UNIFIED, SCALABLE AND REPLICABLE CONNECTED AND AUTOMATED DRIVING FOR A SMART CITY

SAE INTERNATIONAL FROM ADAS TO AUTOMATED DRIVING SYMPOSIUM

COLUMBUS, OH OCTOBER 10-12, 2017

PROF. DR. LEVENT GUVENC

Automated Driving Lab

THE OHIO STATE UNIVERSITY

CENTER FOR AUTOMOTIVE RESEARCH

AUTOMATED DRIVING LAB

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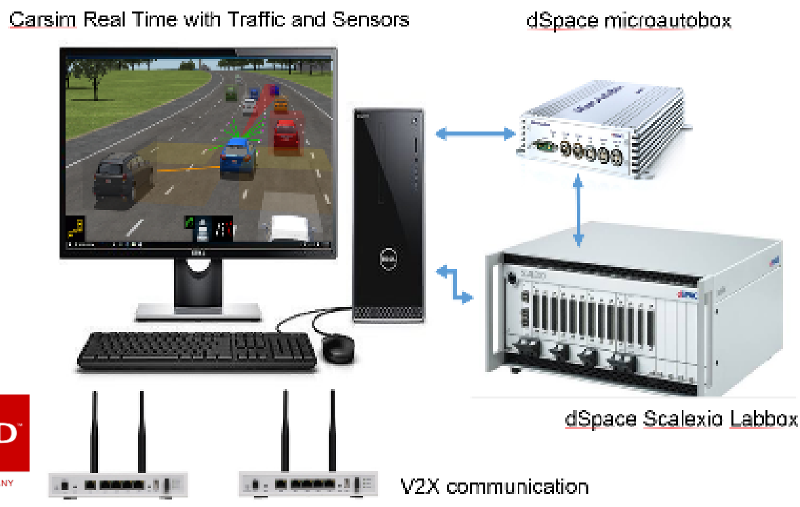
Team overview and key expertise

- Team: two faculty, one researcher, 12+ graduate students with strong focus on connected and automated driving, ADAS, active safety systems, autonomous shuttles for smart cities
- Ford Fusion Hybrid and Dash EV connected and automated driving vehicles with GPS/IMU localization, radar/camera/lidar perception under dSpace microautobox and perception computer control.
- State-of-the-art hardware-in-the-loop simulator with Carsim Real Time with traffic and sensors with interface to the vehicle electronic control unit and DSRC modems for the ego vehicle and the infrastructure and other vehicles.
- Validated models of connected and automated vehicles. Testing capability in parking lot, SR 33, TRC and Smart Columbus deployment sites.

Application areas

- Automated Path Following, **Highway** Chauffer / **Autopilot**
- Low Speed **Autonomous Shuttles for a Smart City**
- Cooperative Adaptive Cruise Control, Platooning
- Pedestrian Collision Avoidance
- Energy Efficient Connected & Autonomous Vehicles
- Cooperative Collision Avoidance



Partners and sponsoring agencies:

TRC DENSO HYUNDAI NSF WIND AN INTEL COMPANY

CATEGORIES OF AUTOMATED DRIVING: FULL AUTOMATION IS THE GOAL

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Research Aim:
Level 4/5

Levels of Driving Automation

Level 0: Non-Automated

The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.

Level 1: Assisted

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.

Level 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.

Level 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

Level 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.

Level 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.

Two many problems in Level 3 due to the presence of the human driver.

SMART COLUMBUS: FOUR DEPLOYMENTS

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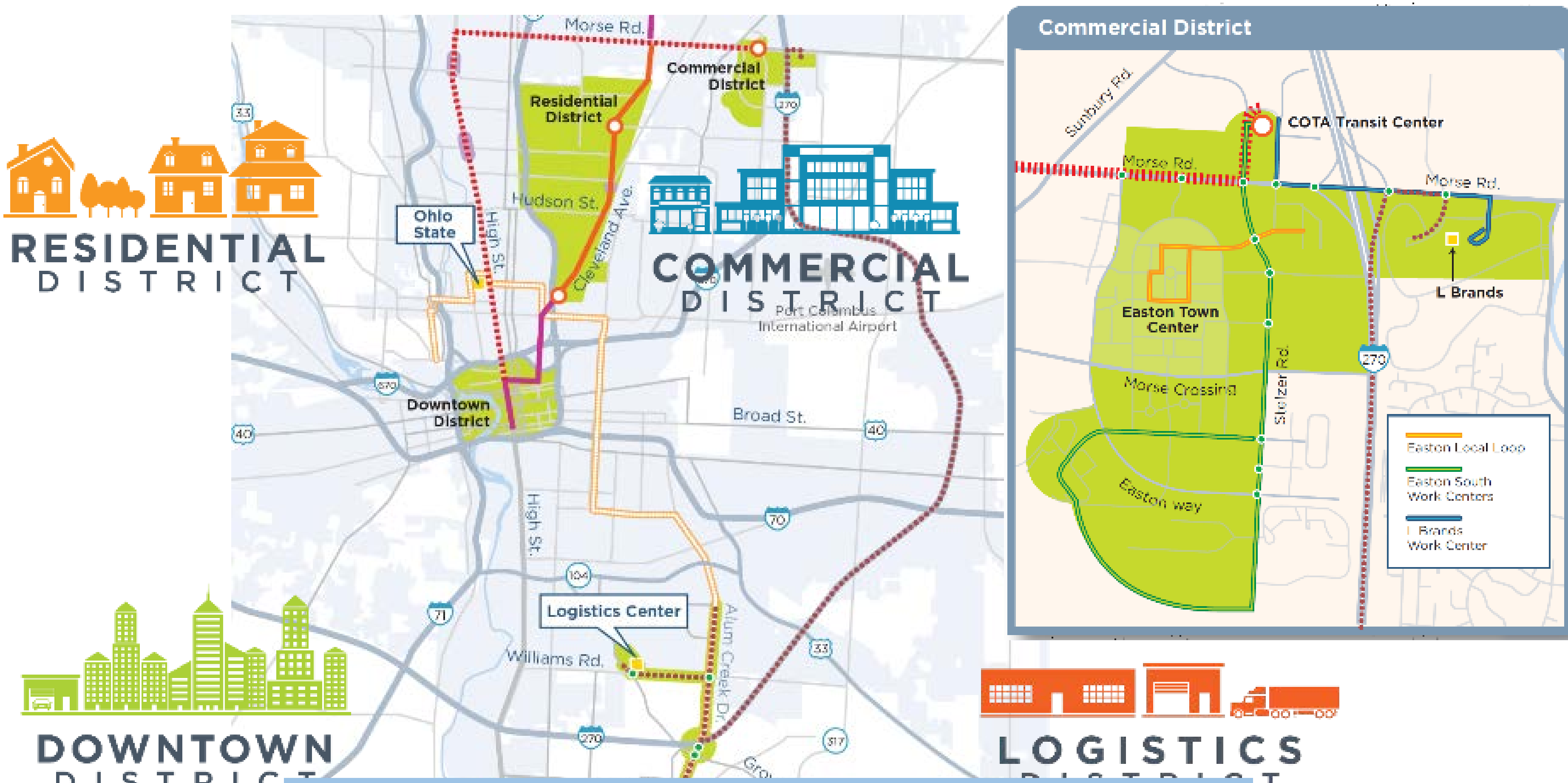

Autonomous electric shuttles will operate in commercial district.

Autonomous electric shuttles planned to operate in Ohio State University campus.

SmartShuttle

THE CITY OF COLUMBUS
ANDREW J. GINTHER, MAYOR

A Scalable and Replicable Architecture for Low Speed Automated Shuttles in Smart Cities



SMART SHUTTLE LEADING TO PROJECT UNIFY

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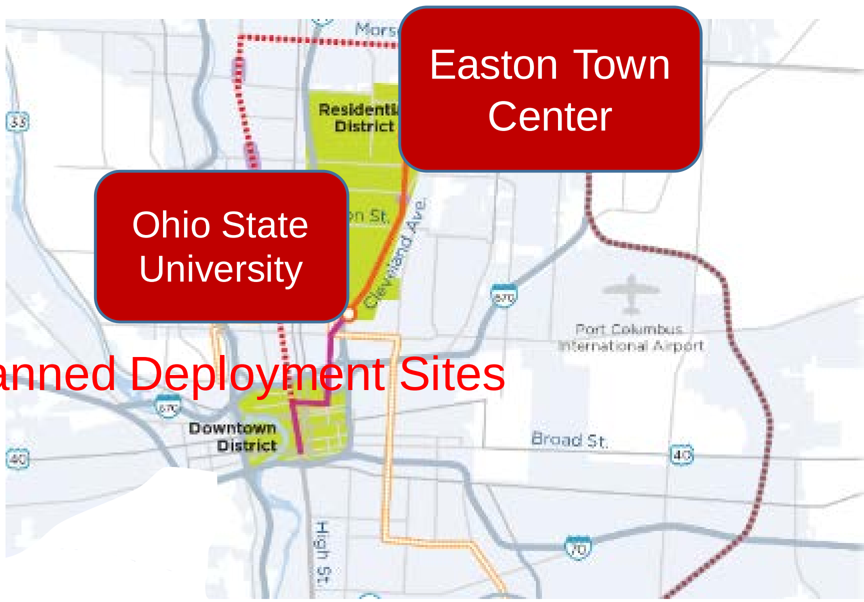
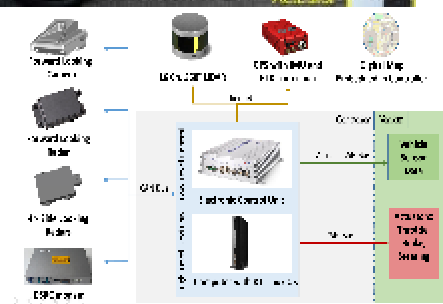
Unified and Scalable Architecture for Low Speed Automated Shuttle Deployment in a Smart City. Source: NSF CPS-EAGER-1640308. Dates: 09/01/2016–08/31/2018.

Different Vehicles



Unified Architecture



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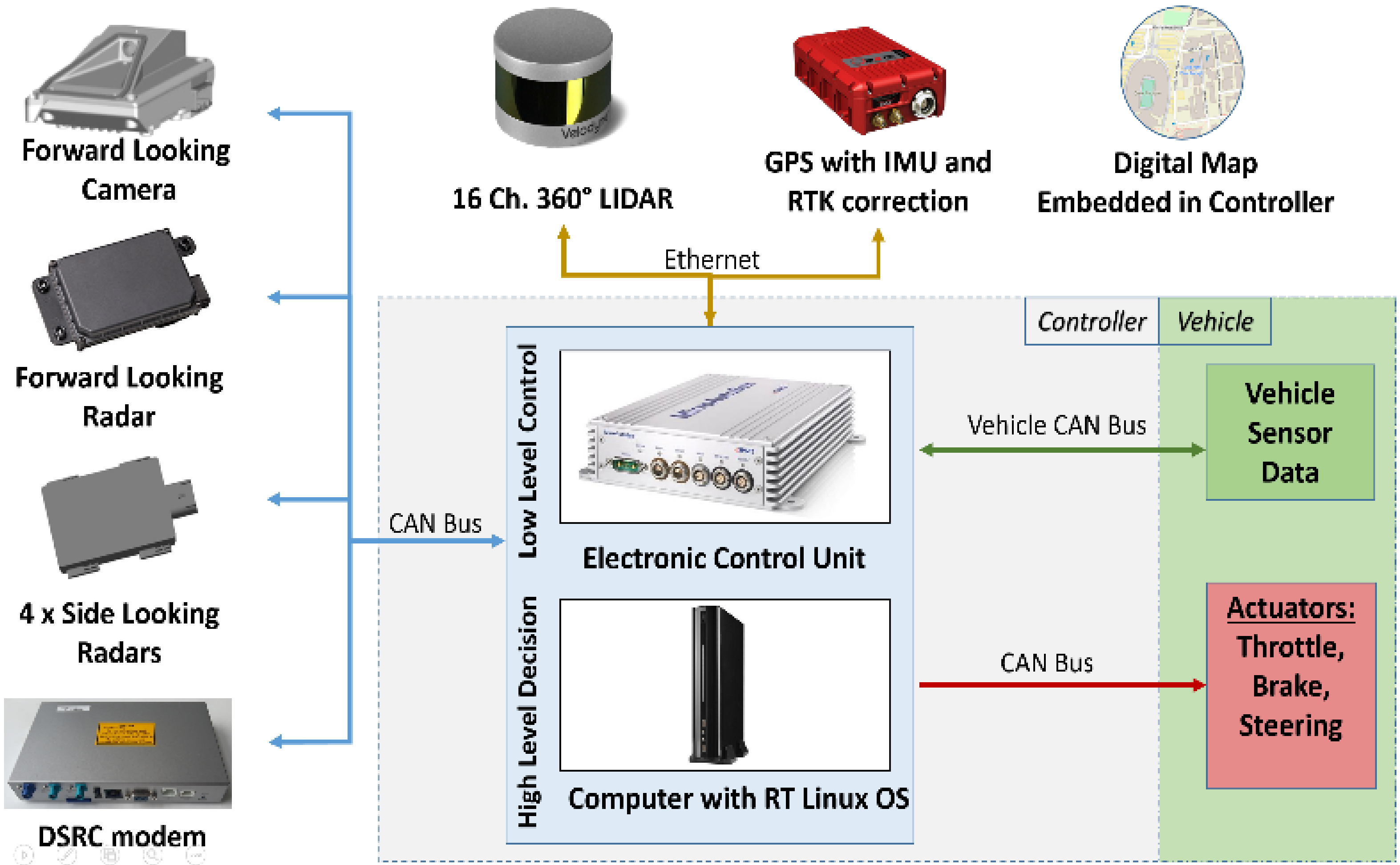
Develop and use a unified software, hardware, control and decision making architecture



