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LEADING THE TRANSFORMATION
TO CONNECTED AND AUTOMATED VEHICLES

Connectivity Enables Automation

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University of Michigan, Ann Arbor

Smoky Mountains Mobility Conference
November 17, 2022

OAK RIDGE National Laboratory

Public-Private Partnership

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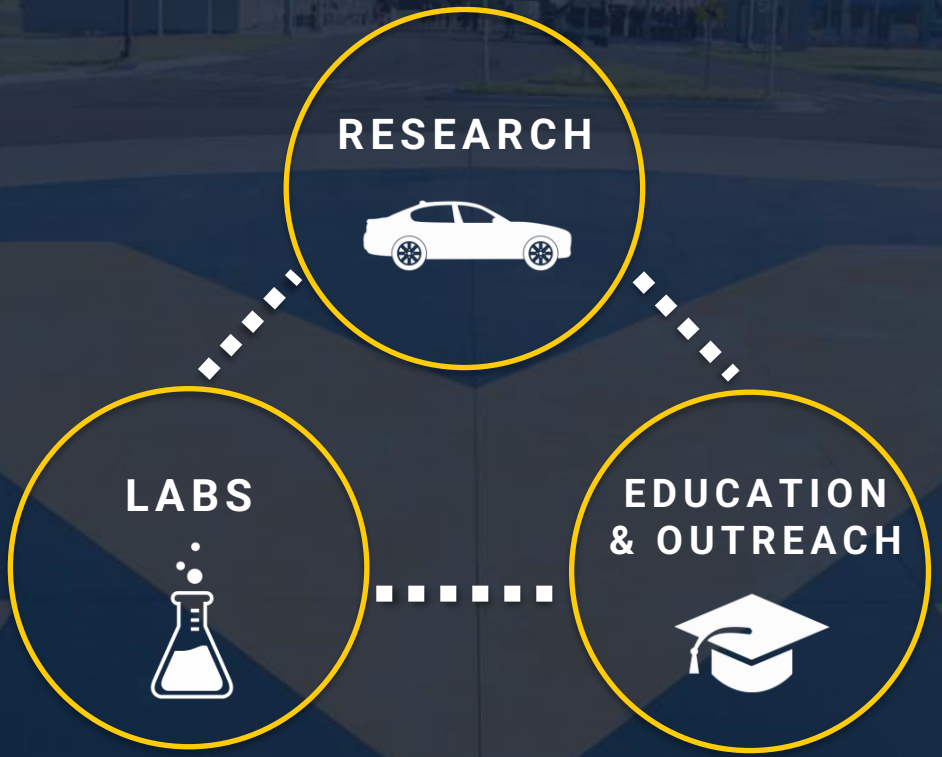
MDOT

M city AFFILIATE UNIVERSITY OF MICHIGAN

- Pre-competitive research
- Pooled and tailored



- Early deployment
- Data collection

- Informing
- Voice of reason
- Talent development

Mcity test facility is the world's first purpose-built proving ground for connected and automated vehicles.

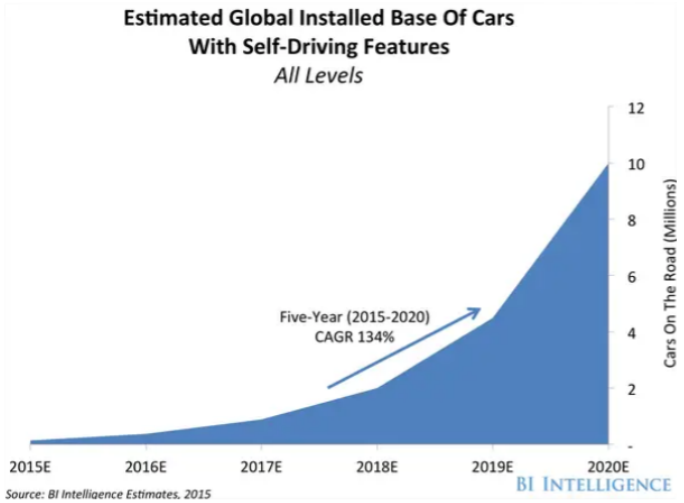
Automated Vehicle Technology Hypes in 2016

HOME > TECH

10 million self-driving cars will be on the road by 2020

Insider Intelligence , BI Intelligence Updated Jun 15, 2016, 7:25 AM

Self-driving cars are no longer a futuristic idea. Companies like Mercedes, BMW, and Tesla have already released, or are soon to release, self-driving features that give the car some ability to drive itself.



BI Intelligence

Automated Vehicle Technology Downfalls in 2022

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A long, cold winter is here for self-driving cars

BY **ALEXEI ORESKOVIC**

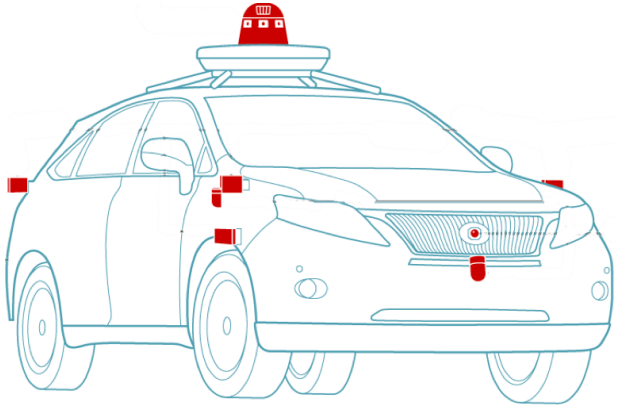
October 18, 2022 at 3:11 PM CDT

Major gap exists in safety performance

Human Drivers

1 accident every ~10^6 miles

Automated Vehicles



1 disengagement every ~10^4 miles

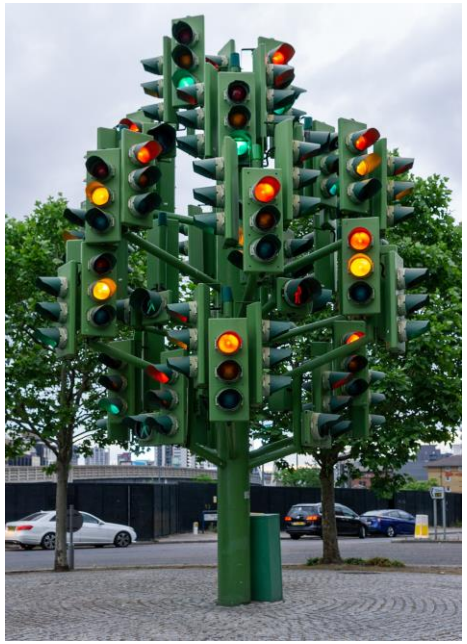
2020 Disengagement Report from California DMV

Curse of Dimensionality (CoD)

The CoD Problem is that when the dimensionality increases, the volume of the space increases so fast that the available data become sparse.

