MEASURING THE SAFETY OF ADS: HOW SAFE IS SAFE ENOUGH?

Eileen Herbers

January 25, 2024

What are ADS?

Automated Driving Systems

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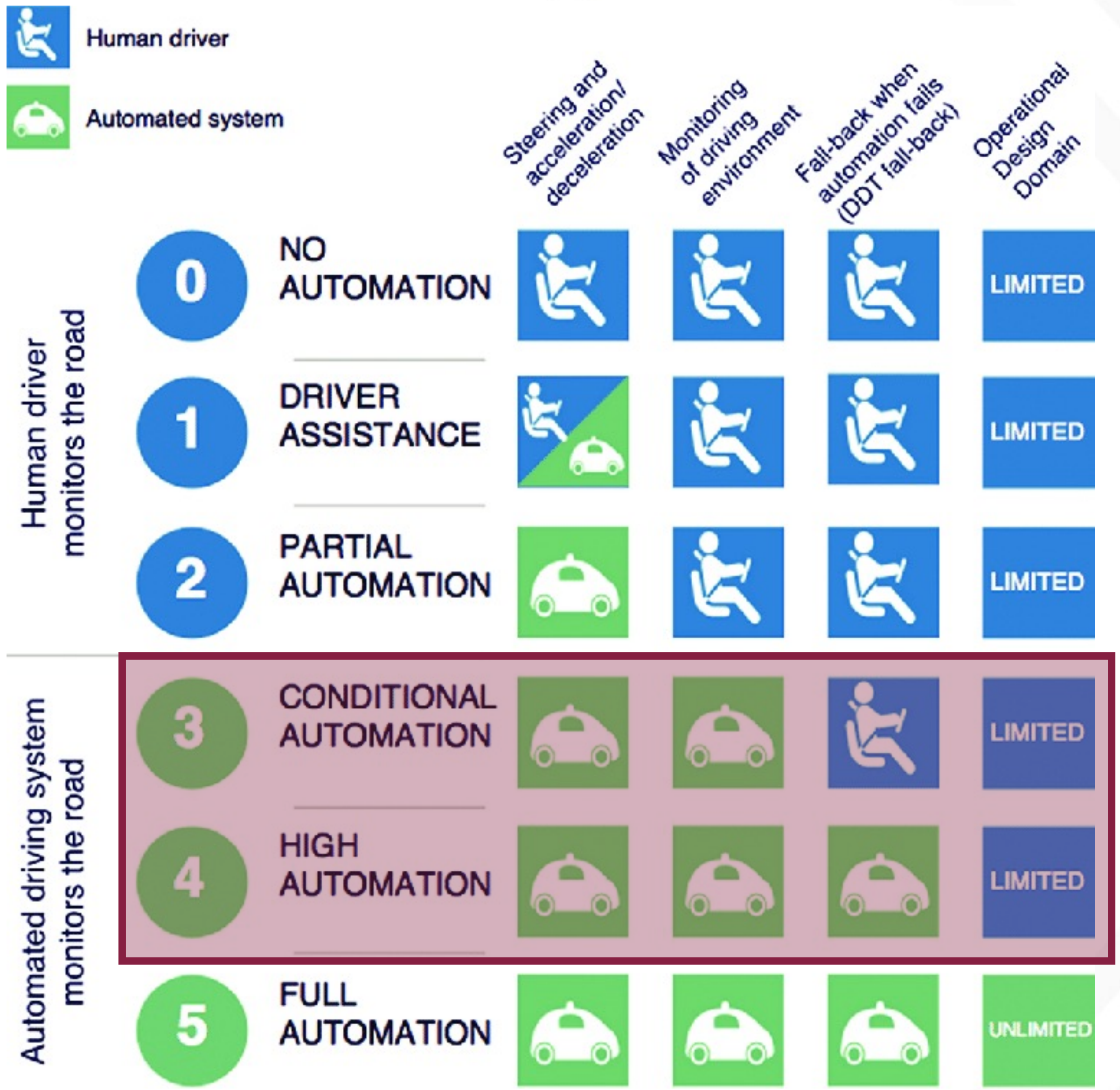


SAE, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*, in *Society of Automotive Engineers (SAE) International*. 2021.

How do we define what is acceptably safe?