2015 FORD FUSION HYBRID SE AUTOMATED DRIVING VEHICLE

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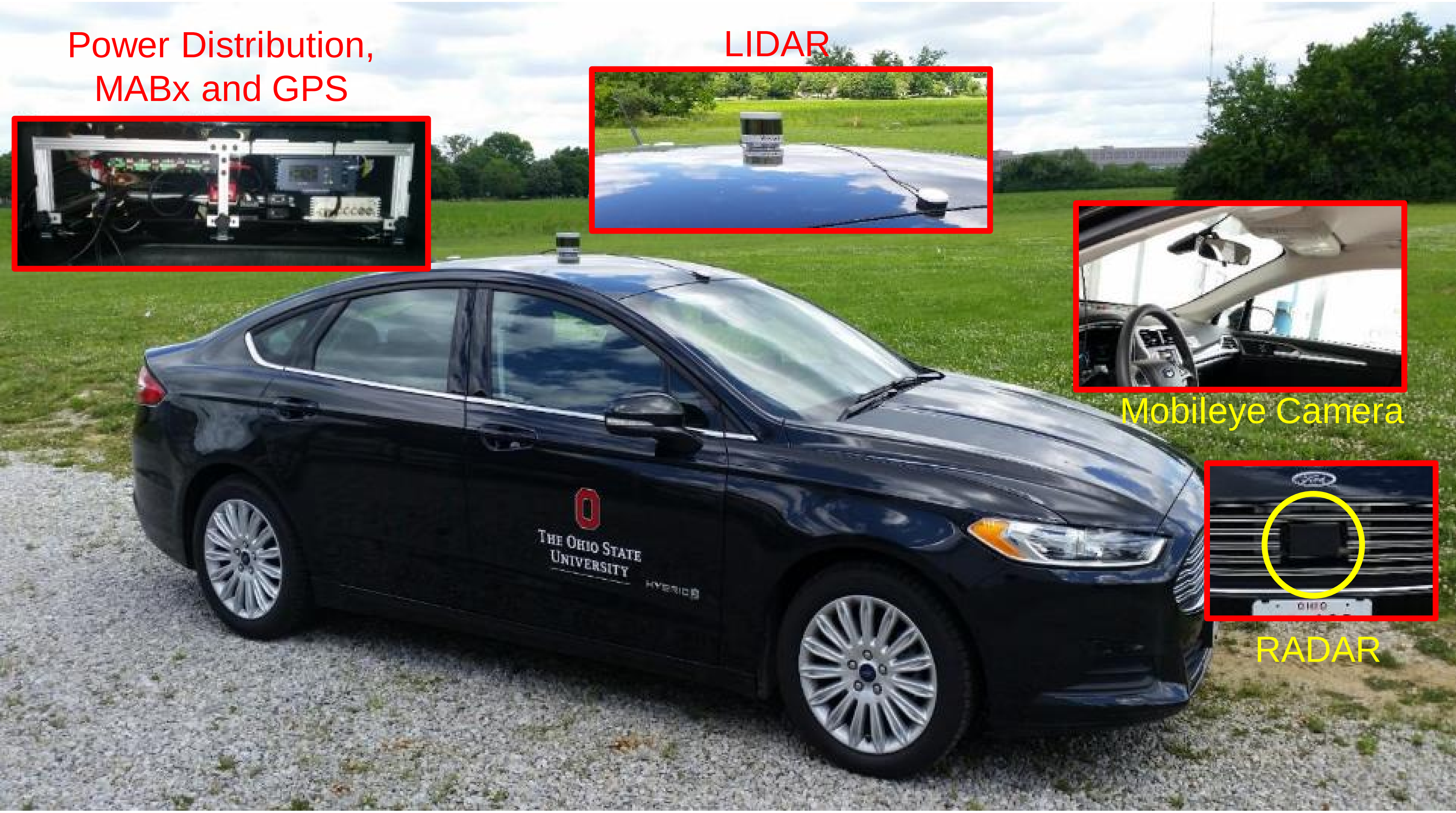

2015 FORD FUSION HYBRID SE AUTOMATED DRIVING VEHICLE

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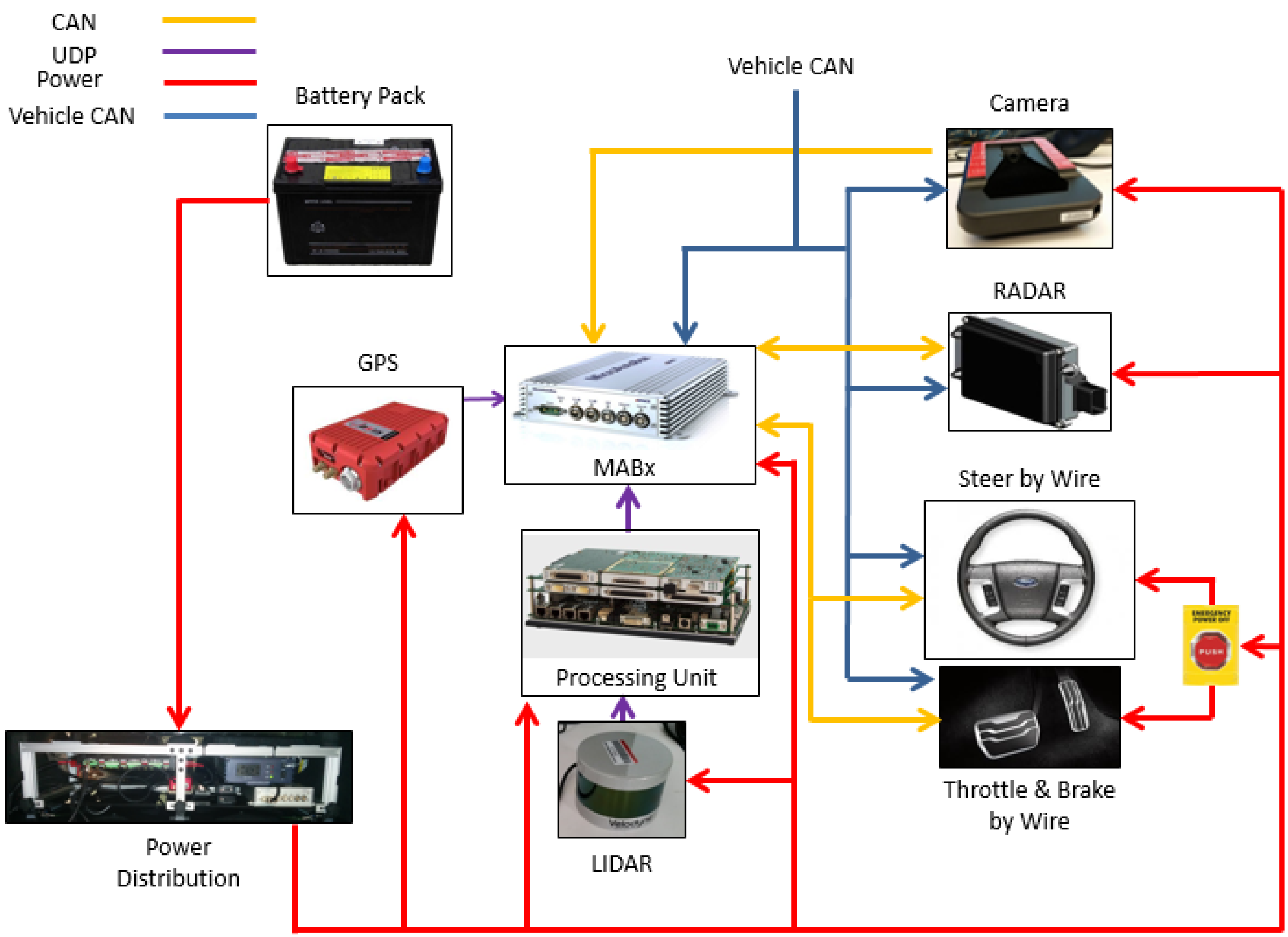

2017 FORD FUSION HYBRID SE

DASH EV AUTOMATED DRIVING VEHICLE

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IN-HOUSE AUTOMATION DASH EV
AUTOMATED DRIVING VEHICLE

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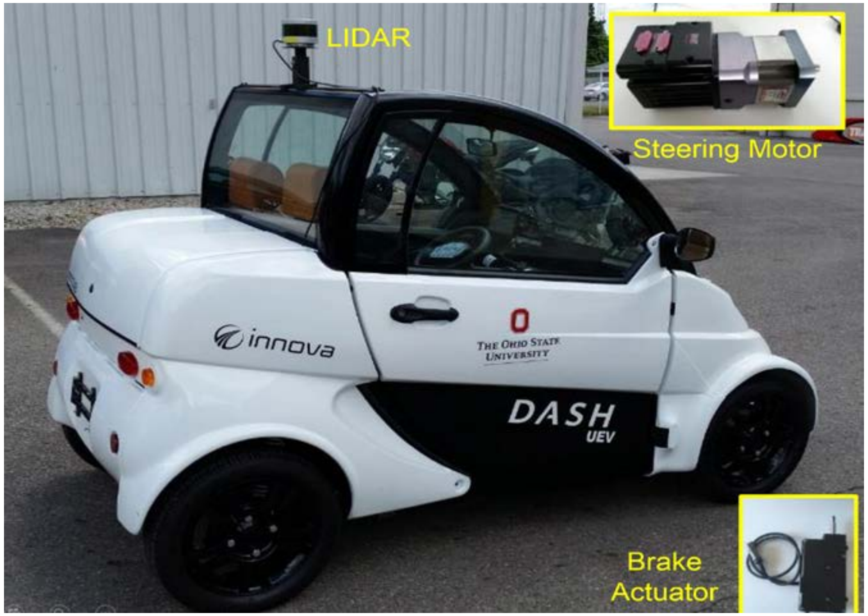

