U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank
Highway Research Center

CARMA

Cooperative Driving Automation Update for the Research and Technology Coordinating Committee Meeting

Brian Cronin, Federal Highway Administration (FHWA)

May 23, 2022

Source: FHWA.

Source: FHWA.

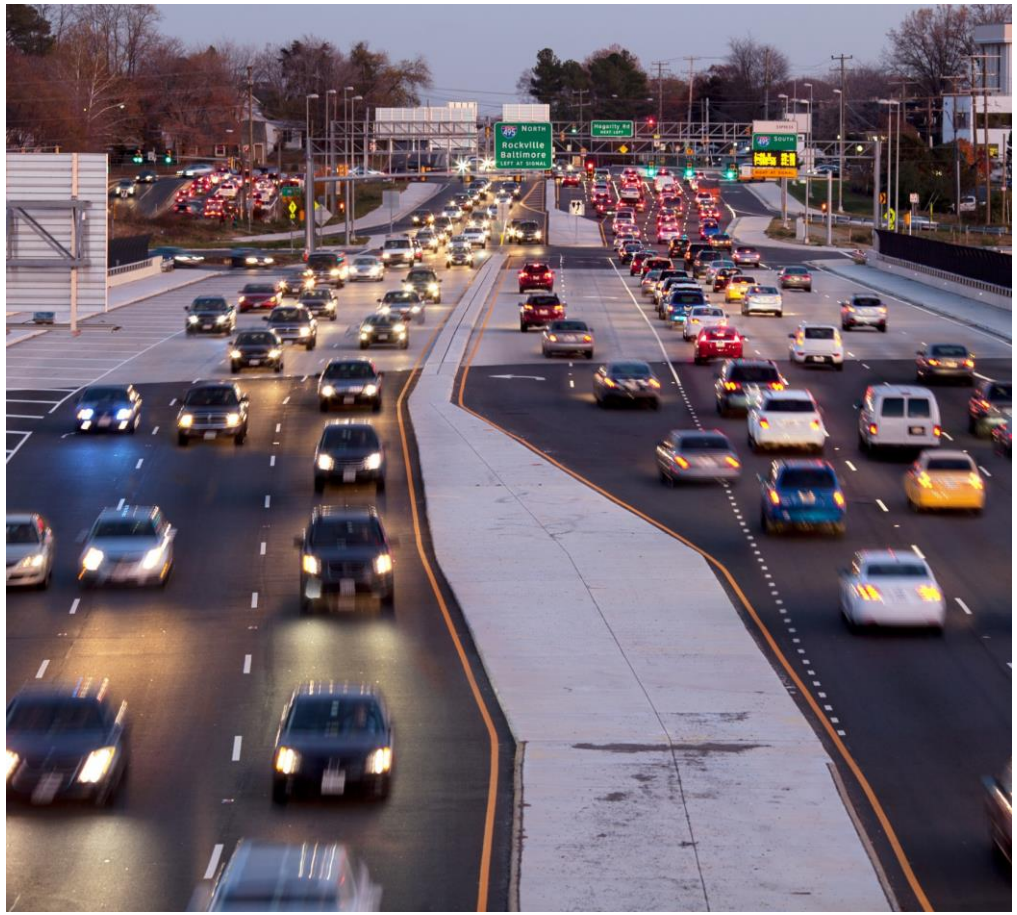
Source: FHWA.

WHAT IS OUR ROLE?

The industry is actively delivering new technologies—that are designed to work independently—to the transportation system.

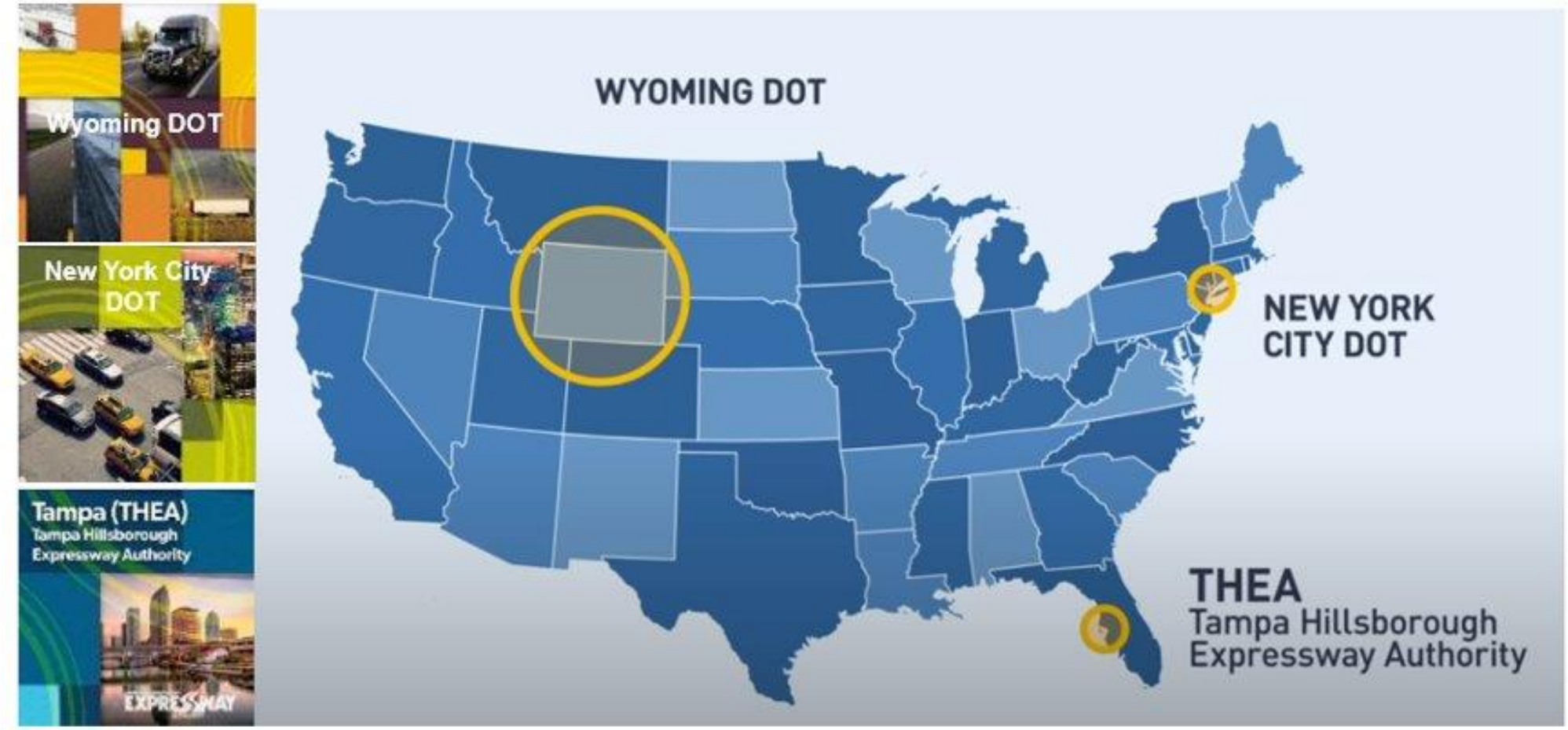
Without cooperation from infrastructure and road users beyond just automated vehicles, these technologies will not be optimized for greater safety and efficiency.

