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OFFICE OF RESEARCH, DEVELOPMENT, AND TECHNOLOGY

FEDERAL HIGHWAY ADMINISTRATION (FHWA) RESEARCH ON EMERGING TECHNOLOGY MODELING

Transportation Research Board (TRB) 2021 Annual Meeting

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Highway Research Center

PRESENTATION OVERVIEW

- Motivation.
- Approach.
- Challenges.
- Data, Model Improvement, and Benefits Estimation.
- Collaboration Examples.
- Conclusions.

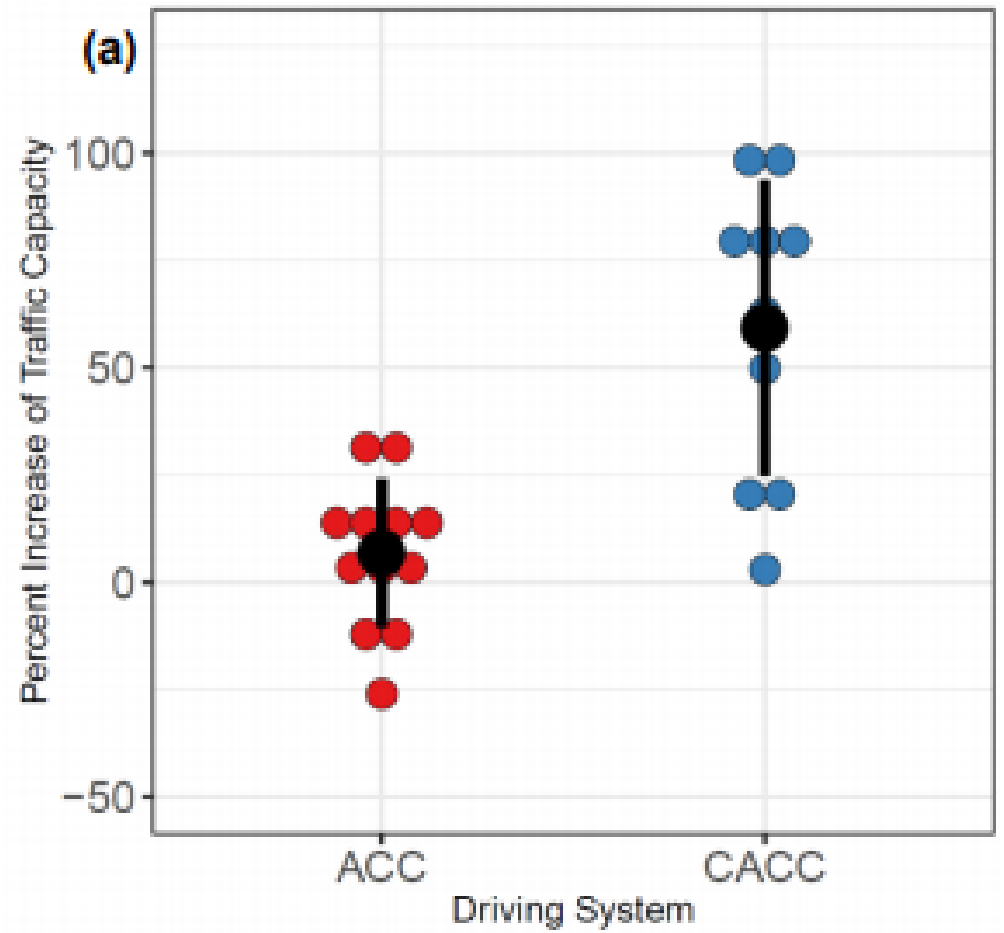
MOTIVATION

- Agencies need a low-cost approach to quantify impacts of connected and automated vehicle (CAV) deployments to make intelligent investment and operational decisions.
- Traffic analysis tools provide an efficient approach to evaluate a new technology or strategy prior to implementation.
- Current analysis, modeling, and simulation (AMS) tools were built to model human driving behavior.
- New CAV behavioral models for microsimulation tools are rapidly under development.

MODELING IMPACTS OF CAVS

Microsimulation model analyses have produced a wide range of possible CAV impacts:

- Eilbert, Berg, and Smith (2019).[1]
- James, Melson, Hu, and Bared (2019).[2]

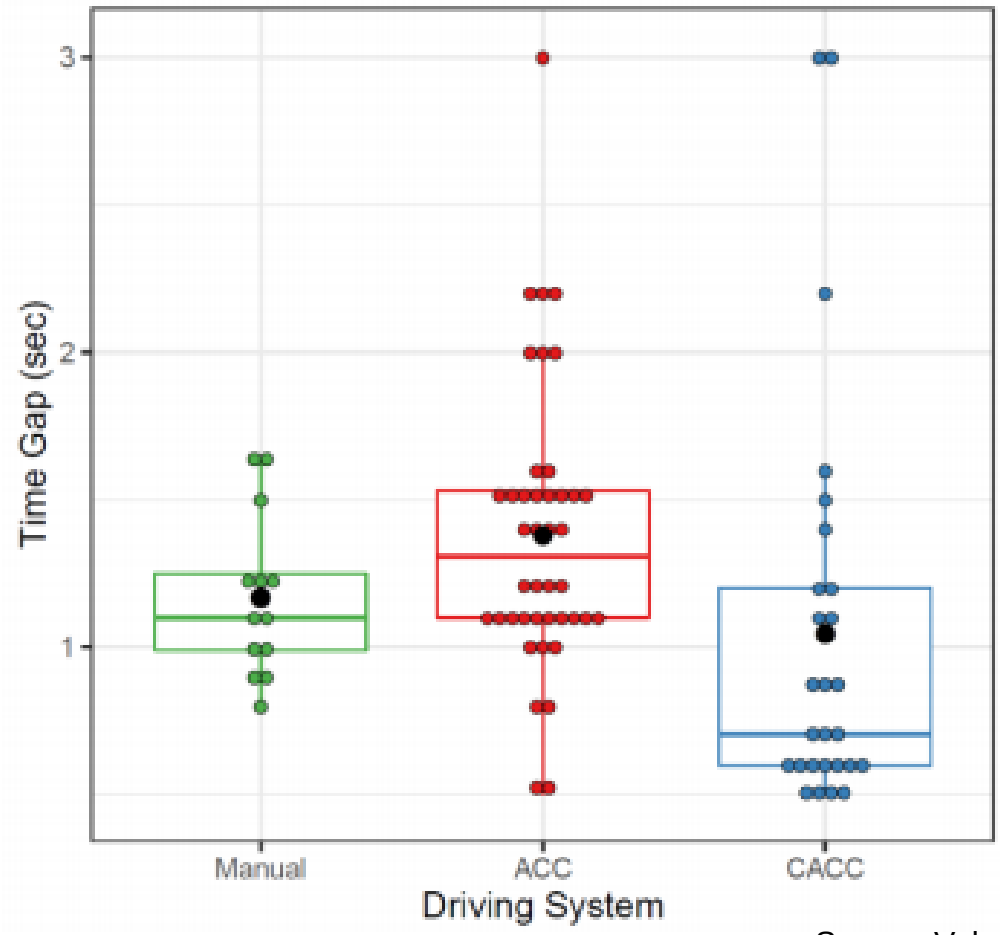


ACC = adaptive cruise control.
CACC = cooperative adaptive cruise control.

Source: Volpe.[1]

MODELING IMPACTS OF CAVS

- Variations in modeling assumptions are partially to blame.
- More confidence in results if models are built from data and rely less on assumptions.

