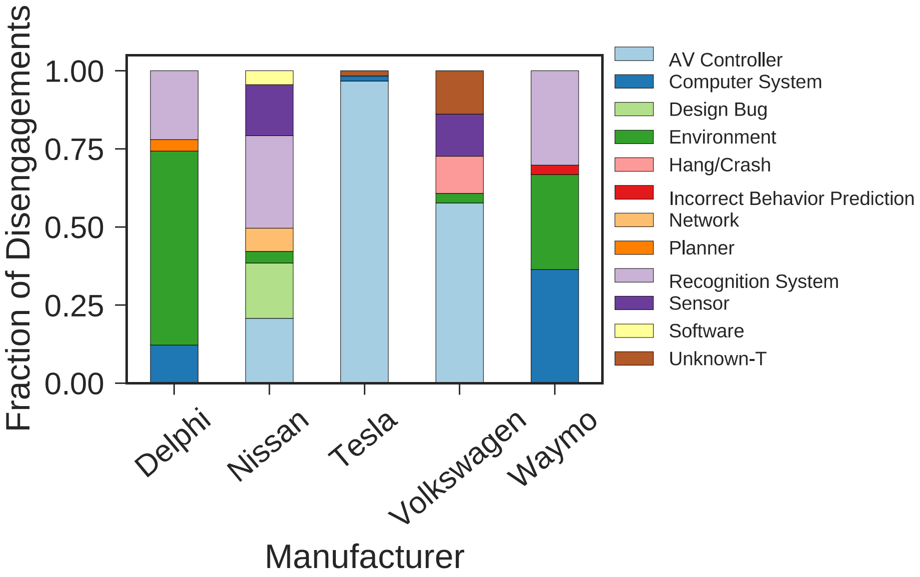
- DPM *related* to cumulative miles driven.
- Maturity: Still in "**burn-in**" phase.

