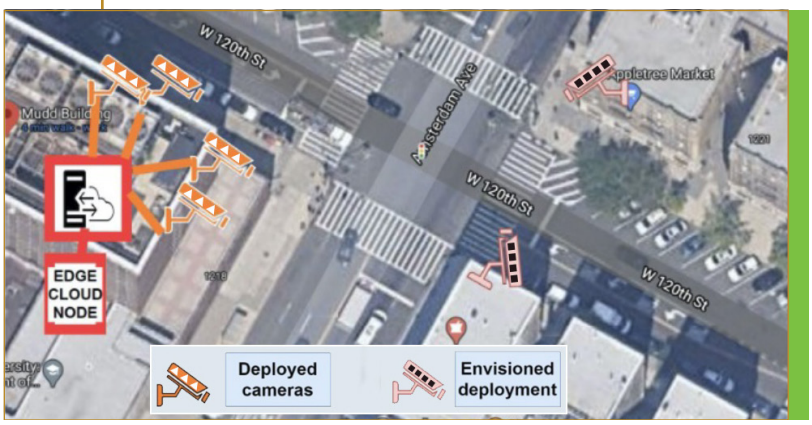
EXPLORATORY ADVANCED RESEARCH

DEVELOPING FUTURE TRAFFIC MANAGEMENT SYSTEMS USING HYBRID TWINS

September 2022

FACT SHEET

Traffic management in metropolitan areas poses distinct challenges. Faced with congested city streets shared by pedestrians, bicyclists, electric-scooter riders, and drivers, traffic managers must find new ways to maintain smooth and safe traffic flow. Traffic managers can harness the data collected by electronic devices that connect to the internet, infrastructural sensors, other devices or systems, and communications networks in the Internet of Things (IoT) to transform urban streets. The Exploratory Advanced Research (EAR) Program of the Federal Highway Administration (FHWA) and the Cyber Physical Systems program at the National Science Foundation (NSF) are supporting a 3-yr research project that leverages the IoT to develop an urban traffic management system that will help improve traffic safety, mobility, and reliability. To explore the possibilities of this advanced traffic management system, the research team at Columbia University is creating a hybrid twin of an area of New York City.



The researchers are using cameras to capture traffic data.

HYBRID TWINS FOR TRAFFIC MODELING

Transportation researchers already employ virtual twins and digital twins to mimic real-world experiences, but the concept of a hybrid twin is still relatively new. A hybrid twin is a simulation model that combines a virtual twin and a digital twin.

Virtual twins are physics-based simulation models; they simulate how objects or systems behave using prior domain knowledge. However, virtual twins sometimes differ from their real-world counterparts and cannot accurately and efficiently simulate large environments. A digital twin gathers and analyzes data from sensors (such as those in vehicles, traffic cameras, radar devices, and infrastructure) to mimic what is happening in the selected real-world environment. Digital twins provide real-time data-based information and allow researchers to model scenarios, make predictions, and test mitigation strategies.(1)

A hybrid twin, combining the concepts of virtual twins and digital twins, leverages both domain knowledge and data to provide a more realistic simulation environment.(2) More accurate simulations offer the following advantages:

- Facilitate test scenarios quickly and safely.
- Advance understanding of urban traffic modeling, computation, and simulation.
- Lead to more informed decisionmaking as traffic managers predict, optimize, and control traffic flow.