THIS IS OUR ROLE



Setting the Stage for Cooperative Driving Automation (CDA)

Connected Vehicle (CV) Pilot Sites: 2015–2022



Source: USDOT.

DOT = department of transportation.

Current Landscape of CV Deployments

Source: USDOT.

Major Efforts Completed or Underway

- CV Pilot deployment projects.
- Connected intersections (red light violation warning).
- MAP guidance/emerging standards.
- Security credentialing management systems.
- Work zone data exchange.

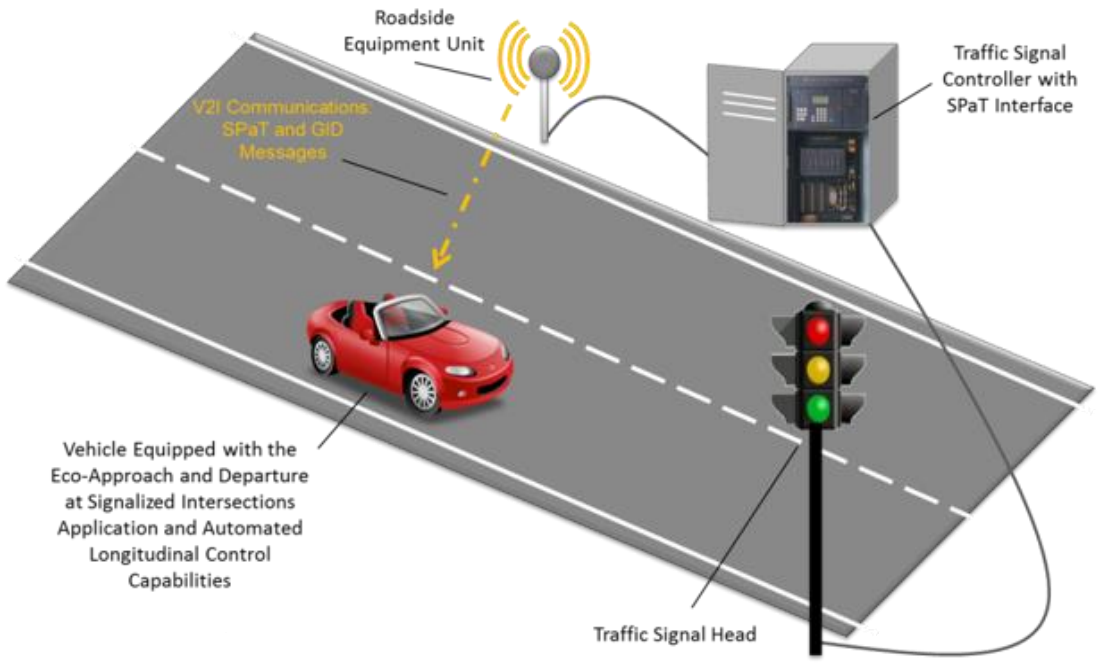
Happening in the middle of spectrum uncertainty.

Merging Connected and Automated Vehicles

- Industry establishes level one and two systems on the market as a catalyst.
- FHWA launches level one connected and automated research:
  - GlidePath (light vehicles through intersections).
  - Cooperative adaptive cruise control (CACC) (light vehicles in platoons).
  - Traffic optimization for signalized corridors (TOSCo) (light vehicles in platoons on arterials).
  - Truck platooning.
  - CARMA℠ integrated highway prototype.

