U.S. Department of Transportation
Federal Highway Administration

Office of Safety and Operations
Research and Development

CARMA℠ SIMULATION

Enabling Cooperative Driving Automation Research

INTRODUCTION

Cooperative driving automation (CDA) enables communication and cooperation between vehicles with driving automation features, other road users, and transportation infrastructure.[1] CDA has the power to solve or mitigate many existing transportation issues such as safety, emissions, and fuel consumption. A low-cost approach to testing CDA features is needed to enable transportation agencies to make intelligent investment and policy decisions.

CDA SIMULATION ENVIRONMENT

The CDA simulation environment (figure 1) will be a multisimulation-focused evolutionary framework for progressing CDA simulation capabilities. The different simulators within the environment are:

- Vehicle simulator: simulates vehicle dynamics and sensing.
- Traffic simulator: simulates the effects of CDA behaviors on the overall traffic stream.
- Traffic management center (TMC) simulator: simulates the effects of a TMC managing a corridor via software such as CARMA Cloud℠.
- Pedestrian simulator: simulates pedestrian behaviors in a CDA environment.
- Driving simulator: integrates the CDA simulation environment with a human factors simulator.
- Simulation manager: coordinates and synchronizes the varying multisimulators to ensure consistent behavior.

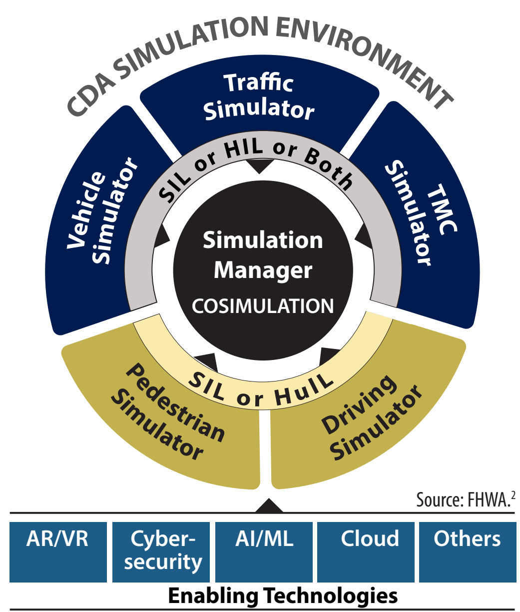
Key enabling technologies—augmented reality/virtual reality, cybersecurity, artificial intelligence/machine learning, and cloud computing—will support this CDA simulation environment.

CARMA℠ Simulation

Currently, there are no software-in-the-loop (SIL), or virtual simulation, capabilities that can support highly detailed CDA simulation. The CARMA simulation project—part of the CARMA Program, the U. S. Department of Transportation's technology-enabling initiative under the Federal Highway Administration (FHWA) CDA Research Program—was developed to address the lack of simulation capabilities.

The goals of CARMA simulation are to:

- Establish everything-in-the-loop (XiL) capabilities to support CDA evaluation in a simulation environment.
- Begin building XiL capabilities through open-source software through collaboration with the Department of Energy and CARMA community to effectively design and build tools to advance the understanding of CDA's impact on the transportation system.



AI = artifical intelligence; AR = augmented reality; CDA = cooperative driving automation; HIL = hardware-in-the-loop; HulL = human-in-the-loop; ML = machine learning; SIL = software-in-the-loop; VR = virtual reality.

Figure 1. Diagram. CDA simulation environment.

[1] SAE International. 2020. Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles 3216_202005, 2020-05-07 revision, United States. Last accessed 2021-06-07: https://www.sae.org/standards/content/j3216_202005/.

CARMA XiL SIMULATION

Based on the developed CDA simulation framework, the CARMA XiL project will initiate the development of an entire CDA simulation environment. Specifically, CARMA XiL will enable SIL simulation by using a vehicle simulator and a traffic simulator (figure 2).

There are six core components to the XiL system (figure 3):

- CARMA Platform[SM].
- CARMA Streets.
- MOSAIC.[3]
- Simulation of Urban Mobility (SUMO).[4]
- Cars Learning to Act (CARLA).[5]
- NS-3.[6]

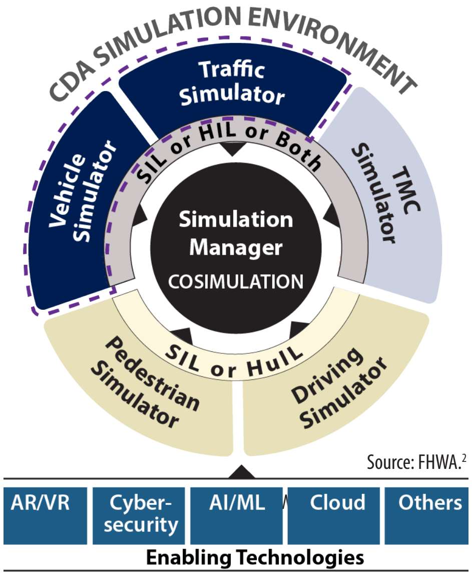


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Figure 2. Diagram. CARMA XiL simulation environment.