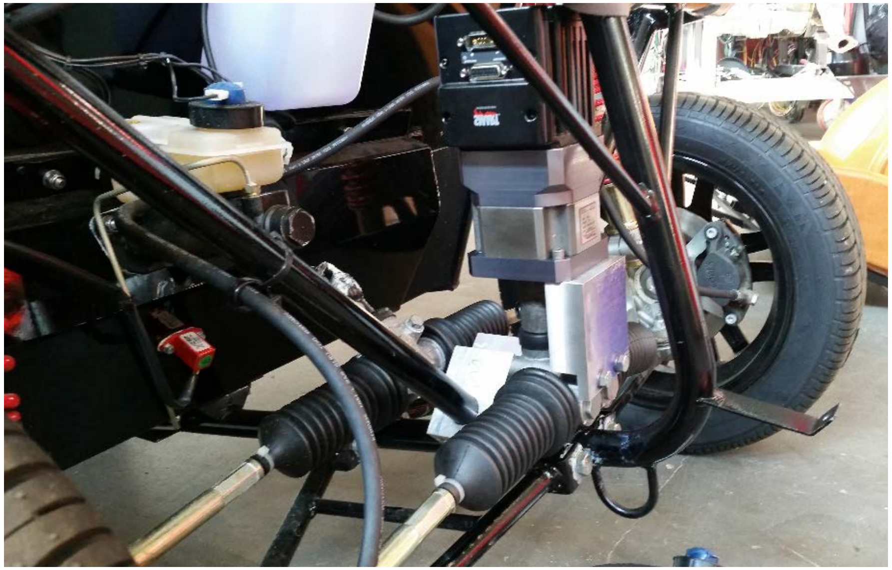

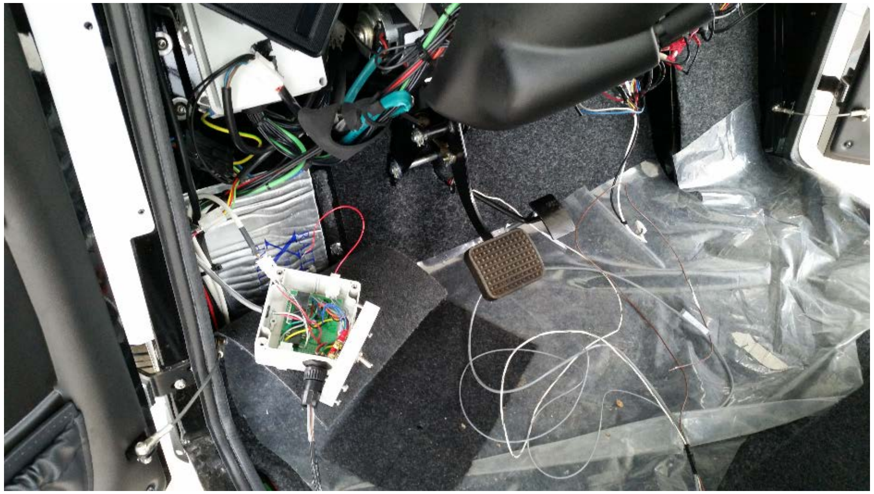

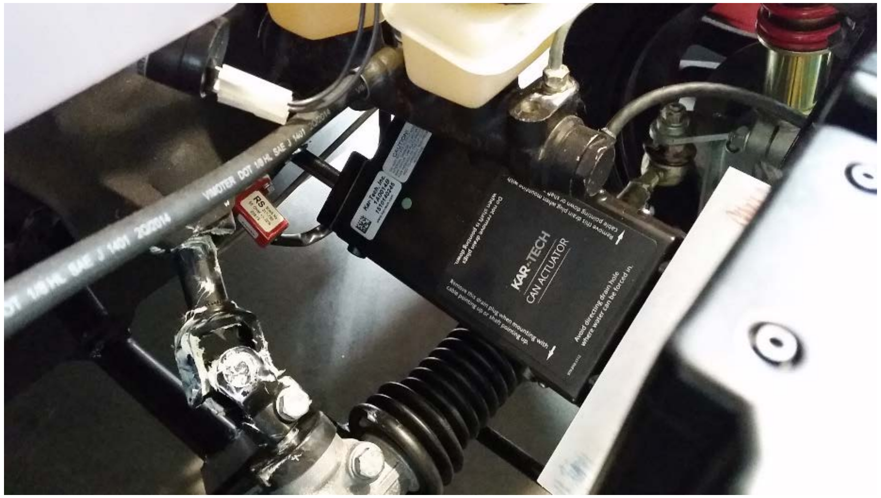

SCALABLE AND REPLICABLE AUTOMATED DRIVING CONTROLLERS

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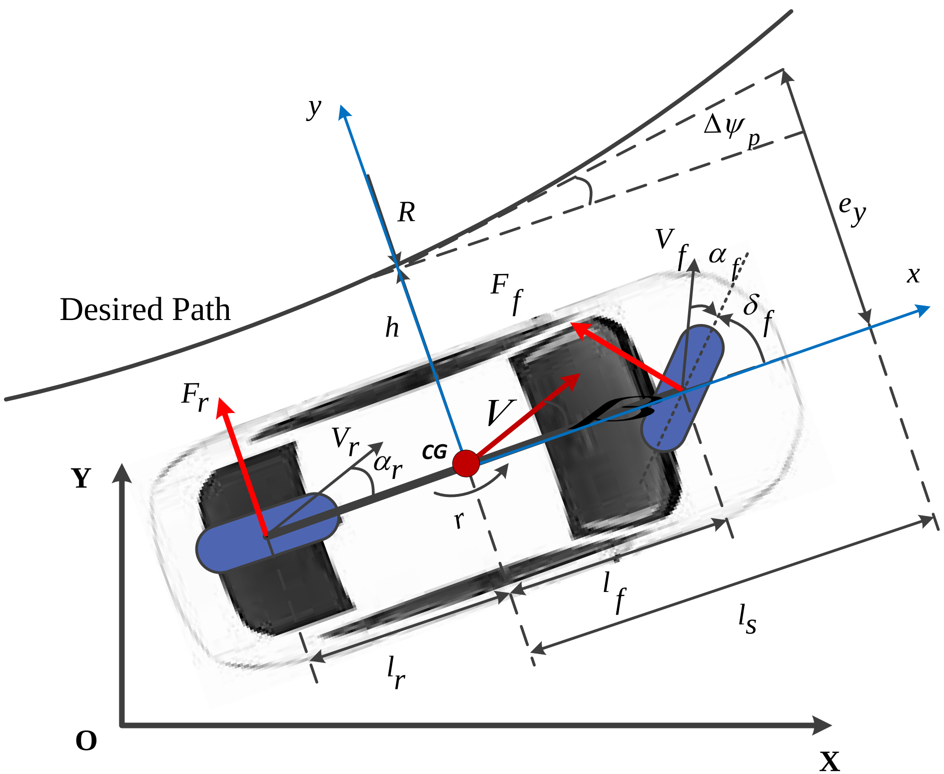
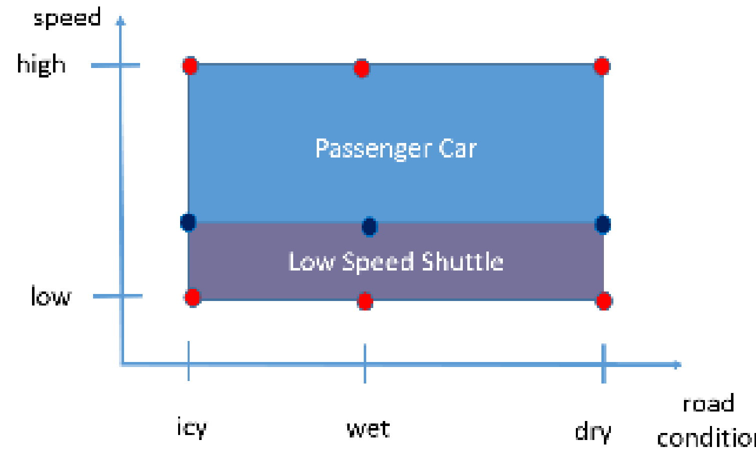
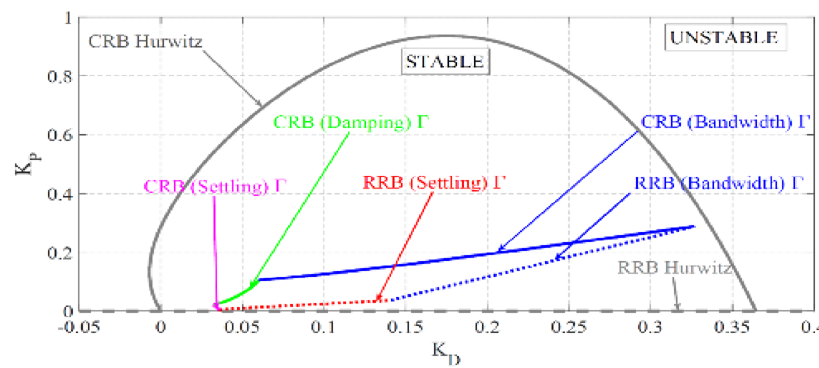
Develop and use **a scalable and replicable method of designing longitudinal and lateral vehicle dynamics controllers** via parametric approach.

Automated path following is used as the first scalable and replicable application.







SCALABLE AND REPLICABLE AUTOMATED PATH FOLLOWING: VEHICLE DYNAMICS MODELING

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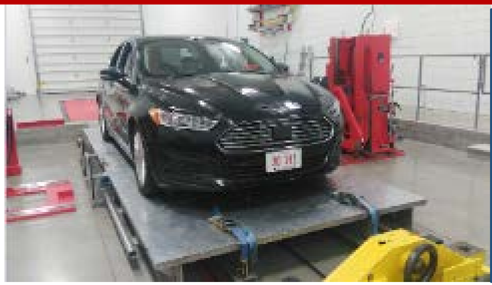
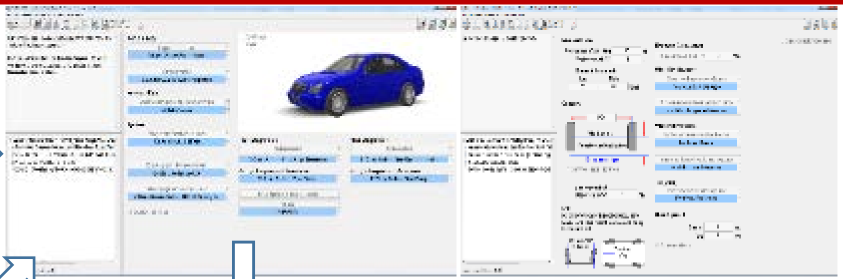


- Weight
- Wheel load
- Location of CoG
- Yaw moment of inertia
- etc

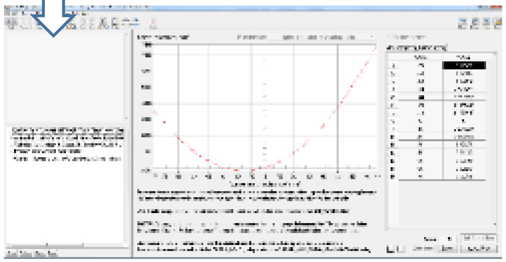
Vehicle Inertia Parameters Test



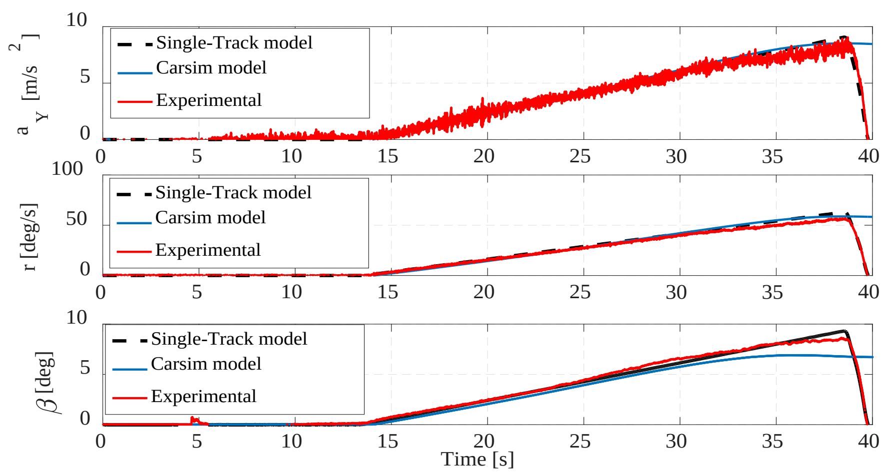
CarSim

- Suspension Vertical Stiffness
- Static Tire Vertical Stiffness
- Bounce Toe, etc