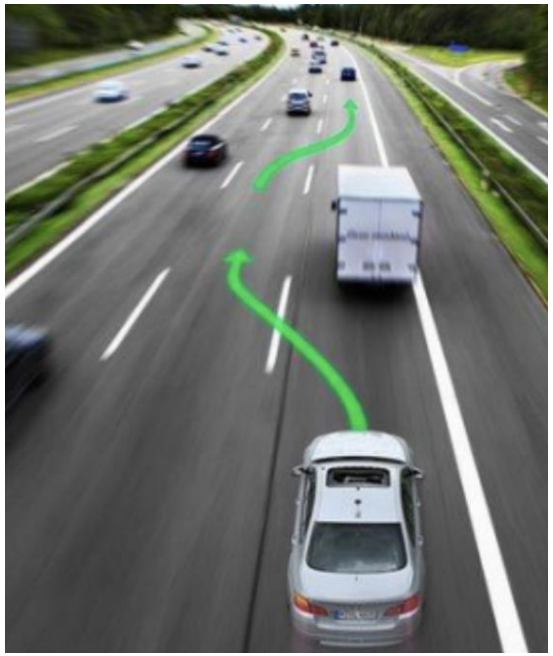
Weather

Road Infrastructure



Road Users

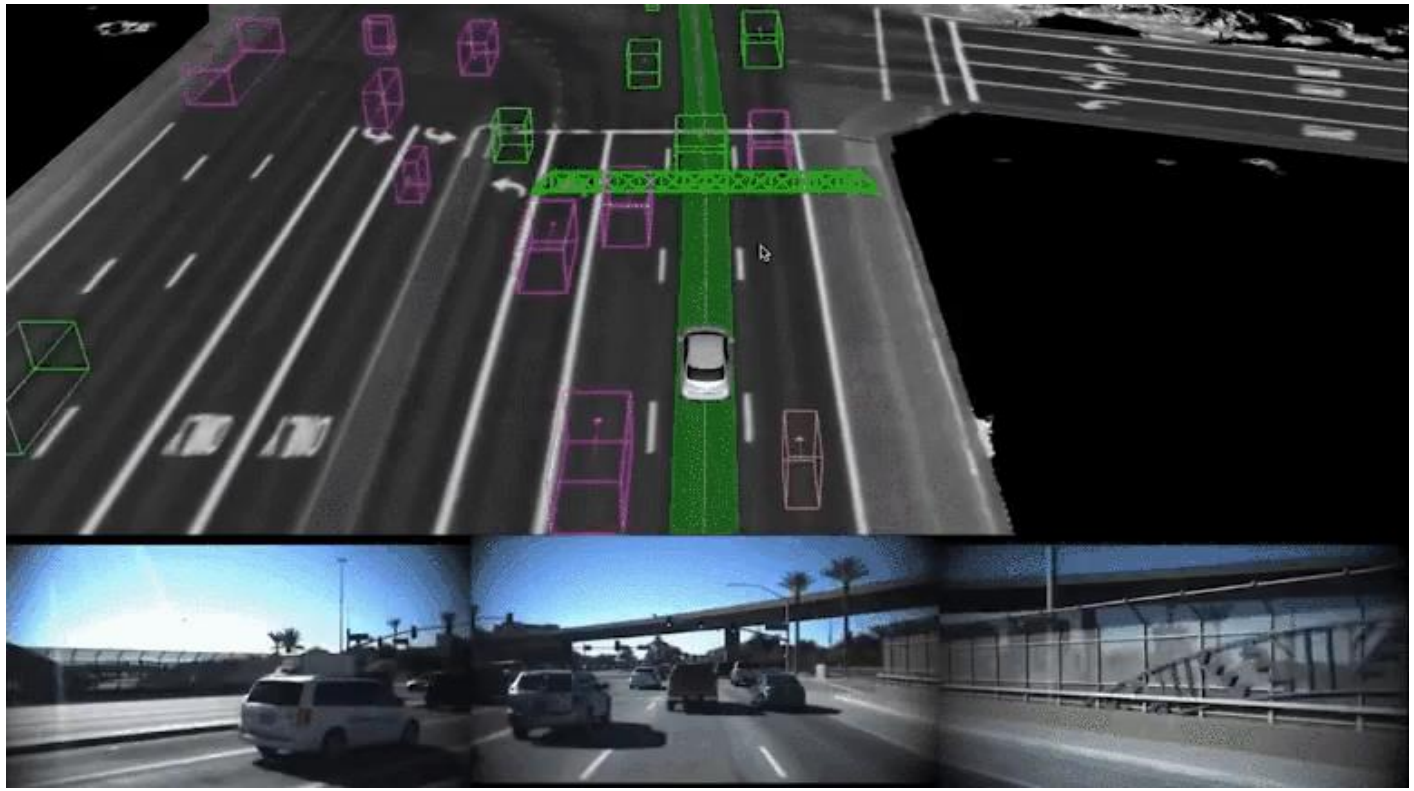
Maneuvers



Curse of Rarity (CoR)

The basic concept of CoR is that the occurrence probability for the events of interest is so rare that most available data contain little information regarding the rare events.

[Liu, H. and Feng, S. (2022)]



The automated vehicle must give way to the emergency vehicle even it has the right of way. A low probability but potentially safety-critical event.
Source: Waymo, https://developpaper.com/waymo-automatic-driving-long-tail-challenge-2019/

For AVs, both CoR and CoD problems exist —the rarity of safety-critical events in high-dimensional driving environments—are the root causes of various safety challenges in the development and deployment of AVs.

The current deep learning algorithms cannot handle this type of cases.

Single Vehicle Intelligence

Picture from autoweek.com

Tesla's evolutionary approach

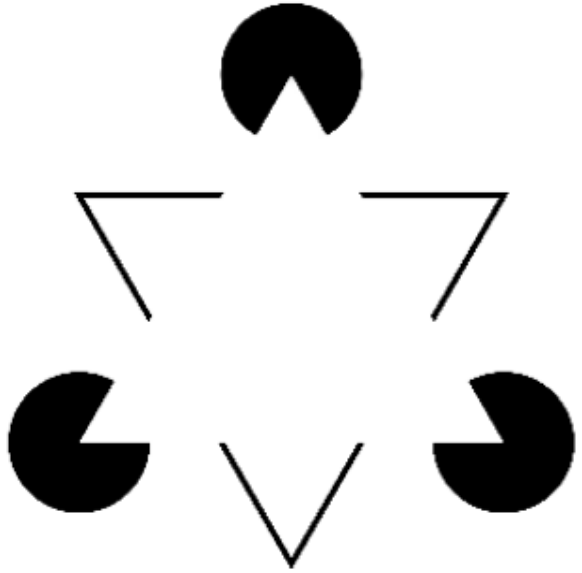
SAE L2

Picture from wired.com

Waymo's revolutionary approach

Target for SAE L4, but no commercial product

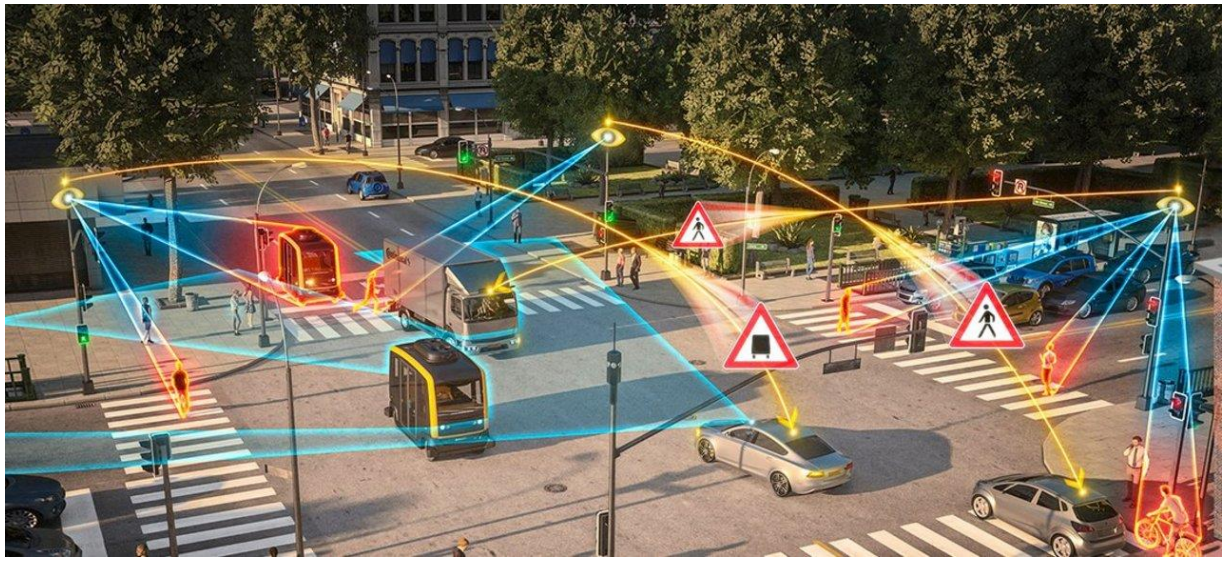
Lack of Top-down Reasoning



The Kanizsa Triangle Visual Illusion

Source: Cummings, M. (2020)

