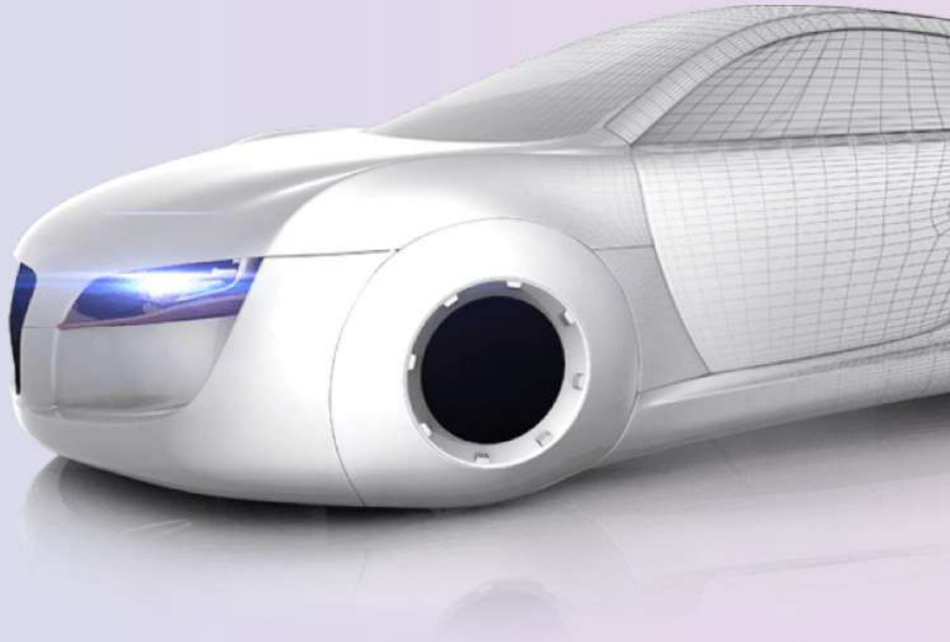
DUBAI WORLD CONGRESS
FOR SELF-DRIVING TRANSPORT
OCT | 2019

What is your car's IQ?



Dan Baxter
Chief Systems Engineer & Practice Director
Stantec

Sama Khazraeian
ITS Analyst
Stantec

www.sdcongress.com

Stantec

OUTLINE

- Introduction
  - Goals
    - Why measure a car's IQ?
  - Driving automation system's past experiences
    - Failures
    - Fatal crashes
    - Testing
- Methodology
  - Multi-Criteria Decision Analysis (MCDA) : AHP method
  - Developed criteria for car's IQ measurement
- Conclusions

INTRODUCTION

How
Connected/Autonomous
Vehicles (CAVs) can help?
Are they reliable?

- In 2018, approximately 40,000 people lost their lives due to road accidents in US
- 94% of these accidents caused by human error

GOALS

- Develop an "automotive intelligence quotient" or "Automotive IQ (AIQ)" number for vehicle types
- Add AIQ to a new car's window sticker
- Propose a method to measures AIQ

Why do we need a quantified measure?

- Easier comparison between CAVs: Consumer satisfaction
- Anticipating some Government regulation

ARE AUTOMATED VEHICLES SAFER THAN CONVENTIONAL VEHICLES?

Some Safety Measures:

- **Infractions**: failure to follow traffic rules
- **Roadmanship**: an integrated measure of driving abilities
- **Disengagements**: Occasions when a person has to take over the control of the vehicle for the automated system