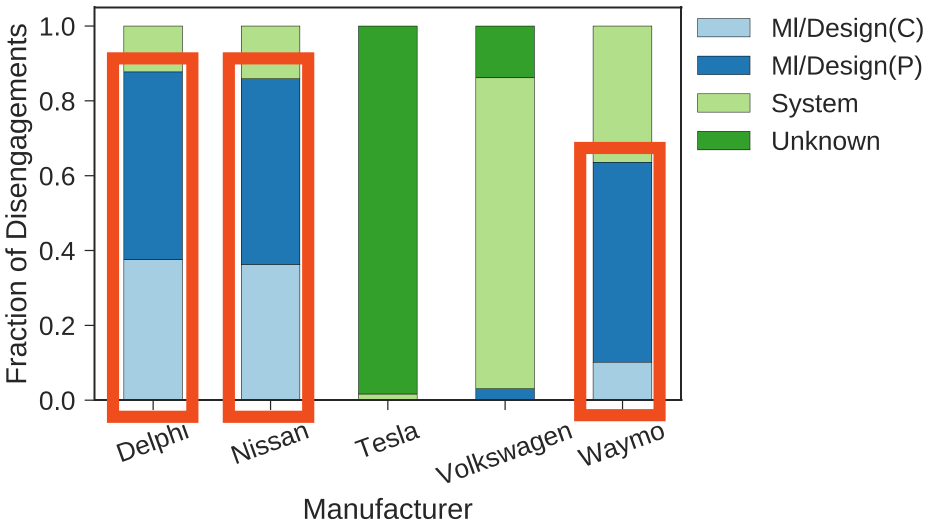


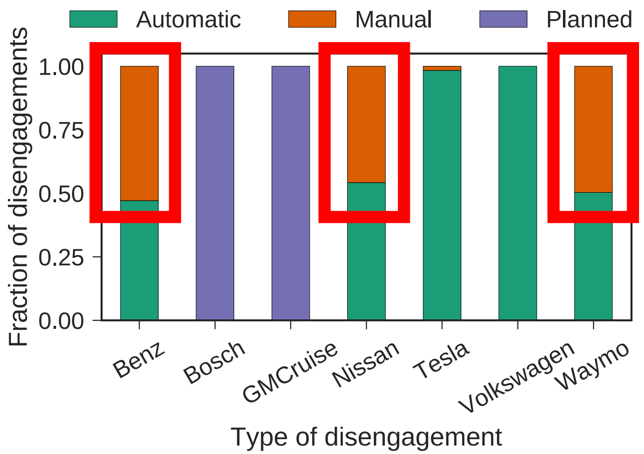


Causes of Failures

- **ML/Design issues** responsible for 65% of failures.
- 48% of disengagements are **human initiated**.







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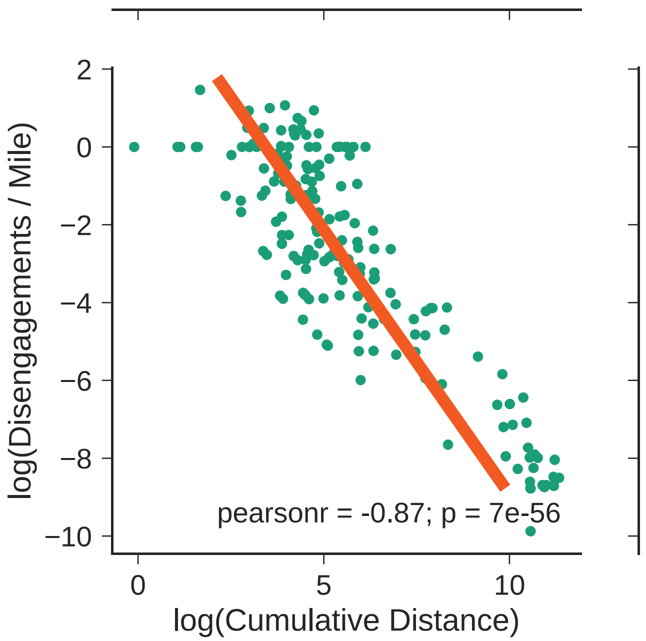
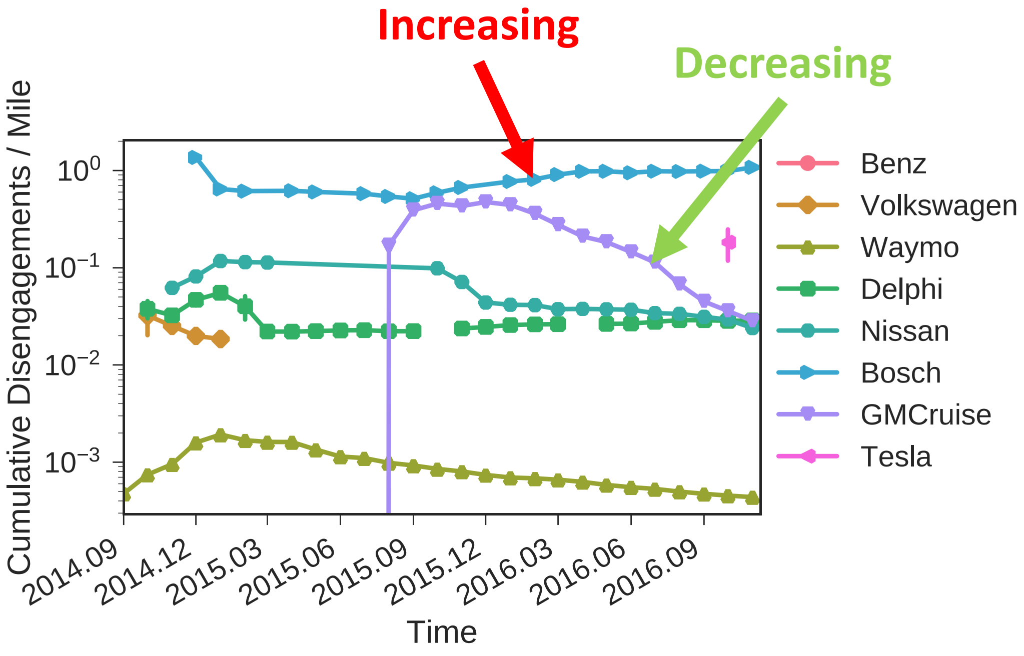
Are AVs improving over time?