Connectivity Enabled Automation



Picture from continental.com

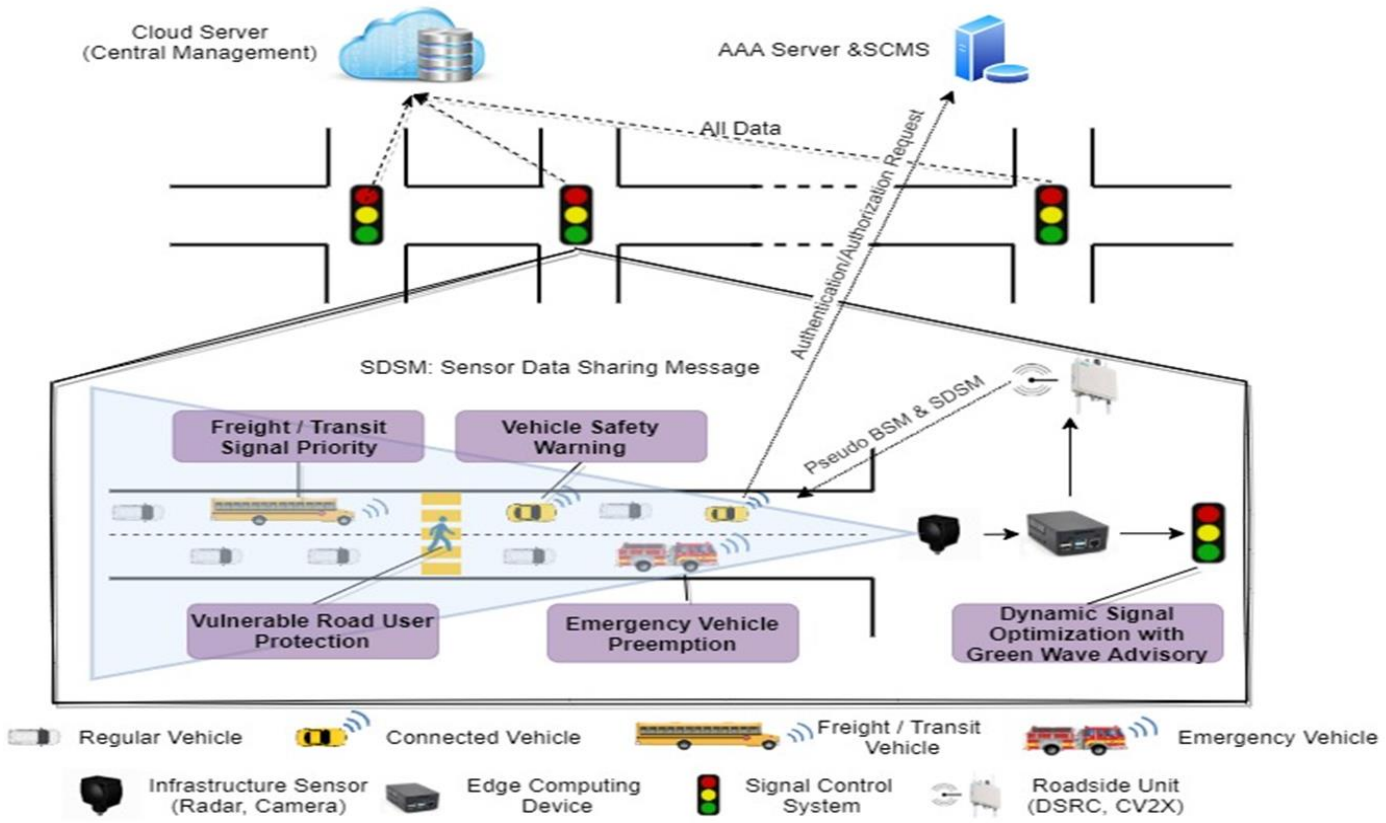
SAE L4 vehicles will need connectivity for wide deployment

Major Roadblocks:

- System Complexity and Vulnerability
- Trust between V2V and V2I

Smart Intersections Project (2021 – 2024)

Develop an infrastructure-assisted cooperative driving automation ***testbed*** to accelerate CAV deployment, funded by USDOT



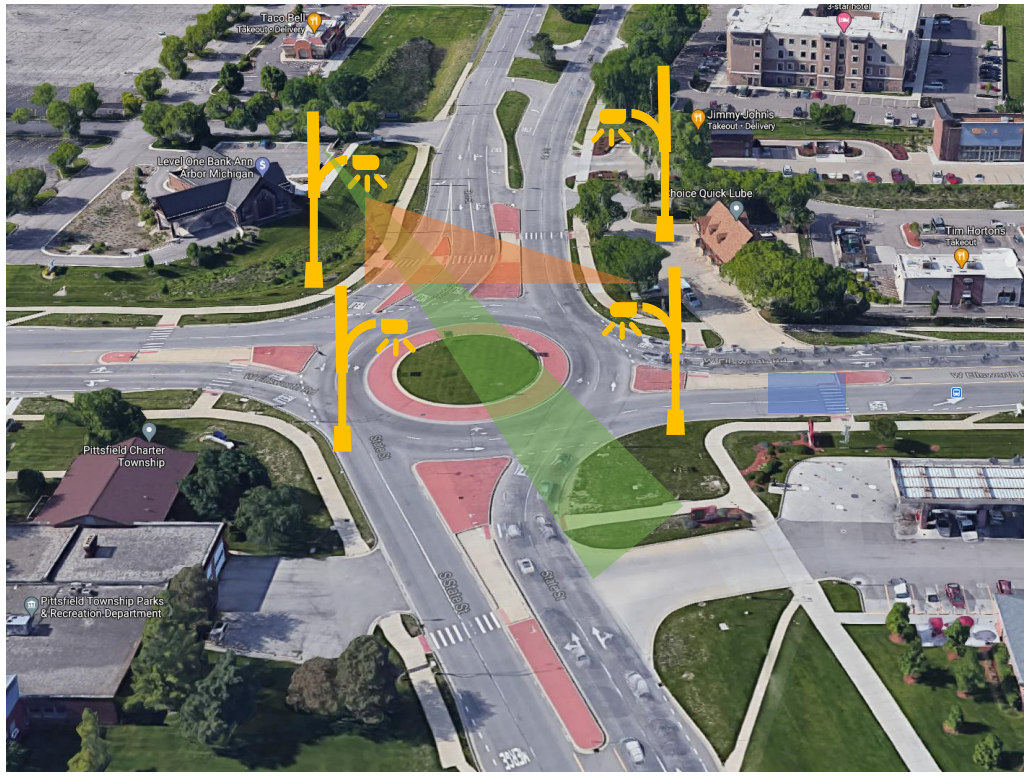
Collaborators

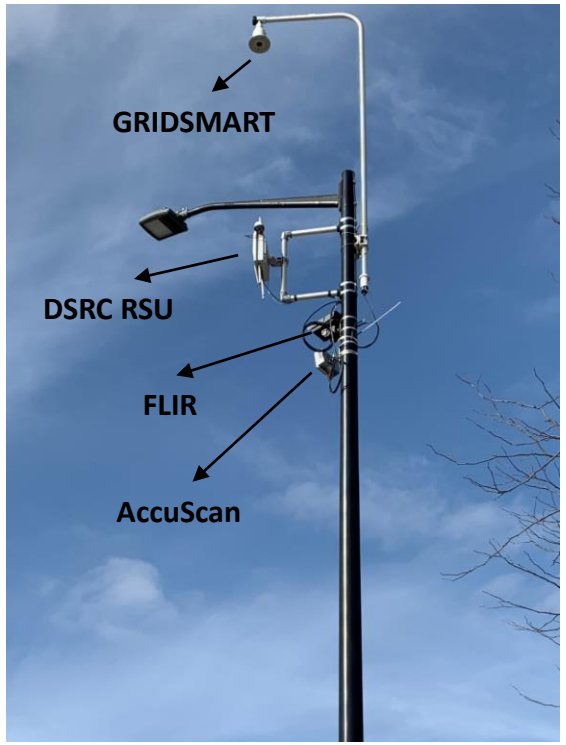
Sub-recipients

Ford
Qualcomm
TOYOTA
City of Ann Arbor Michigan
Continental
iteris
ECONOLITE
P3M
PURDUE UNIVERSITY
WSP

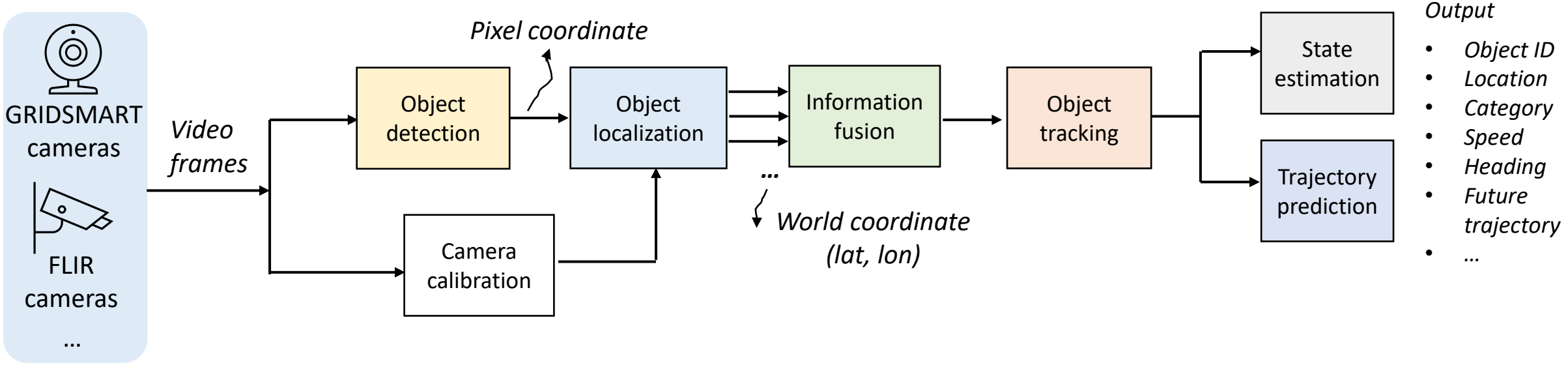
Implementation at State St./Ellsworth

- In 2020, State St./Ellsworth Rd roundabout had 69 crashes and 6 injuries and was ranked #14 for the most dangerous intersections in Michigan.