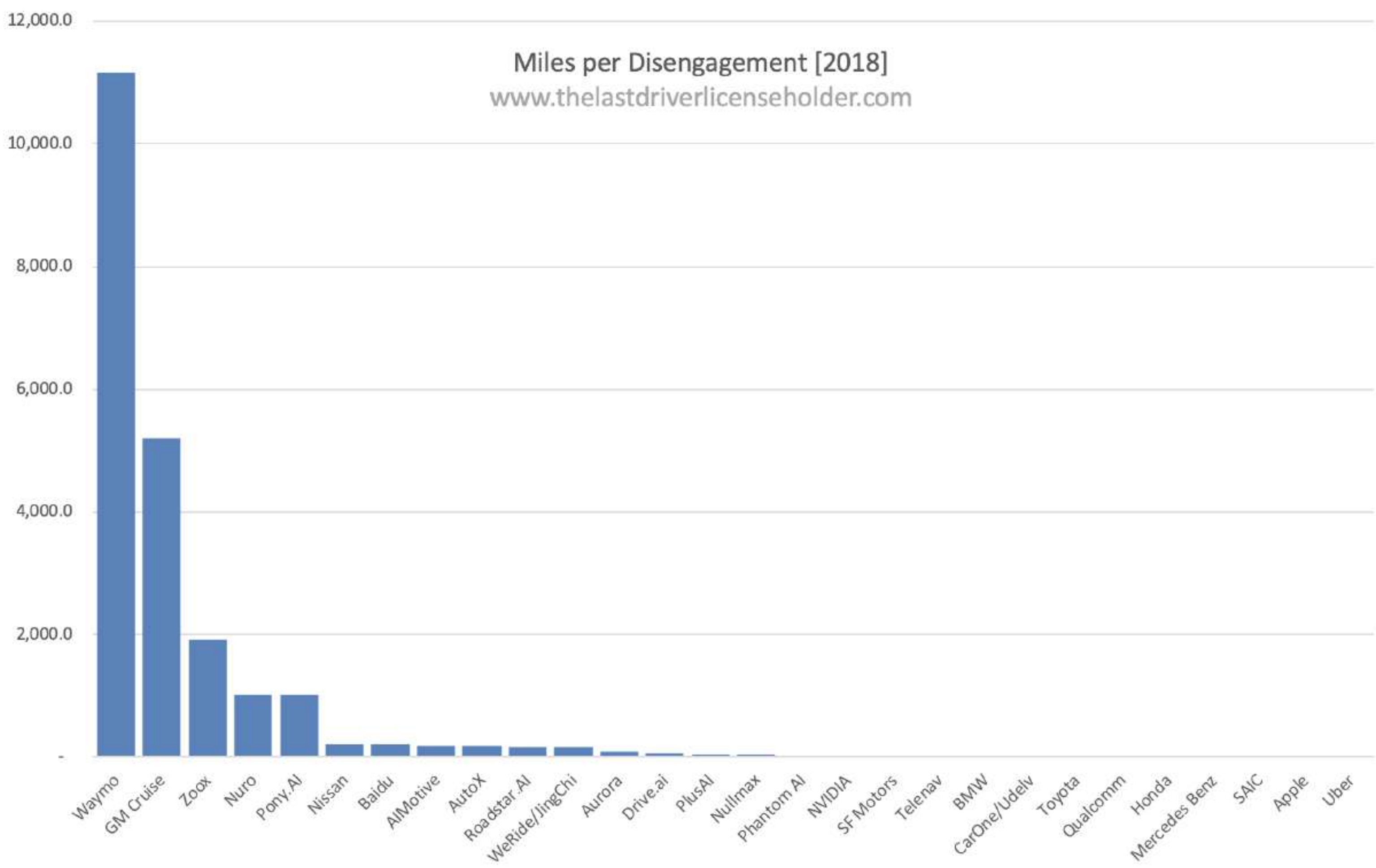
Disengagements are currently used as a nonstandardized safety measure by various companies, states (required of entities testing AVs in California), and even by the federal government!

2018 MILES PER DISENGAGEMENT IN CALIFORNIA

By law, all companies that are actively testing self-driving cars on public roads in California are required to disclose:

-The number of miles driven and
-The frequency in which human drivers were forced to take control of their driverless vehicles

Disengagement



No Tesla Report

2018 DRIVING AUTOMATION SYSTEM FAILURES

Every 3 hours, a driving automation-engaged car failed in California in 2018!