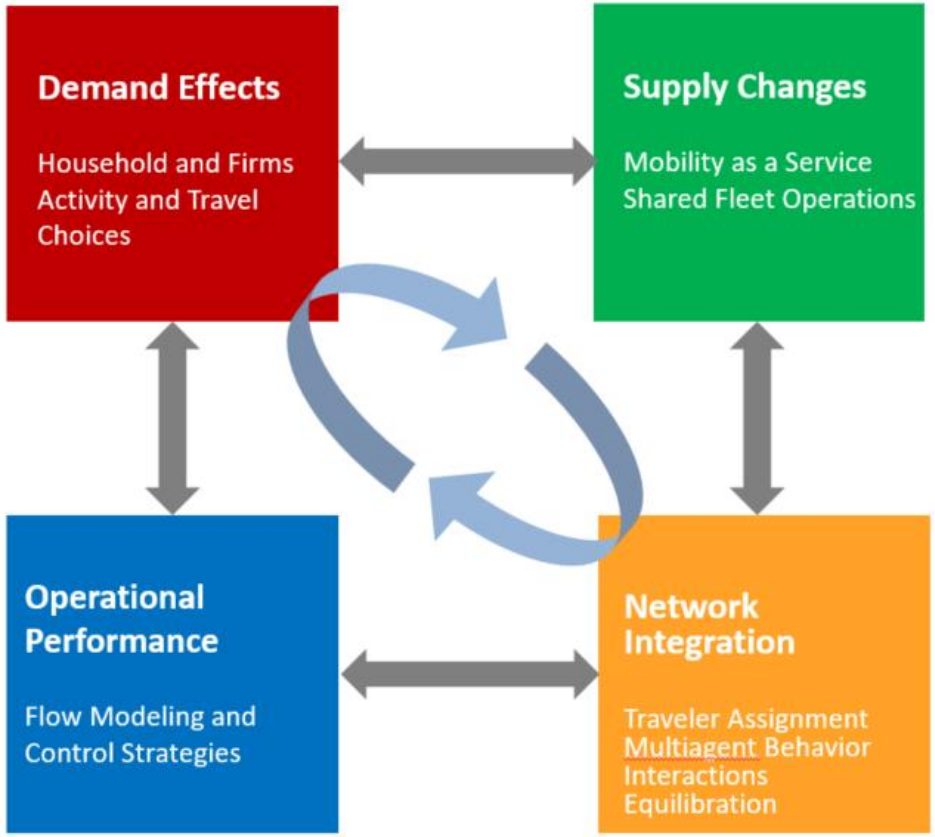


Source: Volpe.[1]

CAV AMS FRAMEWORK AND GAP ANALYSIS

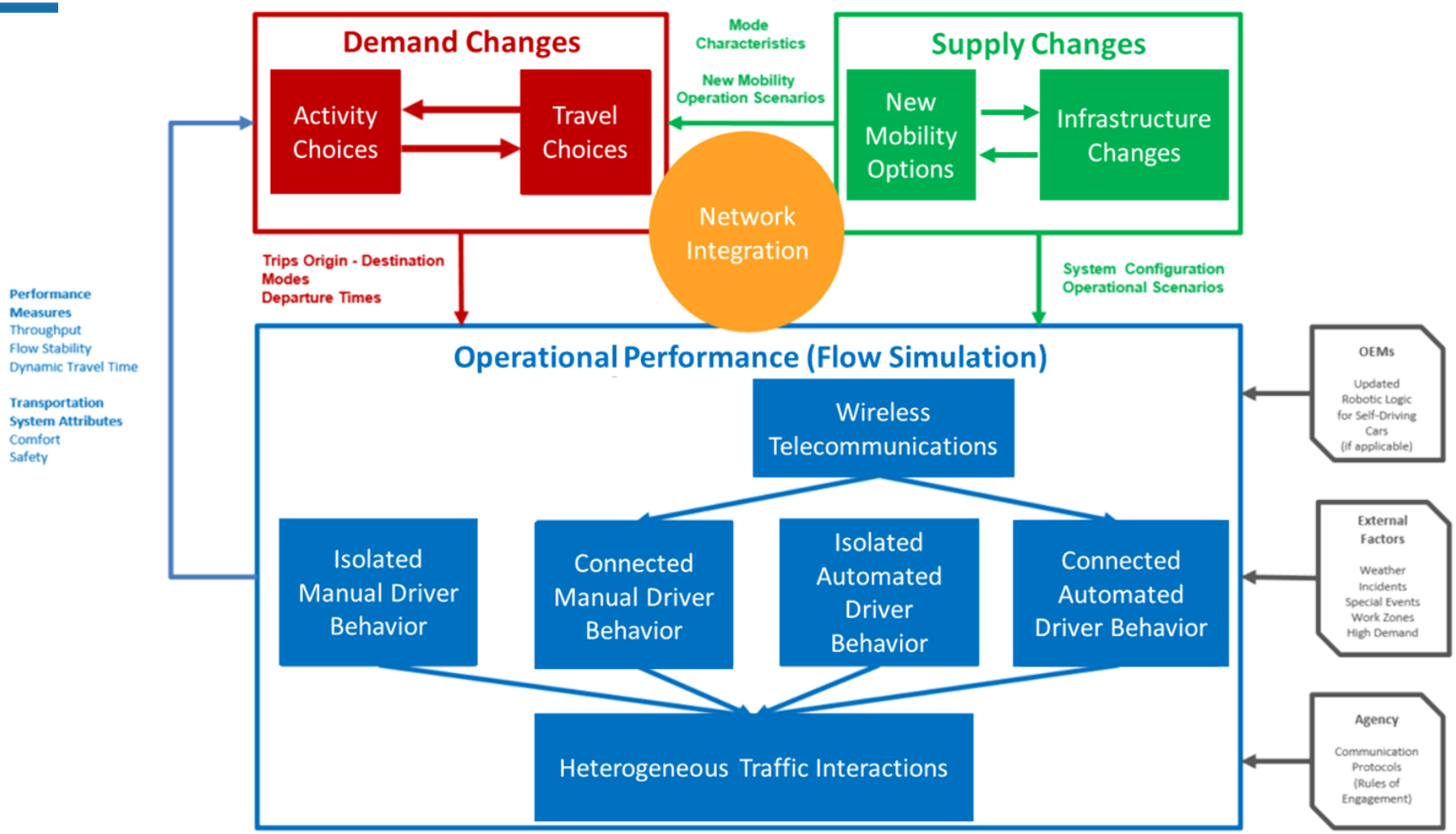
Objectives:

- Build comprehensive methodological framework for developing AMS tools that incorporate the impacts of CAVs.
- Conduct an analysis identifying gaps in existing CAV AMS capabilities.