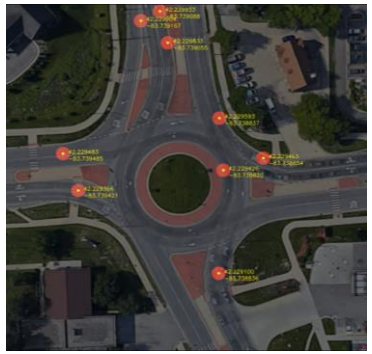


Roadside Perception Pipeline with Edge-Cloud Architecture



Raw image

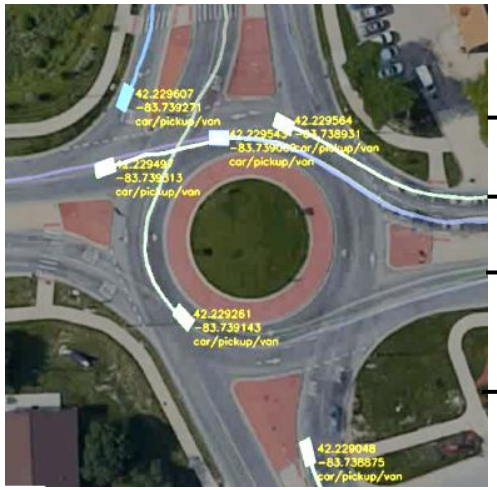
Detection

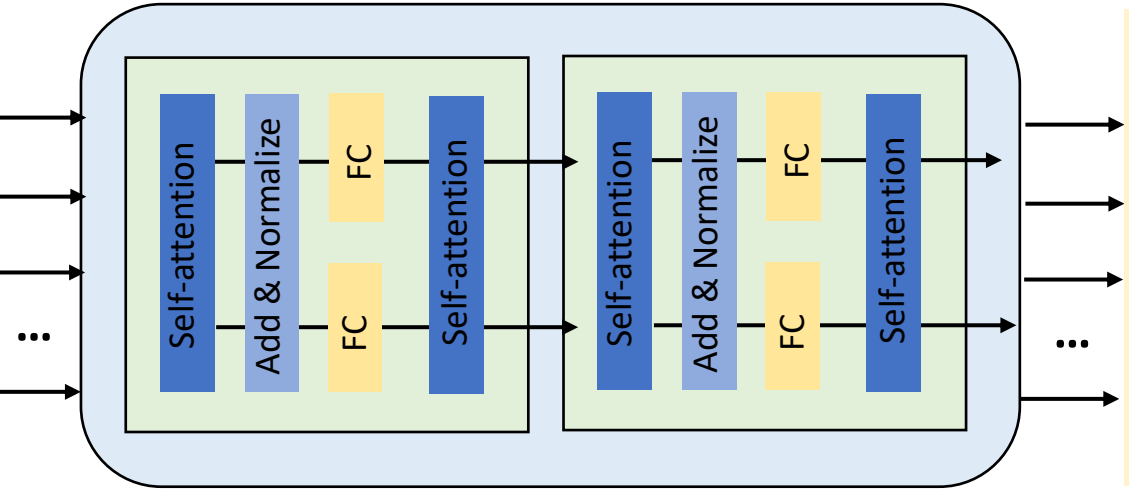


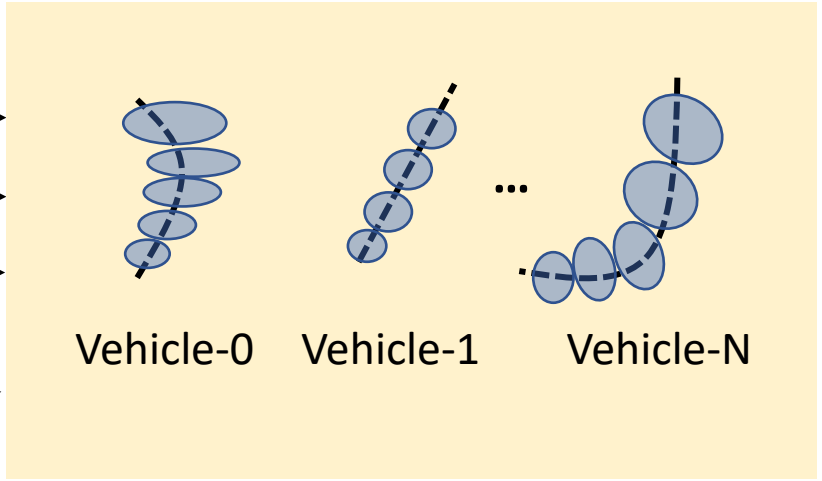
Localization/ Tracking

Motion prediction

Transformer-based Trajectory Prediction



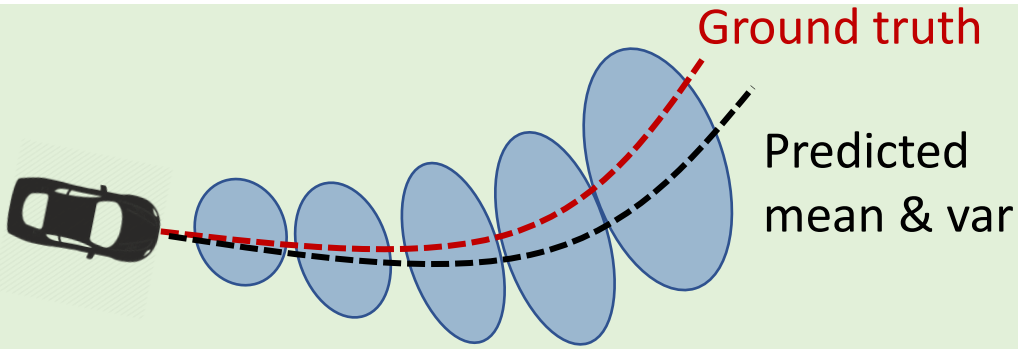




Historical trajectory

Transformer-based trajectory predictor

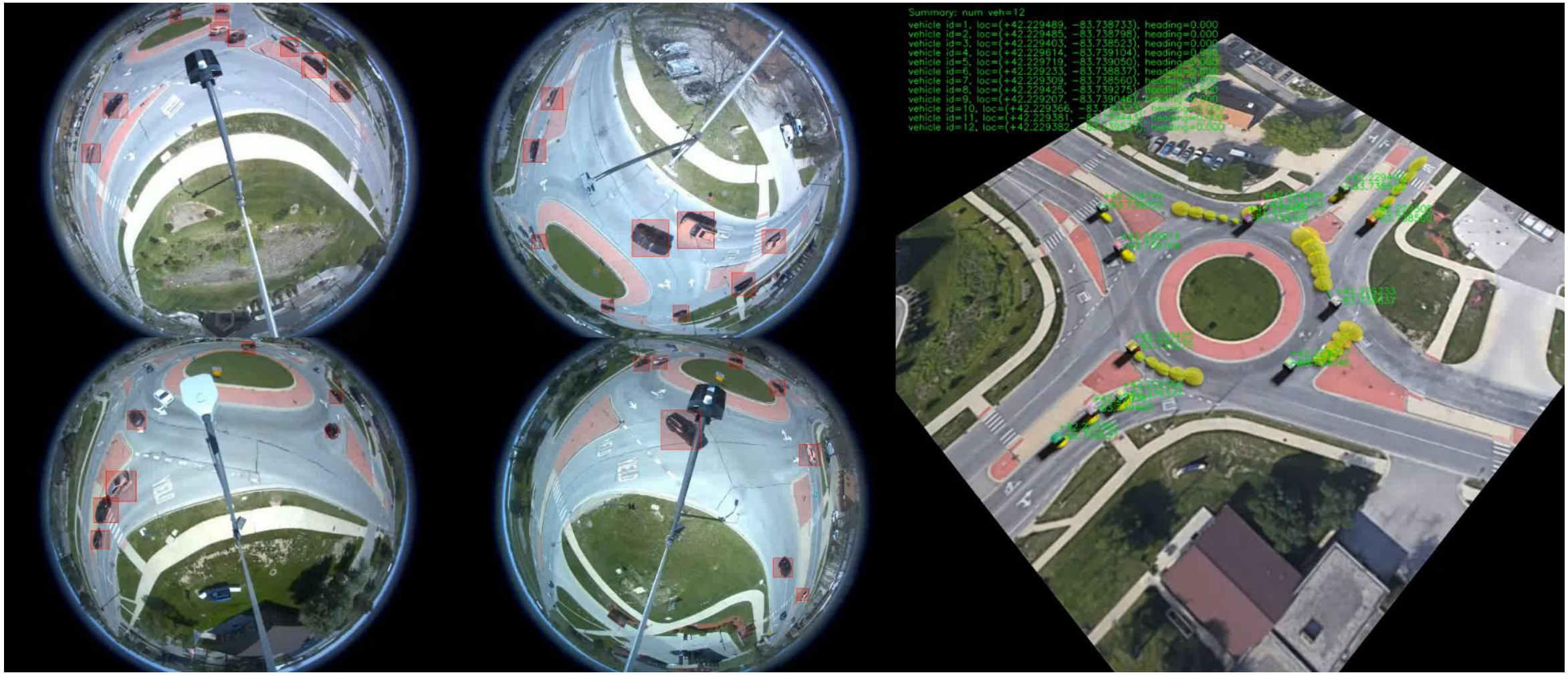
Predicted future trajectory probability distribution