Disengagement rates reported by leading carmakers in 2018 in California

	Disengagements per 1000 miles	Miles per Disengagement	# Vehicles
Waymo	0.09	11,154.3	111
GM Cruise	0.19	5,204.9	162
Zoox	0.52	1,922.8	10
Nuro	0.97	1,028.3	13
Pony.AI	0.98	1,022.3	6
Nissan	4.75	210.5	4
Baidu	4.86	205.6	4
AIMotive	4.96	201.6	2
AutoX	5.24	190.8	6
Roadstar.AI	5.7	175.3	2

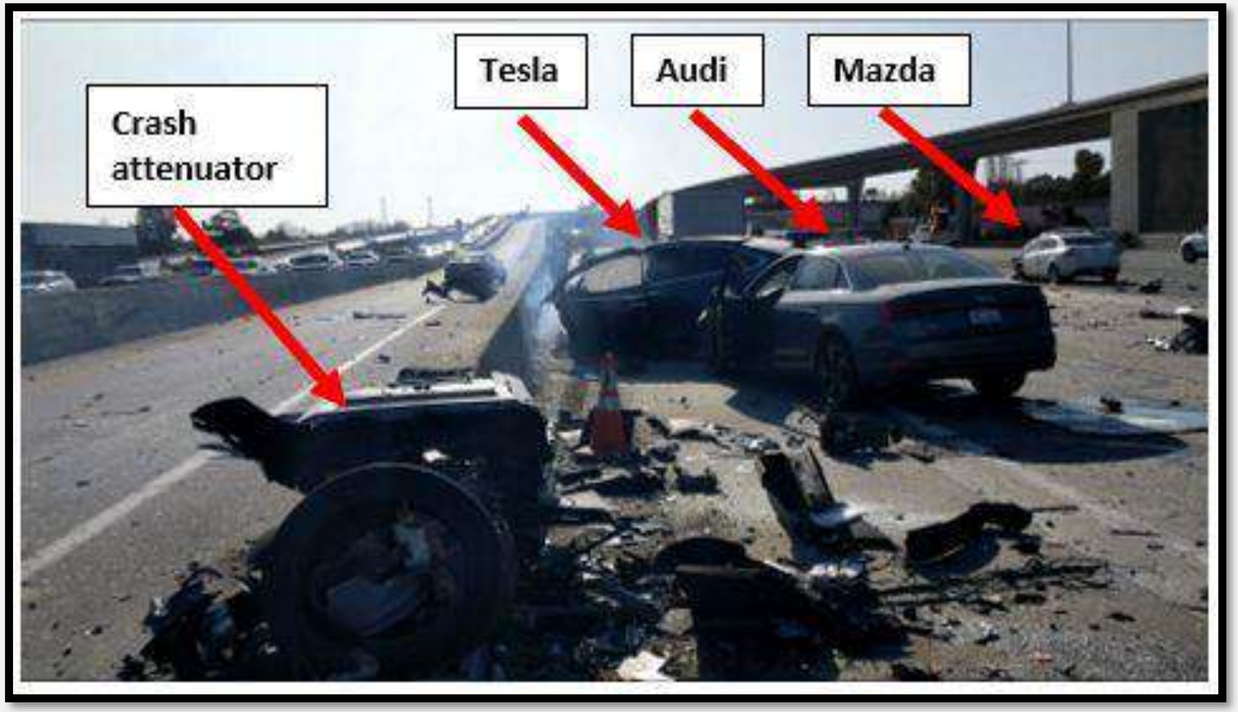
FATAL CRASHES INVOLVING A DRIVING AUTOMATION SYSTEM-ENGAGED CARS

- March 1, 2016
- Florida
- Tesla Model S driver operating on "Autopilot"
- Crashed into the side of a tractor-trailer turning across his path
- Driver Jeremy Banner was killed
- NTSB investigation: fault with Tesla's design of Autopilot?

FATAL CRASHES INVOLVING A DRIVING AUTOMATION SYSTEM-ENGAGED CARS

- On March 23, 2018
- Mountain View, California
- Tesla Model X SUV operating on Autopilot
- Slammed into a concrete highway lane divider
- Driver died!
- Still under investigation by NTSB!