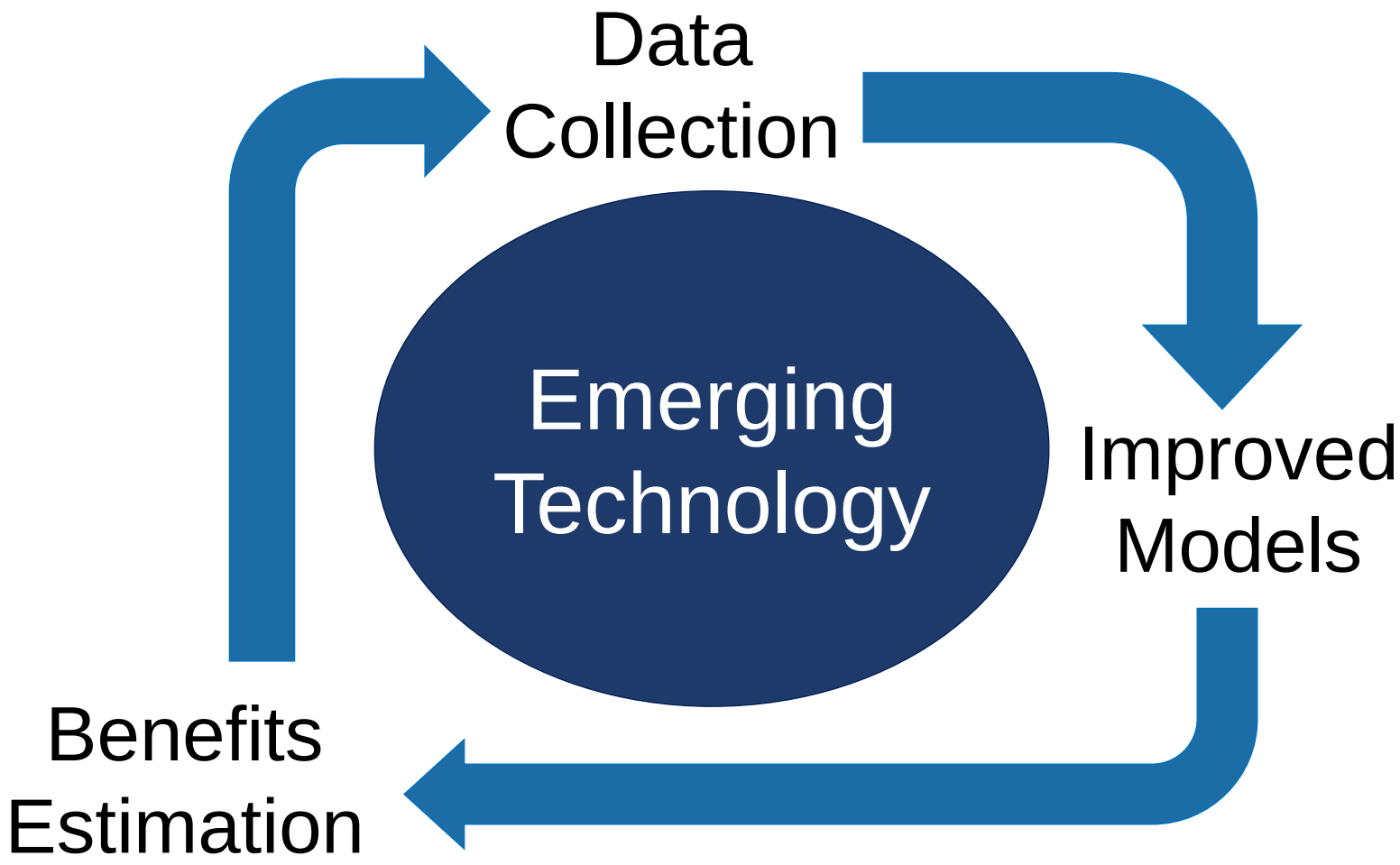


© 2018 Mahmassani, Elfar, Shladover, and Huang.[3]

CAV AMS FRAMEWORK AND GAP ANALYSIS



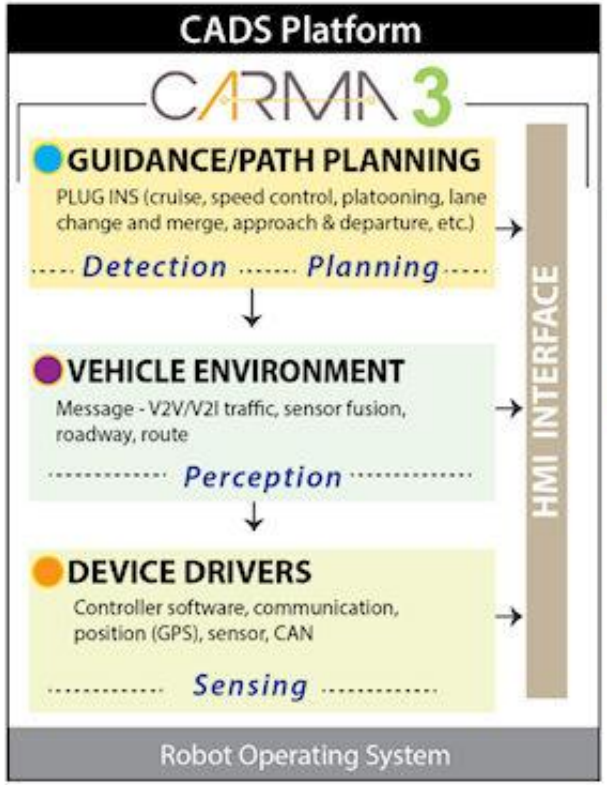
APPROACH

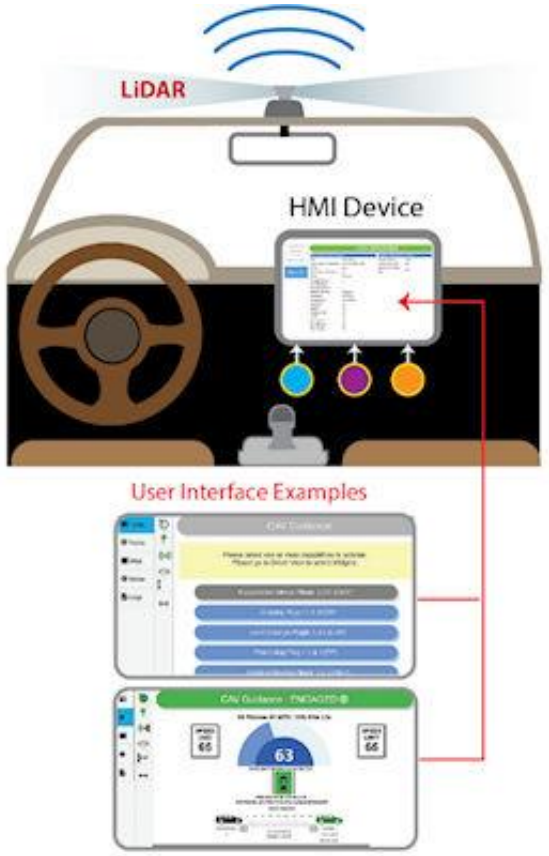


Source: FHWA.

DATA COLLECTION TO SUPPORT THE DEVELOPMENT OF AMS TOOLS

- Objective: Collect a robust dataset about the behavior of a cooperative automated driving system (CADS) and a human driven vehicle (HDV) in naturalistic traffic conditions.
- Data collected will provide complete details regarding the adjacent vehicles surrounding the subject vehicle(s).
- Subject vehicles will be deployed in similar traffic conditions during a data run.



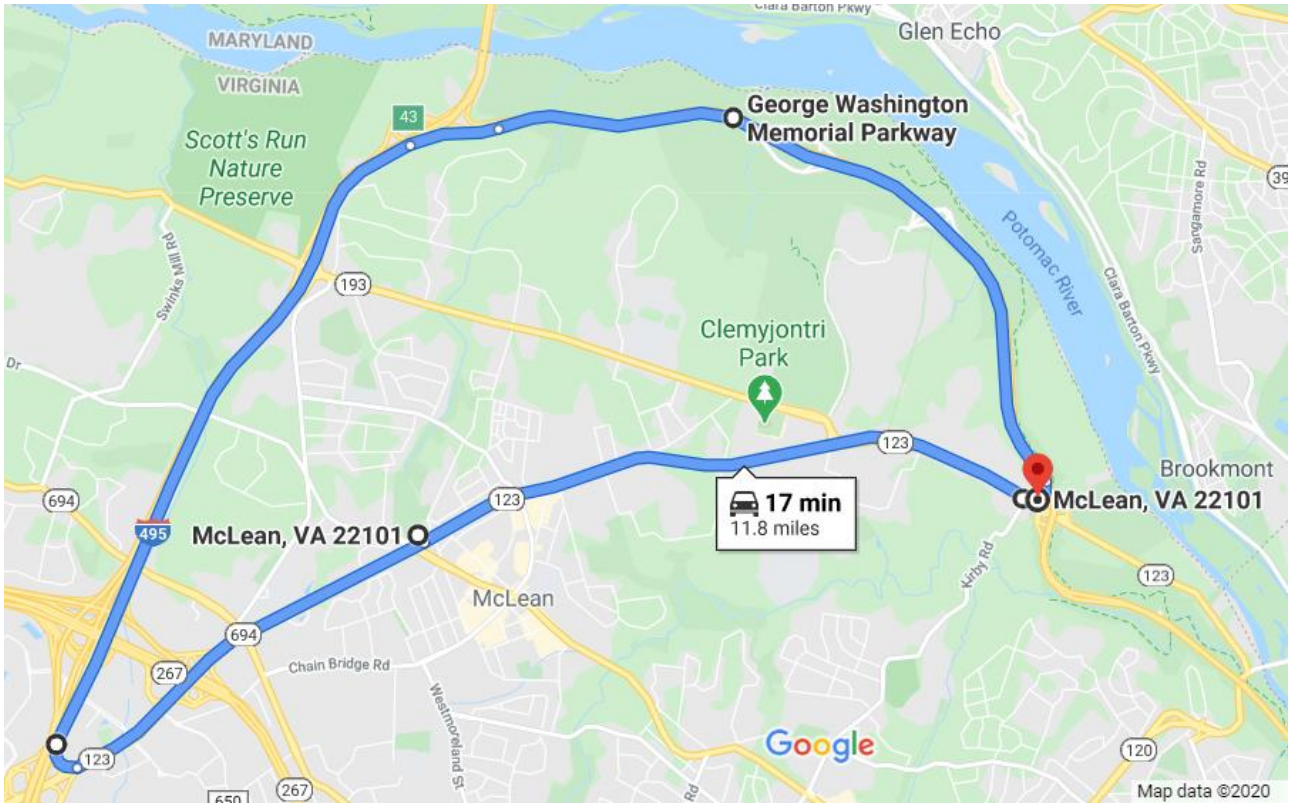


All photos source: FHWA.