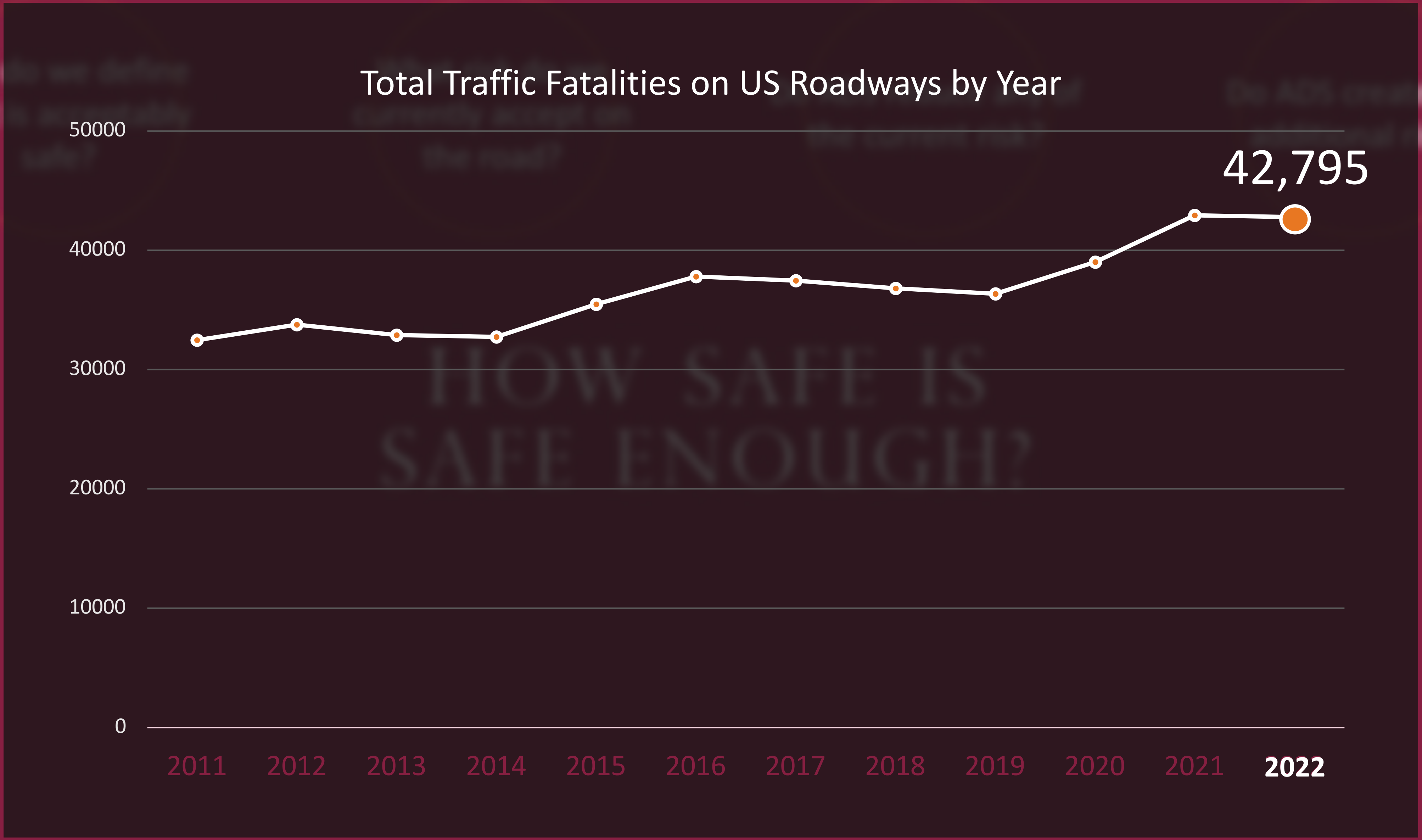
What risk do we currently accept on the road?

Do ADS reduce any of the current risk?

Do ADS create any additional risk?

HOW SAFE IS SAFE ENOUGH?

SAFER THAN A HUMAN DRIVER



NHTSA, *Early Estimate of Motor Vehicle Traffic Fatalities in 2022*, in *National Traffic Safety Facts: Crash Stats*. 2023.

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HOW SAFE IS SAFE ENOUGH?

Who defines what is acceptably safe?

How is ADS safety and performance tested?

What metrics and thresholds are used to determine safety?

Who is at fault if ADS are involved in a crash?

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PURPOSE

Use naturalistic driving data to inform scenario selection that will be used to measure how ADS might perform in these scenarios.

Determine and analyze some scenarios in which ADS may not provide the predicted advantage of reducing or mitigating safety-critical events (SCEs).

METHODS

Naturalistic Driving Data

- Operator Factor: Fault of the other driver
- Visual Obstruction: Present

Configuration Category		Number of Events
	Angle, Sideswipe, Merge, Cut-in	1325
	Forward Impact	665
	Perpendicular	608
	Head on (Initial Opposite Direction)	285
	Backing Up	107
	Roadside Departure	17

METHODS

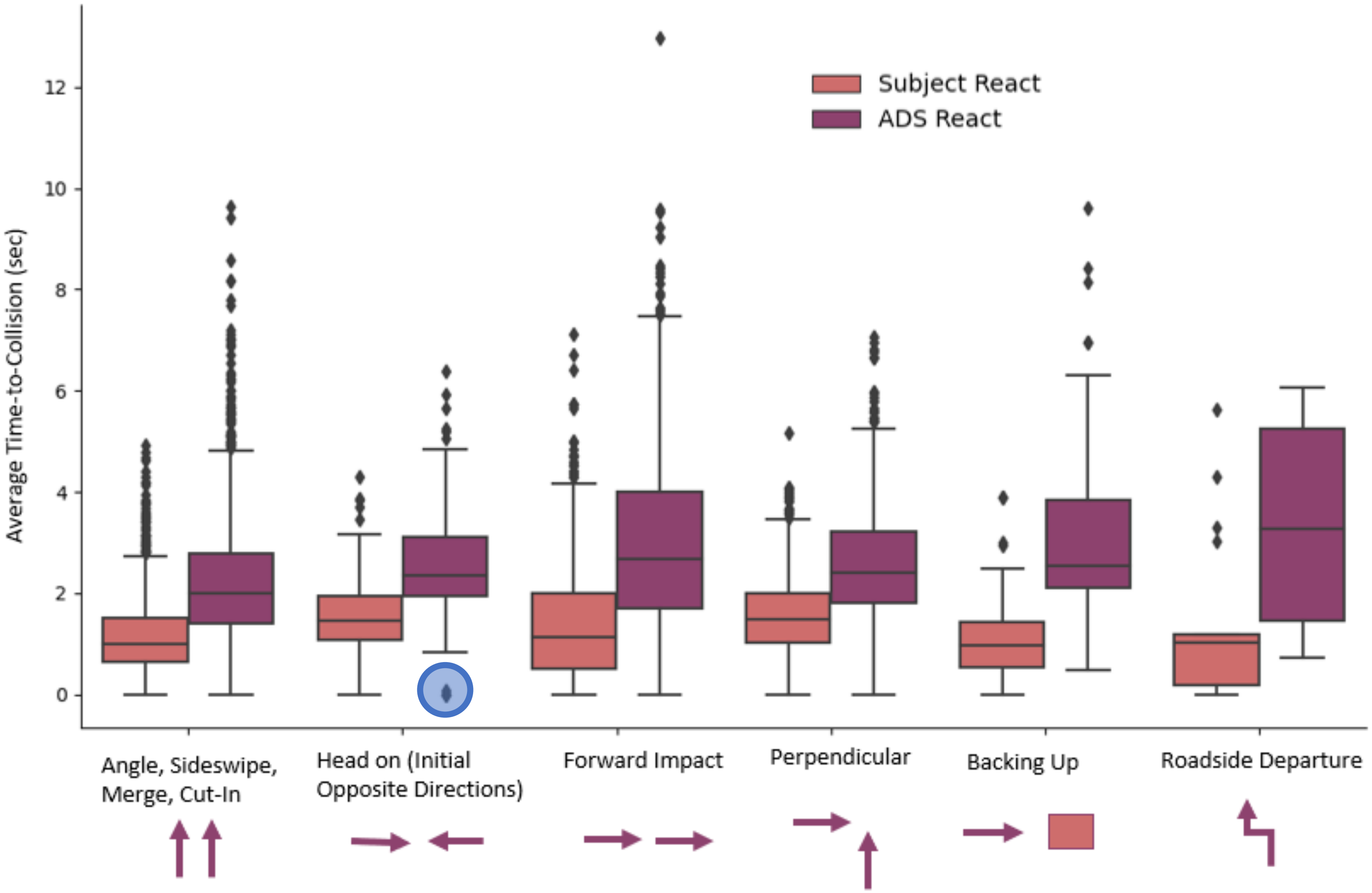
Variable	Definition
T0	Conflict Object Identified
T1	Conflict Begin
T2	Subject Reaction Start
T3	Impact or Proximity Frame

