Virtual Open Innovation Collaborative Environment for Safety (VOICES) Public Engagement Webinar 2

Use Cases and System Integration

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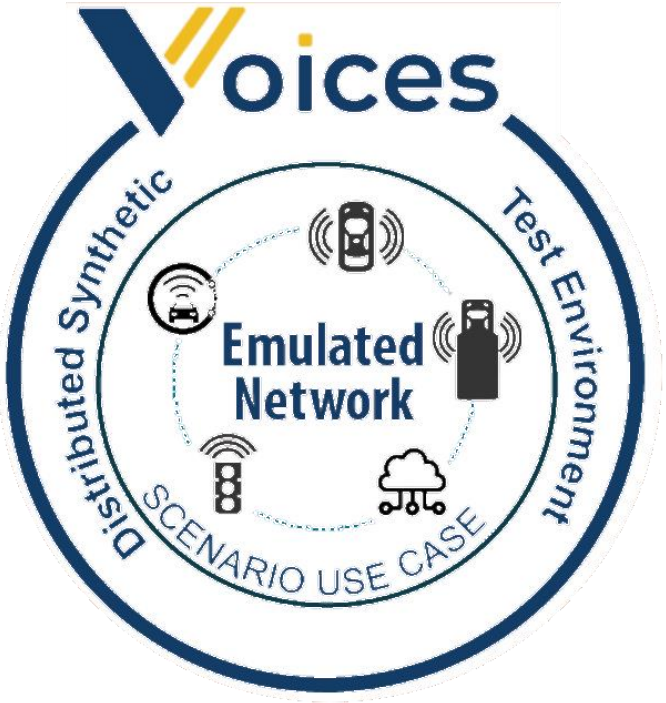
Agenda

- Introduction: The future of transportation.
- VOICES Overview.
- VOICES use cases.
- System integration.
- VOICES schedule.
- Questions and answers.

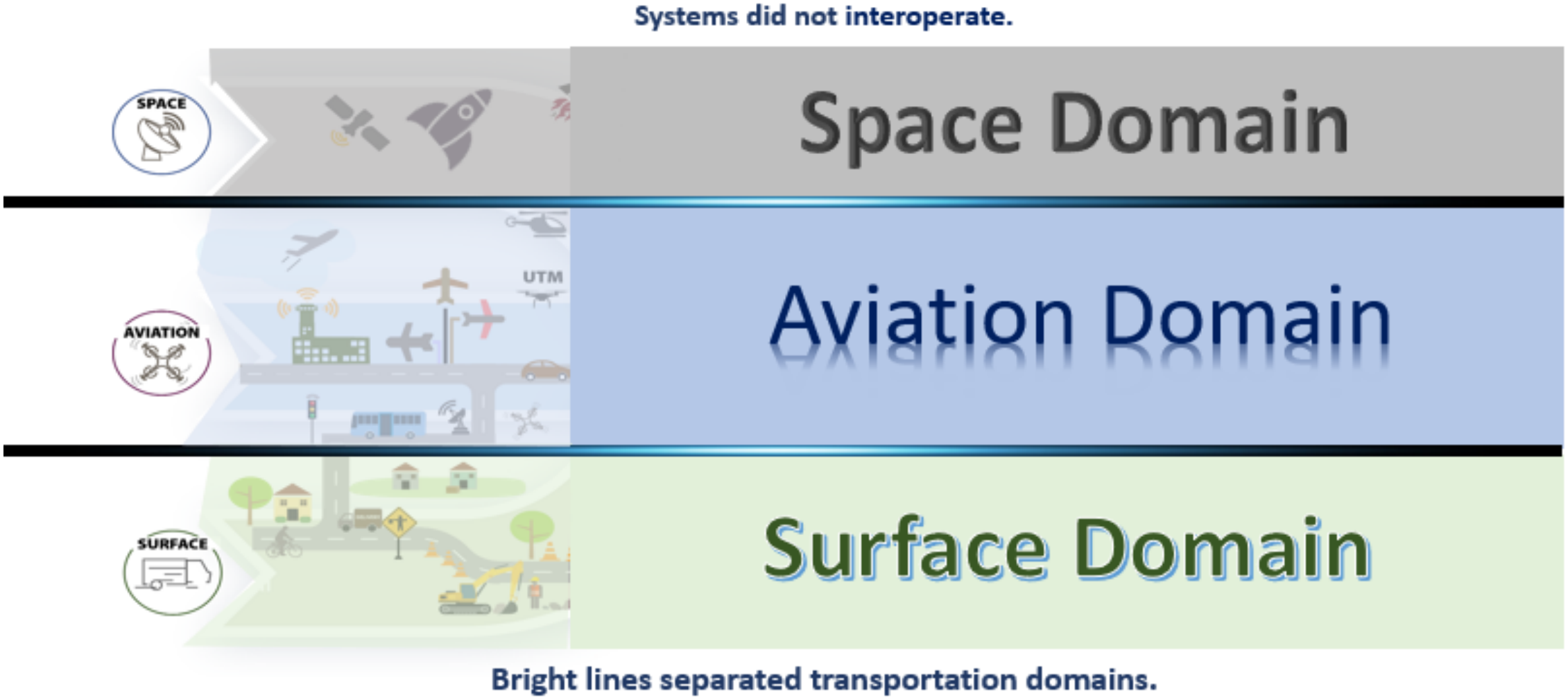


Source: USDOT.