GlidePath

- A field test was conducted at Turner-Fairbank Highway Research Center in 2012 with a single vehicle at a single intersection with no traffic. The vehicle drivers maintained recommended speeds by using a digital visual interface incorporated into the speedometer.
- GlidePath was expanded to create a prototype with automated longitudinal control.
- Significant benefits were realized after changing from driver-controlled speed to automated operation.



V2I = vehicle-to-infrastructure;
GID = geographic intersection description;
SPaT = signal phase and timing.

Source: USDOT.

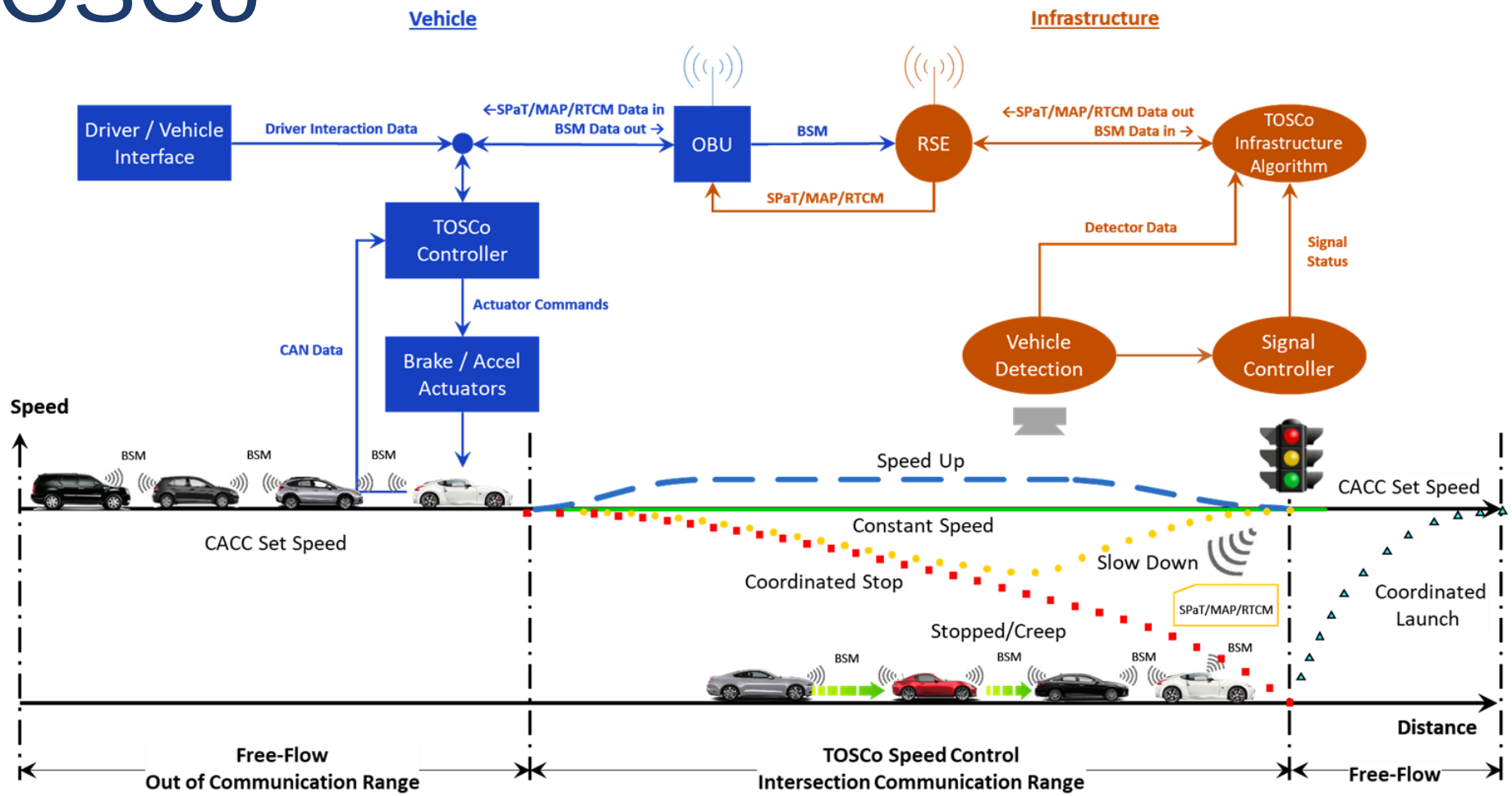
CACC

- Worked with Collision Avoidance Metrics Partners, LLC using a reference adaptive cruise control (ACC) system in four different vehicle makes/models to establish a baseline performance of strings under ACC.
- Established environment for modeling behavior of vehicle strings under automated longitudinal control.
- Developed and evaluated (via simulation) CACC algorithms. The results suggested improvements in string stability and reduced time gaps may be possible with vehicle-to-vehicle (V2V) communications.

Source: FHWA.

CACC fleet

TOSCo



RSM = roadside safety message;
RTCM = Radio Technical Commission for Maritime Services;
OBU = onboard unit;

BSM = basic safety message;
RSE = roadside equipment;
CAN = controller area network.

Level 1 Truck Platooning

- Employs longitudinal control only (throttle and brakes). The driver steers the truck.
- Builds on production ACC.
- Uses V2V communication to deploy CACC.

Source: FHWA.

Benefits of Initial CDA Research

The simulation showed that speed-harmonization, CACC, and cooperative-merge applications bundled together have the potential to:

- **Double capacity** on freeways.
- **Reduce fuel consumption** in truck platoons by **10 percent.**
- **Reduce vehicle emissions** and **delays** on arterials.