CADS = cooperative automated driving system.
CAN = controller area network.
GPS = global positioning satellite.
HMI = human machine interface.
LiDAR = light detection and ranging.
V2I = vehicle-to-infrastructure.
V2V = vehicle-to-vehicle.

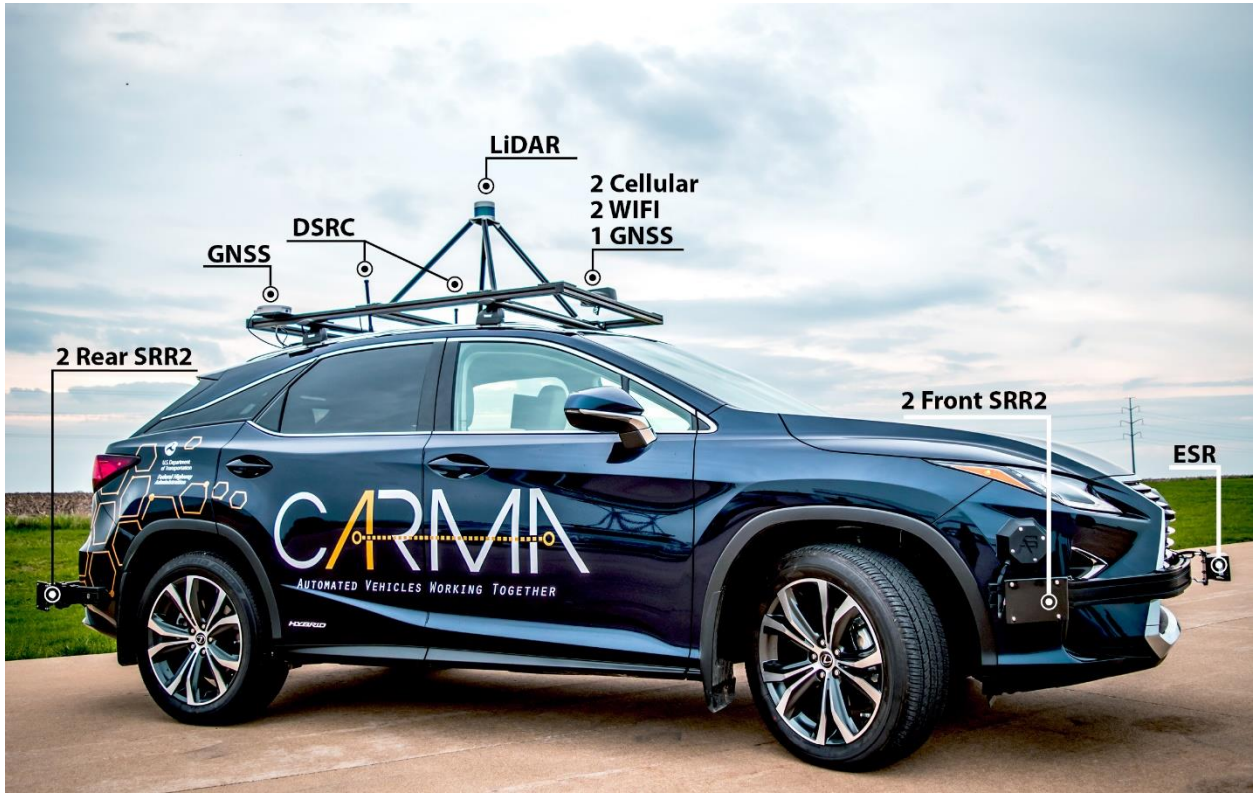
DATA COLLECTION ROUTE

- Data collection plan developed based on literature review and listening sessions[4] conducted by FHWA in 2019.
- Data will be collected in Northern Virginia in 2021.
- Data collection will occur in level of service (LOS) C traffic conditions.
- Data collection route will include both multilane arterial and interstate.



Original Maps: © 2020 Google 2020. Map Data: © 2020 Google.

CADS SENSORS

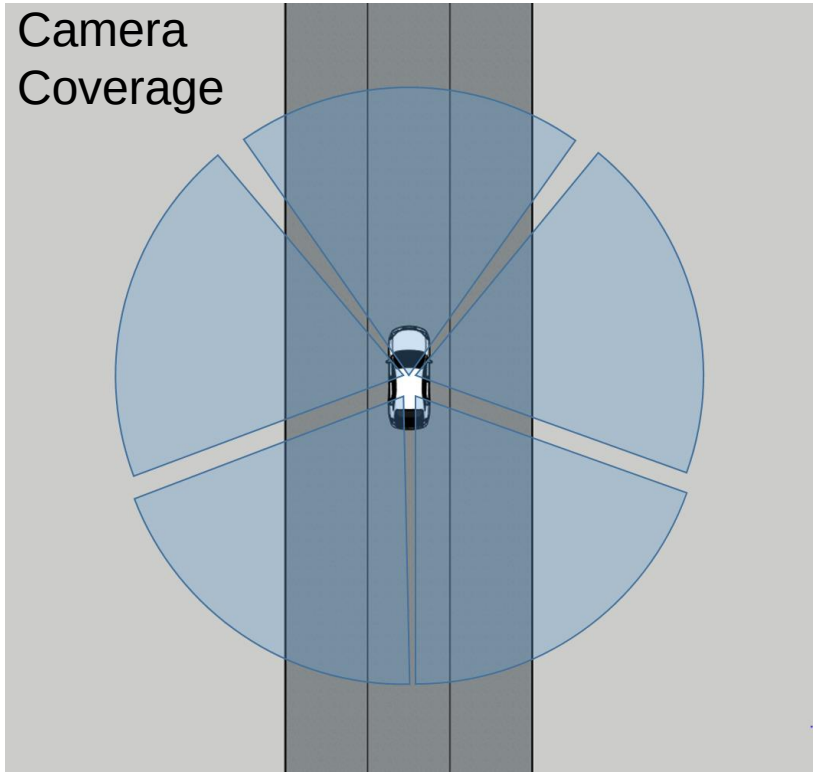


Source: FHWA.

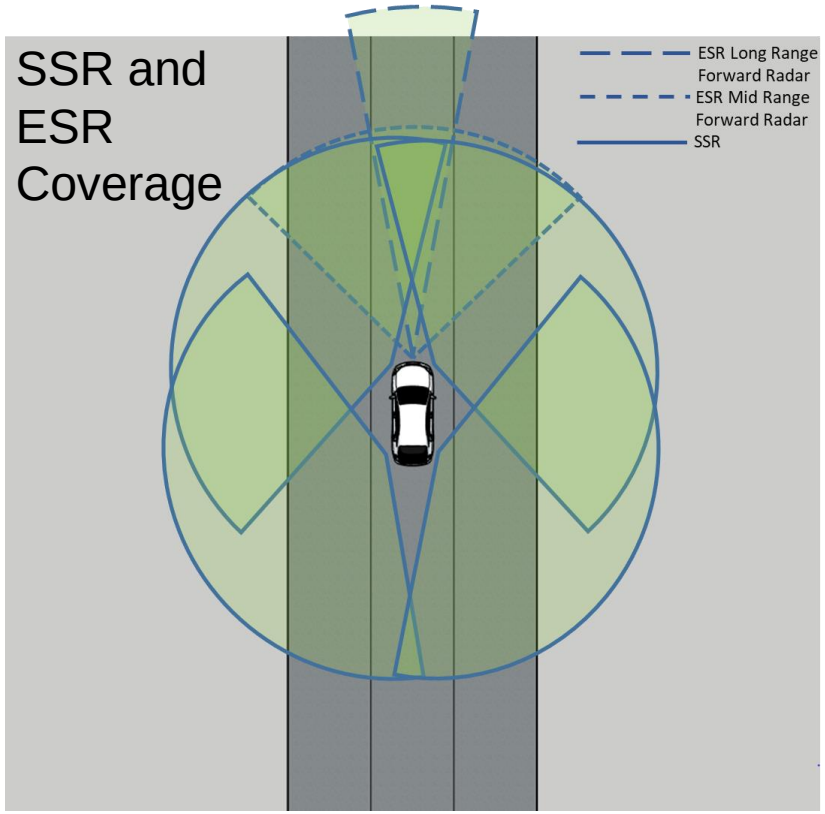
DSRC = dedicated short-range communication.
ESR = electronically scanning radar.
GNSS = global navigation satellite system.
LiDAR = light detection and ranging.
SRR = side and rear radar.