Meeting Objectives

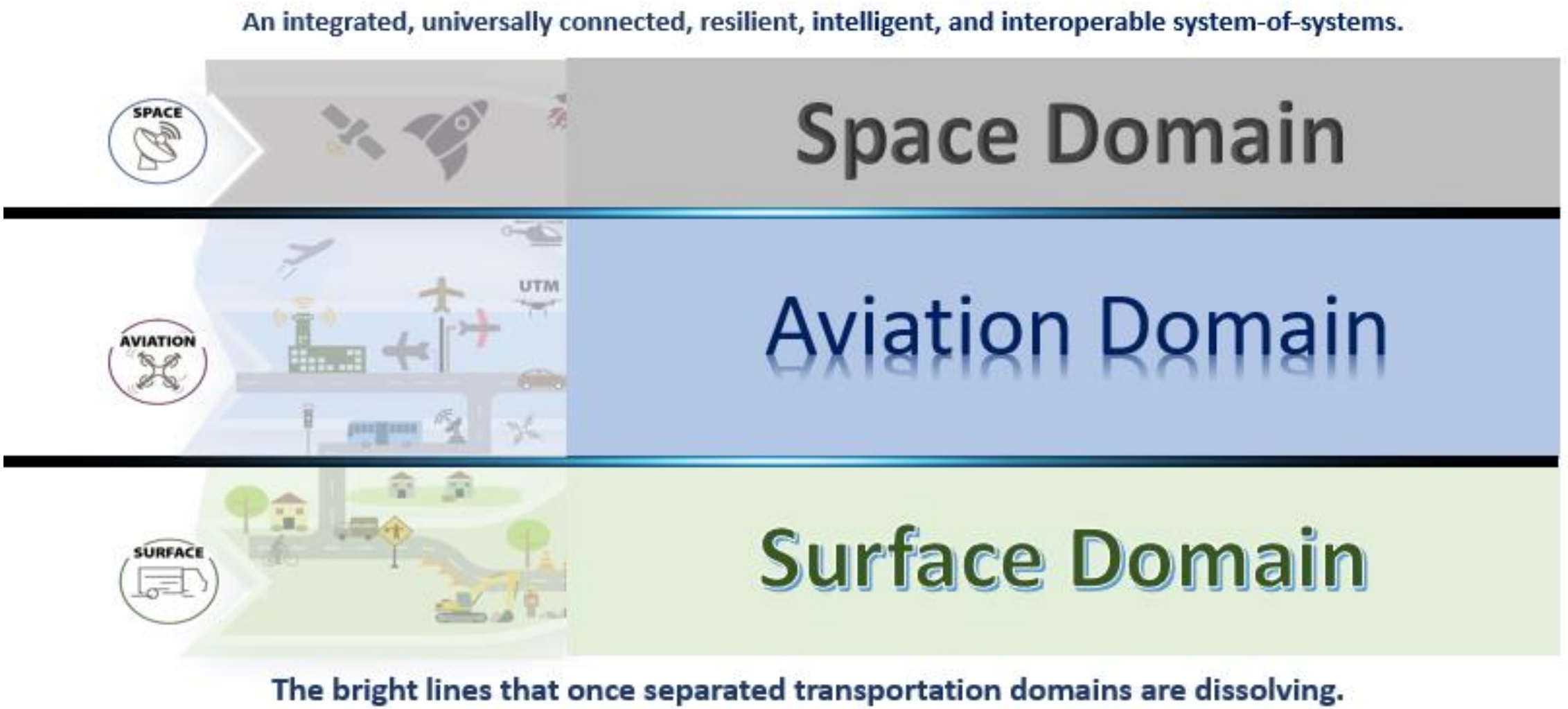
- Provide high-level background and overview of VOICES.
- Describe VOICES use cases and refinement process.
- Describe system integration and initial architecture.
- Lay out VOICES schedule and future webinar topics.
- Address feedback and questions from attendees.

The Transportation Systems of Our Recent Past



Source: FHWA.

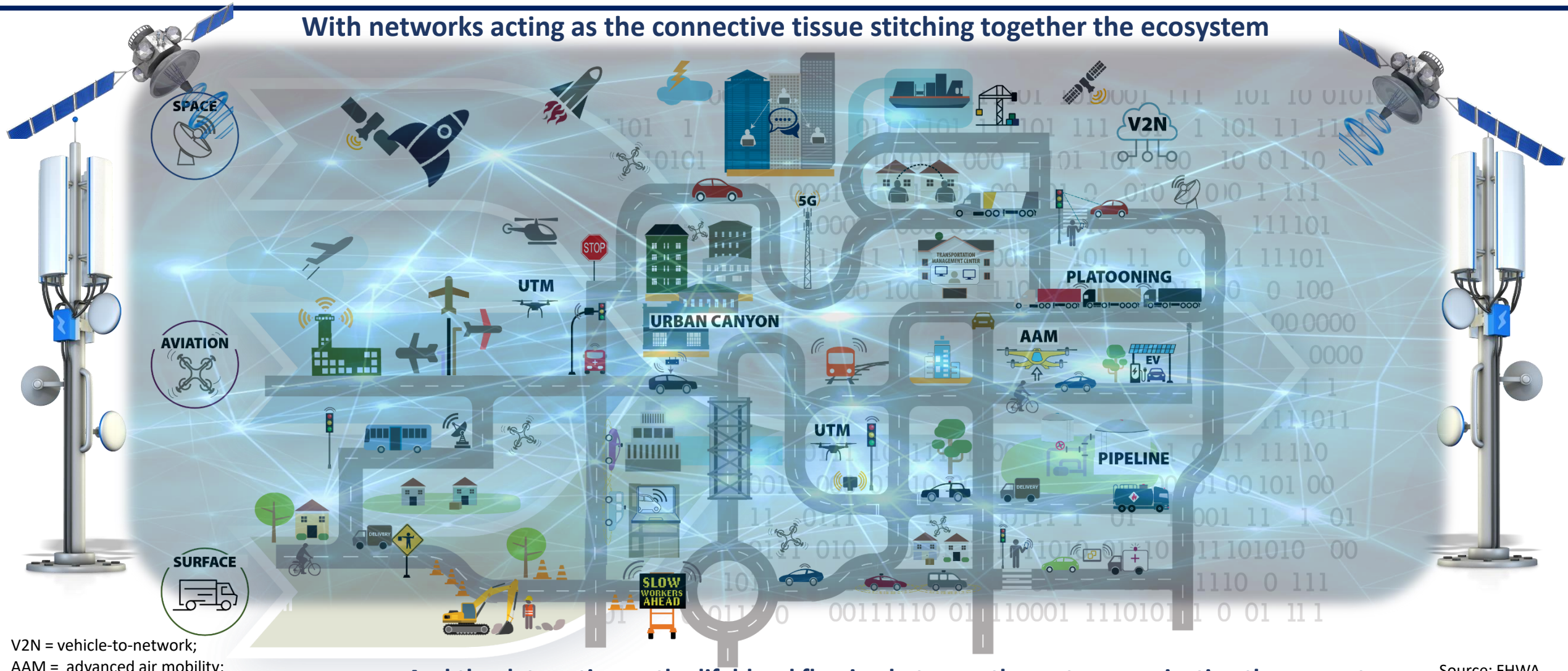
Can This Structure Represent the Transportation System of the Future?



Source: FHWA.