Source: FHWA.

Early Industry Adoption of Level 4 Automation

The automotive industry has begun to investigate the possibility of level 4 automated vehicles and discovered challenges with dynamic roadway environments:

- Lane closures.
- Speed limit changes.
- Traffic signal timing patterns changes.

FHWA Launched CARMA3 in 2019

What is the CARMA Program?

- Uses smart infrastructure and level 3 and 4 automated driving systems to improve the transportation system.
- Includes various research tracks to address different aspects of transportation using transportation systems management and operations (TSMO) strategies.
- Leverages open-source software (OSS) to collaborate with researchers and industry.
- Educates and builds the future workforce.

Source: FHWA.

Research Tracks

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TRAFFIC

Recurring traffic congestion research on freeways and arterials.

- Congestion.
- Transit.
- Traffic signals.

USDOT Partners:
FHWA | FMCSA | FTA | ITSJPO
OST-R | HASS COE

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RELIABILITY

Non-recurring traffic congestion research on freeways and arterials.

- Work zones.
- Weather.
- Traffic incident management.

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FREIGHT

Commercial motor vehicle (CMV) and port use cases.

- Port drayage.
- CMV.
- Truck platooning.

USDOT Partners:
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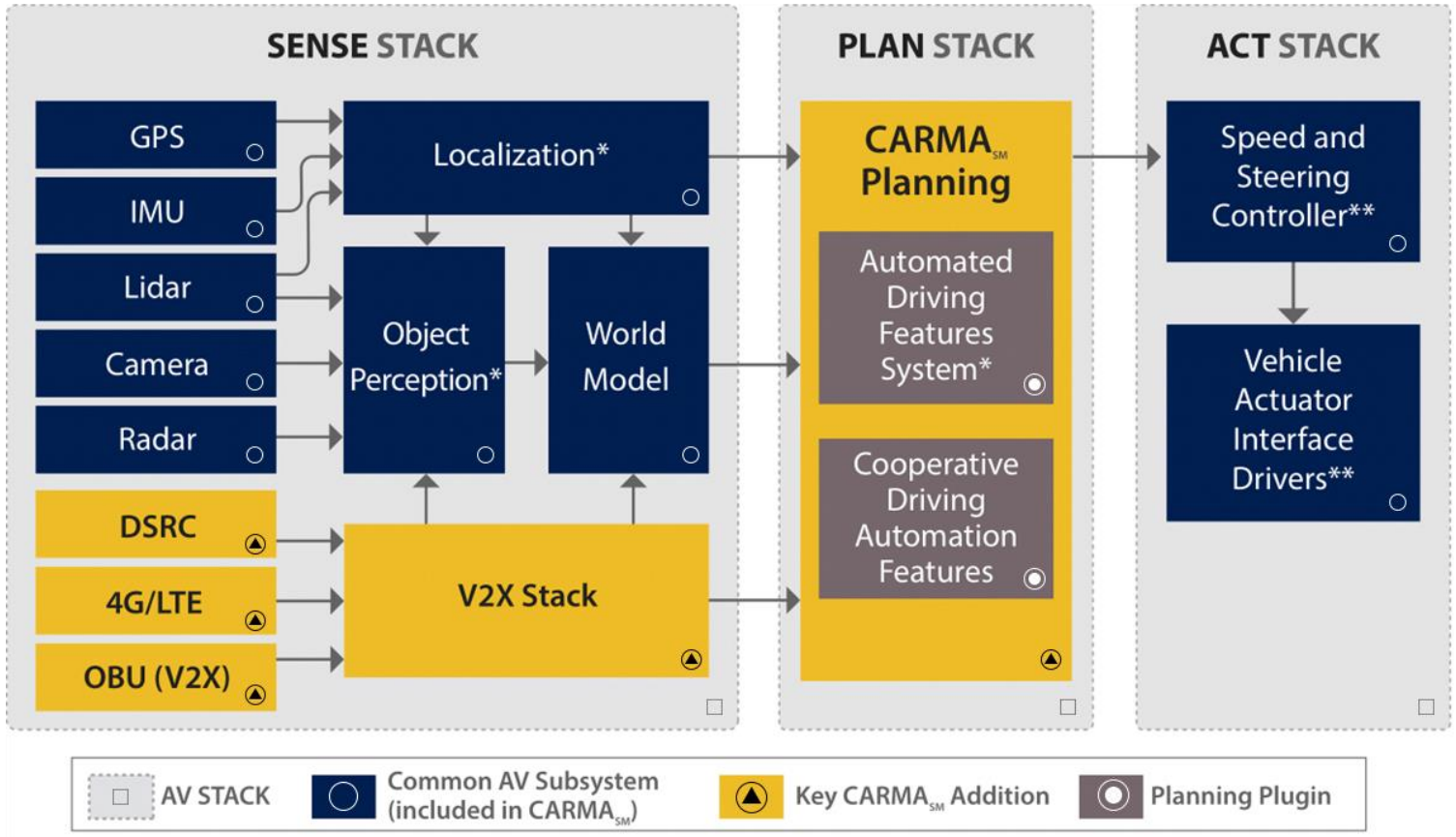
FMCSA = Federal Motor Carrier Safety Administration;
FTA = Federal Transit Administration;
MARAD = U.S. Maritime Administration;
ITSJPO = Intelligent Transportation Systems Joint Program Office;
OST-R = Office of the Assistant Secretary for Research and Technology;
HASS COE = Highly Automated Safety Systems Center of Excellence

Source: FHWA.