Suspension Kinematics & Compliance Test



Vehicle Dynamics Simulation



AUTOMATED PATH FOLLOWING IMPLEMENTATION AND MIL AND HIL EVALUATION

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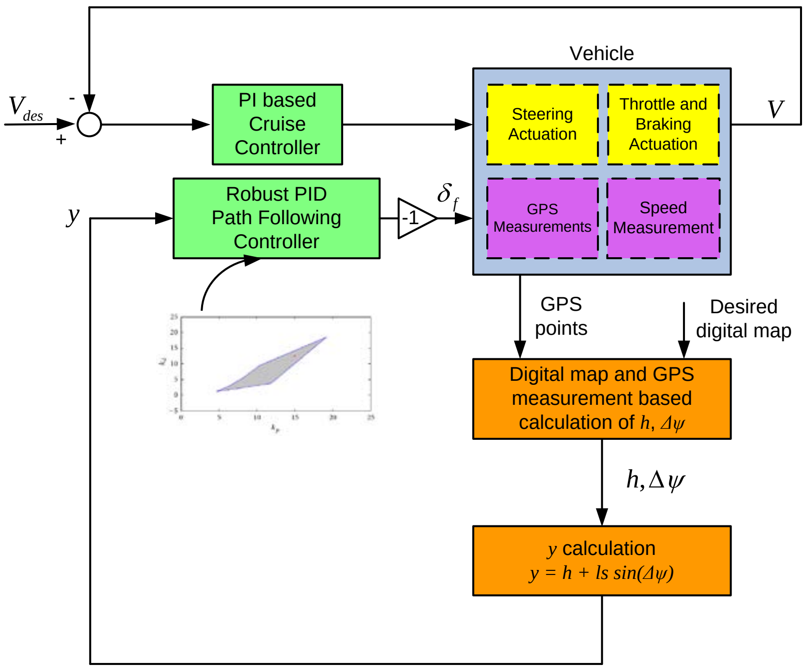
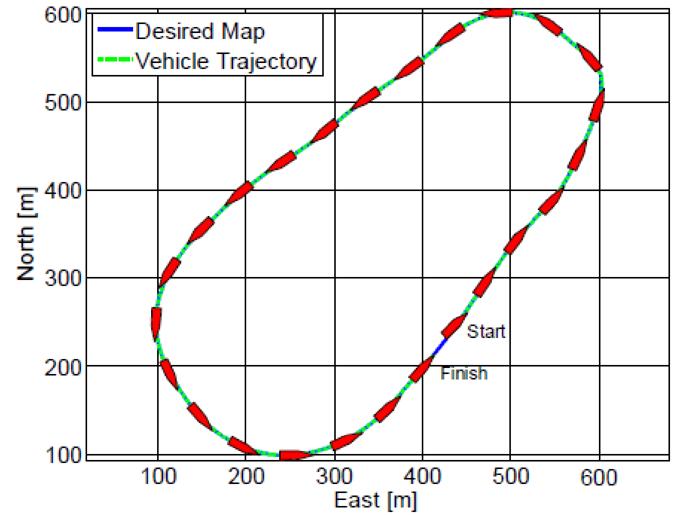
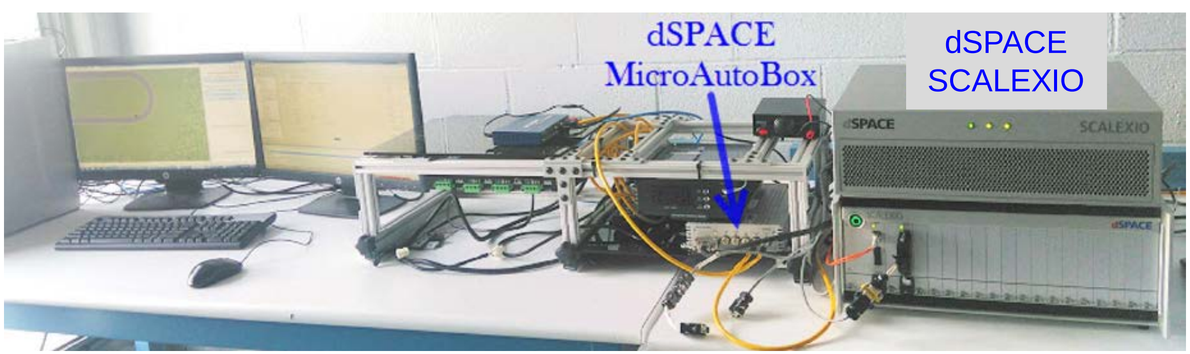
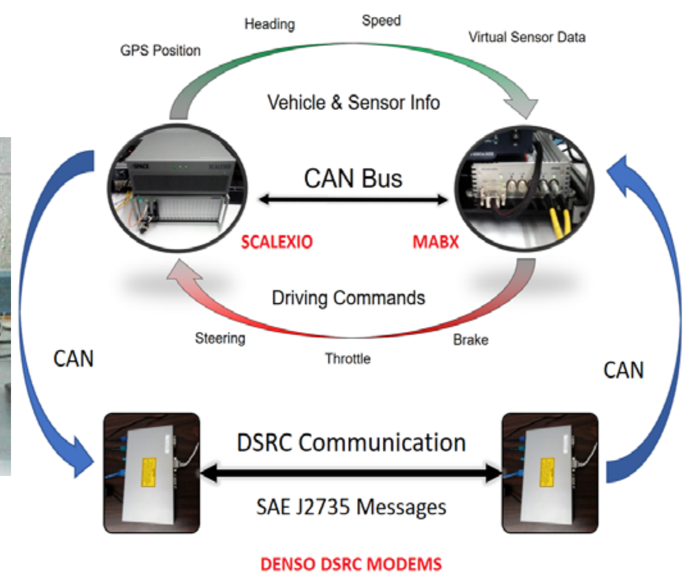
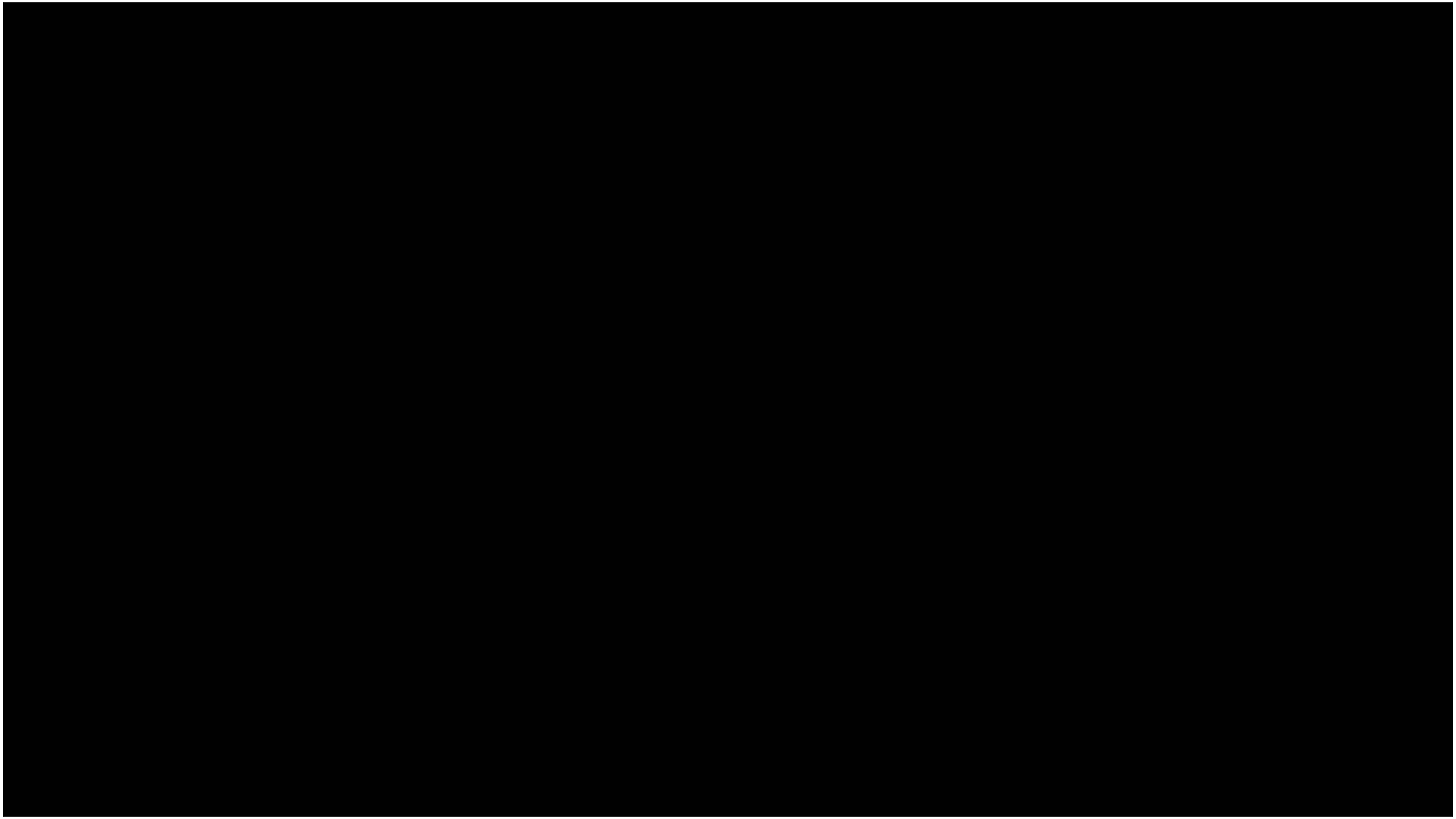








AUTOMATED PATH FOLLOWING OF FORD FUSION HYBRID IN CARMACK PARKING LOT



AUTOMATED PATH FOLLOWING IMPLEMENTATION AND PROVING GROUND EVALUATION

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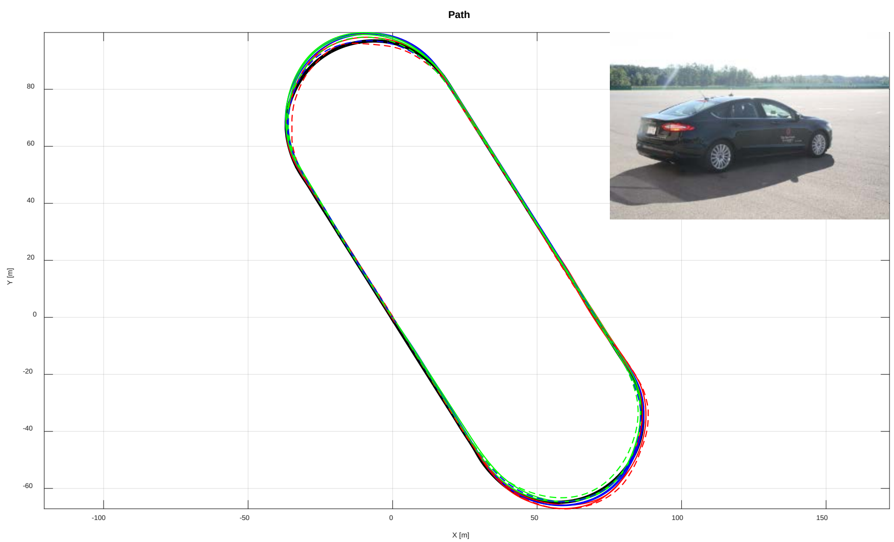