The instrumented research vehicle (IRV) is an SAE International CADS Level 3 Class A–D vehicle equipped with the CARMA Platform℠

CADS SENSOR COVERAGE MAPS

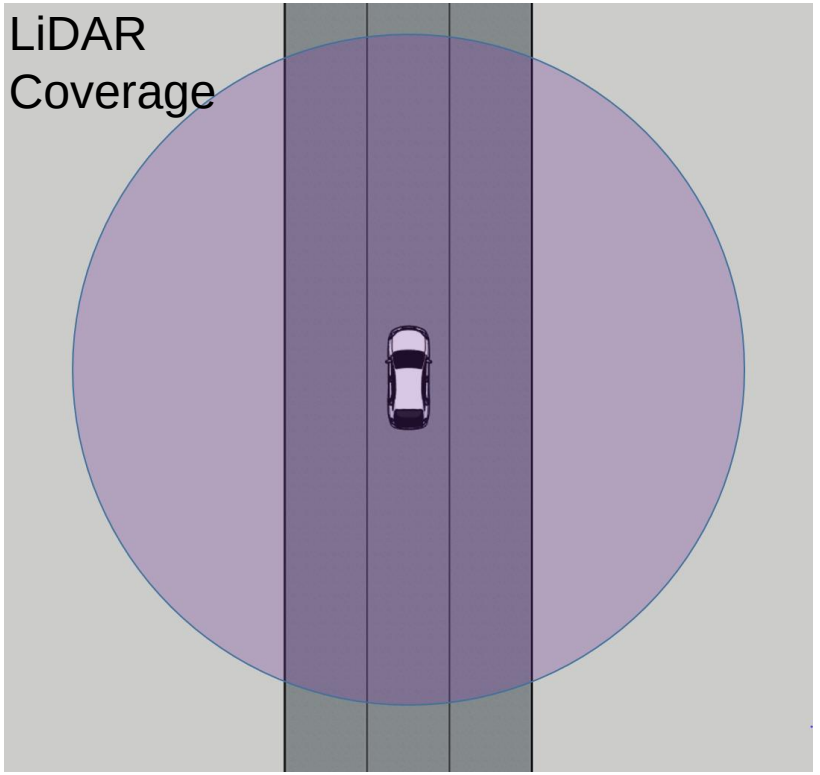


Source: FHWA.



Source: FHWA.

ESR = electronically scanning radar.
SRR = side and rear radar.

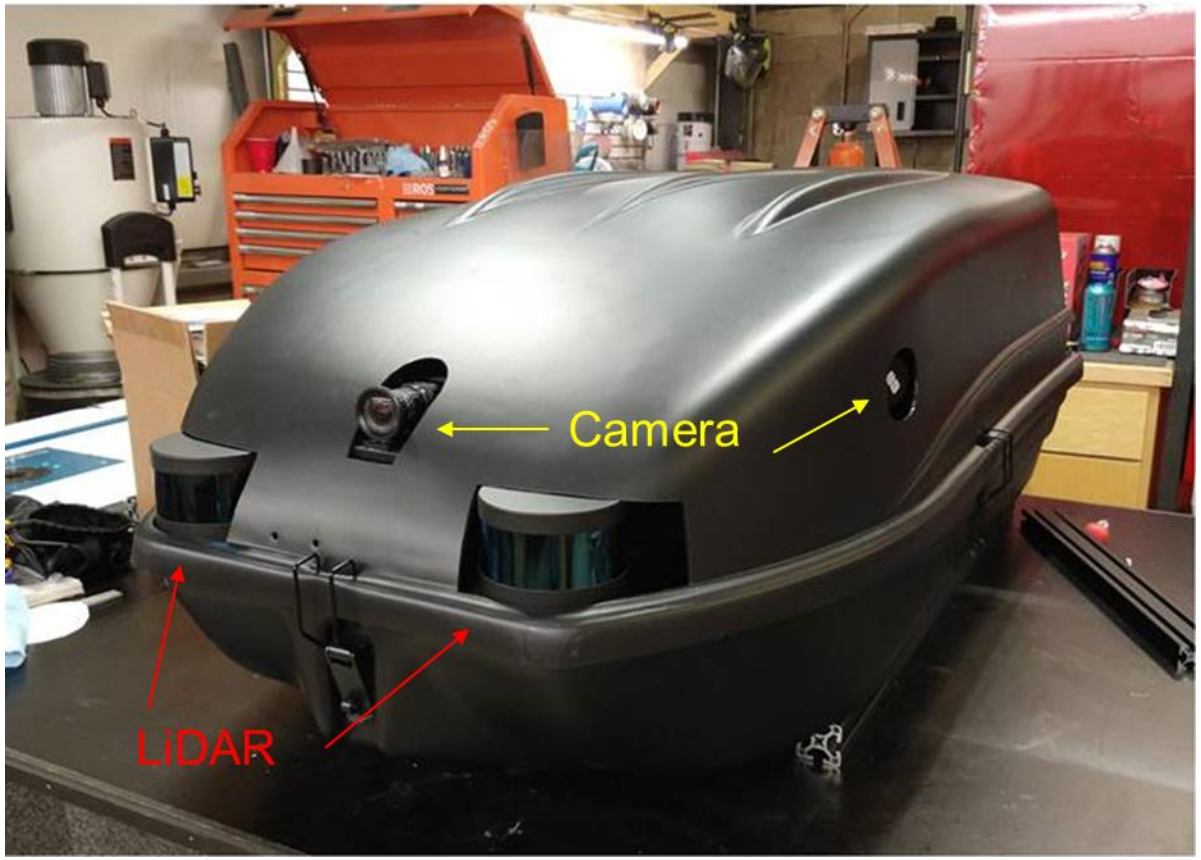


Source: FHWA.

LiDAR = light detection and ranging.

HDV SENSORS

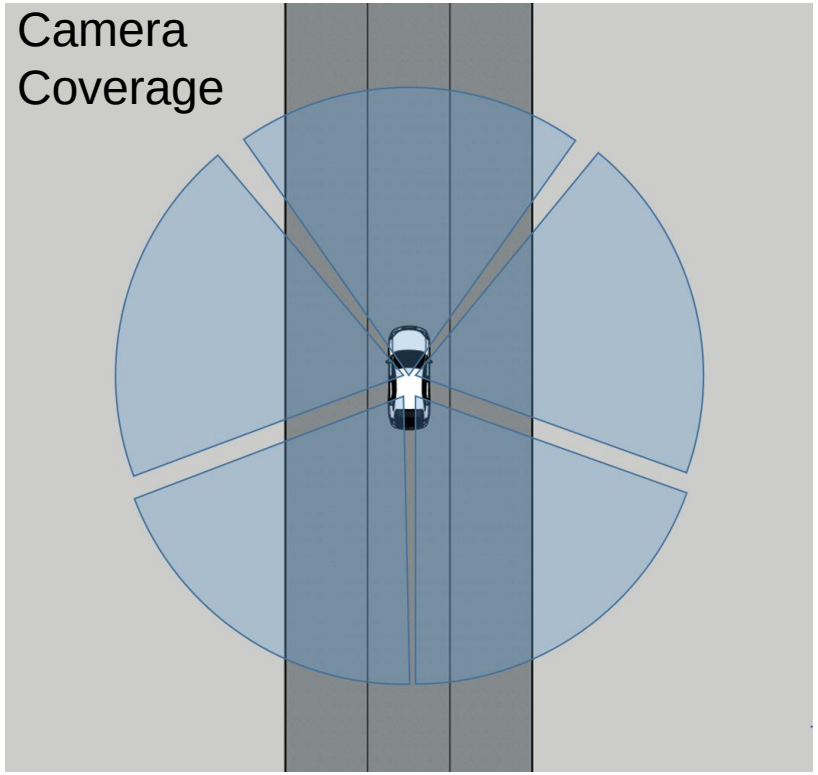
Challenge: all sensors need to be well hidden to make sure HDV looks like a regular vehicle to avoid influencing driver behavior.