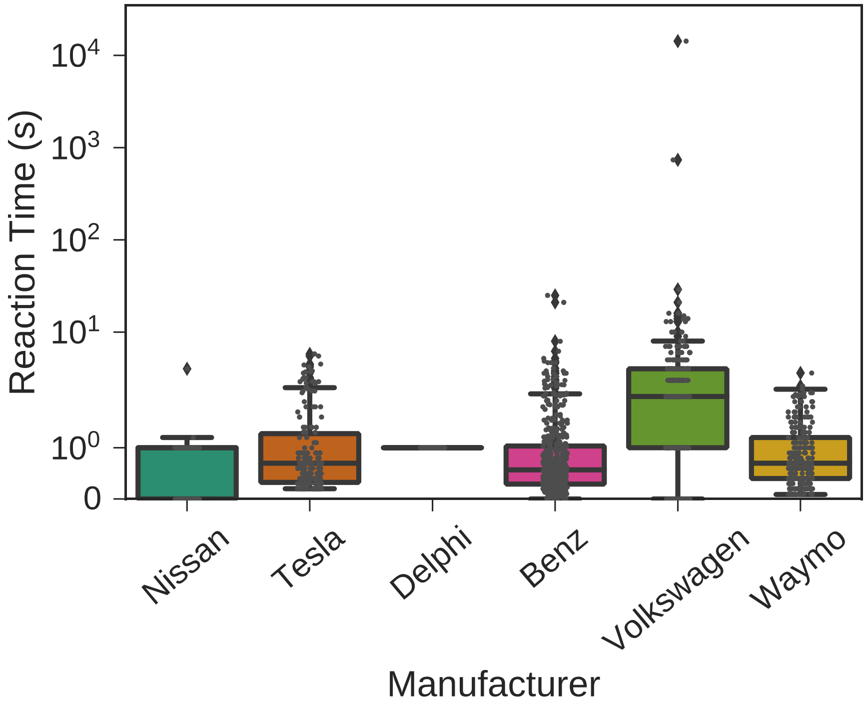
- **Strong negative correlation** of DPM with miles driven.
    - Some manufacturers show increasing DPM trends