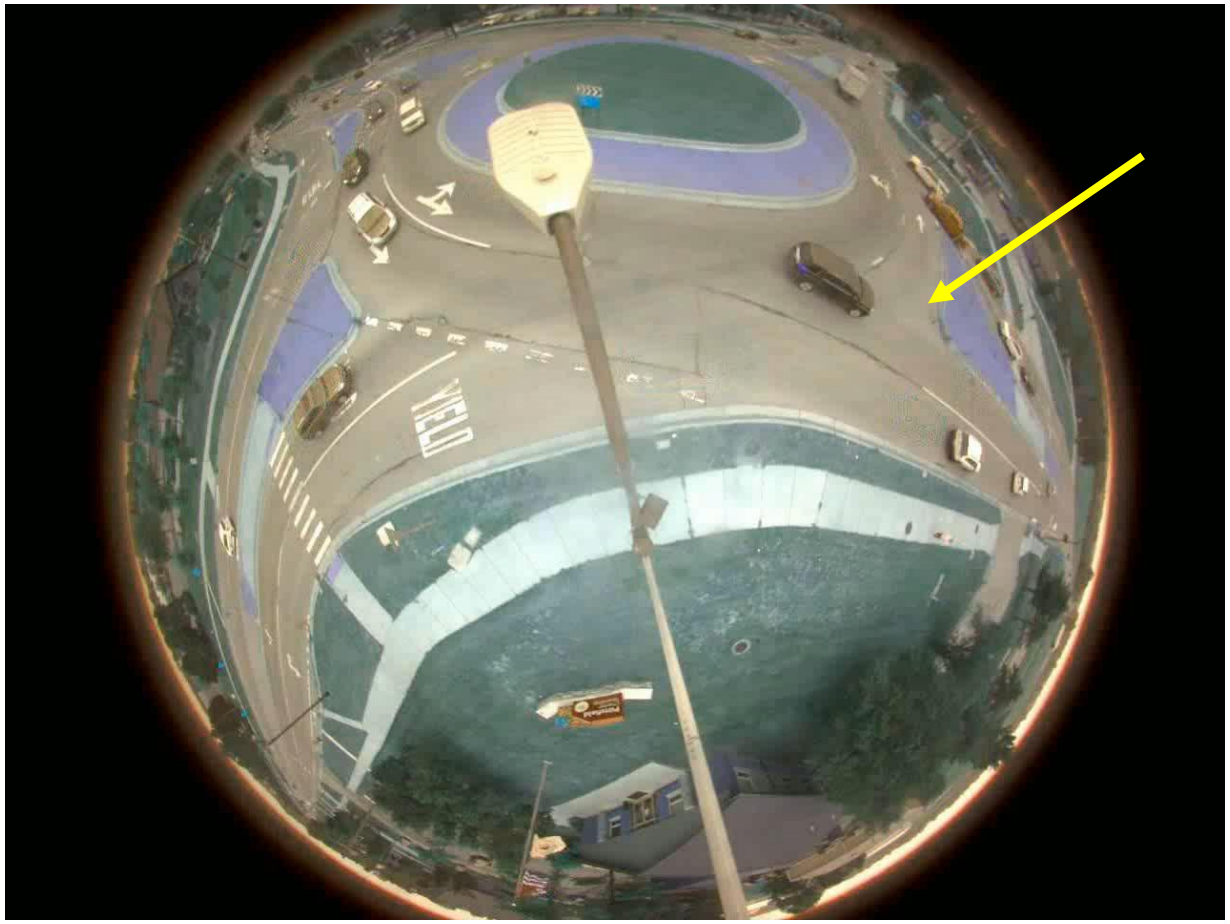
$$argmax\ \mathcal{L}_w = \prod_{t=1}^{T_{out}} \prod_{i=1}^{N} p(z_i^{(t)} | x_i^{(\{-T_{in},\dots 0\})}, w)$$

$$p\left(z_i^{(t)} \middle| x_i^{(\{-T_{in},\dots 0\})}, w\right) = BERT\left(\boldsymbol{X}_{i=\{1,\dots,N\}}^{t=\{-T_{in},\dots 0\}}\right) \sim N(\boldsymbol{\mu}(x), \boldsymbol{\Sigma})$$

Object Detection, Fusion, Tracking, and Prediction



Identified Crash/Near-Miss Events



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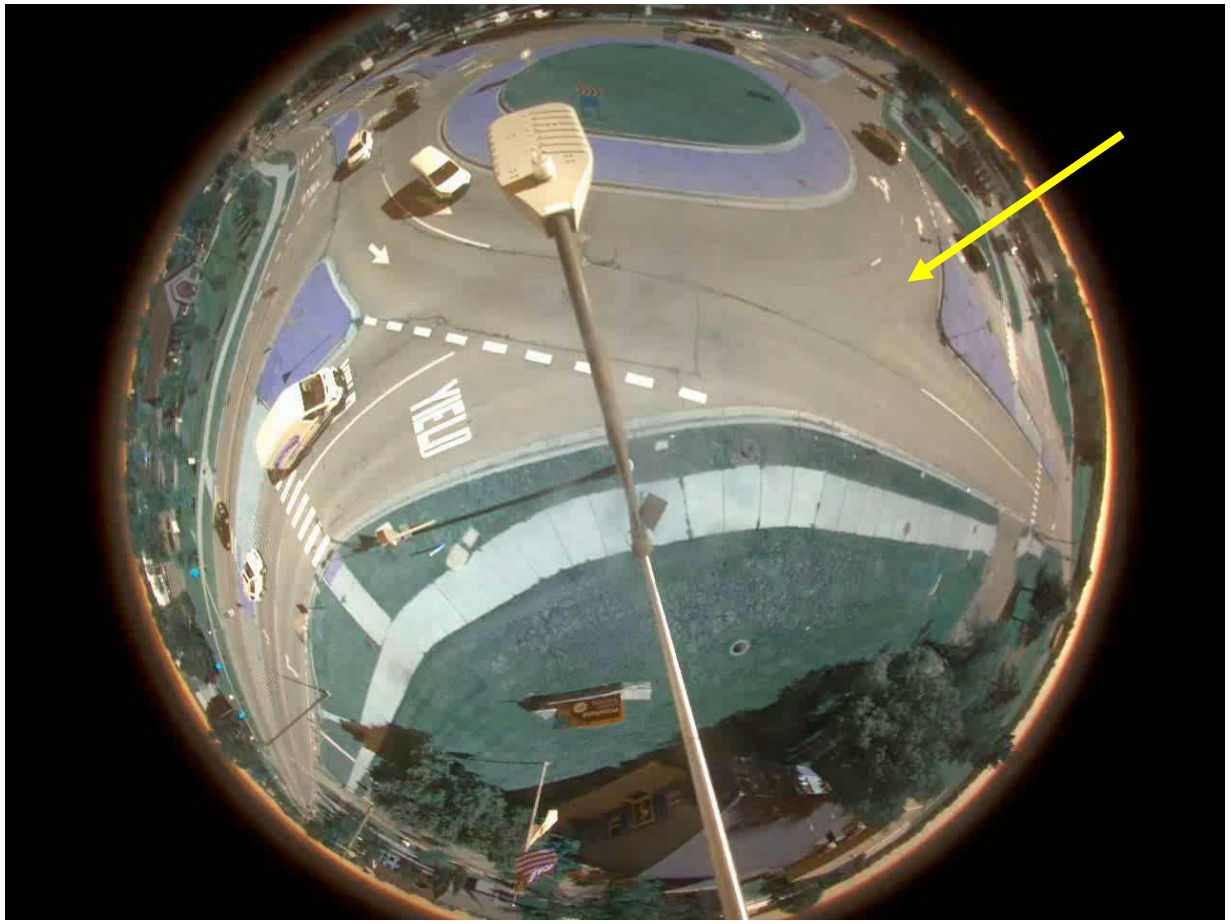