CDA Vehicle and Automated Driving System (ADS) Differences



AV - Automated Vehicle, **CARMA** - Cooperative Automation Research Mobility Applications, **GPS** - Global Positioning System, **IMU** - Inertial Measurement Unit, **OBU** - On-Board Units, **V2X** - Vehicle-to-Everything
* Supported by Autoware, **Supported vehicle controllers: Dataspeed, PACMOD, and New Eagle.

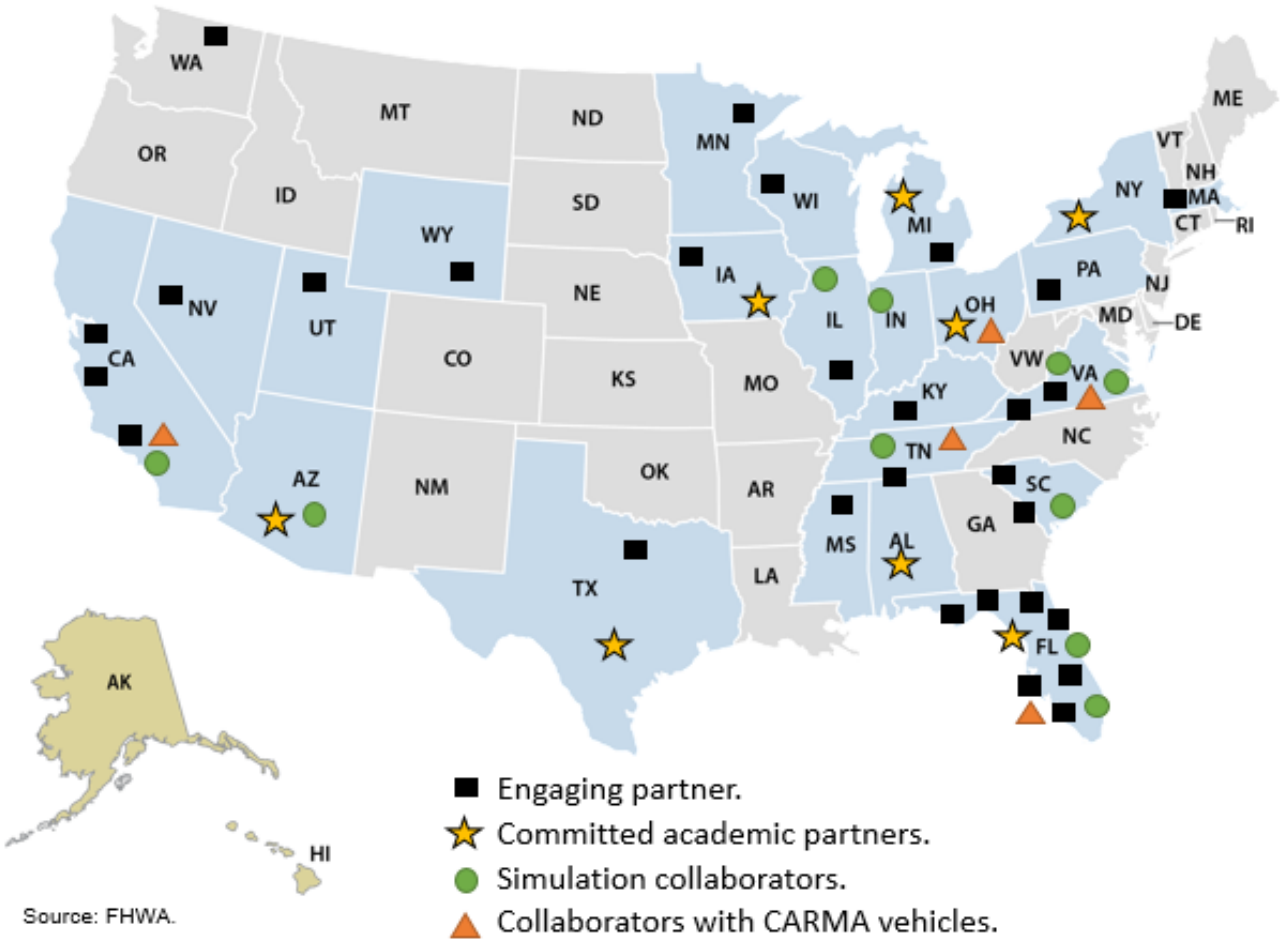
Source: FHWA.

CARMA Ecosystem

A network of OSS and support services that focus on how smart infrastructure can move traffic more efficiently by advancing TSMO strategies.

Source: FHWA.

CARMA Partners



Source: FHWA.

COMMITTED ACADEMIC PARTNERS

University of Iowa
University of Cincinnati
University of Buffalo
Michigan State University
University of Southern Florida
Auburn University
Texas A&M University
University of Arizona

SIMULATION COLLABORATORS

University of Tennessee at Chattanooga
University of Arizona
Clemson University
Purdue University
University of Illinois Urbana-Champaign
Virginia Tech Transportation Institute
University of California Los Angeles
Florida International University
University of South Florida
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University of South Florida
University of California, Los Angeles
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The University of Tennessee at Chattanooga

CARMA3 Results

- The proof-of-concept use cases were validated.
- The CARMA OSS tools are available.
- The SAE International standard defining CDA is available and expanding.
- Use cases were expanded to include other modes, including port drayage, freight automation, and transit operations.
- The community of stakeholders was engaged.