FATAL CRASHES INVOLVING A DRIVING AUTOMATION SYSTEM-ENGAGED CARS

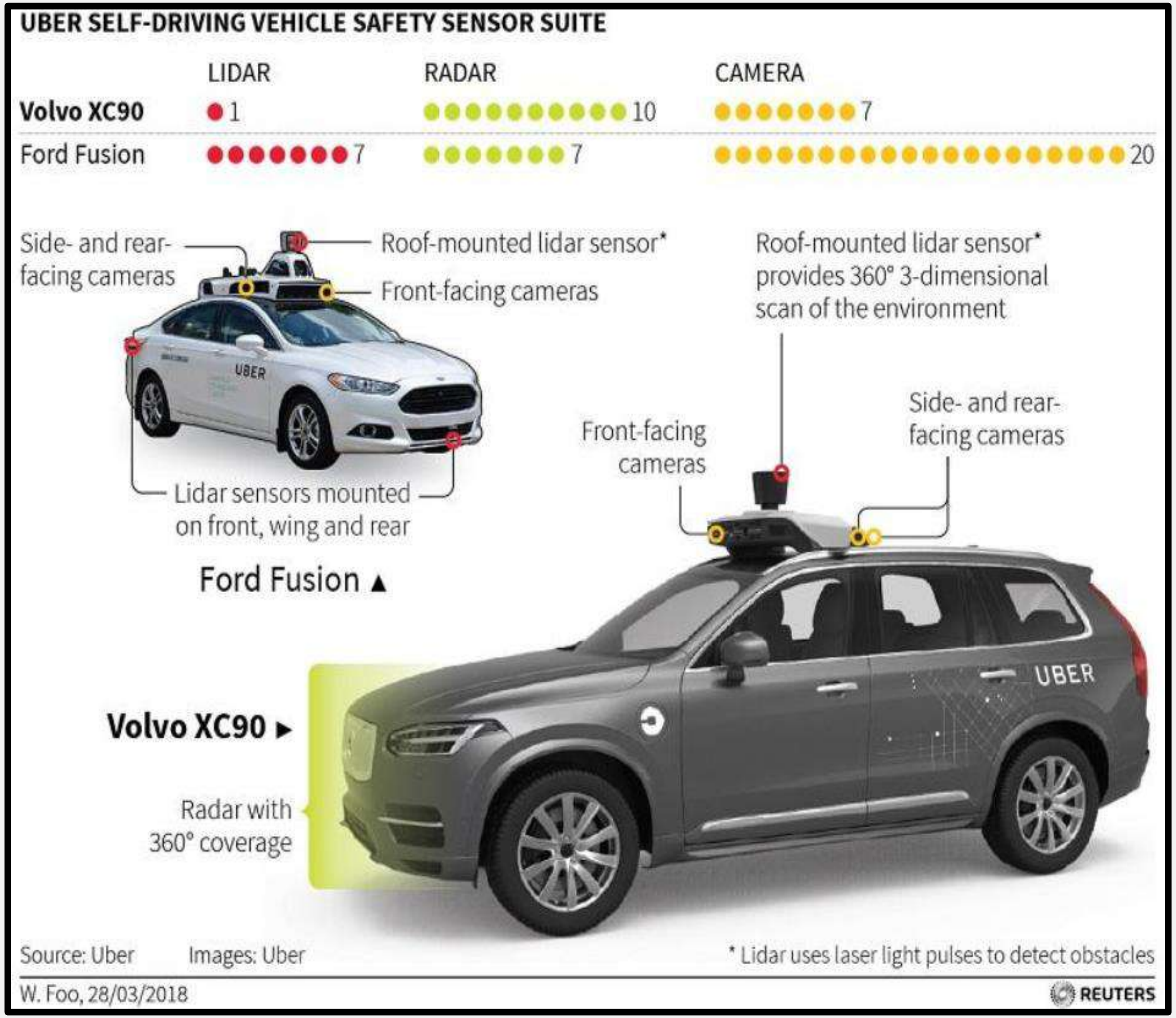


- Autopilot system was engaged in continuous operation for 18 minutes and 55 seconds prior to the crash.
- The Tesla provided two visual and one auditory alert for the driver to place his hands on the steering wheel 15 minutes before the crash.
- The driver's hands were not on the steering wheel in the six seconds before the crash.
- The Tesla was following a lead vehicle and traveling about 65 mph, and began a left steering movement, seven seconds before the crash, and stopped following at 4 seconds.
- The Tesla's speed increased — starting three seconds before impact and continuing until the crash — from 62 to 70.8 mph. There was no braking or evasive steering detected prior to impact.