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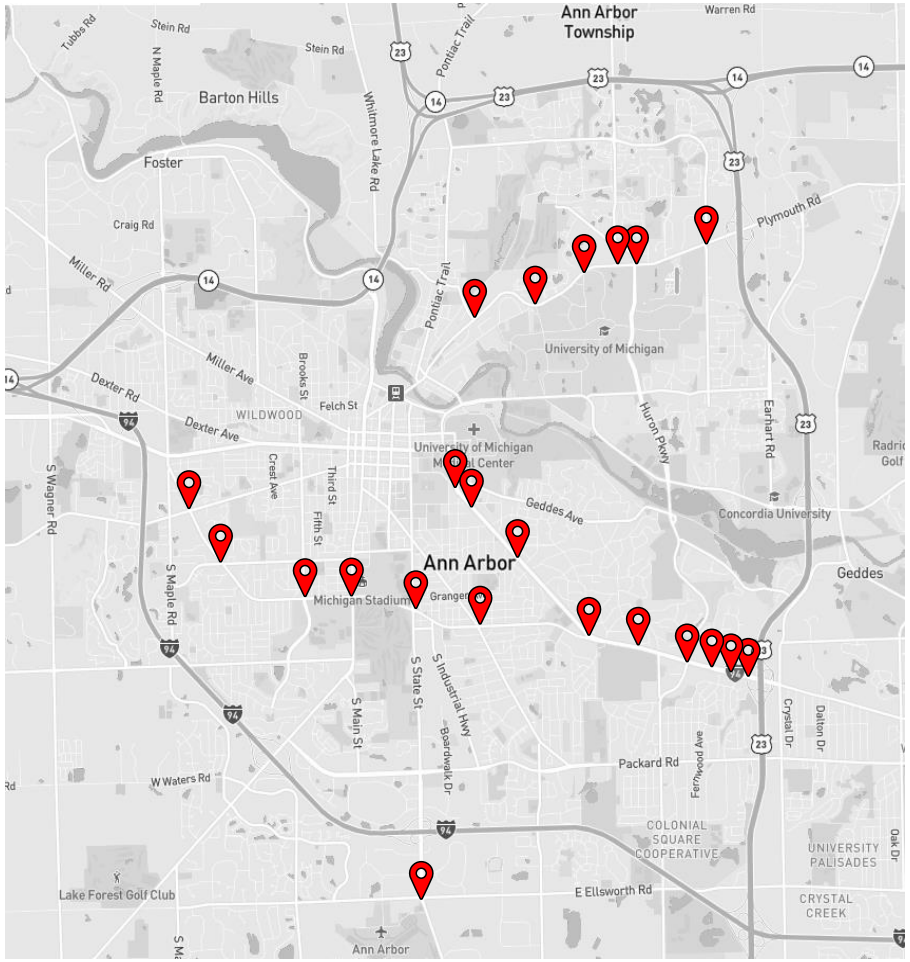
Smart Intersection Deployment

- Support cooperative driving automation
- Support traffic management
  - Signal optimization
  - Green wave speed advisory
  - Improve environmental sustainability
- AWS-based mobility data center



Mcity 2.0: An Autonomous Testbed for Autonomous Vehicles

- Develop the Mcity Test Facility into a **fully autonomous, mixed reality, remote-capable facility**.
- The focus of the project is to build digital infrastructure upon physical infrastructure for AV testing.
- Funded by NSF with additional funding from U of M
- 48 days/year of track time reserved for NSF-funded research

Mcity 2.0

Mcity is developing digital infrastructure to overlay the physical Mcity Test Facility that will enable remote use of the Mcity track and set it apart as the next-generation autonomous vehicle test facility.

HOW IT WORKS

1. Researcher uploads code that controls vehicle or infrastructure and test scenarios using Mcity OS app.
2. Researchers test, tweak, retest scenarios in naturalistic driving environment (NDE) simulation before sending to Mcity Test Facility for execution.
3. Test scenarios designed using Mcity OS are executed at Mcity Test Facility, where real vehicles interact with and respond to virtual vehicles and proxy objects.
4. Researcher participates remotely while test scenario they designed is conducted at the Mcity Test Facility. Test results are accessible remotely via Mcity OS.

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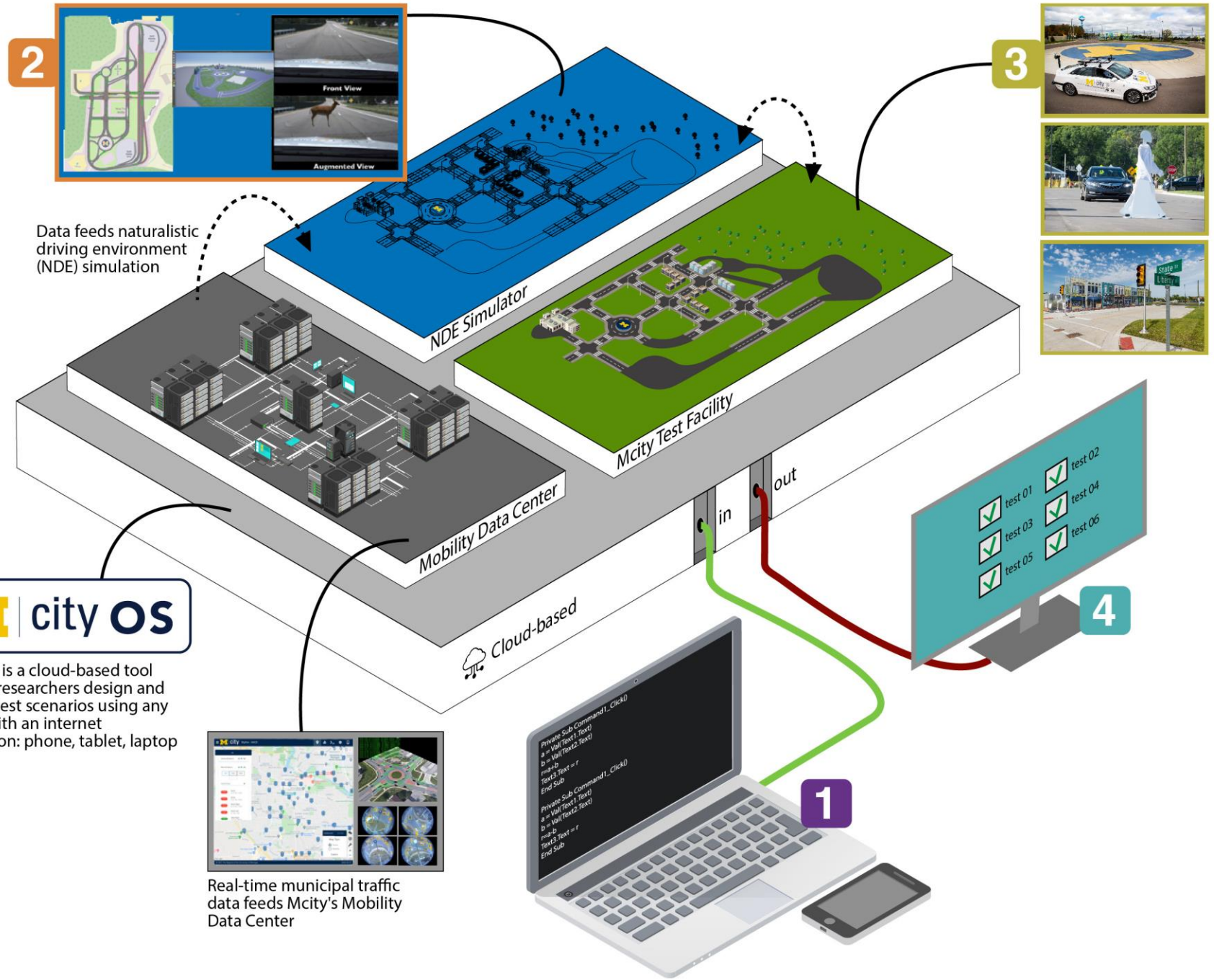