Safety Surrogate Measures

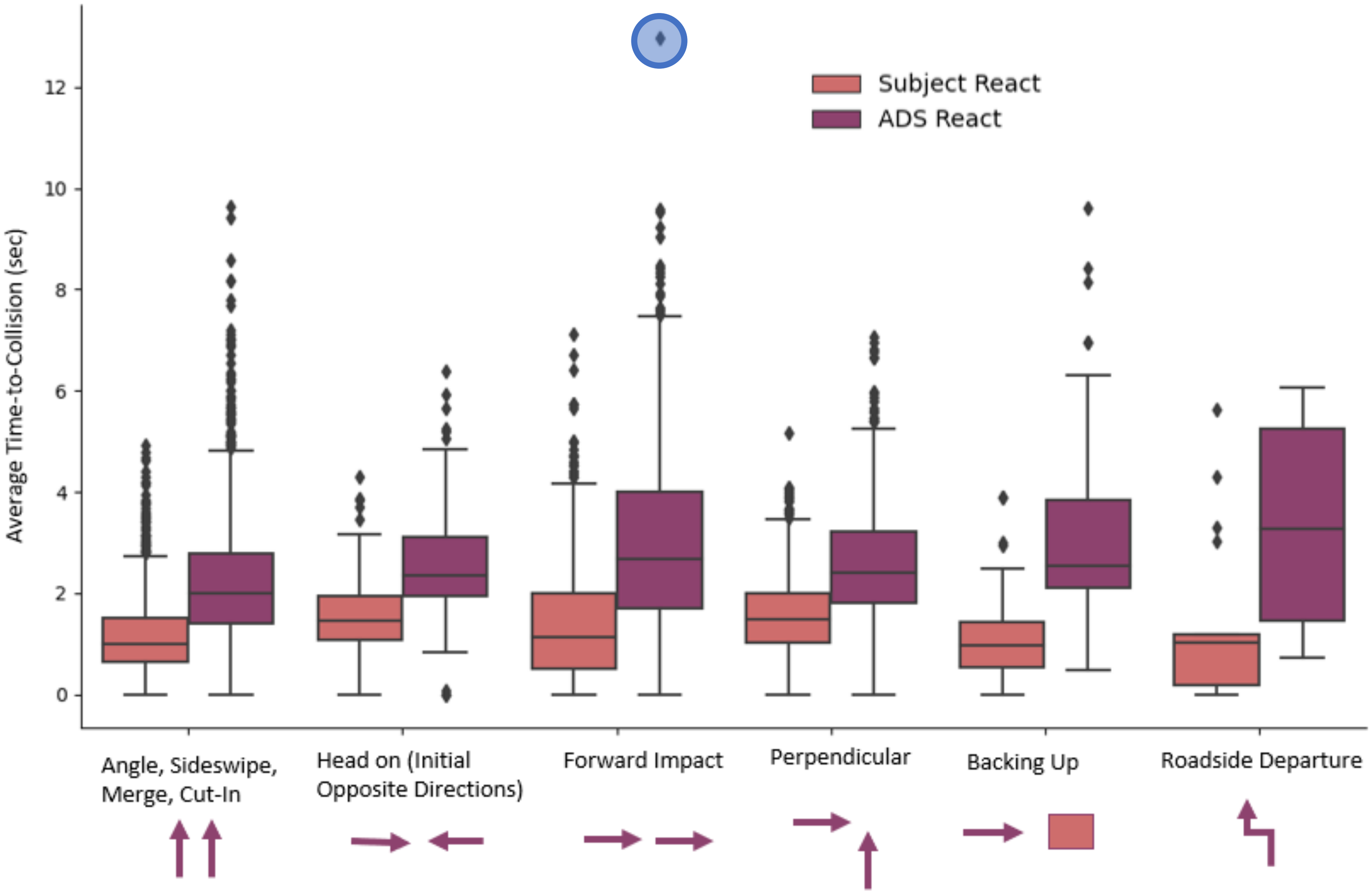
- Relative Velocity
- TTC
- Minimum Required Deceleration

Video Review

- Validate that timestamps and values are reasonable
- Identify outlying cases
- Categorize scenarios


Subject React
ADS React
Average Time-to-Collision (sec)
0
2
4
6
8
10
12
Angle, Sideswipe, Merge, Cut-In
Head on (Initial Opposite Directions)
Forward Impact
Perpendicular
Backing Up
Roadside Departure