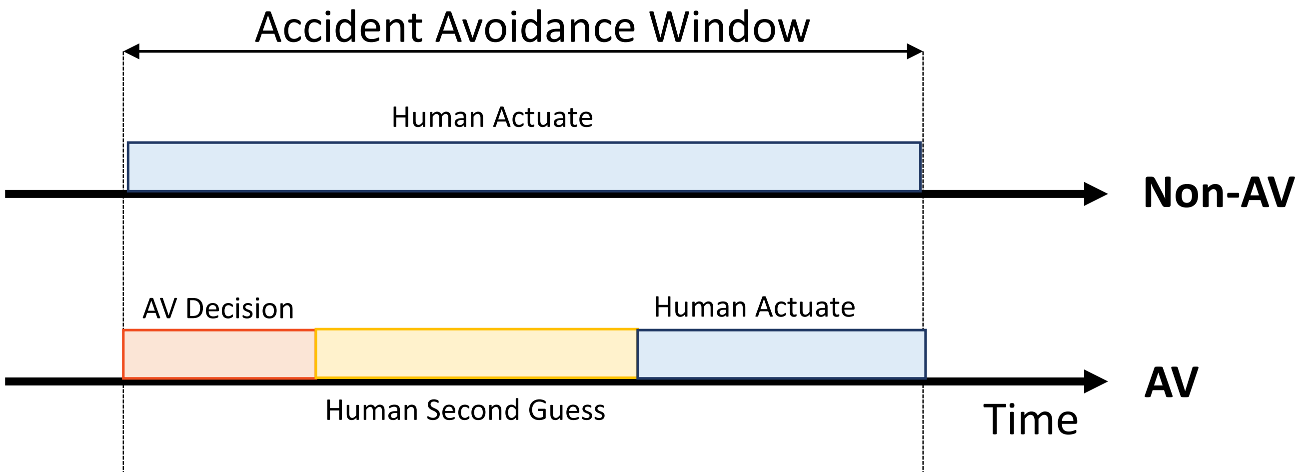




Hands off the wheel?

- **Accident Avoidance Times less than non-AVs:** 0.82 s (for AVs) vs 1.09 s (for non-AVs)
- 69% of reports accidents are **“Latency Accidents”**





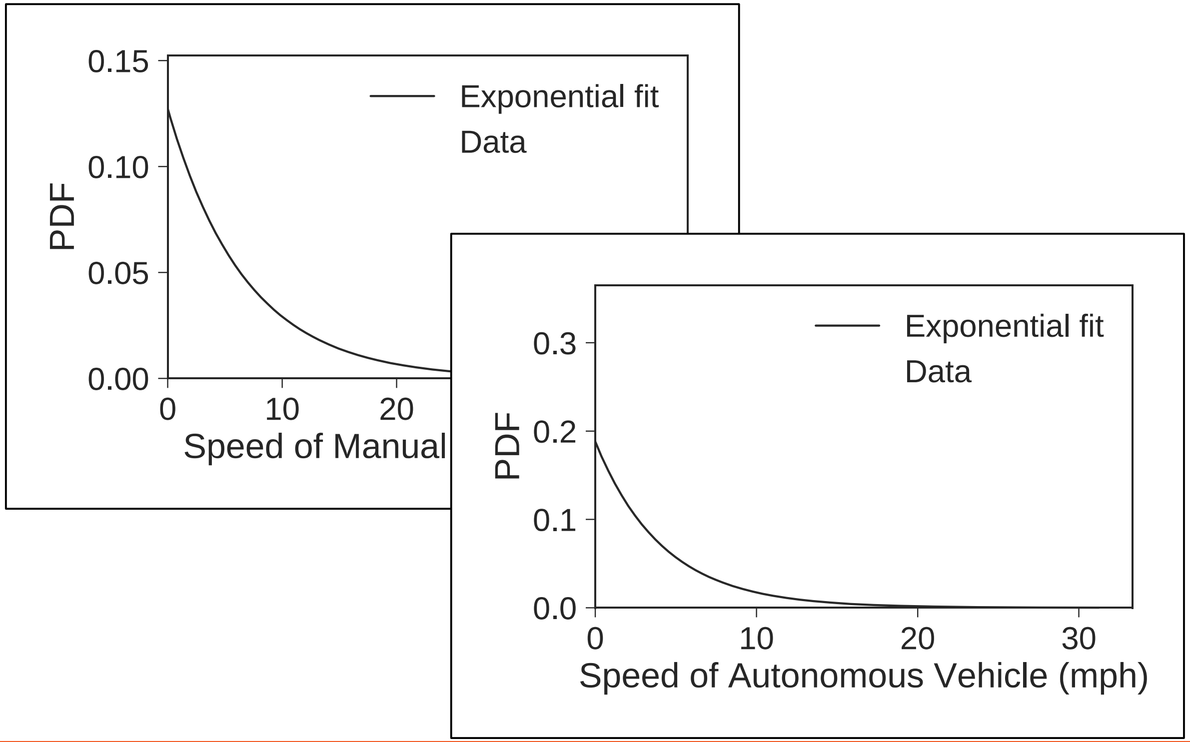
Comparison to human drivers

- Non-AVs are **15 – 4000×** less likely to have an accident.
- All accidents happen at intersection of urban streets.
- All accidents at low speeds: Human drivers cannot predict behavior.