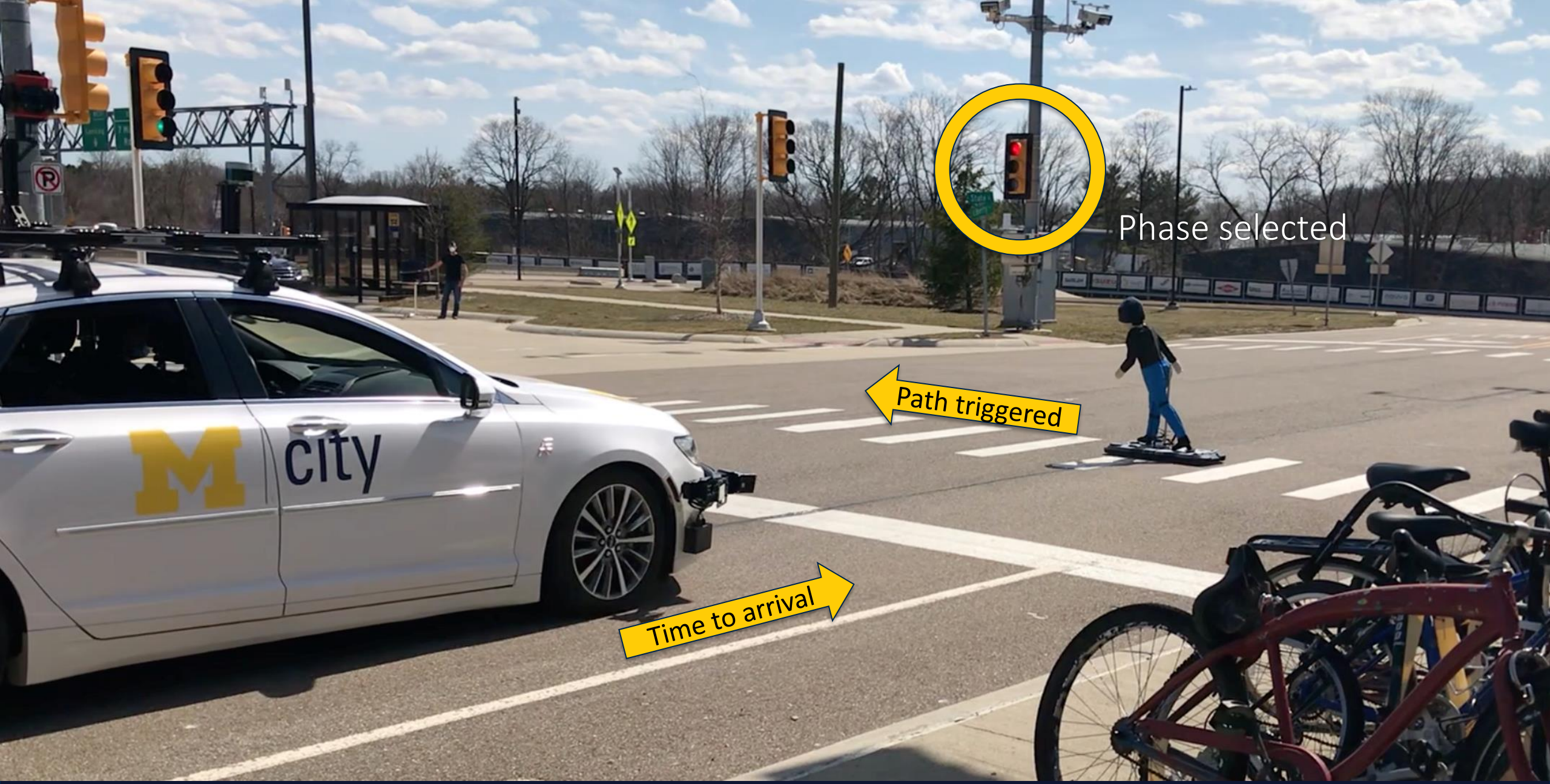
city OS

Mcity OS is a cloud-based tool that lets researchers design and execute test scenarios using any device with an internet connection: phone, tablet, laptop

Real-time municipal traffic data feeds Mcity's Mobility Data Center

Mcity OS makes it possible for researchers to create and execute complex, sophisticated, and easily repeatable test scenarios. Mcity OS runs on any internet-enabled device to control all the features of the facility.

Intelligent tools for AV testing.