1720754


Subject React
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0
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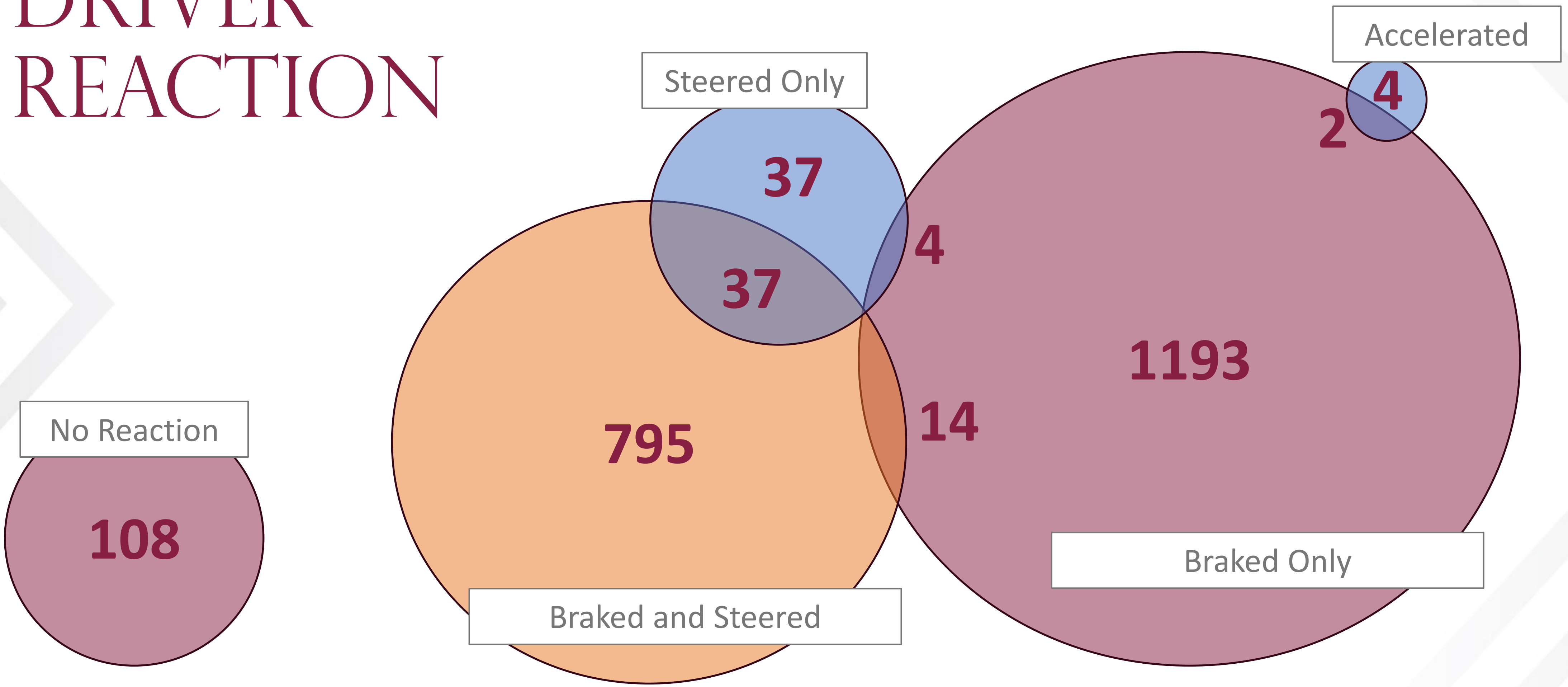
Roadside Departure