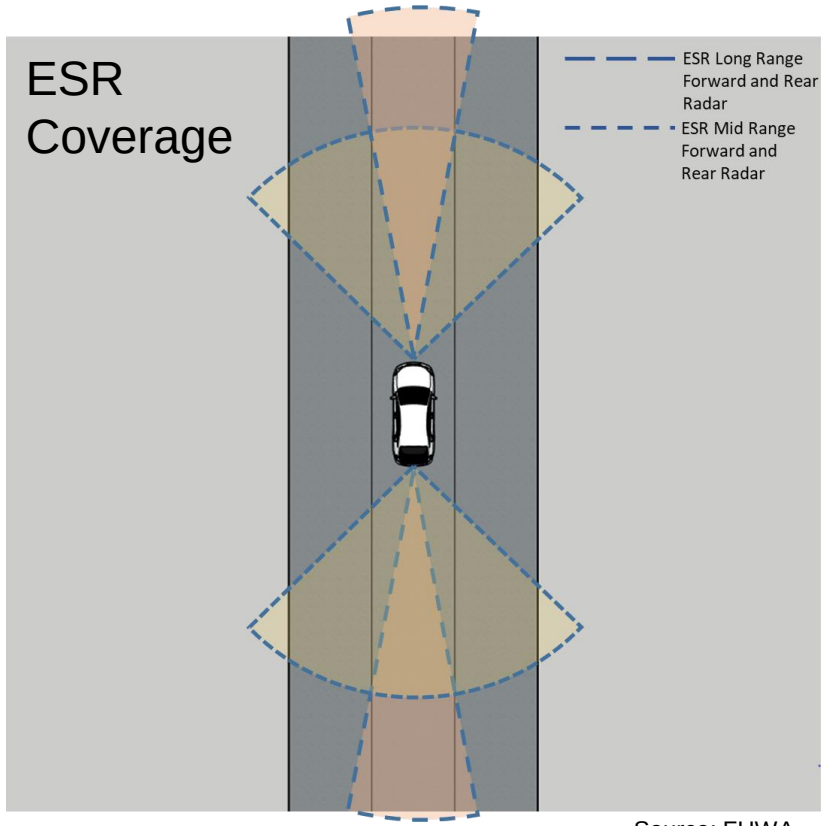
Original photo: © 2020 AutonomouStuff.
Modifications: FHWA.

LiDAR = light detection and ranging.

HDV SENSOR COVERAGE MAPS



Source: FHWA.



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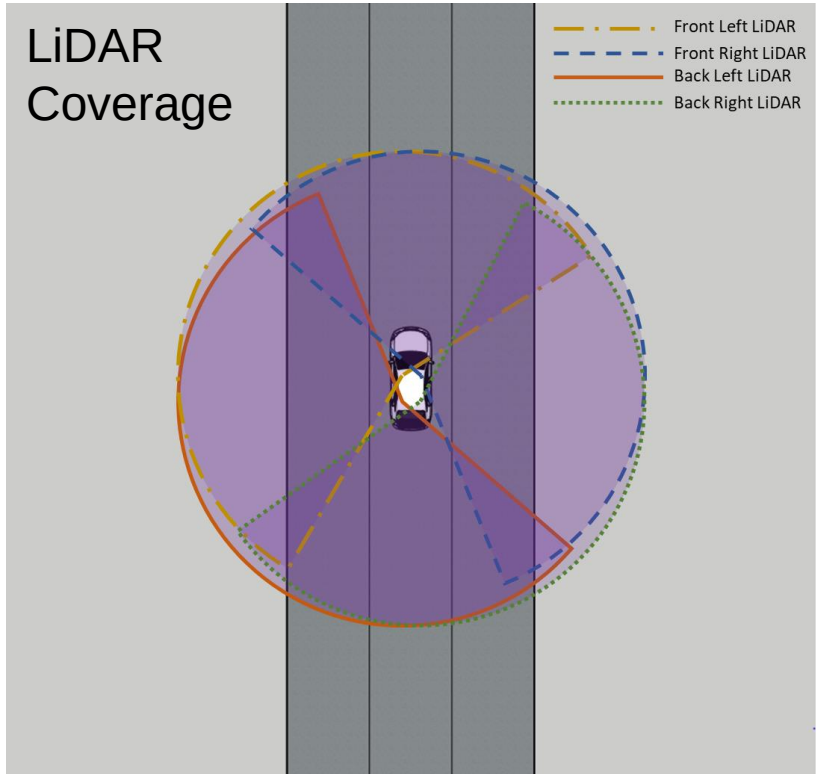


Source: FHWA.

ESR = electronically scanning radar.

LiDAR = light detection and ranging.

DATA ELEMENTS OF INTEREST

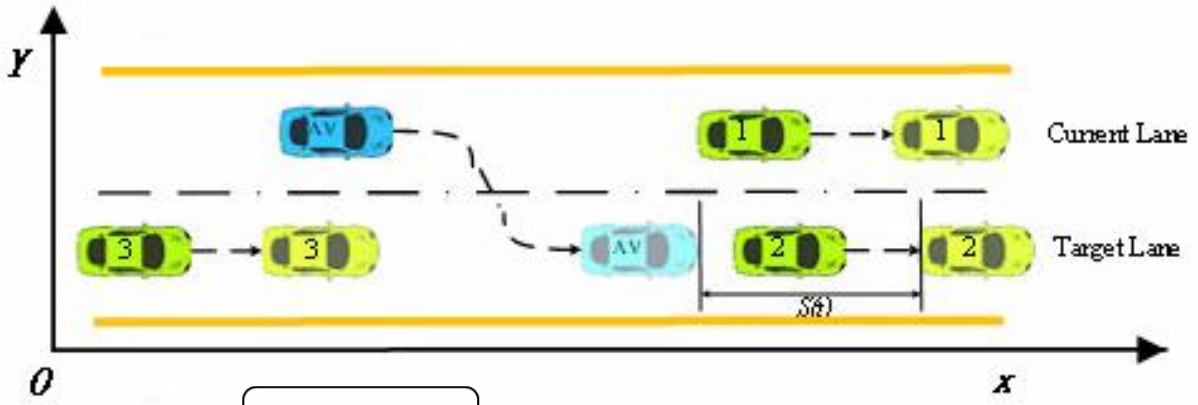
Instrumented Vehicle Data Fields	Adjacent Vehicle Data Fields	Roadway Data Fields
Position	Vehicle ID	Current roadway
Speed	Vehicle current travel lane	Functional classification
Acceleration	Relative position in traffic to IRV	Elevation
Current travel lane	Lateral distance to IRV	Local traffic density
Total number of travel lanes	Longitudinal distance to IRV	Local traffic speed
Current travel lane	Vehicle speed—calculated and measured	
Lane width	Vehicle acceleration	
Brake status	Leading and following vehicle ID	
Turn signal status	Gap to leading and following vehicle	
Brake pedal depression	Brake signal status (if visible)	
Gas pedal depression	Turn signal status (if visible)	
Steering wheel angle	Vehicle classification	
Wiper status	Vehicle length	
	Distance to an MLC event	
	Distance from left lane marking	