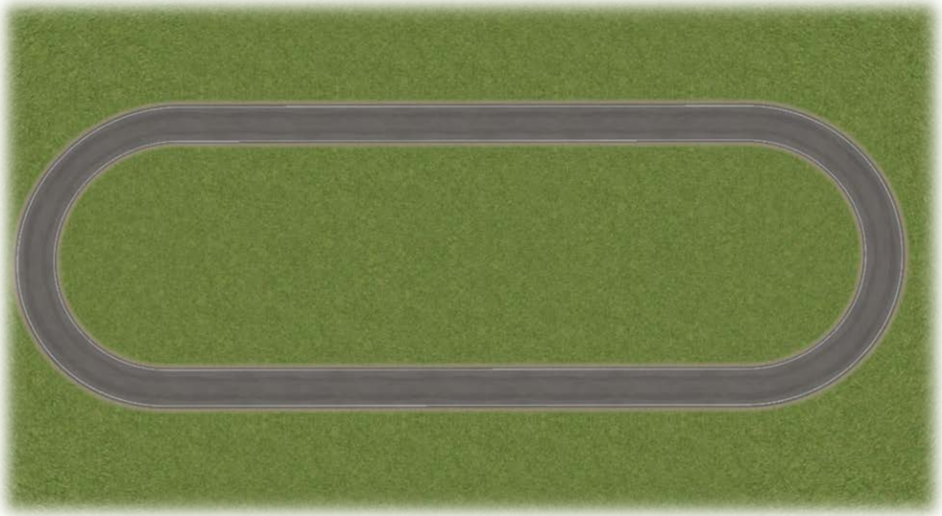

AUTOMATED PATH FOLLOWING OF FORD FUSION HYBRID IN TRC VDA

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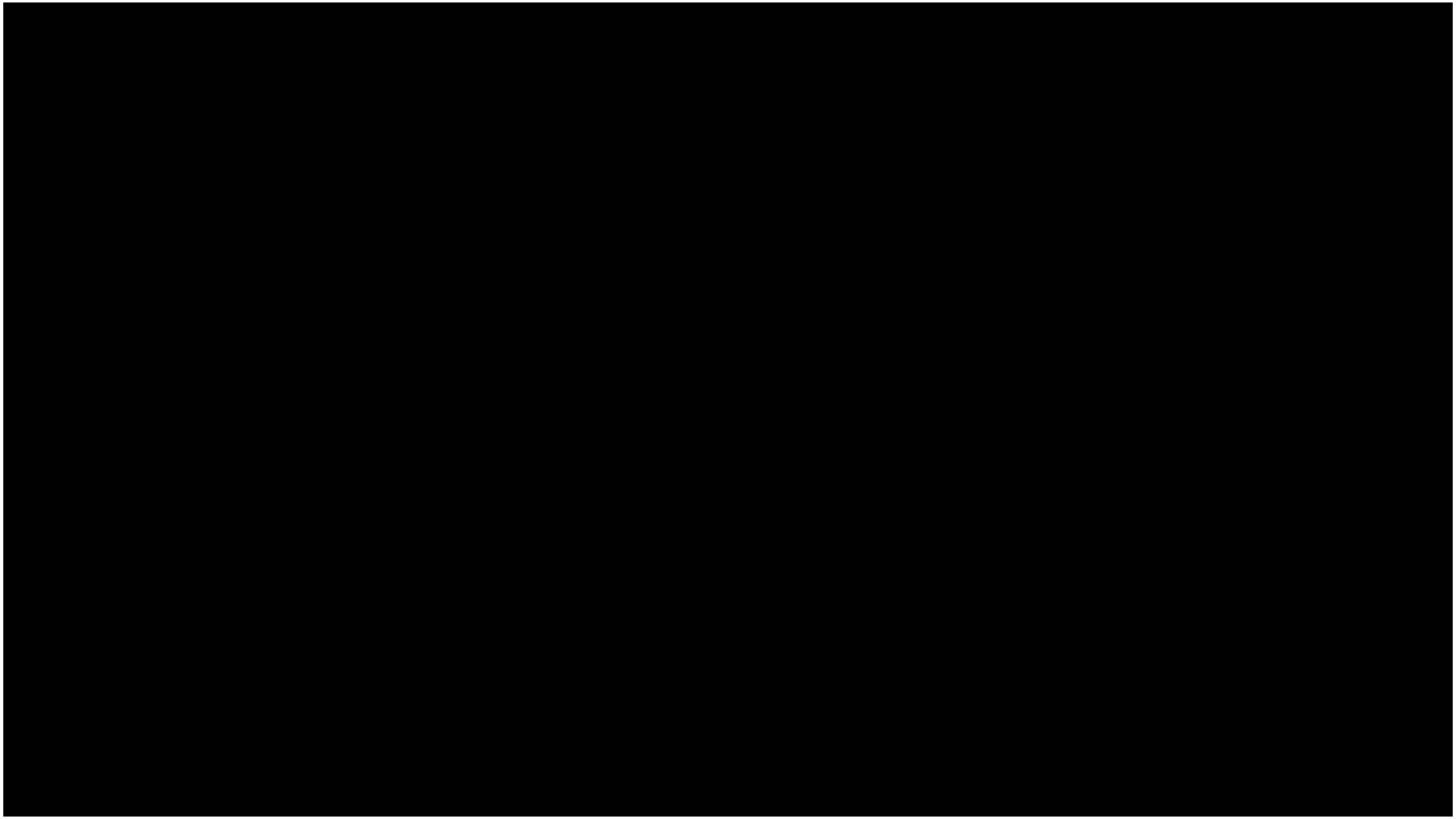

SCALE AND REPLICATE AUTOMATED PATH FOLLOWING TO SECOND VEHICLE (DASH EV)

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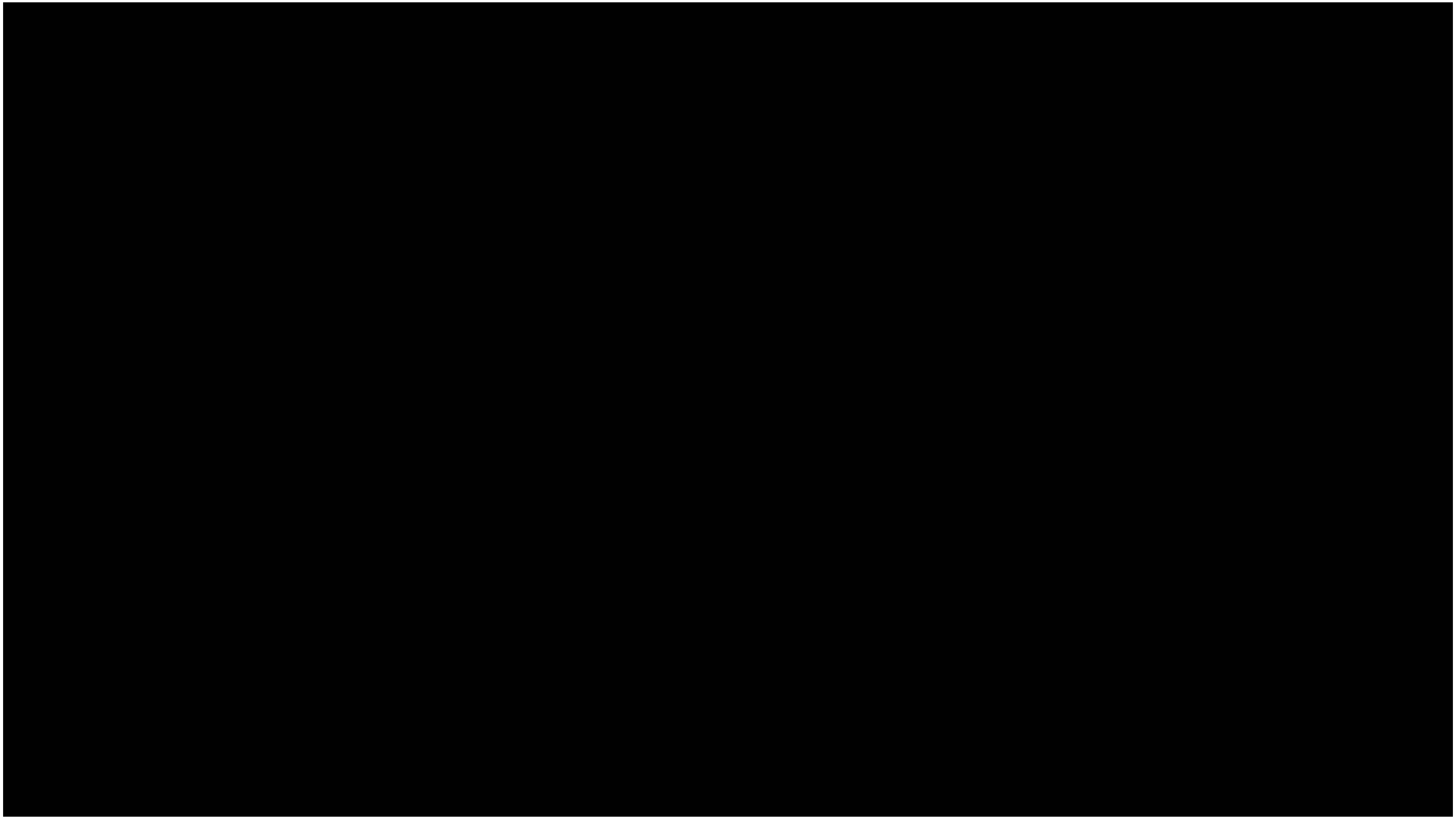

EXTEND SCALED AND REPLICATED SOLUTION TO SMART SHUTTLE PROOF-OF-CONCEPT TESTING

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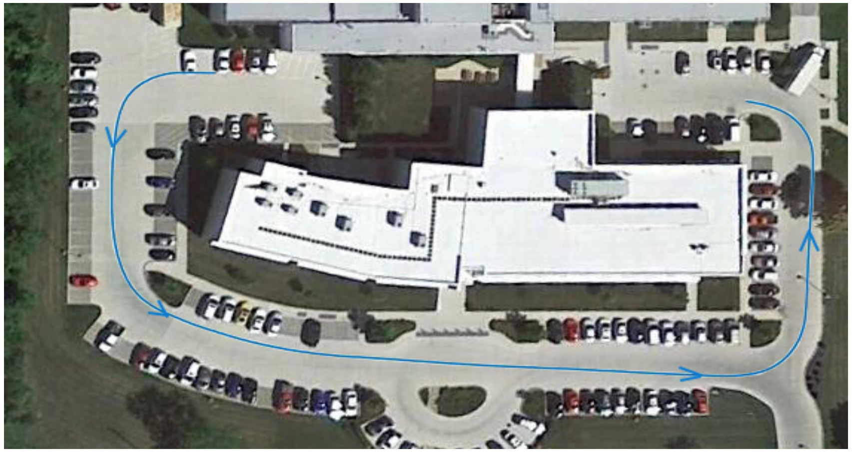
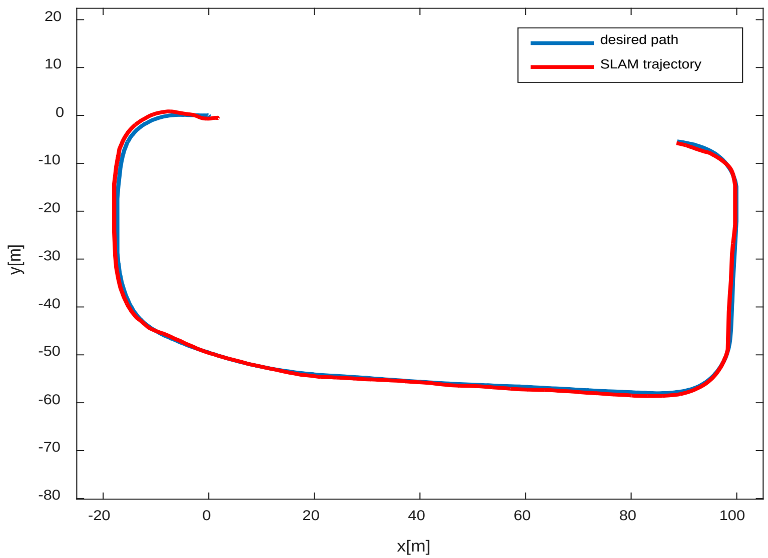
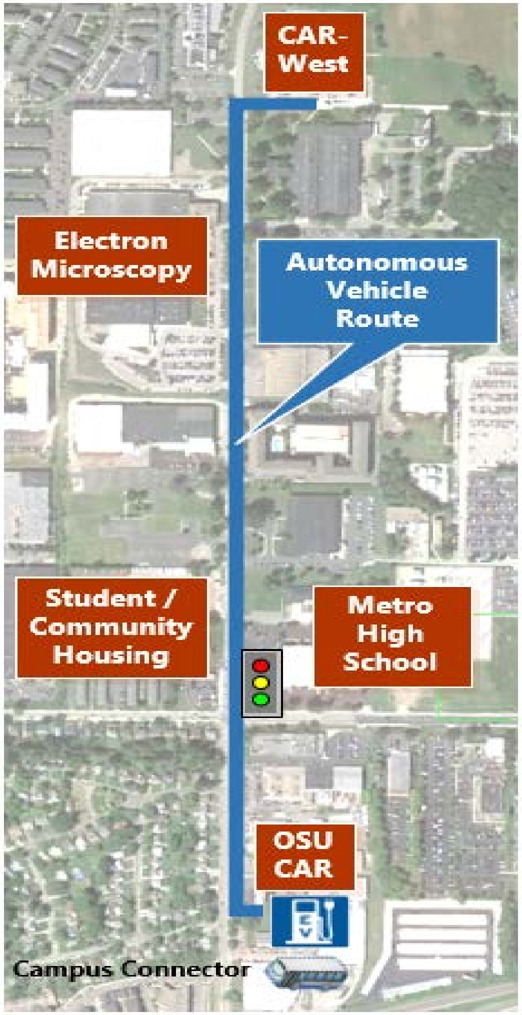