Challenges:

- Availability of an open-source ADS to safely operate at freeway speeds.
- Availability and resources of test tracks.

2020–2022—Changing Transportation System

- Pedestrian fatality crisis.
- Work zone fatality crisis.
- Speed increase.
- Equity.
- Climate.
- Workforce development.

FHWA Rebrands CARMA to CDA

2022—Launching the CDA Program for the Next Five Years

Goal—Advance from proof-of-concept research to industry-supported pilots.

- Develop the next phase of CDA.
- Advance safety applications and consider complete streets.
- Use CARMA OSS research tools.
- Leverage simulation capability and test tracks.
- Develop the future transportation workforce.

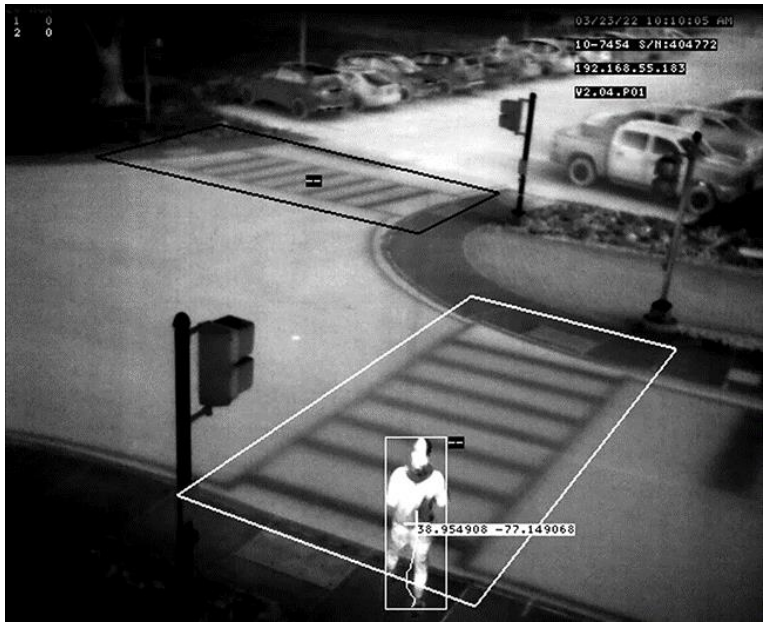
Advance Safety Example
CDA Cooperative Perception (CP)

Roadway and infrastructure entities share perception data about the driving environment for improved situational awareness, with applications in:

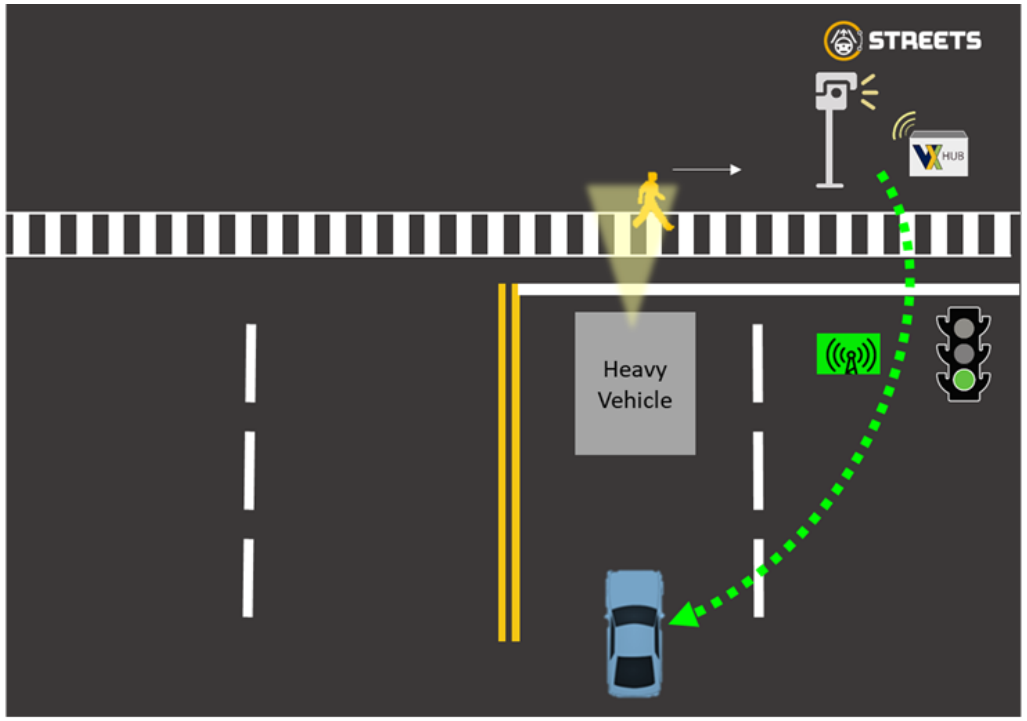
- Immediate collision avoidance, especially for vulnerable road users (VRUs).
- Safer trajectory planning.
- Path and trajectory planning for improved mobility and energy performances.

CDA CP

Development work is underway for a proof-of-concept CP demonstration using infrastructure-based sensing.



Source: FHWA.



Source: FHWA.