Digital Infrastructure and Connectivity Will Take Center Stage

With networks acting as the connective tissue stitching together the ecosystem



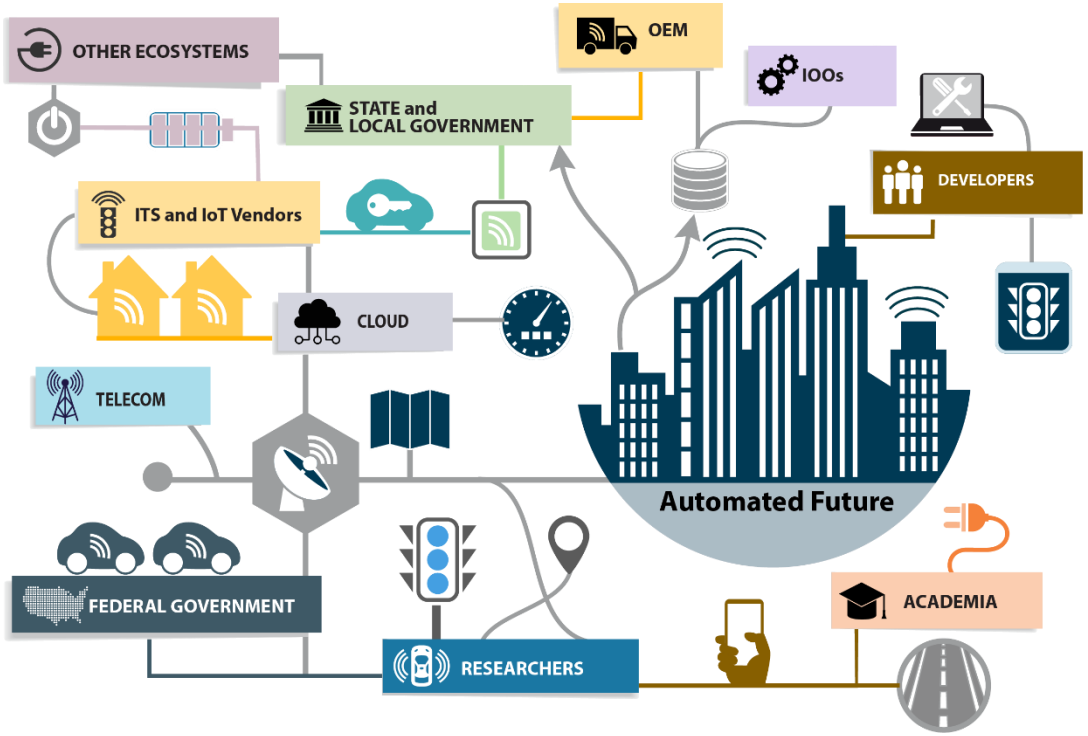
V2N = vehicle-to-network;
AAM = advanced air mobility;
UTM = unmanned aircraft systems traffic management.

And the data acting as the lifeblood flowing between the systems navigating the ecosystem

Source: FHWA.

The Challenge of Collaboration

- Lack of a simple, effective, and efficient mechanism to perform collaborative research and testing.
- Multiplicity of stakeholders.
- Natural Silos.
- Trust deficit.
- Pressures resulting from intellectual property and competition.
- Cost and resource barriers.
- Lack of interoperable test tools and environment.

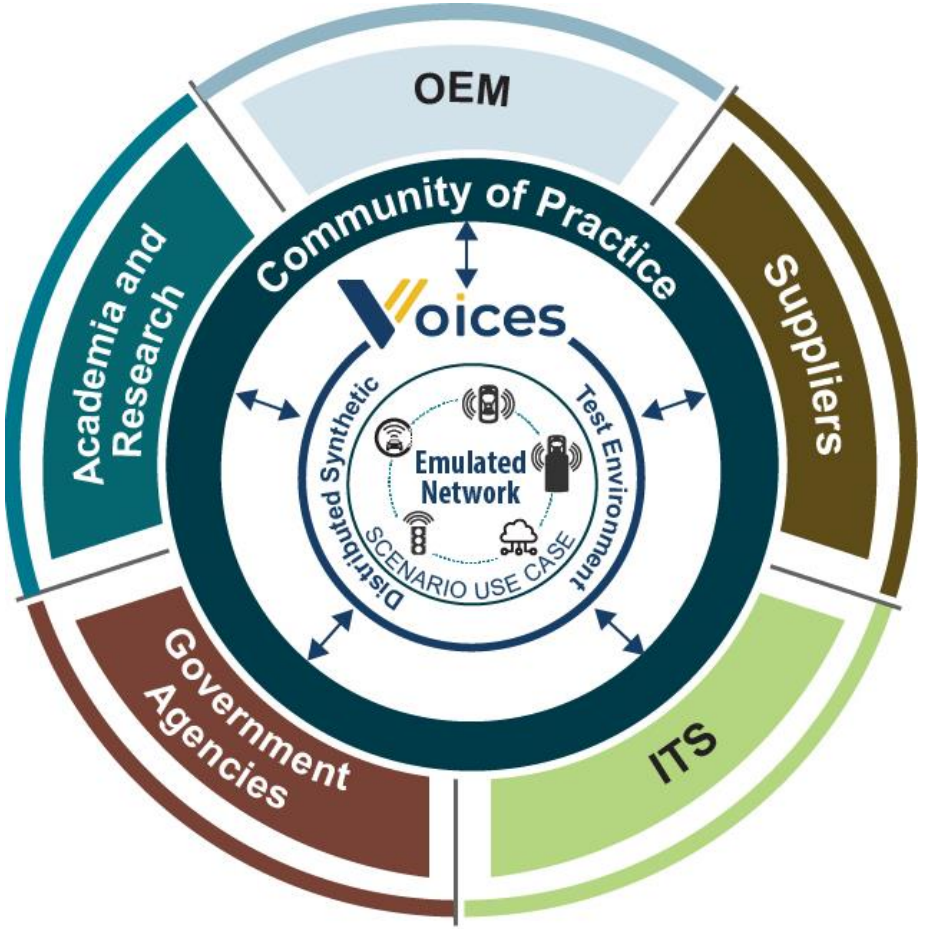


Source: USDOT. (1)

OEM = original equipment manufacturer; ITS = intelligent transportation systems; IoT = Internet of things; IOOs = infrastructure owner operators.

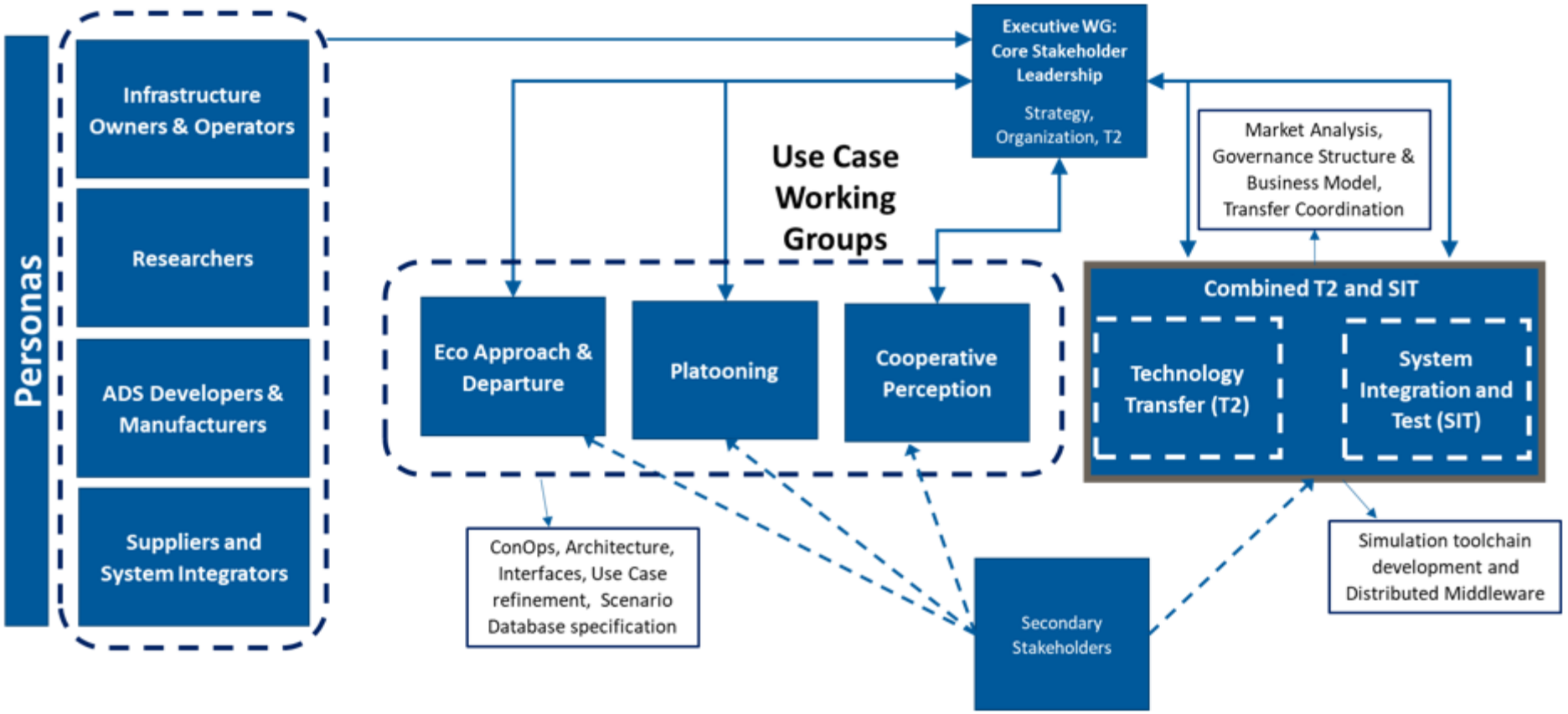
What Is VOICES?