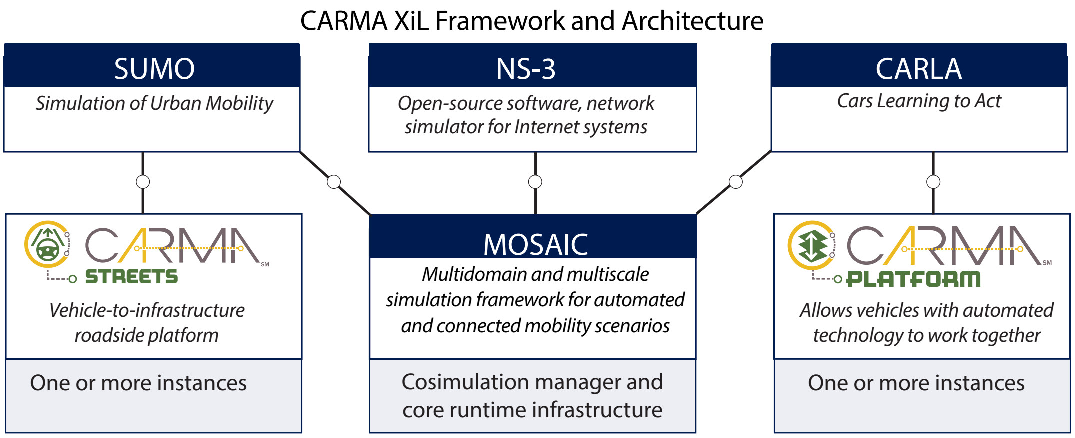


Figure 3. Diagram. CARMA XiL components.

Source: FHWA.[2]

Each component may contain multiple software packages necessary for XiL functionality. The system assumes each component has baseline functionality and focuses on describing XiL-specific modifications.

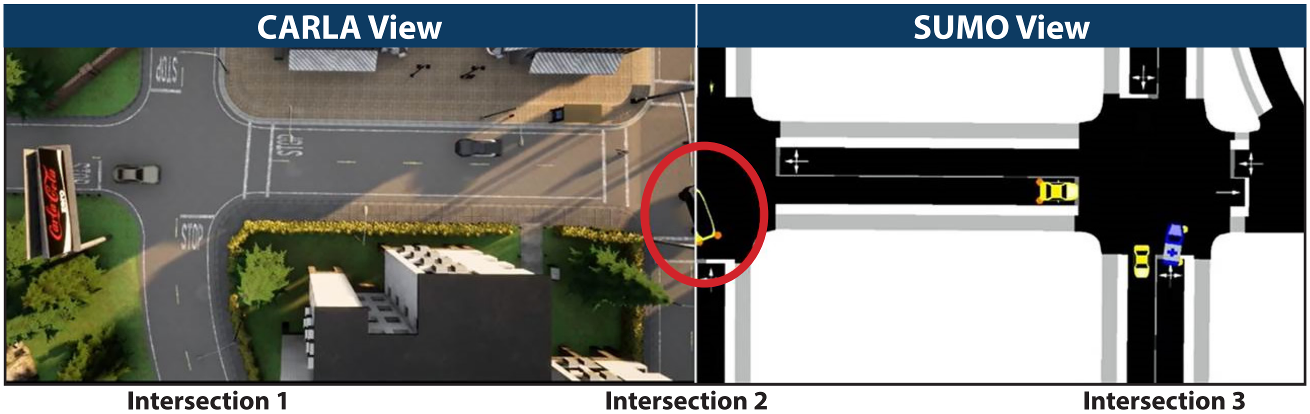
The first and fundamental steps of the CARMA XiL project are to:

- Develop the cosimulation platform by integrating CARLA and SUMO.
- Integrate the CARMA Platform with CARLA and enable sensor simulation and interactions between multiple virtual CARMA Platform-equipped vehicles.
- Integrate the NS-3 communication simulator into the cosimulation platform and add cellular vehicle-to-everything (C-V2X) simulation capability to NS-3.

Then, a major CARMA component, CARMA Streets, will be integrated into the cosimulation platform.

[2] FHWA. 2021. "CARMA Simulation" (web page). https://usdot-carma.atlassian.net/wiki/spaces/CRMSIM/overview, last accessed November 23, 2021.
[3] Eclipse. 2021. MOSAIC (software). Version 21.1. https://www.eclipse.org/mosaic/, last accessed Novermber 23, 2021.
[4] Eclipse. 2021. Simulation of Urban Mobility (software). Version 1.10.0. https://www.eclipse.org/sumo/, last accessed Novermber 23, 2021.
[5] CARLA. 2021. Cars Learning to Act (software). Version 0.9.10. https://carla.org/, last accessed November 23, 2021.
[6] nsnam. 2021. NS-3 (software). Version 3.35. https://www.nsnam.org/, last accessed Novermber 23, 2021.

PROJECT STATUS



CARLA = Cars Learning to Act; SUMO = Simulation of Urban Mobility.

Source: FHWA.

Figure 4. Image. Render of CARLA and SUMO cosimulation environment.

The CARMA simulation project will provide cosimulation capabilities that were not previously available. Recent work involved developing a MOSAIC-SUMO-CARLA cosimulation framework, creating an interface between MOSAIC and CARLA, and enhancing the existing SUMO and MOSAIC interface to facilitate data exchange between SUMO and CARLA. Additionally, the project team worked to ensure CARMA and CARLA could work together in a cosimulator.

The MOSAIC-CARLA-SUMO cosimulation environment utilizes the same network with one vehicle that spans both simulation environments (figure 4).

After development and testing, this low-cost cosimulation tool will be released to the public to:

- Support the development, testing, and deployment of CDA algorithms and applications.
- Evaluate CDA algorithms and applications.
- Help users to adapt and use CARMA Platform to support their CDA research.

The project team will provide technical support to users under the FHWA's CARMA Support Services project (CARMAsupport@dot.gov).

To learn more and follow updates:

CARMA Simulation Confluence

https://bit.ly/3o6Uixq

CARMA Simulation GitHub

https://bit.ly/2YqHn0o

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For more information, please contact the CARMA Program at CARMA@dot.gov

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