Initial proof-of-concept deployment in parking lot



Subsequent proof-of-concept deployment planned on OSU AV pilot route between Car-West and Car



Sub-project Smart Shuttle of CMU Mobility 21 National UTC (US DOT)

SMART SHUTTLE: PARKING LOT DEPLOYMENT

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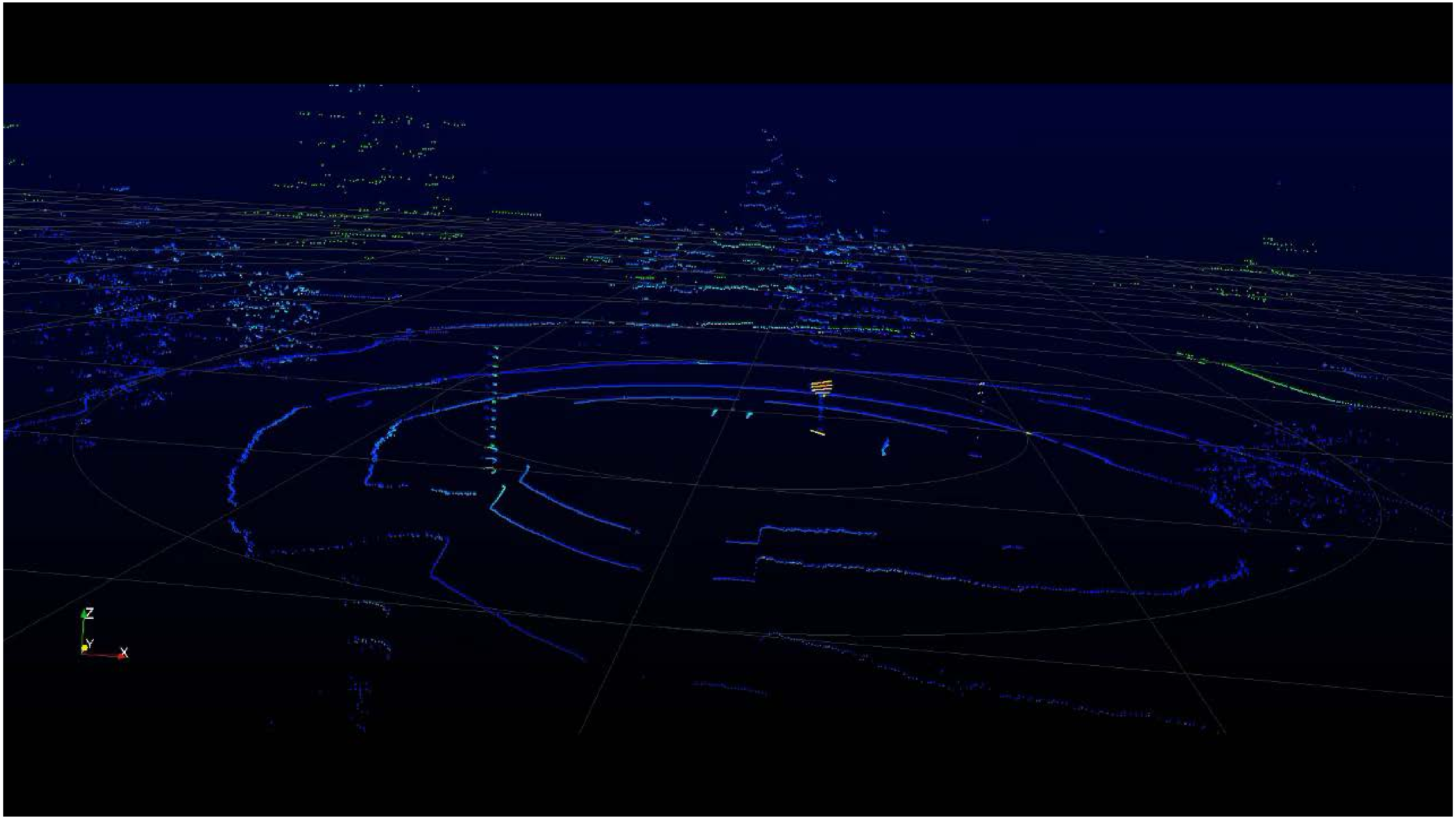
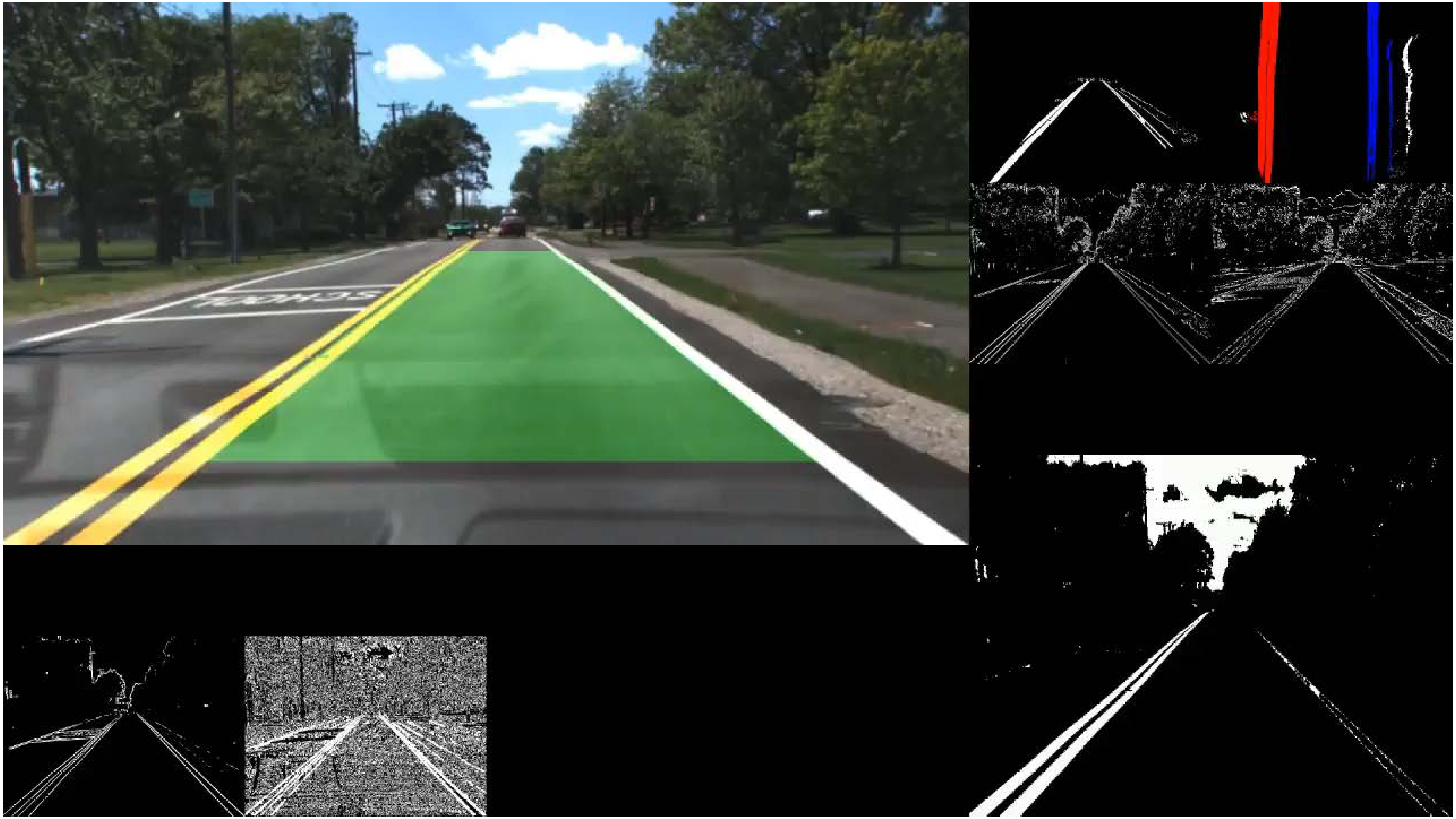
SMART SHUTTLE: OSU AV PILOT ROUTE POINT CLOUD DATA FROM CAR WEST TO CAR



SMART SHUTTLE: OSU AV PILOT ROUTE LANE DETECTION



CAV HIL SIMULATOR: OSU AV PILOT ROUTE IN CARSIM REAL TIME WITH SENSORS AND TRAFFIC

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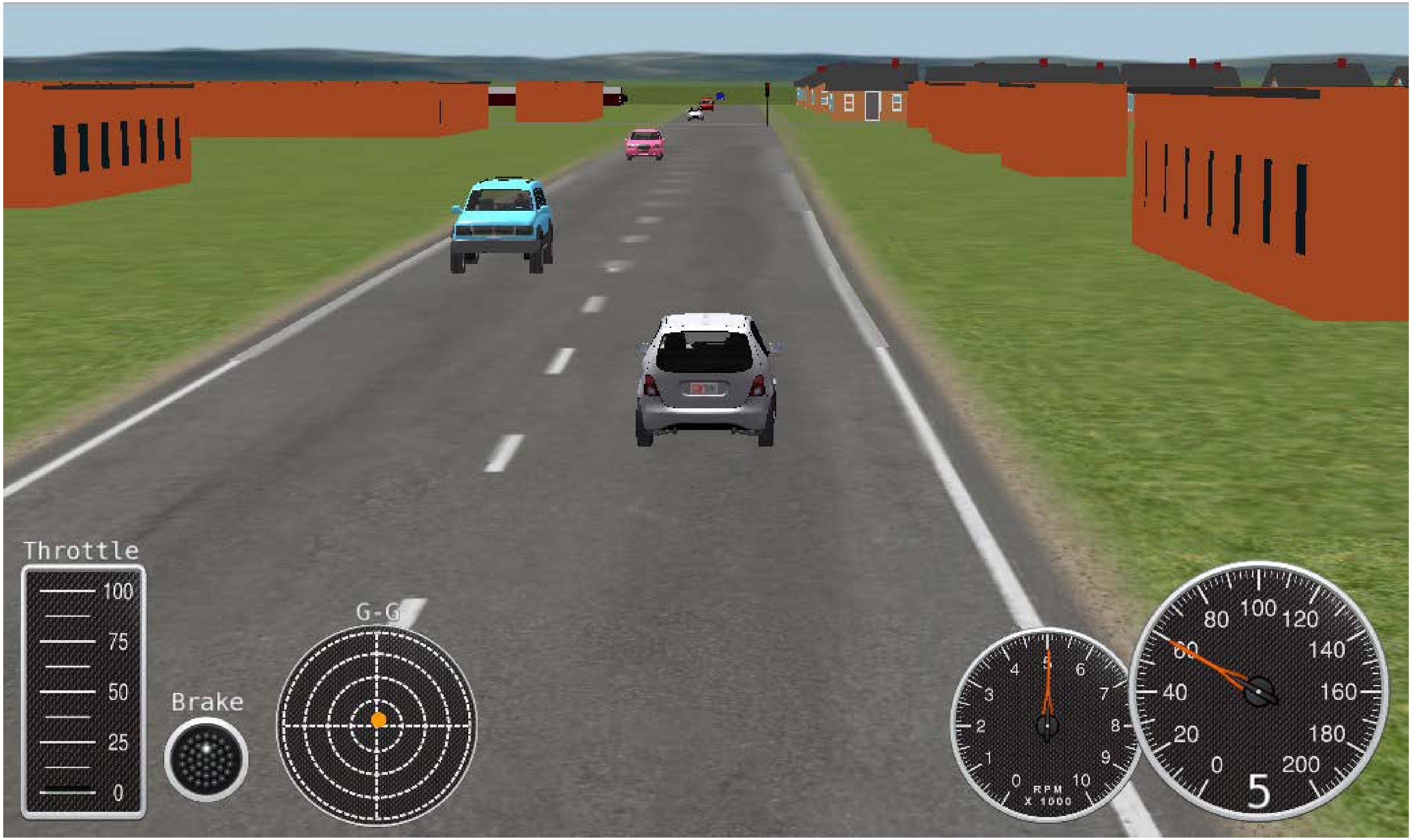