- A platform that enables distributed virtual collaboration among stakeholders for research and interoperability testing of cooperative driving automation (CDA) applications.
- An intellectual property-protected environment.
- A collaboration tool for participating entities:
  - Public sector.
  - Private sector.
  - Academic institutions.



Source: USDOT. [2]

VOICES Engagement

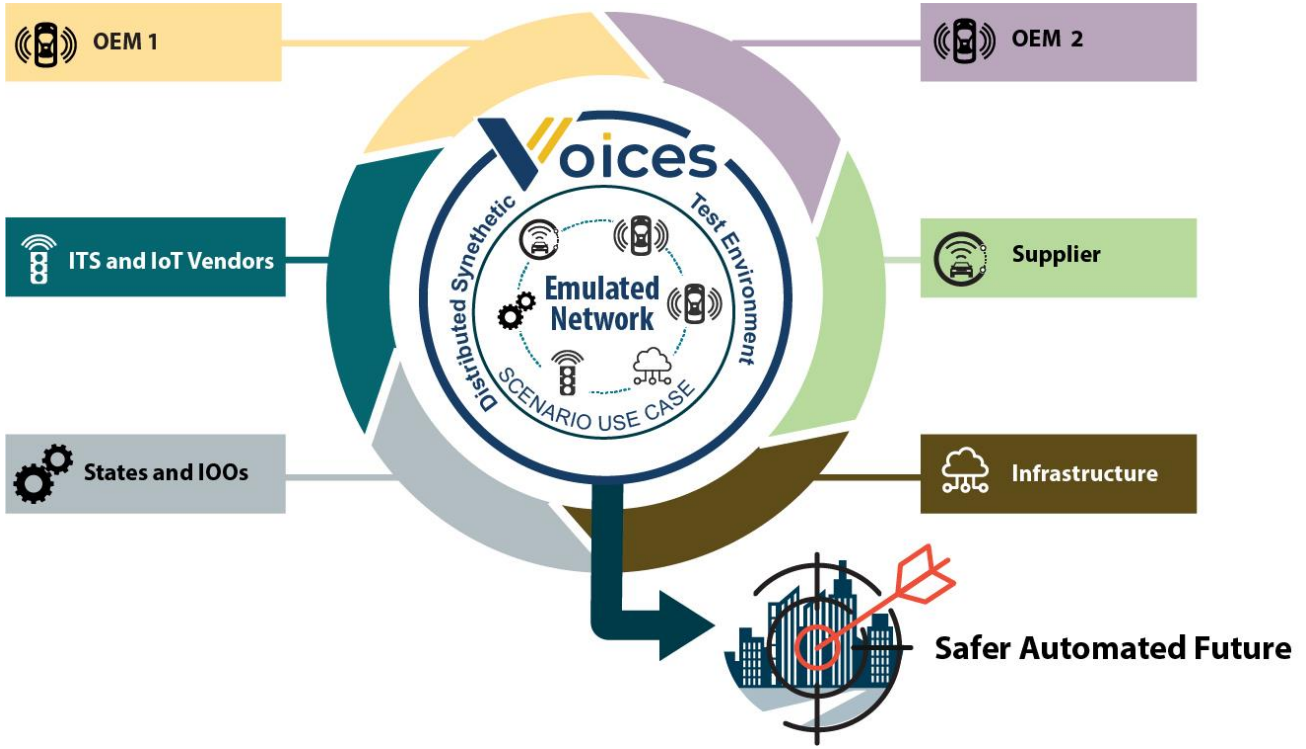


ADS = automated driving system; Eco = economic;
ConOps = concept of operations; WG = working group.

Source: USDOT.

Use Case Selection Criteria

- Produces safety or energy efficiency outcome unachievable by ADS-operated vehicles operating independently.
- Addresses a real-world safety need of sufficient magnitude to support a business case (for production-level capabilities).
- Possesses attributes useful for exercising CDA virtual testing platform at proof-of-concept level.
- Executes in both simulated and controlled track settings (i.e., for validation purposes) without excessive development effort due to its simple nature.



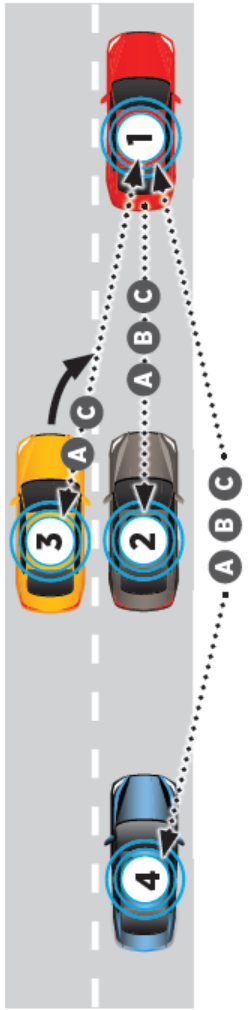
Source: USDOT. [1]