Standardization of CDA Message Sets

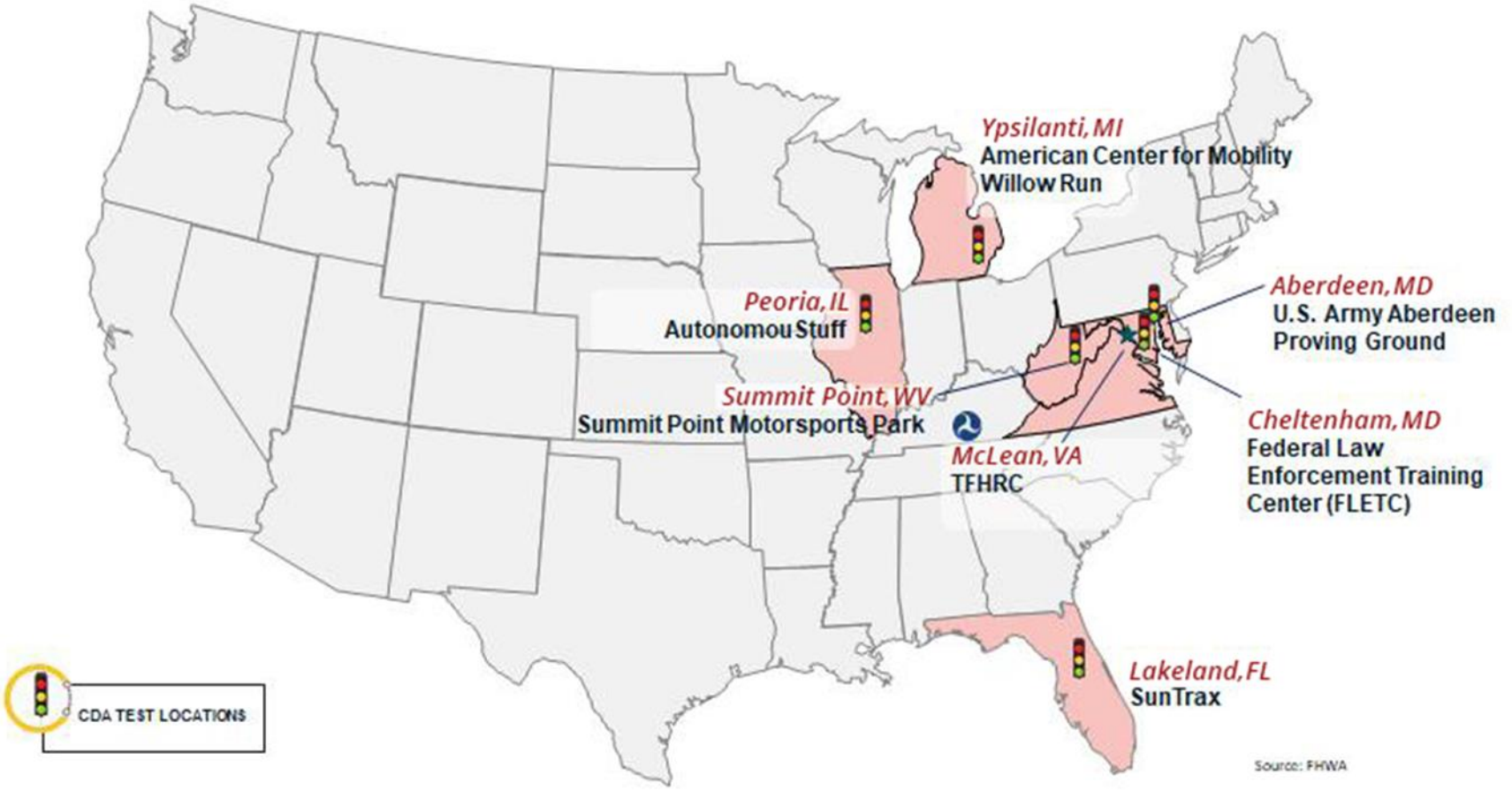
- CDA message sets were developed to enable the testing of various use cases, including platooning, traffic incident management, and work zone safety.
- These message sets will have to be integrated into new and existing standards to maximize industry adoption of CDA.
- CDA messages were developed using existing SAE International standards as a reference to support an effective and efficient adoption.

CDA Use Case Adoption and Testing

The various use cases demonstrated using CARMA Platform may be used as a reference for real-world deployment:

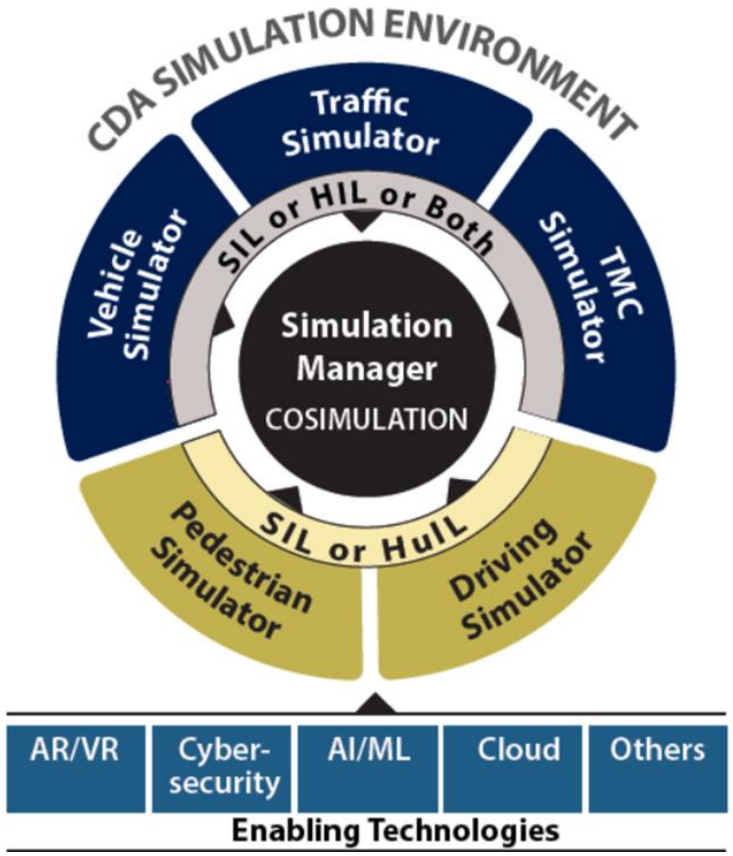
- **Arterial management** use cases can provide optimization of traffic through adaptive traffic signal control and optimized vehicle trajectories through signalized and stop controlled intersections.
- **Work zone management** use case may be applied to improve work zone safety.
- **Traffic incident management** use case may be applied to enable law enforcement and emergency medical services to interact with automated vehicles in a safe environment.
- **Integrated highway prototype** use case will lead to improved travel times on freeways, smoother traffic flow, and reduced congestion.
- **CP** will enable city and State DOTs to improve pedestrian and VRU safety.