FATAL CRASHES INVOLVING A DRIVING AUTOMATION SYSTEM-ENGAGED CARS

- On March 18, 2018
- Tempe, Arizona
- Ubers' Volvos
- Killed a pedestrian
- Tempe police investigation: the incident was avoidable! Ongoing investigation.

SPECULATIONS AROUND THE UBER CRASH



UBER Ford Fusion and Volvo XC90 Sensor Suite
Image Source: Reuters (Uber)

DRIVING AUTOMATION SYSTEM-EQUIPPED CARS TESTING

- Autonomous Vehicle Technologies
  - LIDAR (Light-Detecting And Ranging)
  - Radar
  - GPS and is some cases RTK radio

- Traditional /Scanned LIDAR
  - Uses a thin, concentrated laser beam
  - Single receiver (eye)
- Flash LIDAR
  - Floods the scene with a wide light beam
  - Several receivers

DRIVING AUTOMATION SYSTEM-EQUIPPED CARS TESTING

- Uber: Pittsburg
- Ford: Pizza delivery in Miami
- NuTonomy: Boston
- General Motors: San Francisco
- Waymo: Mountain View
- Zoox: San Francisco
- And so on…

PROVING GROUNDS

SunTrax

Orlando, Florida

475-acre

Features:

Roadway Geometry Track

Loop Tracks

High Speed Oval

Urban/Suburban

Pick-Up/Drop-Off

Sensor Test Chamber (future phase)

Braking and Handling

PROVING GROUNDS

Mcity

- Ann Arbor, Michigan
- 32-acre

Features:

- State-of-the-art instruments: wireless, fiber optics, ethernet and a highly accurate kinematic positioning system
- Patent-pending augmented realty testing technology
- V2X communication through out the facility with 5G connectivity