Use Case 1: Platooning

FEATURE	CLASS OF CDA	CDA DEVICE TRANSMISSION MODE AND DIRECTIONALITY	INFORMATION EXCHANGED	LEVEL OF FUNCTIONALITY
Platooning Awareness and CACC* vehicle control**	SAE CLASS A STATUS SHARING	Two-way: CDA Vehicle 1 <--> CDA Vehicle 2, 4 CDA Vehicles 1 --> CDA Vehicle 3	Platooning/CACC activation status; speed, trajectory, and location of vehicles in platoon	**Supporting:** Follower vehicles in platoon can follow more closely and stably than they could otherwise
				Supporting: CDA Vehicle 3 has additional awareness that CDA Vehicle 1 is platooning with other vehicles
Advance notice of braking maneuver	SAE CLASS B INTENT SHARING	One-way: C-ADS 1 --> C-ADS 2, 4	Planned speed reduction	**Supporting:** C-ADS 1 detects forward hazard that may require deceleration of platoon, enabling smoother deceleration of all vehicles
Platoon Joining	SAE CLASS C AGREEMENT SEEKING	One-/Two-way: C-ADS 1 --> C-ADS 2,4 C-ADS 3 <--> C-ADS 1	Seeking to join platoon; allow to join platoon in the middle; inform other platooners	**Enabling:** C-ADS 3 can join the platoon in the middle (otherwise it would have had to join at the end)

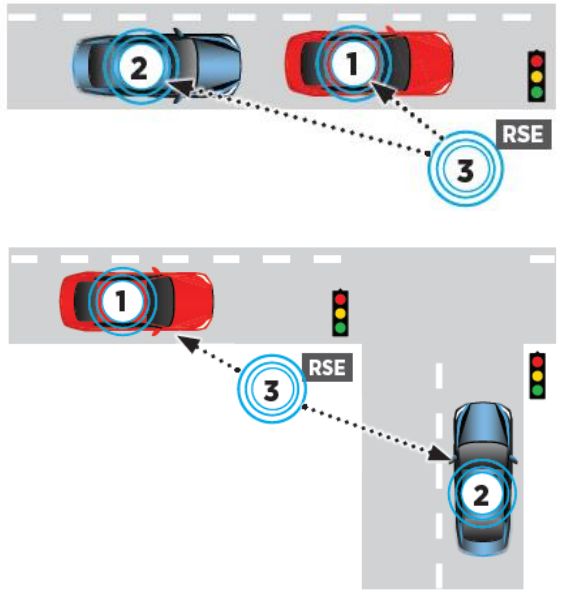
*CACC: Cooperative Adaptive Cruise Control.
**Note example A has been defined using CDA vehicles (i.e., SAE Levels 1 to 5 automation), and the B and C examples have been defined for C-ADS (i.e., SAE Levels 3 to 5 automation).
NOTE: In practice, one-way transmission will typically send the message to multiple CDA devices in the vicinity.

C-ADS = cooperative-automated driving system.



Use Case 2: Eco Approach and Departure

FEATURE	CLASS OF CDA	CDA DEVICE TRANSMISSION MODE AND DIRECTIONALITY	INFORMATION EXCHANGED	LEVEL OF FUNCTIONALITY
Eco-Approach and Departure (Figure 4)	SAE CLASS A STATUS SHARING	One-way: RSE 3 --> C-ADS 1, 2	Signal phase	**Supporting:** C-ADS 1, 2, plan motion more effectively with increased reliability and look ahead distance to reduce energy consumption and emissions
Signal Priority (Figure 5)	SAE CLASS A STATUS SHARING	One-way: C-ADS 1 --> RSE 3	Vehicle location, speed, and priority status (e.g., emergency vehicles)	**Enabling:** Signal timing changed based on the approaching vehicle
Eco-Approach and Departure (Figure 4)	SAE CLASS B INTENT SHARING	One-way: RSE 3 --> C-ADS 1, 2	SPaT information	**Enabling:** C-ADS 1, 2, plan motion based on the future signal phase information that would otherwise be unavailable
Tandem Approach and Departure (Figure 5)	SAE CLASS C AGREEMENT SEEKING	One-/Two-way: RSE 3 --> C-ADS 1, 2 C-ADS 1 <--> C-ADS 2	SPaT information C-ADS 2 proposes velocity profile to C-ADS 1 C-ADS 1 agrees	**Enabling:** C-ADS 1, 2, and RSE 3 plan motion and future signal phase to enable velocity optimization for both vehicles



 (3)

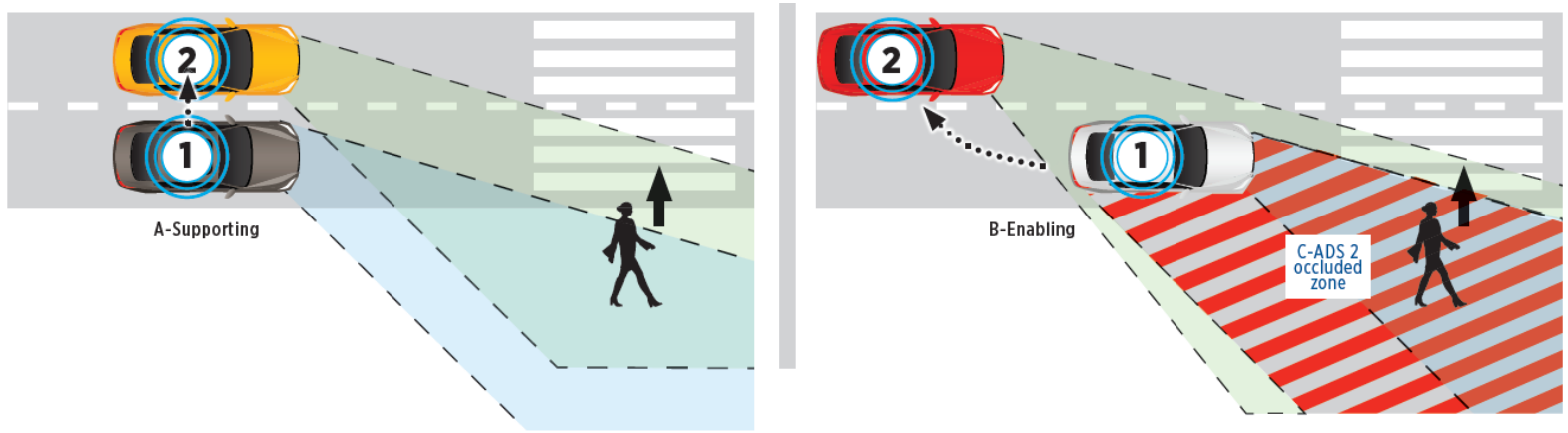
NOTE: In practice, one-way transmission will typically send the message to multiple CDA devices in the vicinity.

SPaT = signal phase and timing.
RSE = roadside equipment.

Use Case 3: Cooperative Perception

FEATURE	CLASS OF CDA	CDA DEVICE TRANSMISSION MODE AND DIRECTIONALITY	INFORMATION EXCHANGED	LEVEL OF FUNCTIONALITY
Object Tracking: C-ADS 1 shares pedestrian location and classification with C-ADS 2	SAE CLASS A STATUS SHARING	One-way: C-ADS 1 --> C-ADS 2	Object geospatial location, and classification ("pedestrian")	**Supporting:** C-ADS 2 can sense the pedestrian, and uses the information to improve reliability and accuracy of pedestrian location and classification
				Enabling: Pedestrian was occluded from C-ADS 2 field of view (e.g., by C ADS 1), and now C-ADS 2 is aware of pedestrian

NOTE: In practice, one-way transmission will typically send the message to multiple CDA devices in the vicinity.