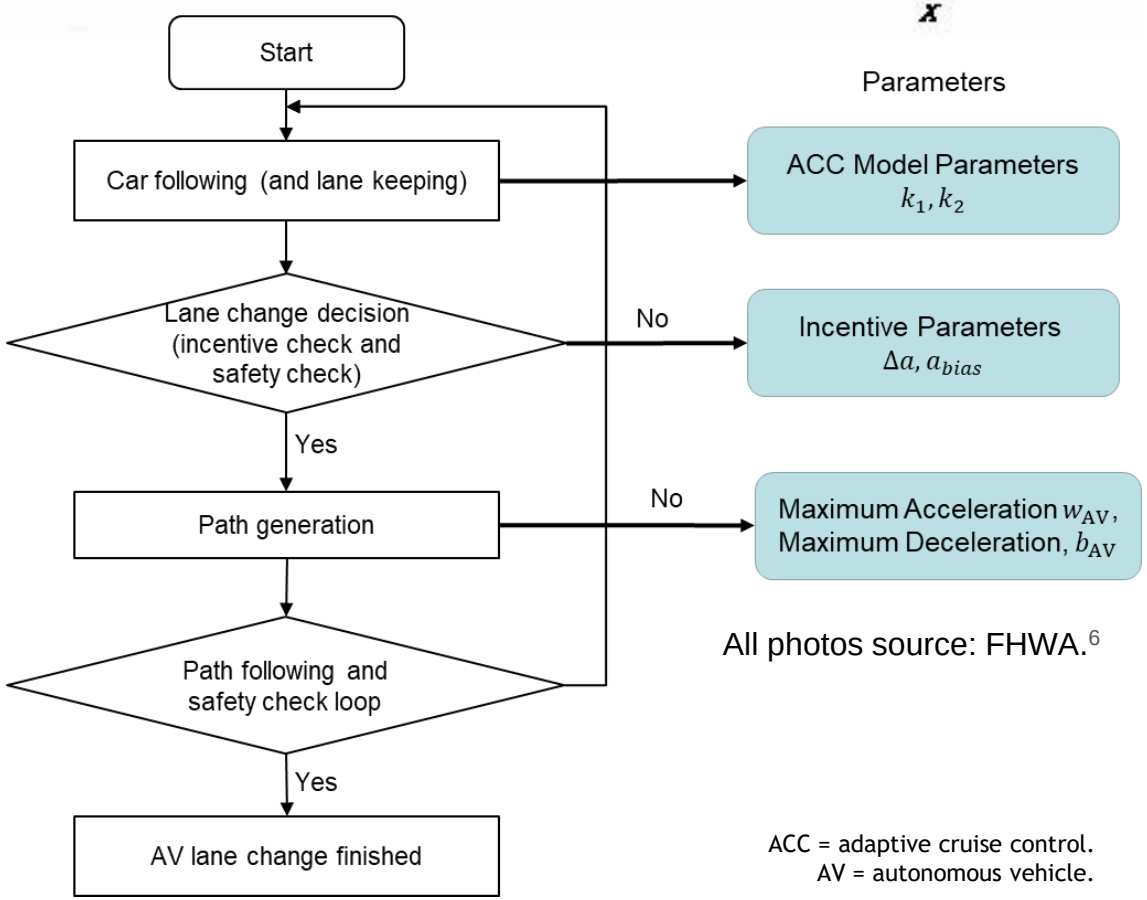
IRV = instrumented research vehicle.
MLC = mandatory lane change.

CAV DATA COLLECTION BROAD AGENCY ANNOUNCEMENT

MODEL IMPROVEMENT: TOOLS DEVELOPMENT

- Focus is on developing new tools to enable more robust impact assessments.
- Open-source tools are being developed:
  - Automated vehicle lane changing algorithm.
  - Improved CACC algorithm and connected vehicle algorithm.
  - Improved speed harmonization algorithm.
  - Cooperative merge algorithm.



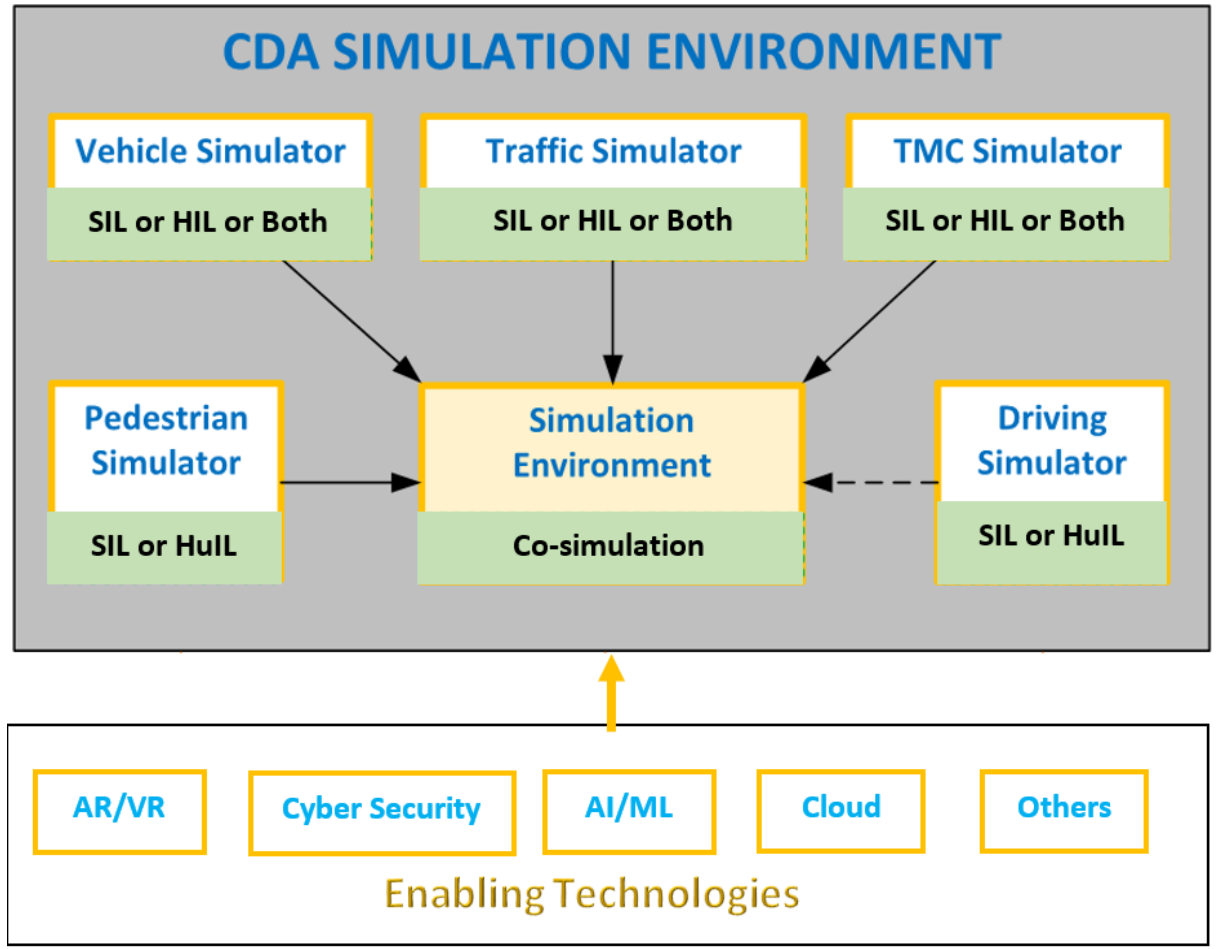


All photos source: FHWA.[6]

ACC = adaptive cruise control.
AV = autonomous vehicle.

TOOLS DEVELOPMENT: FHWA CDA SIMULATION ENVIRONMENT

- A multisimulation-focused evolutionary framework for progressing CDA simulation capabilities.
- Supports sophisticated simulation of CDA for efficient and effective development, testing, and evaluation.
- Key enabling technologies:
  - Augmented reality (AR)/virtual reality (VR).
  - Cybersecurity.
  - Artificial intelligence (AI)/machine learning (ML).
  - Cloud computing.