847269

DRIVER REACTION

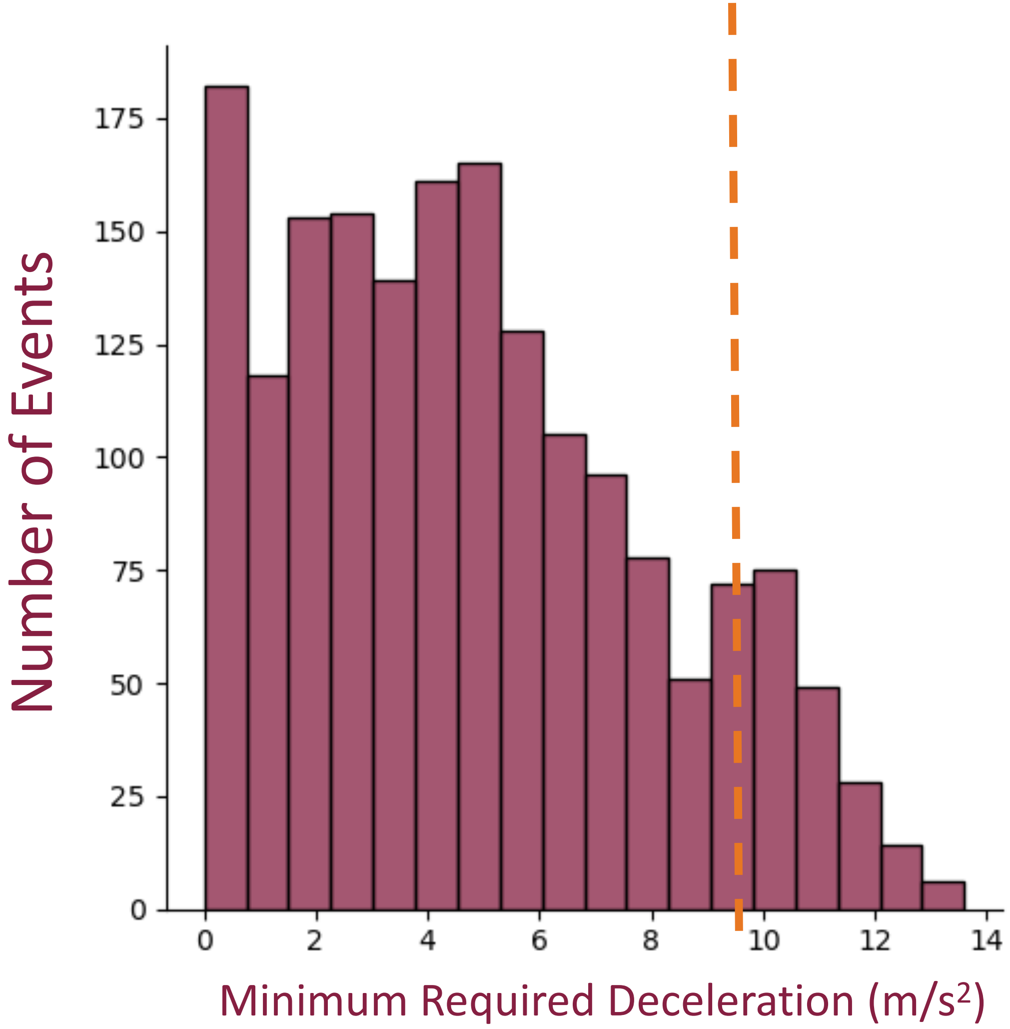



198718


1314200

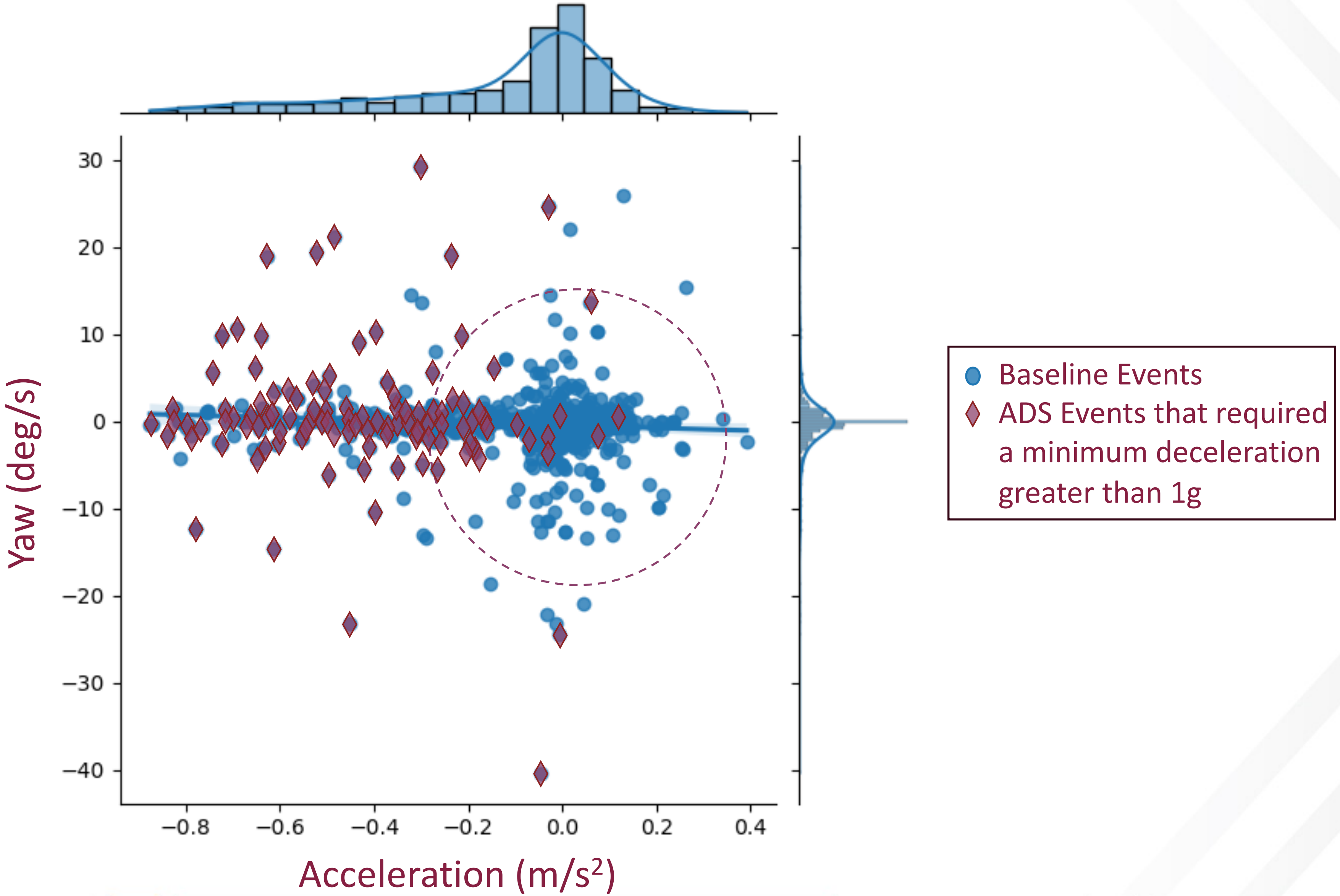

263284

Minimum required deceleration to avoid a crash if the subject vehicle were equipped with ADS.



11.57%

Percentage of events analyzed that required a minimum required deceleration value greater than 1g


30
20
10
0
−10
−20
−30
−40
Yaw (deg/s)
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
Acceleration (m/s²)
Baseline Events
ADS Events that required a minimum deceleration greater than 1g

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SAFER THAN A HUMAN DRIVER

CONCLUSION

- Using a small set of naturalistic data has the potential to convey important information to wide-scale ADS deployment that simulation or closed-track testing cannot.
- Human drivers are generally good at performing evasive maneuvers that require braking and steering, which requires a complex set of decisions for ADS.