Use Case Refinement Framework

Behavioral Competency

Expected capability from a C-ADS feature operating a vehicle within its operational design domain (ODD) (if any), including **measure of the ability** for an ADS to execute one or more behaviors within an ODD.[4]

Functional Scenario

Describe scenarios on a semantic level by specifying the entities and relationships between the entities of the application domain **expressed in linguistic form.**[5]

Logical Scenario

Describe scenarios with entities and between the entities and their relationships based on **parameter ranges in the state space**.[5]

Concrete Scenario

Describe scenarios explicitly with entities and their relationships **expressed in fixed values within the state space.**[5]

Test Case

1. A set of test inputs, execution conditions, and expected results developed for a particular objective.
2. Documentation specifying inputs, predicted results, and a set of execution conditions for a test item.[6]

Example Platooning Use Case Refinement

- Behavioral Competency
- Functional Scenario
- Logical Scenario
- Concrete Scenario
- Test Case

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Source: FHWA.(7)

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A platoon of ADS-operated, heavy-duty trucks is traveling on a rural motorway with little to no traffic and a 45-mph speed limit sign. The platoon approaches a work zone that forces vehicles traveling in the left-most lane to merge with vehicles in the lane to the right. The work zone has limited lane access, a slower speed limit, and equipment and workers near the roadway.

Work zone speed limit	Lane markings	Number of workers	Lighting
20–35 mph	White/yellow; solid/striped	5–30	Daytime/nighttime

Lanes: 2 with white-striped divide

Signs: 1 road work ahead, 2 work zone speed limit

Roadway condition: minor cracking

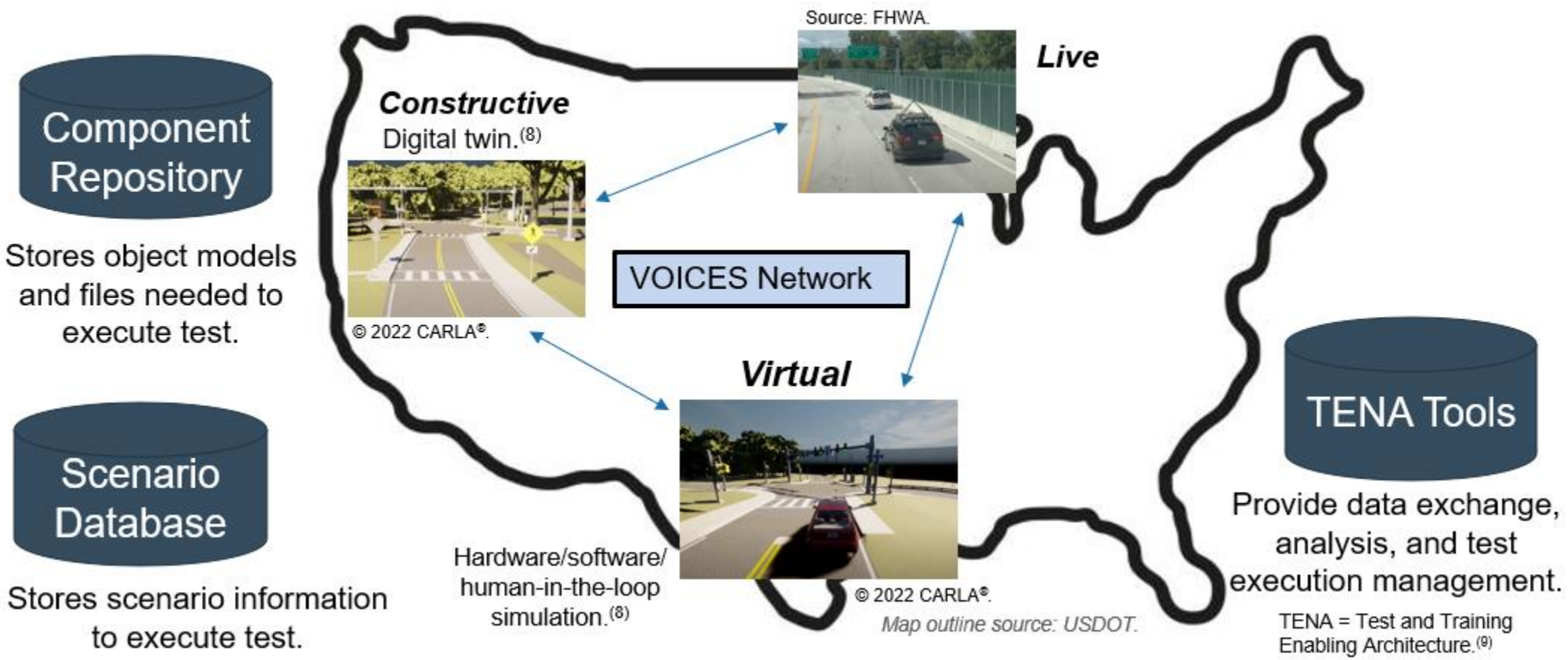
Vehicle time-based gap: 1–1.7 s

Lighting: nighttime with streetlights

Vehicle-to-Everything (V2X) messages: work zone message, basic safety message

The lead vehicle is a virtual vehicle represented in a simulator that is sending status information to live vehicles traveling by using the time-based gaps on a rural highway in an ODD matching the concrete scenario conditions.

High-Level Architecture



Arrows indicate interoperability between sites.

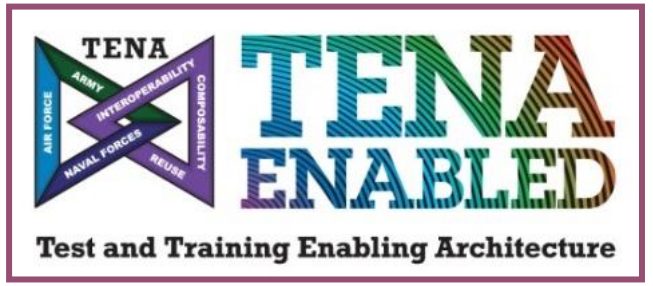
Overview of TENA

What does TENA enable?

- Effective integration of disparate proprietary interfaces.
- Integration of live, virtual, and constructive assets (locally or distributed).
- Sharing and reuse of common capabilities.

What is included in the TENA architecture?