Manufacturer	**Median DPM** (mile^{-1})	**Median APM** (mile^{-1})	**Rel. to HAPM**
Mercedes-Benz	0.565	–	–
Volkswagen	0.0181	–	–
Waymo	0.000745	4.140×10^{-5}	20.7×
Delphi	0.0263	4.599×10^{-5}	22.99×
Nissan	0.0413	3.057×10^{-4}	15.285×
Bosch	0.811	–	–
GMCruise	0.177	8.843×10^{-3}	4421.5×
Tesla	0.250	–	–

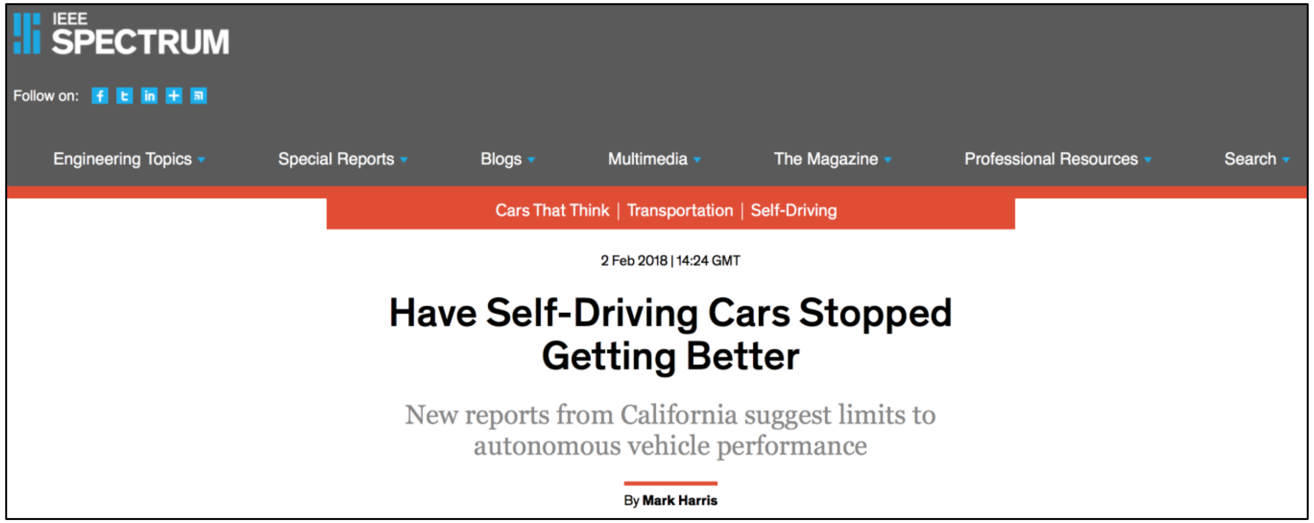
HAPM – Human APM.
Human APM $= 2 \times 10^{-6} \text{mile}^{-1}$ [37], [38].
Column 4 $=$ AV APM/Human APM.

>300×



Trends in 2017 Reports

- Vendors have moved away from testing vehicles in California.
  - BMW, Ford, Tesla, Honda, Volkswagen
- Decreasing DPM trend?
  - Not anymore…
- Serious issue:
  - Ridesharing as primary application.
  - Thousands vehicles.
  - 4.14×10^{-5} DPM corresponds to multiple failures daily.



Looking Forward

- Functionality first => Resilience second

- AVs are here to stay
  - ML Perception/Decision Control is key culprit
  - Traditional reliability bugs (bit flips) seem less important
  - Foundation of new research thrust

- Need for new reliability metrics

Questions?