- ADS may not perform as expected in:
  - High-speed turns
  - Blind turns and hills
  - Lane-change events with other vehicles
  - Scenarios with significant occlusion
- Near-crash and crash-relevant events are crucial to understanding the complex driving context

THANK YOU

SAFE-D
SAFETY THROUGH DISRUPTION

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Texas A&M Transportation Institute
VirginiaTech Transportation Institute

Absolute Safety vs. Relative Safety

Objective Safety vs. Subjective Safety

Variables of Safety

Harm
Probability
Uncertainty
Control

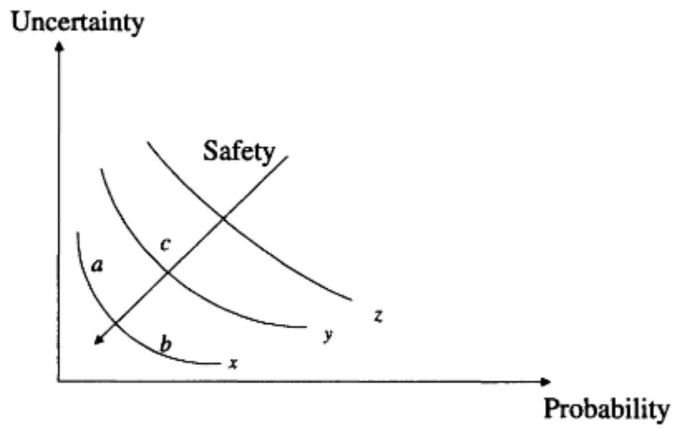


Figure 1. Safety as a function of probability and uncertainty. x, y and z are levels of safety such that $x>y>z$.

MÖLLER, N., HANSSON, S. O., & PETERSON, M. (2006). Safety is more than the antonym of risk. *Journal of Applied Philosophy*, 23(4), 419–432. http://www.jstor.org/stable/24354864

HOW SAFETY IS CURRENTLY MEASURED

ADAS (L1 & L2)	ADS (L3 & L4)
Crash Statistics	
Simulation	Simulation
Closed Test-Track Testing	Closed Test-Track Testing
Field Testing	
Insurance Claims	

HOW SAFETY IS CURRENTLY MEASURED

Crash Rates

$$\frac{\text{\# of crashes of ADS}}{\text{\# of miles driven by ADS}} < \frac{\text{\# of crashes of human-driven vehicles}}{\text{\# of miles driven by human drivers}}$$

HOW DO CURRENT ADS MEASURE SAFETY?

Collision Frequency

“Cruise relied upon factors of collision frequency, primary contribution and risk of injury when comparing its AVs to the human ride-hail benchmark.”

Cruise’s “first million driverless miles resulted in only 36 collisions, of which 94% were caused by the behavior of other parties.”

- 21% other parties reversed into a stationary Cruise AV
- 26% other parties rear-ended Cruise AV often at stop signs or red lights
- 3% other parties drove the wrong way on a one-way road
- 9% other parties blowing through red lights or stop signs and made contact with a stationary Cruise AV

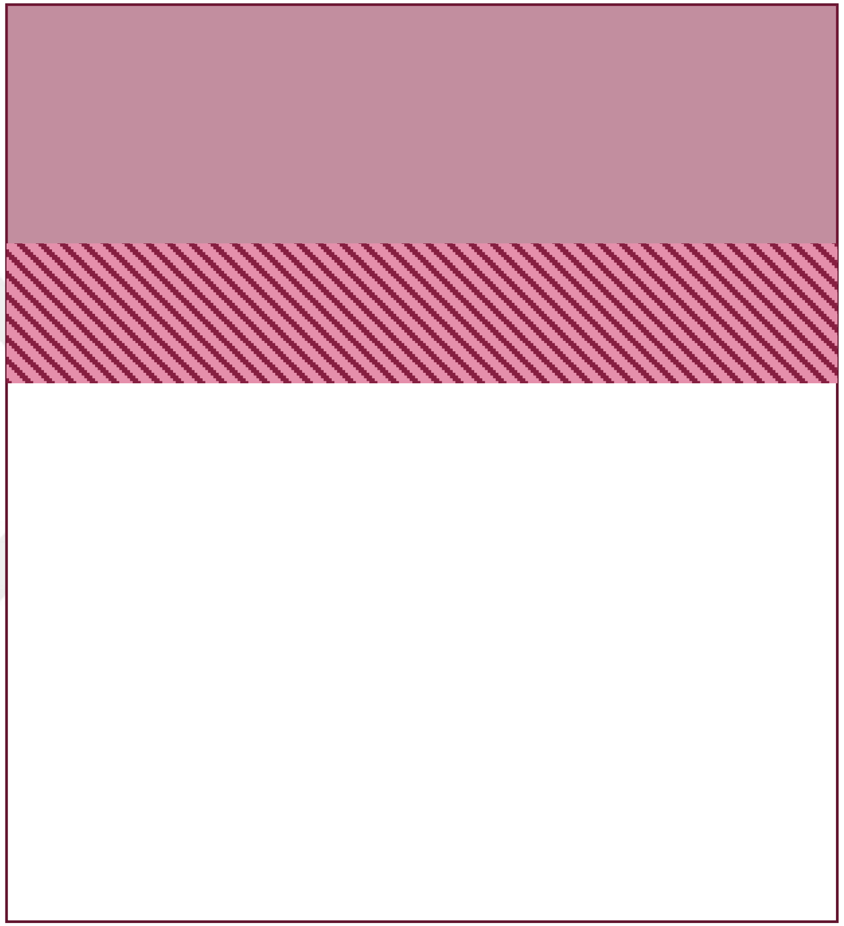
Insurance Claims

Waymo vehicles “reduced the frequency of bodily injury claims by 100 percent, compared to Swiss Re’s human baseline of 1.11 claims per million miles.”

https://theavindustry.org/resources/blog/research-discoveries-rd-cruises-safety-record-over-1-million-driverless-miles#:~:text=HUMAN%20DRIVERS%20VS.-,CRUISE%20AVS,the%20human%20ride%2Dhail%20benchmark.