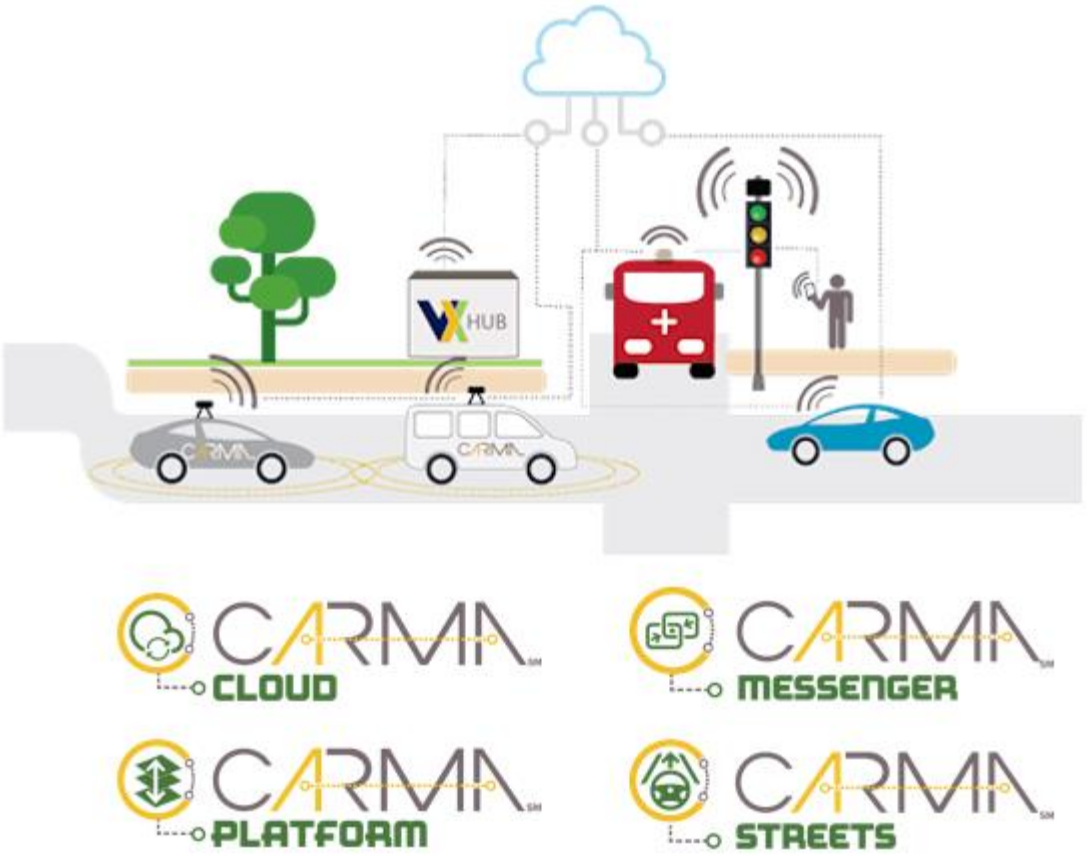
- "Data contracts" that standardize repeatable information exchange and are customizable.
- Software libraries that enable interoperability and are generated by auto-code.
- A core set of tools that address common test requirements.
- Collaboration mechanisms that facilitate sharing and reuse.



Source: U.S. Department of Defense. [9]

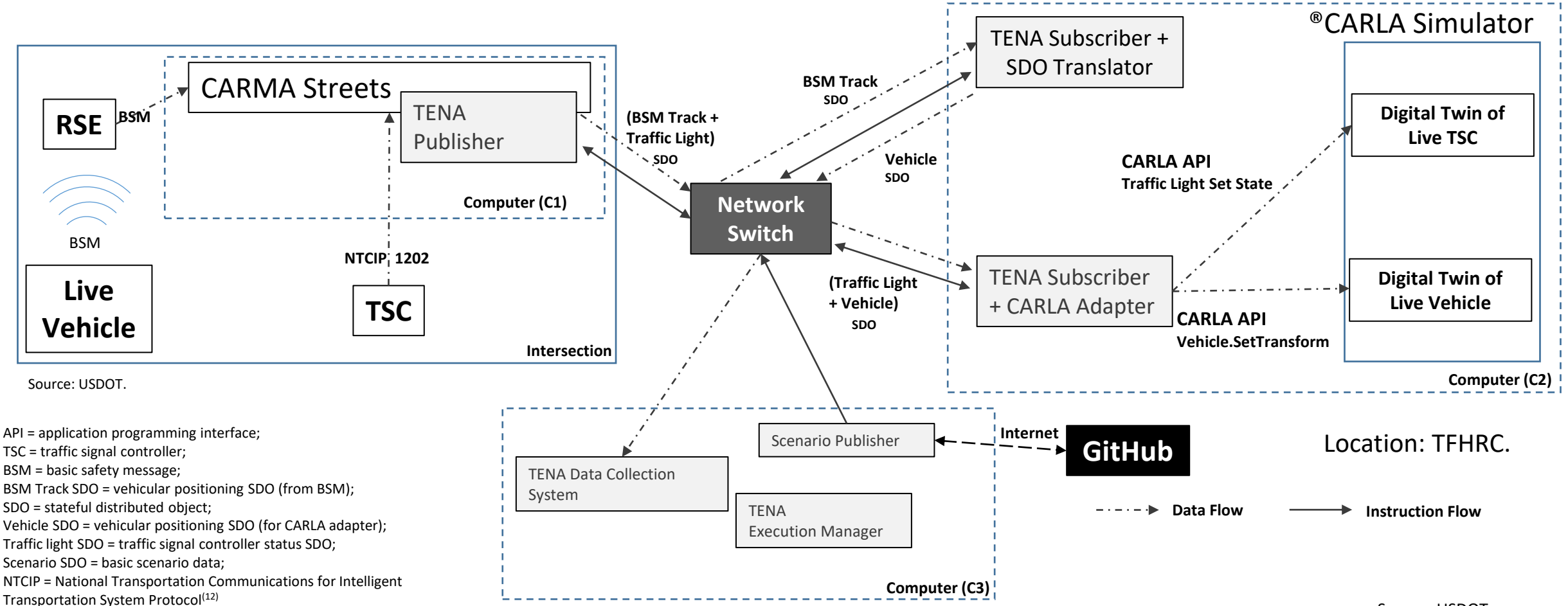
Overview of CARMA[SM]

- FHWA developed the program to spearhead research and development of CDA concepts.
- CARMA product suite provides software for conducting CDA research and testing.
  - CARMA Cloud[SM].
  - CARMA Platform[SM].
  - CARMA Messenger.
  - CARMA Streets.
- CARMA is an example of CDA products that can be used with VOICES.