PEDESTRIAN COLLISION AVOIDANCE USING V2P COMMUNICATION

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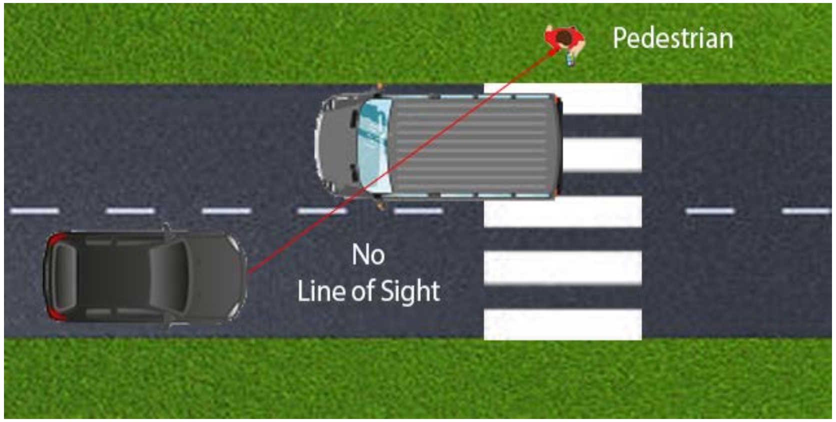

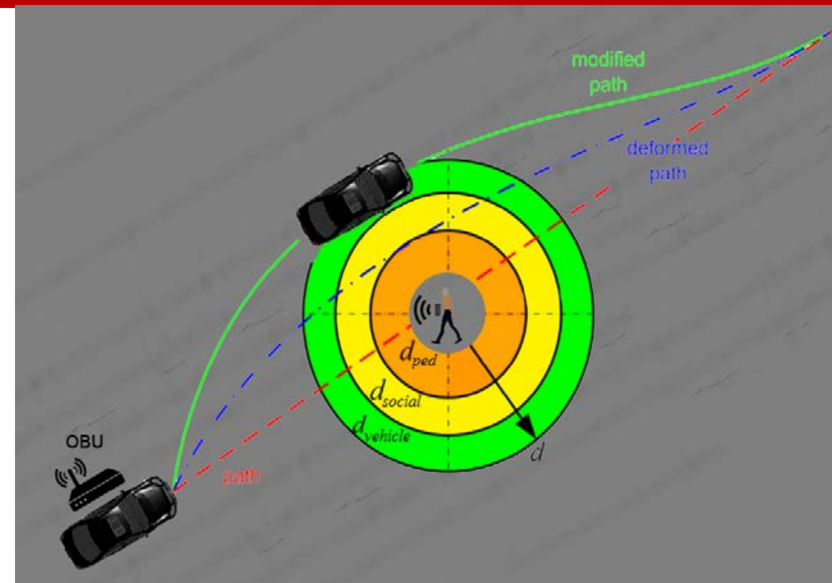

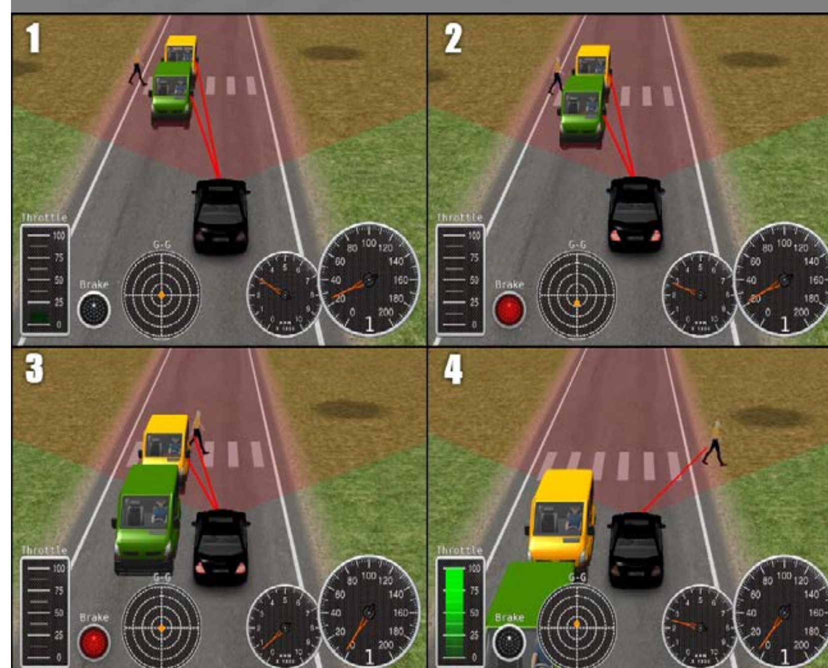

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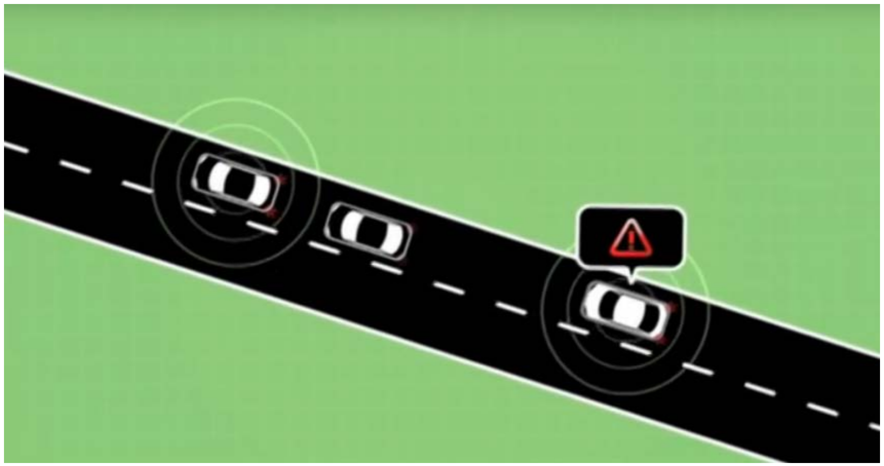
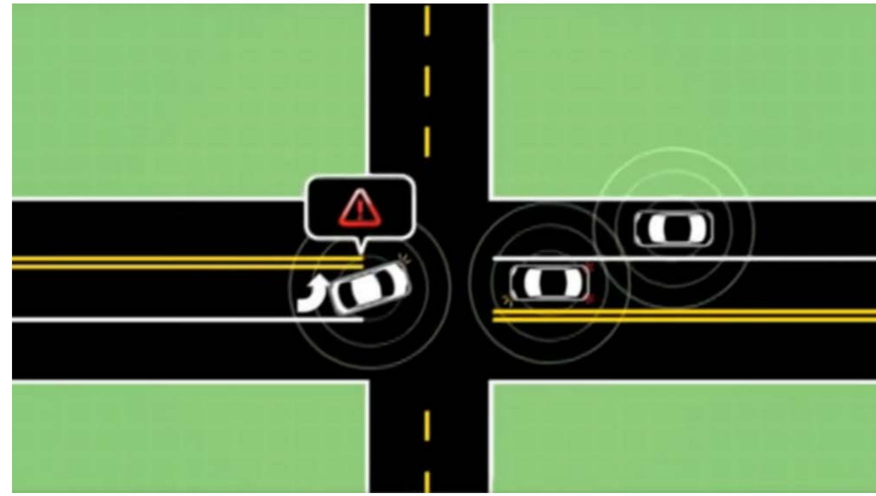
COOPERATIVE COLLISION AVOIDANCE

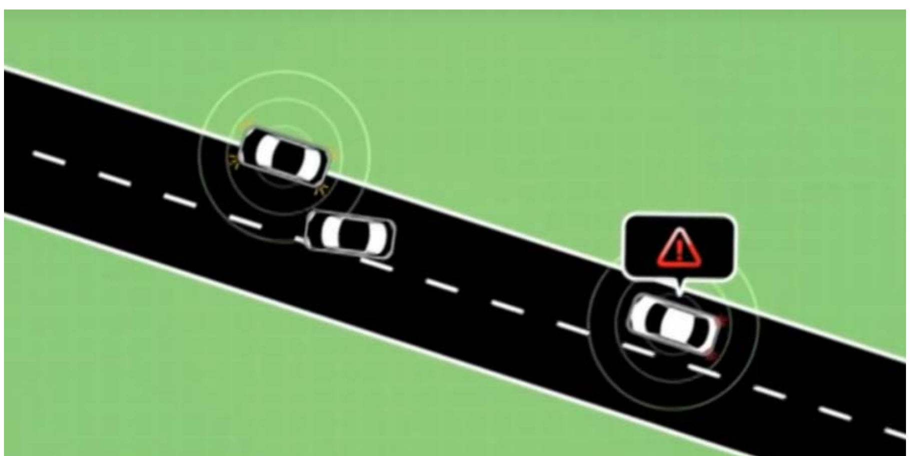
Electronic Emergency Brake Light (EEBL)

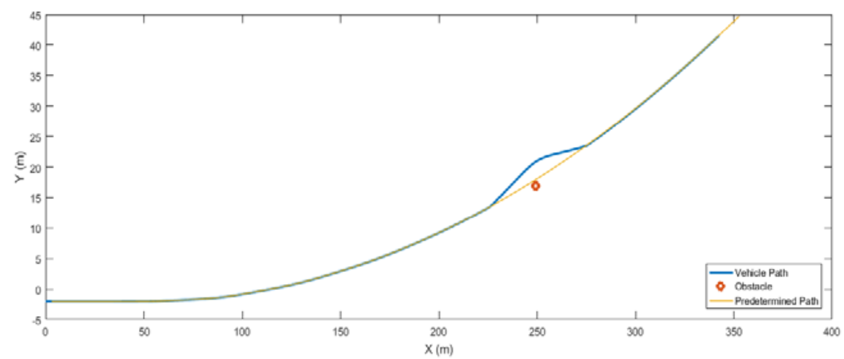


Intersection Movement Assist (IMA)