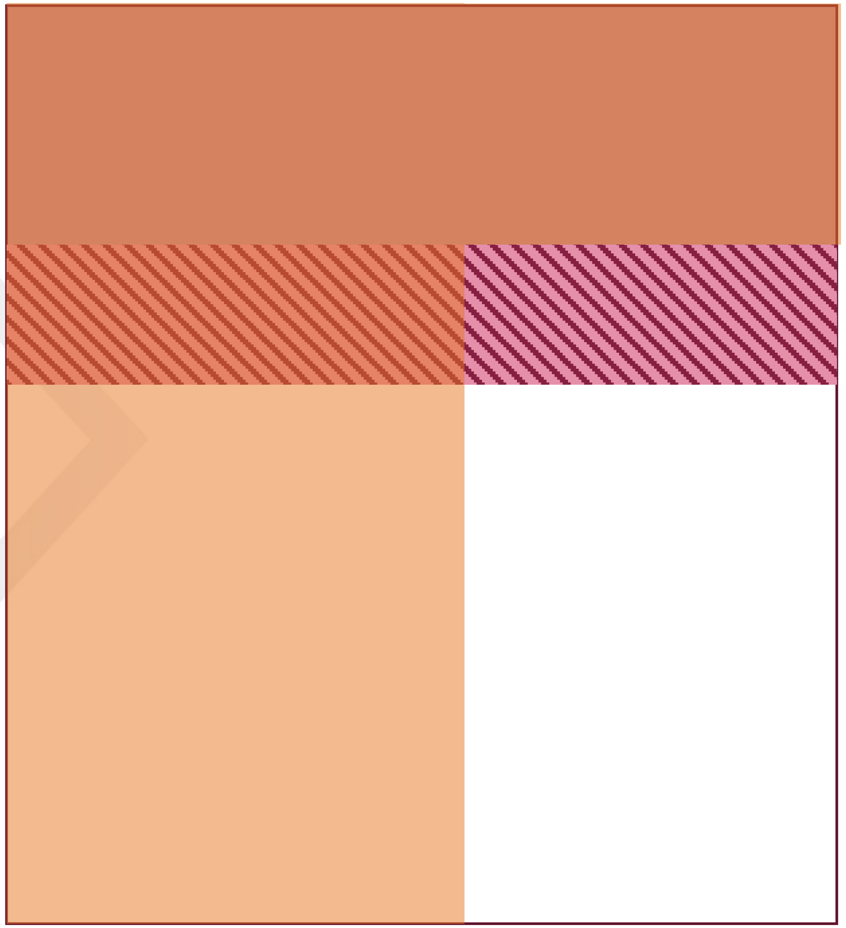
https://www.theverge.com/2023/9/6/23860029/waymo-insurance-injury-claims-autonomous-vehicle-swiss-re

Population of Crashes



- Population of crashes that could potentially be mitigated by ADAS features
- Crashes within the above population that can’t actually be mitigated by ADAS or ADS features because information is unknown

Population of Crashes



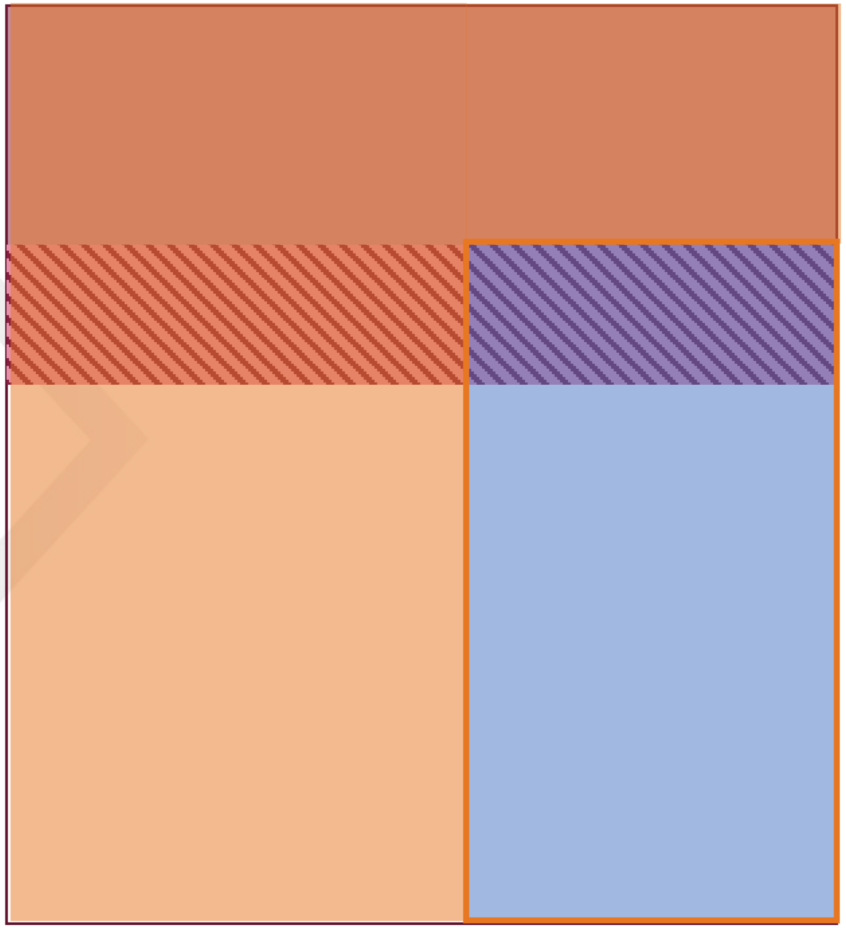
Population of crashes that could potentially be mitigated by ADAS features