CDA Test Locations



Everything-in-the-Loop Simulation

- The CDA simulation environment is a multisimulation-focused framework to support development, testing, and deployment of CDA technology.
- Different simulators handle their respective domains and are synchronized and orchestrated by a central simulation environment.
- The key enabling technologies are:
  - Augmented reality (AR)/virtual reality (VR).
  - Cybersecurity.
  - Artificial intelligence (AI)/machine learning (ML).
  - Cloud computing.

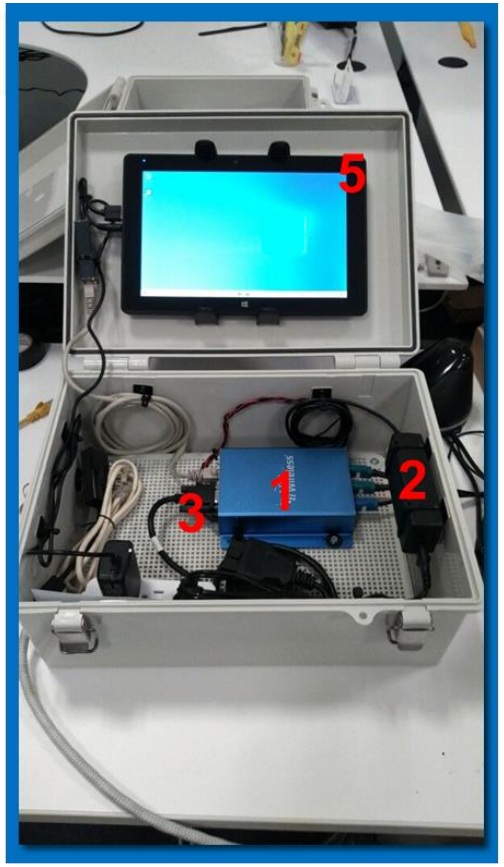


SIL = software-in-the-loop;
HIL = hardware-in-the-loop;
HuIL = human-in-the-loop;
TMC = traffic management controller.

Source: FHWA.

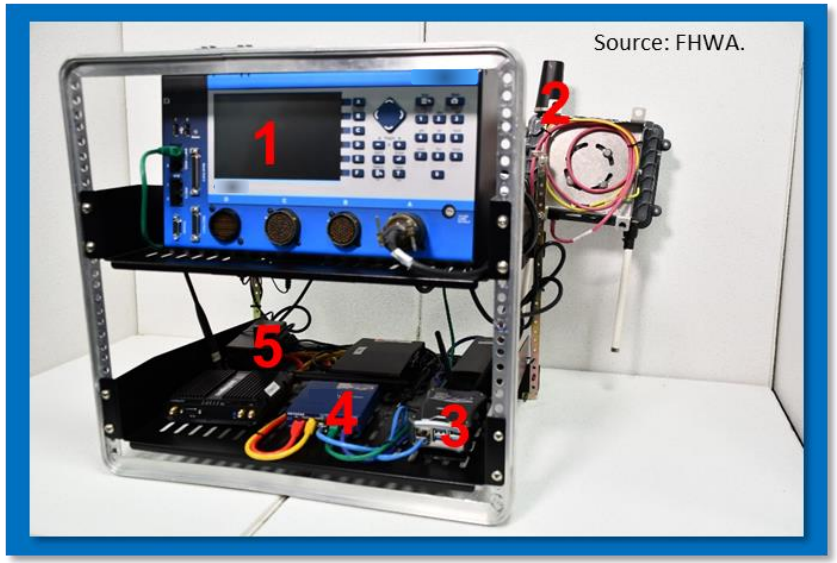
Workforce Development: CAVE-IN-A Box and CARMA 1/10th

Mobile Kit



Source: FHWA.

Infrastructure Kit



Source: FHWA.

CONNECTED AND AUTOMATED VEHICLES SUPPORT SERVICES

Source: FHWA.

Discussion

1. Does this approach resonate with you?
2. What barriers do you envision to widespread adoption of CDA?
3. How can we accelerate the adoption of CDA?
4. Do you see any gaps in our approach to date?
5. What resources would the industry need to adopt CDA?
6. What resources should FHWA provide to State and local agencies?

Questions?

Contacts

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