PROVING GROUNDS

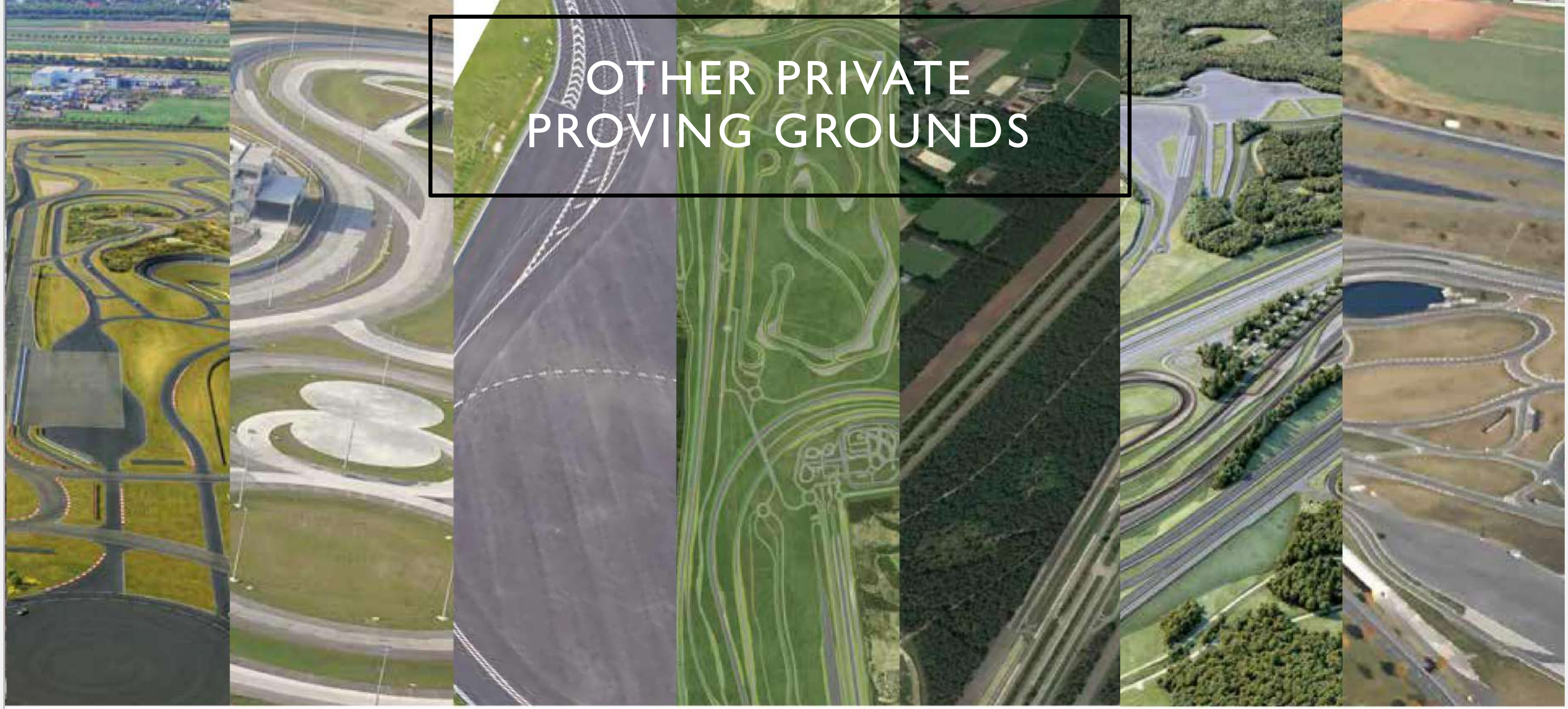
SMARTCenter

- Marysville, Ohio
- 540-acre

Features:

- Dedicated AV/CV Test Facility
- High Speed Intersection
- Urban Network
- Control Building
- V2X communications
- Test Support Infrastructure

OTHER PRIVATE PROVING GROUNDS



LEIPZIG (PORSCHE)	WÖRTH (FORMER DAIMLER CHRYSLER AG)	ZAVENTEM (TOYOTA MOTOR EUROPE)	SOKOLOV (BMW GROUP)	LOMMEL (FORD)	IMMENDINGEN (DAIMLER AG)	BOXBERG (ROBERT BOSCH GMBH)

Source: Tilke

Infor

METHODOLOGY

- Multi-Criteria Decision Analysis (MCDA)
  - Helps decision makers customize their desired evaluation of alternatives and select the best alternative even in the presence of conflicting criteria
- MCDA Methods:
  - Simple Additive Weighting (SAW)
  - Analytic Hierarchy Process (AHP) → Most widely used MCDA method in the transportation field
  - Technique for Order Preference Similarity to Ideal Solution (TOPSIS)
  - Fuzzy TOPSIS

METHODOLOGY

AHP Steps

1. Assigning a weight to each evaluation criterion based on decision makers' pairwise comparisons of the criteria
2. Assigning a score to each alternative based on the decision maker's pairwise comparison of the alternatives for each criterion. The higher the score, the better the alternative with respect to the corresponding criterion.
3. Combining the criteria weights and alternative scores and generating a global score for each alternative.

METHODOLOGY

Oppositional testing strategy:

- Adding to the efficiency of the proposed method

METHODOLOGY

Developed Criteria for Automotive IQ Measurement

- Compliance with standards
  - Functional Safety
    - ISO 26262
  - Cyber Security
    - SAE J3061™ ISO/SAE 21434
    - General IT security standards: ISO 27001, ISO 15408
    - Security standards for V2X communication: IEEE 1609.2
- Hardware characteristics
  - Redundancy
  - Hardware diversity
  - System on Chips (SoC)
- Designed test results
  - Disengagement rate
  - Mean time before failure

PAIRWISE COMPARISON OF THE HIGH-LEVEL CRITERIA

Criteria	Standard Compliance	Hardware Characteristics	Designed Test Results
Standard Compliance	I		
Hardware Characteristics	?	I	
Designed Test Results	?	?	I

CONCLUSIONS

- Multi Criteria Decision-Making methodology (MCDA) to measure a vehicle’s intelligence
- Lessons learnt from the Uber crash:
  - Sensor redundancy
  - Adverse environmental condition
- The three high level criteria defined for MCDA analysis:
  - Compliance with standards,
  - Hardware characteristics and
  - Designed test results
- The outcome of the MCDA analysis ➡ A numeric value assigned to each vehicle’s intelligence
  - Consumers can compare vehicles and select the best one
  - A platform for the government to regulate CAV operation

QUESTIONS?