Crashes within the above population that can’t actually be mitigated by ADAS or ADS features because information is unknown

Population of crashes that could potentially be mitigated by ADS

Population of crashes that cannot be avoided by ADAS or ADS

Population of Crashes



Population of crashes that could potentially be mitigated by ADAS features

Ex: Rear-end crashes (AEB)

Crashes within the above population that can't actually be mitigated by ADAS or ADS features because information is unknown

Ex: Rear-end crashes (AEB) but driver doesn't have enough time to warnings OR car does not have enough time to brake

Population of crashes that could potentially be mitigated by ADS

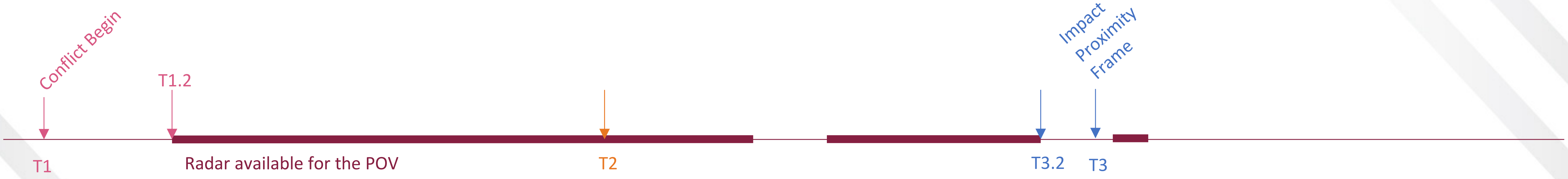
Ex: Rear-end crash, but vehicle is able to swerve

Population of crashes that cannot be avoided by ADAS or ADS

Ex: Rear-end crash around a tight curve or over the crest of a hill

Population of crashes this research focuses on

HOW TO DETERMINE CONFLICT OBJECT



T	Time point	Host Speed	Range Rate x
T1	Conflict Begin	x	
T1.2	Closest radar point to conflict begin	x	x
T2	Subject reaction start	x	
T2.2	Closest radar point to subject reaction start	x	x
T3	Impact proximity frame	x	
T3.2	Closest radar point to impact proximity frame	x	x

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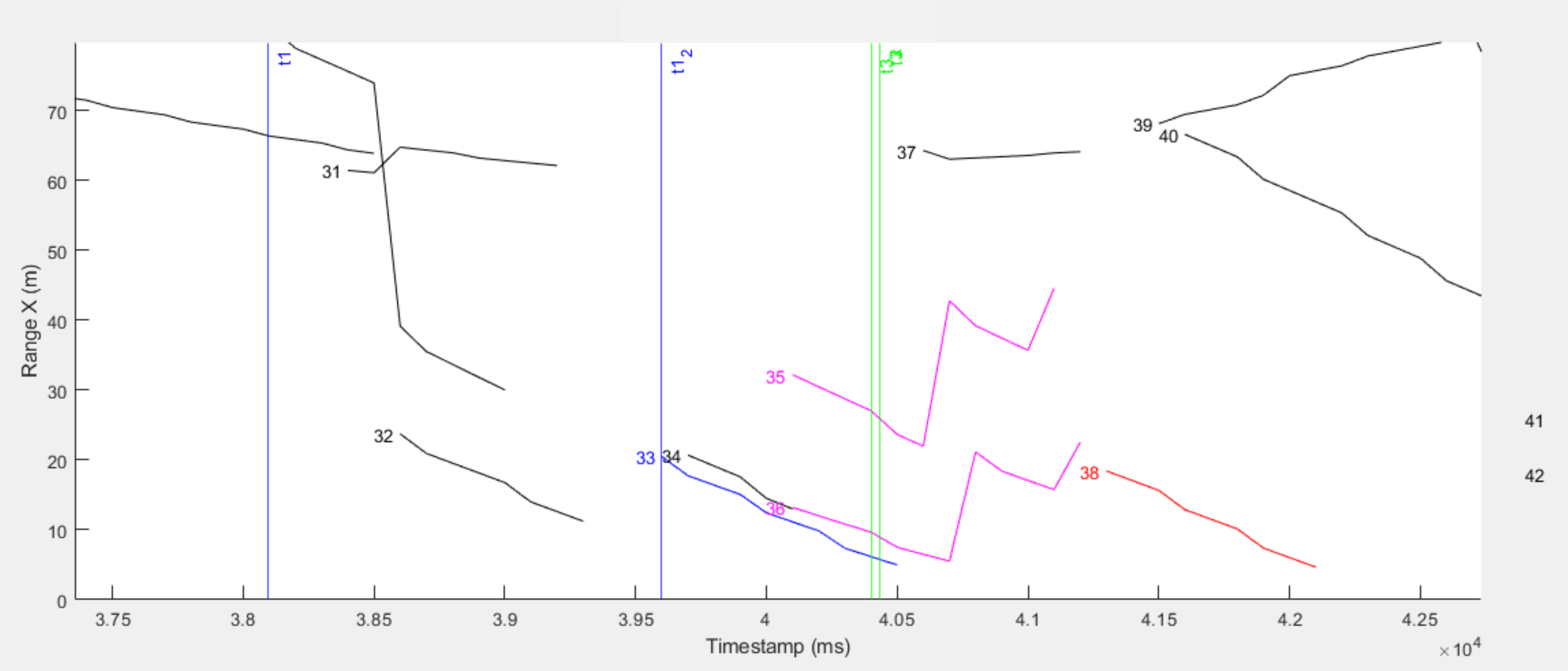

DATA BY CRASH AND NEAR CRASH

Configuration Category		Crash	Near Crash
	Angle, Sideswipe, Merge, Cut-in	26	1299
	Forward Impact	158	507
	Perpendicular	43	565
	Head on (Initial Opposite Direction)	18	267
	Backing Up	20	87
	Roadside Departure	12	5