Source: FHWA.[(10)]

Initial Demonstration Architecture

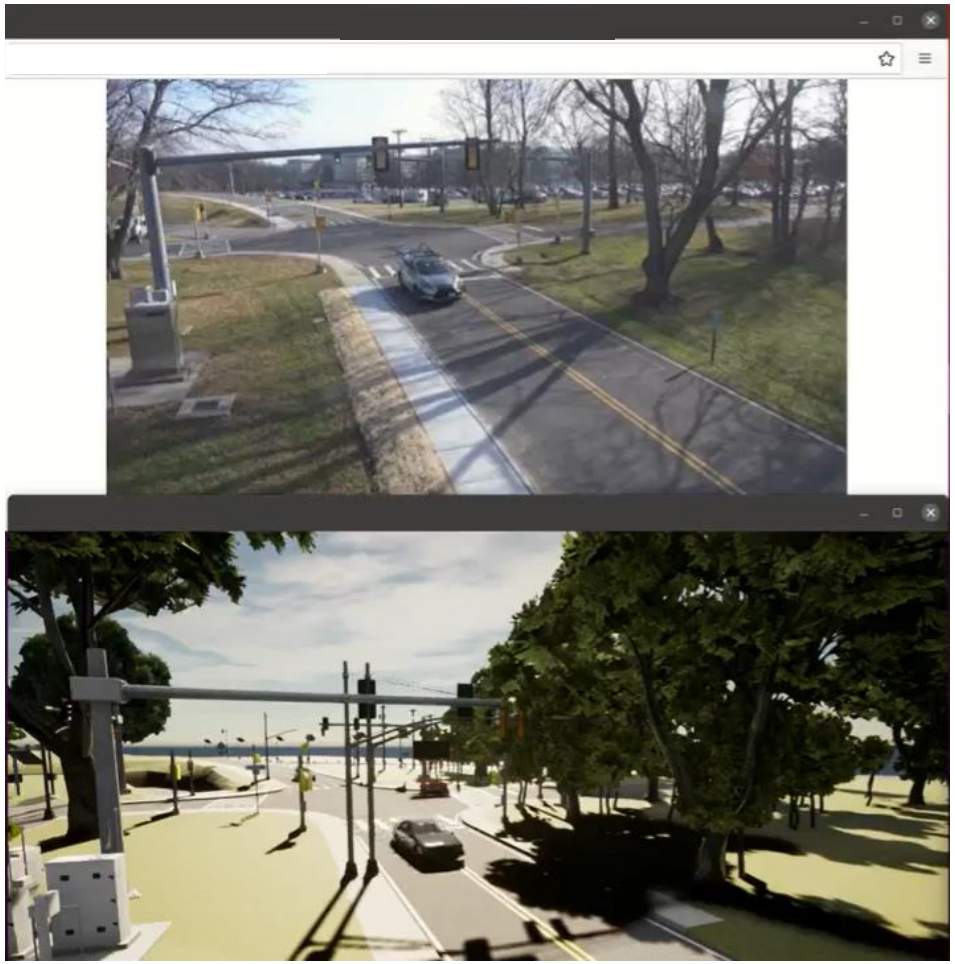


Source: USDOT.

API = application programming interface;
TSC = traffic signal controller;
BSM = basic safety message;
BSM Track SDO = vehicular positioning SDO (from BSM);
SDO = stateful distributed object;
Vehicle SDO = vehicular positioning SDO (for CARLA adapter);
Traffic light SDO = traffic signal controller status SDO;
Scenario SDO = basic scenario data;
NTCIP = National Transportation Communications for Intelligent Transportation System Protocol[12]
TFHRC = Turner-Fairbank Highway Research Center.

Source: USDOT.

Initial Demonstration Results



All photos source: FHWA.

VOICES is demonstrated in this image, which depicts a live vehicle driving along a roadway while its virtual counterpart is displayed in a CARLA simulation running in a computer. This image highlights the possibility of experimenting with live and virtual interactions using a common set of adapters and interfaces.

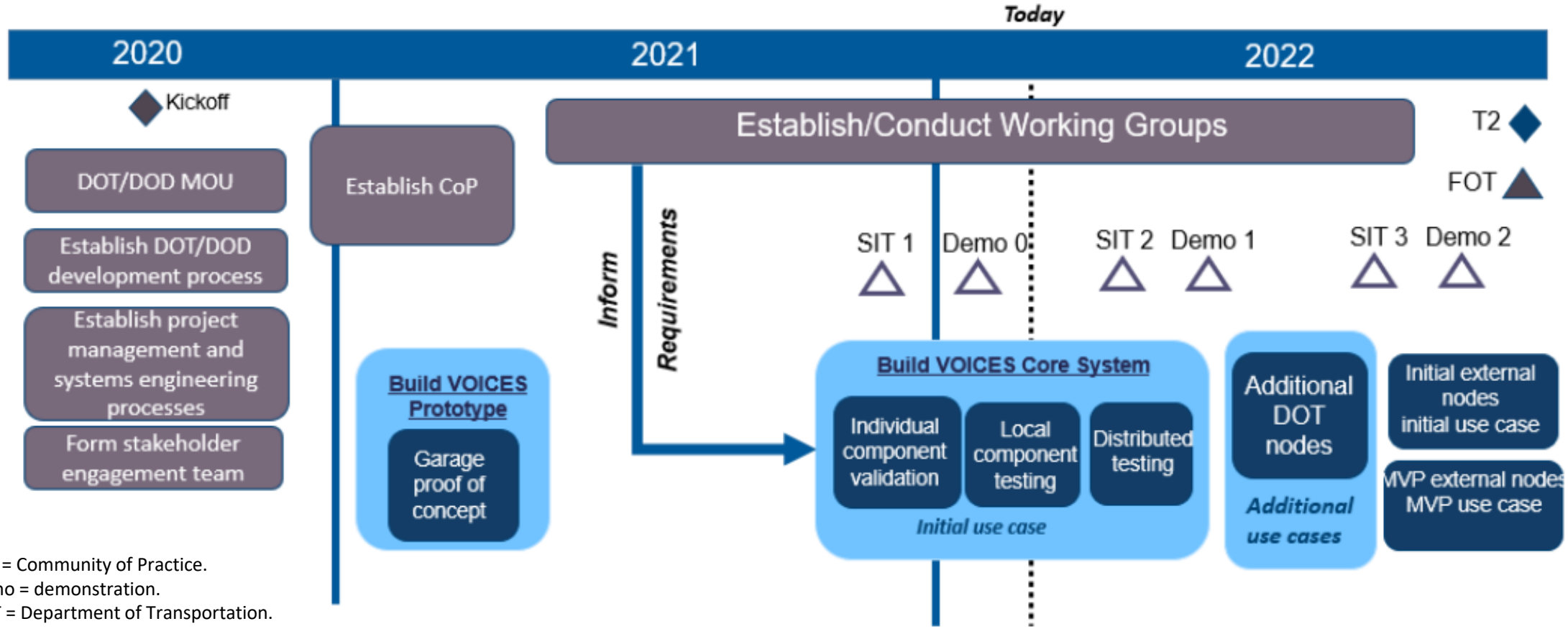
(Top) A live vehicle is shown driving along a roadway at TFHRC in McLean, VA.

(Bottom) The live vehicle's state (position, speed profile, heading, and so on) is depicted in a CARLA simulator running on a computer.

Initial Demonstration Results (Continued)

All photos source: FHWA.

Schedule and Milestones



CoP = Community of Practice.
Demo = demonstration.
DOT = Department of Transportation.
MOU = memorandum of understanding.
MVP = minimum viable product.
SIT = system integration test.
FOT = final operational test.

Source: USDOT.

Upcoming Webinars

- VOICES updates and material will be presented at webinars, and attendees are encouraged to provide written feedback or questions after each webinar.
- Webinars on the following topics are planned for every 3–4 mo:
  - VOICES Overview.
  - Use case development.
  - System integration.
  - Technology transfer.
  - Use case testing and reporting.

Questions and Answers

Please submit questions via the chat pod.

Contacts

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