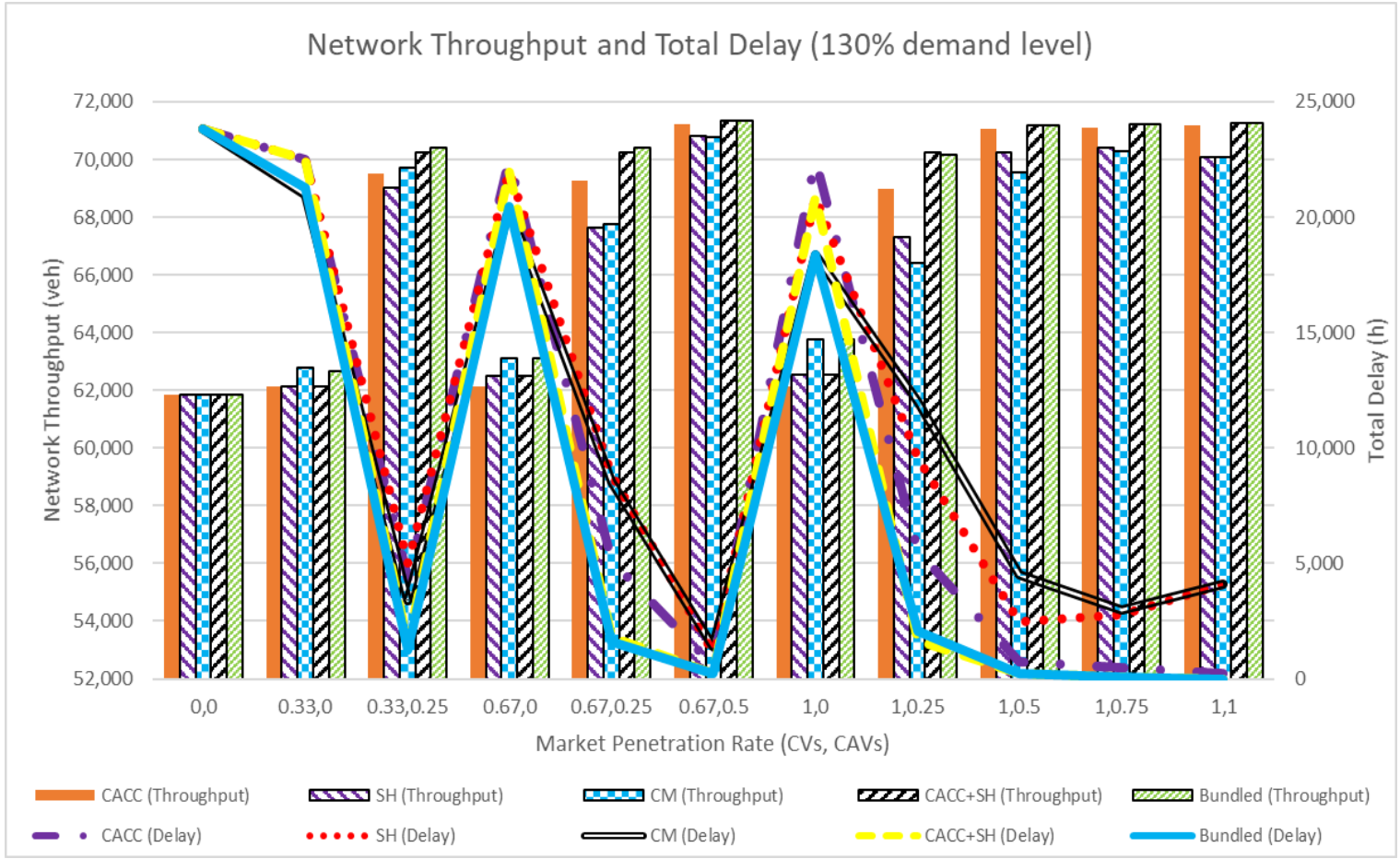


Source: FHWA.

SIL = software-in-the-loop.
HIL = hardware-in-the-loop.
HuIL = human-in-the-loop.

BENEFITS ESTIMATION: CASE STUDIES

- Benefits assessment using *existing* tools and capabilities.
- Local agencies are involved to ensure simulations represent realistic, near-term deployments.
- Freeway case studies:
  - I–66.
  - SR–99.
- Arterial case studies:
  - Ann Arbor, MI.
  - Conroe, TX.



CACC = cooperative adaptive cruise control.
CAV = connected automated vehicle.
CM = cooperative merge.
CV = connected vehicle.
SH = speed harmonization.

Source: FHWA.[7]

COLLABORATION EXAMPLES

- Stakeholder Groups.
- TRB Committees.
- Institute of Transportation Engineers (ITE) Simulation and Capacity Analysis User Group (SimCap).
- AMS Pooled Fund Study: One of the Four Charter Topics: “Evaluation of Innovation Applications.”
- Twinning with European Commission’s CoEXist® project.
- U.S. Department of Energy collaboration.

CONCLUSIONS

- Microsimulation tools were developed to model human driver behavior. New tools are needed to appropriately emulate CAV driving behavior and human drivers' response to this behavior.
- FHWA has funded several recent efforts related to AMS and CAVs.
- FHWA is continuing efforts on data collection, model improvements, and benefits estimation to support the needs of the broader stakeholder community.

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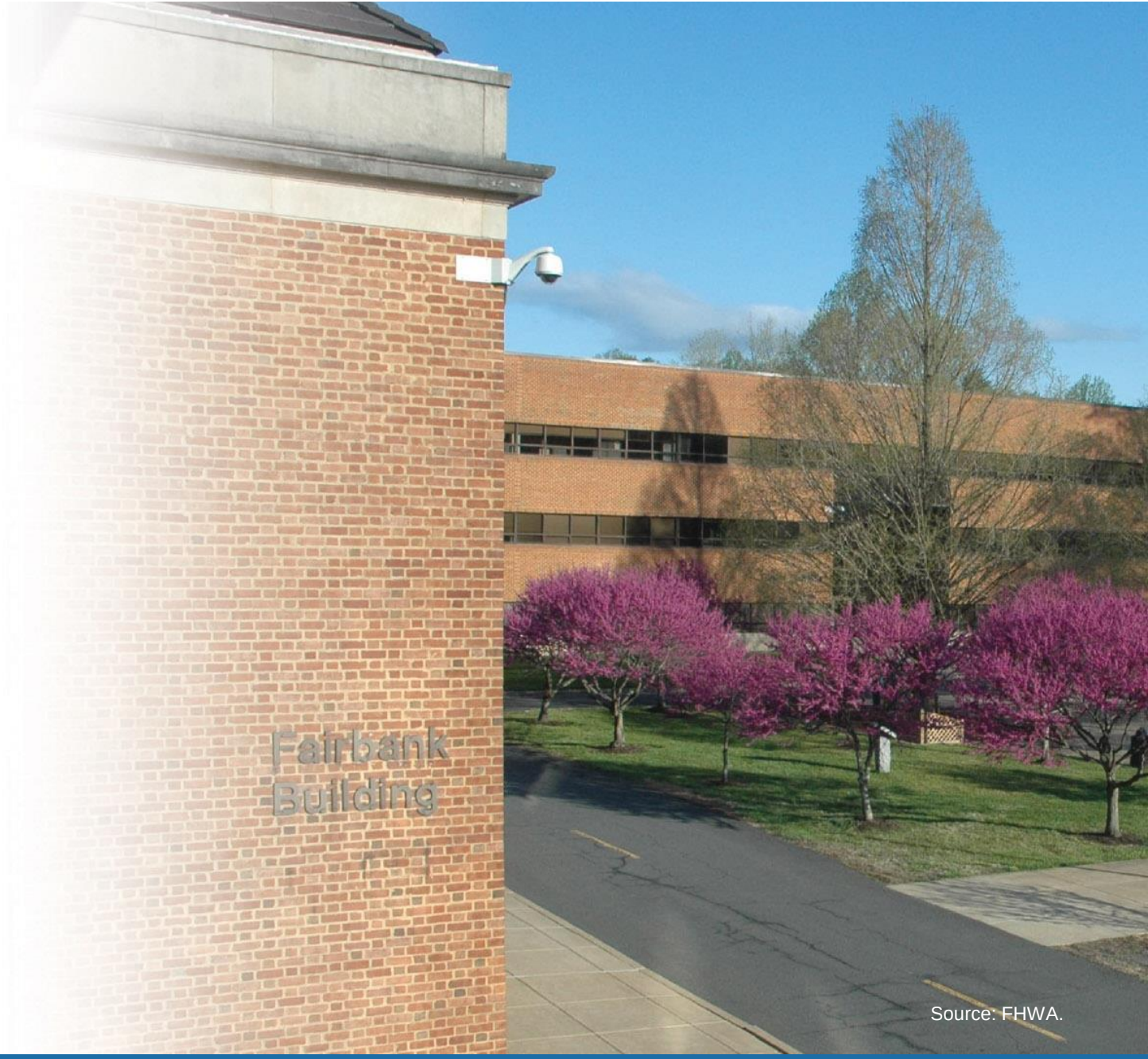

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