Curb Side Vehicle Alert





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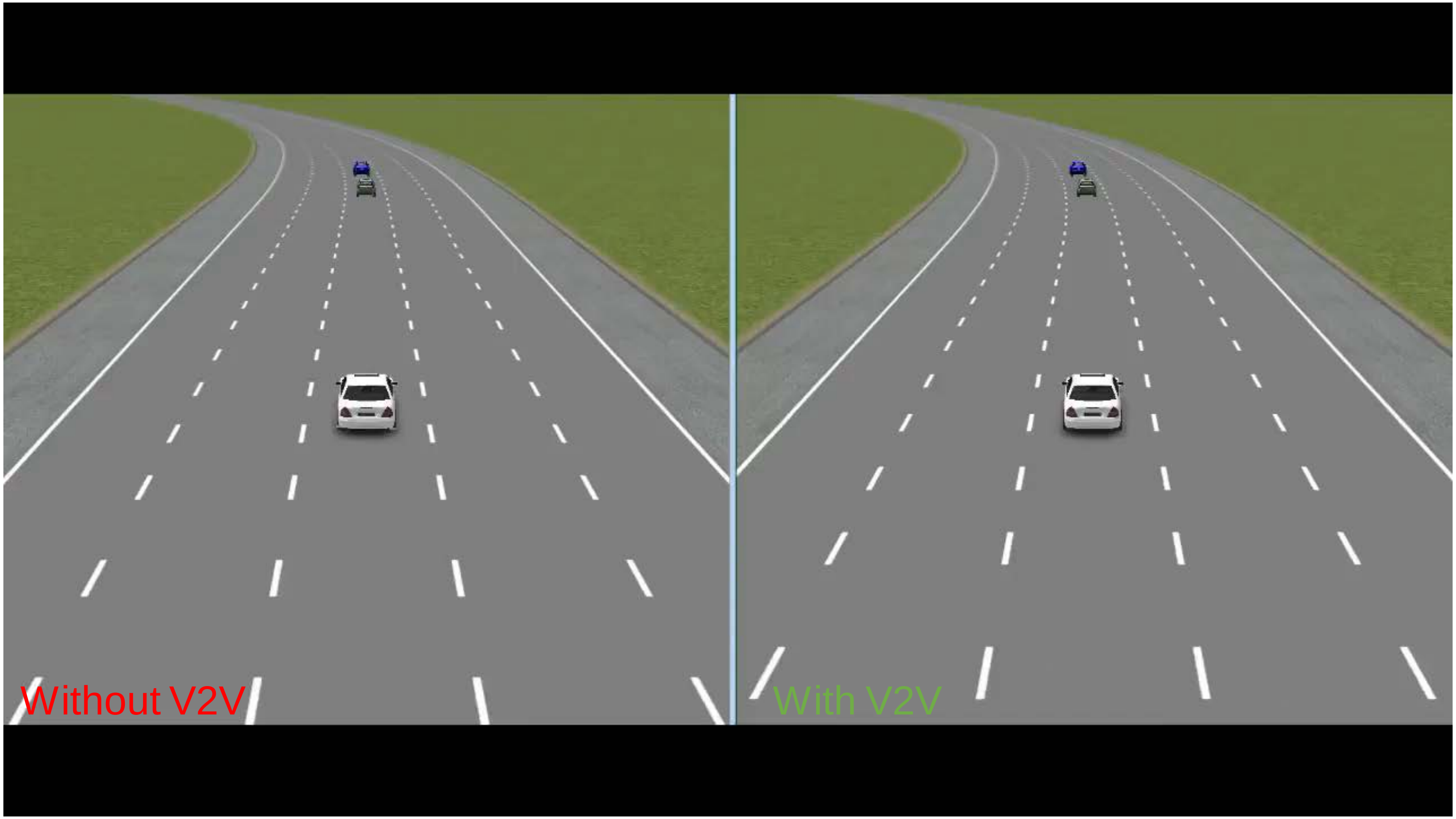
ELECTRONIC EMERGENCY BRAKE LIGHT (EEBL)



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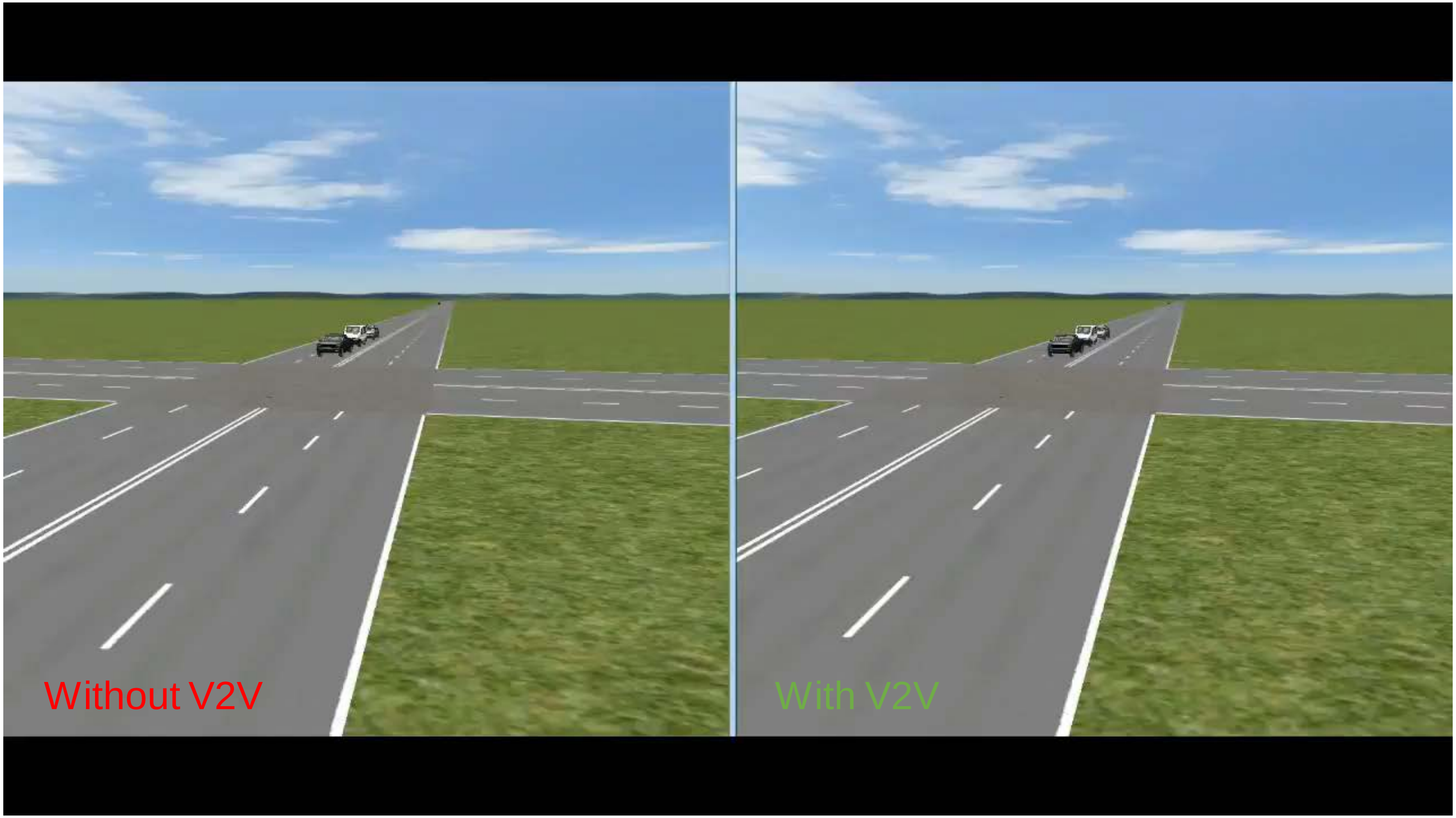
INTERSECTION MOVEMENT ASSIST (IMA)



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CURB SIDE VEHICLE ALERT

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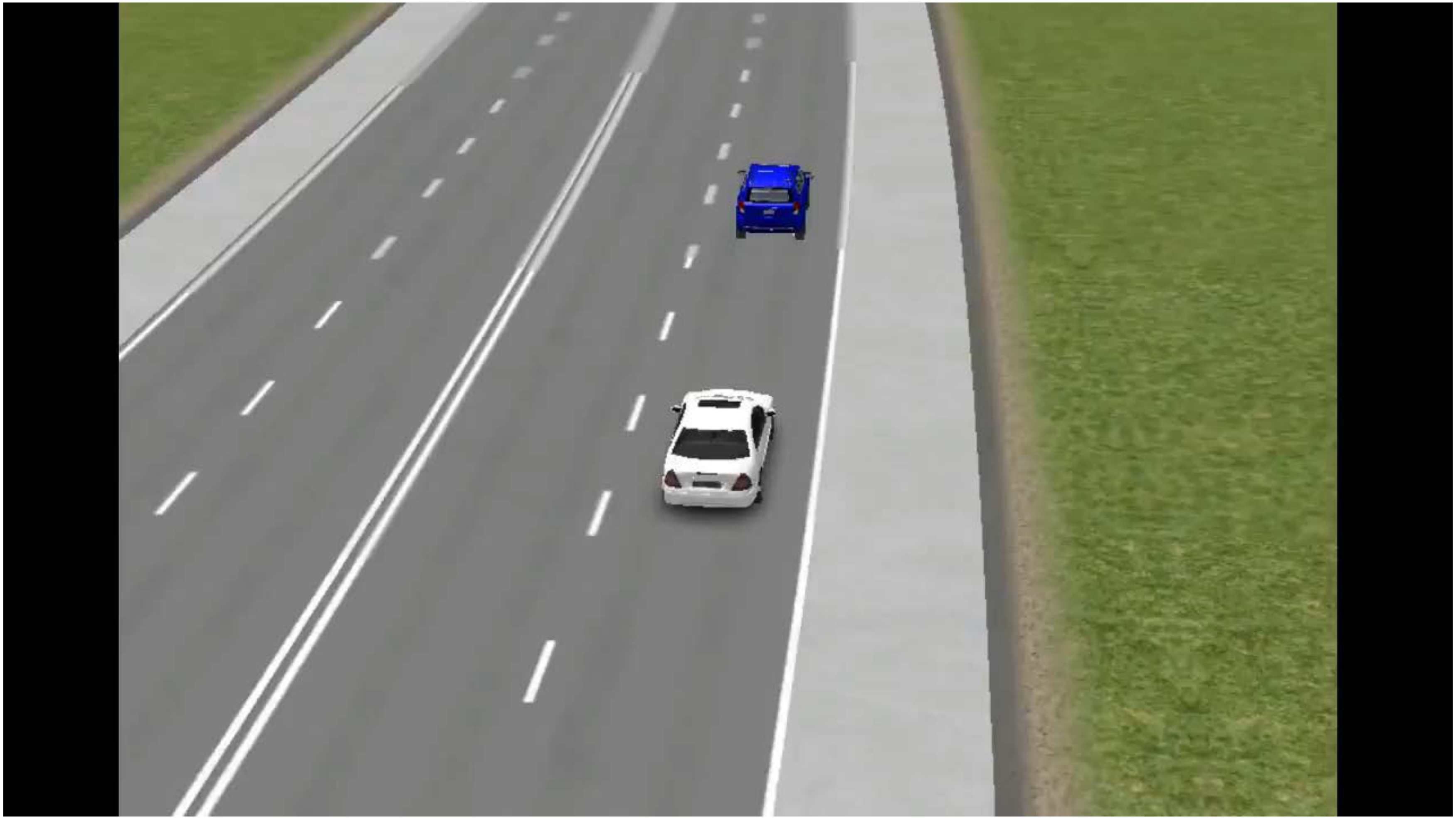

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COOPERATIVE COLLISION AVOIDANCE

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END OF PRESENTATION
QUESTIONS ???

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Thank you!

U.S. Department of Transportation Mobility 21: National University Transportation Center for Improving Mobility - CMU (sub-project titled: SmartShuttle: Model Based Design and Evaluation of Automated On-Demand Shuttles for Solving the First-Mile and Last-Mile Problem in a Smart City)

National Science Foundation under Grant No.:1640308 for the NIST GCTC Smart City EAGER project UNIFY titled: Unified and Scalable Architecture for Low Speed Automated Shuttle Deployment in a Smart City