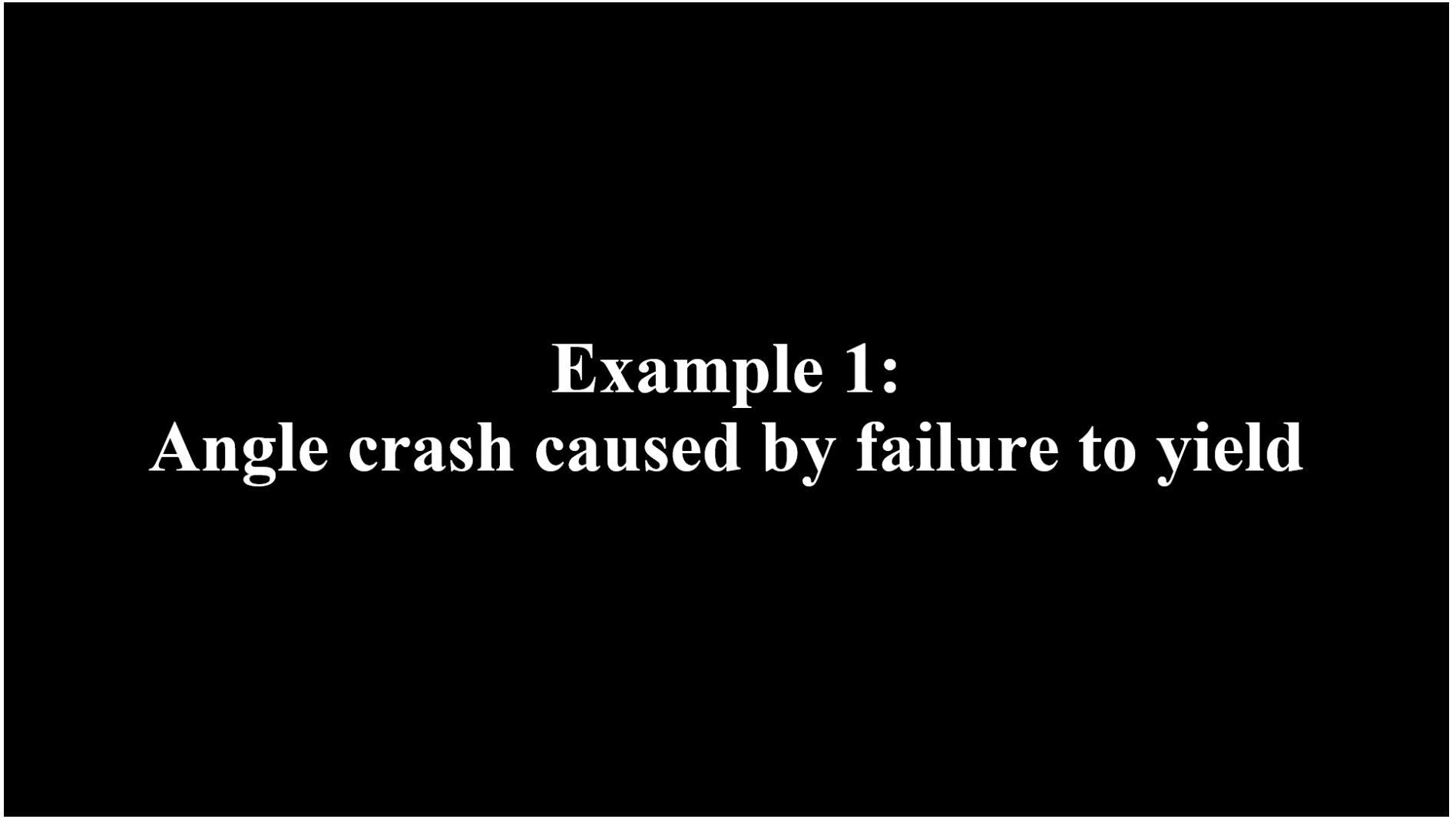

Phase selected
Path triggered
Time to arrival
city

Proxies & VRUs | AV System Testing

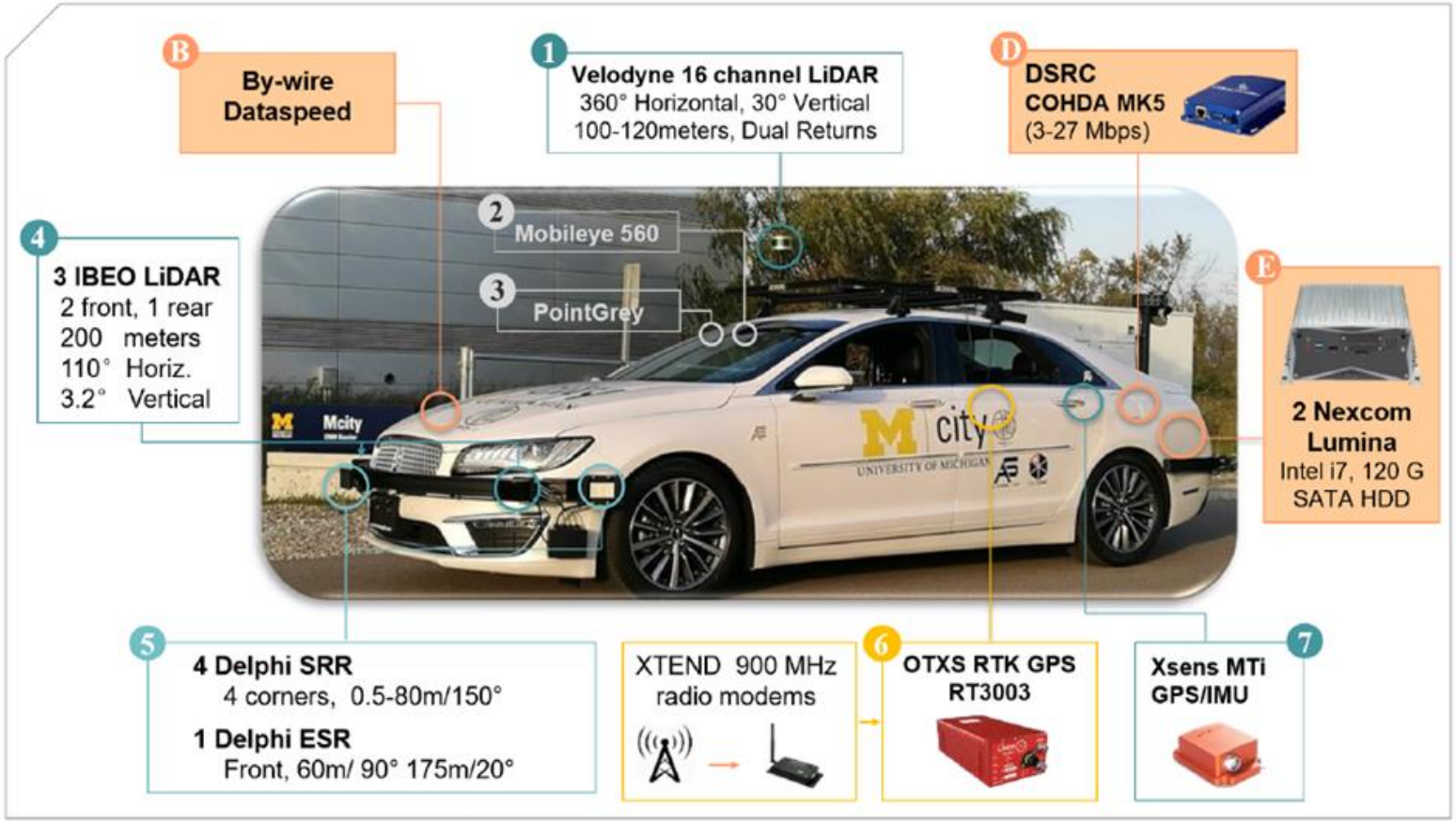
Goals

- Easily Repeatable Testing
- Fleet of “low cost”” Proxies
- High Level of availability and integration
- 3rd Party Robots as a Service

Naturalistic Driving Environment Simulation



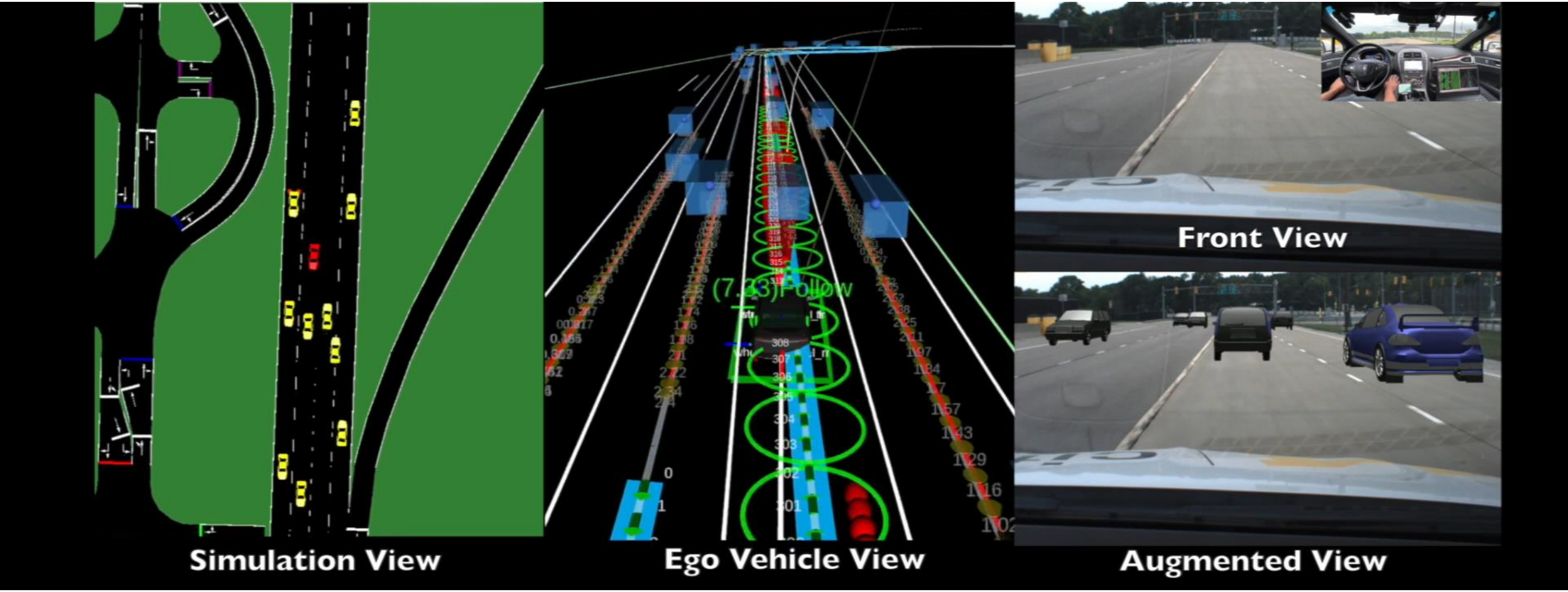
Mcity OpenCAV



AutoWare

apollo

Mcity Mixed Reality Testing



[Feng et al., *Nature Communications*, 2021]

Related Publications

- Liu, H. and Feng, S. (2022) “Curse of rarity” for autonomous vehicles, under review. https://arxiv.org/abs/2207.02749.
- Zou. Z., Zhang R., Shen, S., Pandey G., Chakravarty P., Parchami A., H. X., and Liu, H. (2022). Real-time Full-stack Traffic Scene Perception for Autonomous Driving with Roadside Cameras. International conference of Robotics Automation (ICRA). 10.1109/ICRA46639.2022.9812137
- Feng, S., Yan, X., Sun, H., Feng Y., and Liu H. (2021). Intelligent driving intelligence test for autonomous vehicles with naturalistic and adversarial environment. Nature communications, 12(1), 1-14. https://doi.org/10.1038/s41467-021-21007-8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