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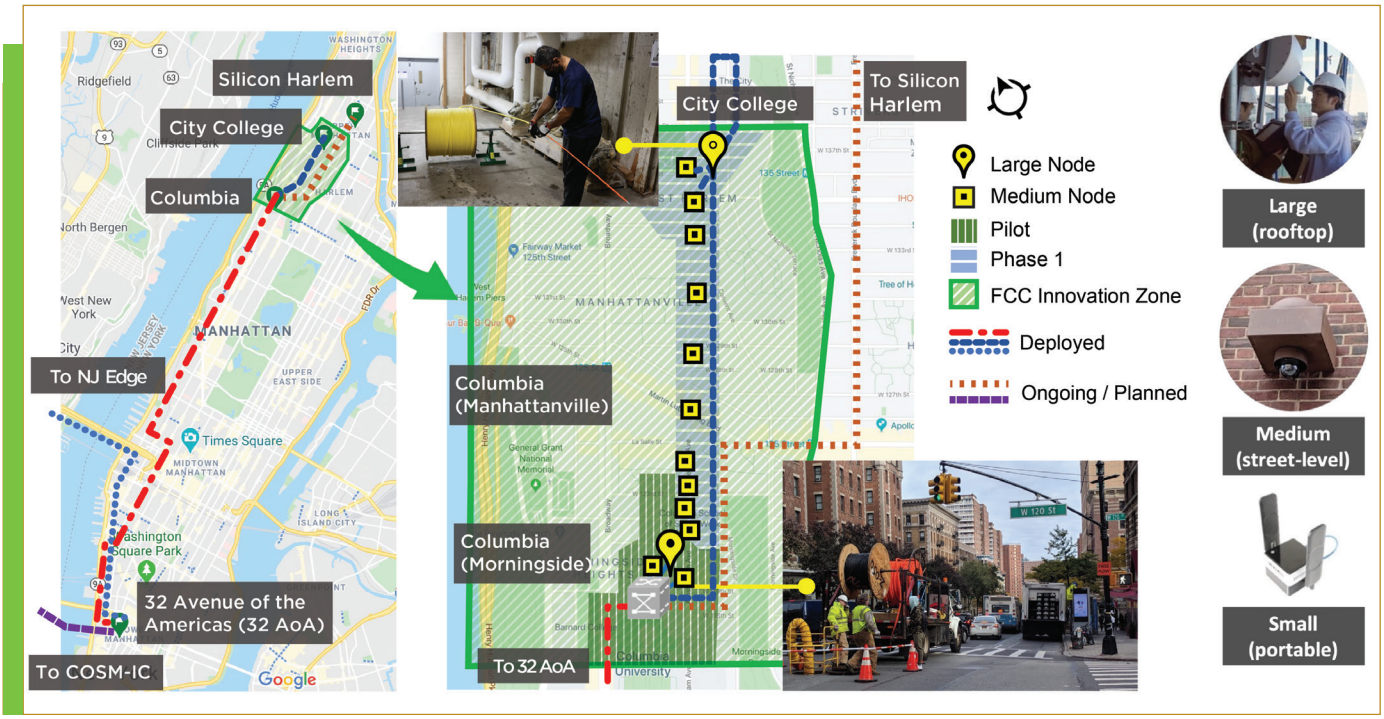

Phase 1 deployment.

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For example, the hybrid-twin system could assist with incident management. When a traffic incident occurs, the system could propose options, such as detours or road closures, to reduce the impact on traffic flow.

In the project titled "Hybrid Twins for Urban Transportation: From Intersections to Citywide Management," the Columbia University research team is developing a hybrid twin that integrates artificial intelligence, machine-learning algorithms, edge-cloud computing, and advanced communications networks to simulate and predict traffic states for various traffic scenarios. The hybrid twin will operate parallel and in realtime with the real-world environment it mimics.

A NEW LEVEL OF TRAFFIC MANAGEMENT

In the first phase of the project, the researchers are using artificial intelligence to extract data from sensors to develop the digital twin. The researchers also are integrating a traffic simulator, a communications network simulator, and a three-dimensional autonomous driving simulator. With the traffic simulator, the researchers can generate each vehicle and let each one move in its own network.

Eventually, the researchers plan to integrate FHWA's CARMA Platform to simulate how vehicles generate messages and communicate with other vehicles.[3] Based on those messages, the system will be able to interact with vehicles.

The researchers are deploying the Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment (COSMOS) testbed in the West Harlem neighborhood streets of New York City, NY, to evaluate and validate the traffic management system.[4] The COSMOS testbed, a component of the NSF Platforms for Advanced Wireless Research, will soon cover a corridor of 20 city blocks.

In the second phase of the project, the researchers will begin adding real-time data to the simulation environment to create the hybrid twin. The hybrid twin will incorporate real-time data and domain knowledge to make more accurate predictions, such as traffic state

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estimations—the speed and density of traffic in an area—every 5 min. The system will use existing models within the simulator to make those predictions.

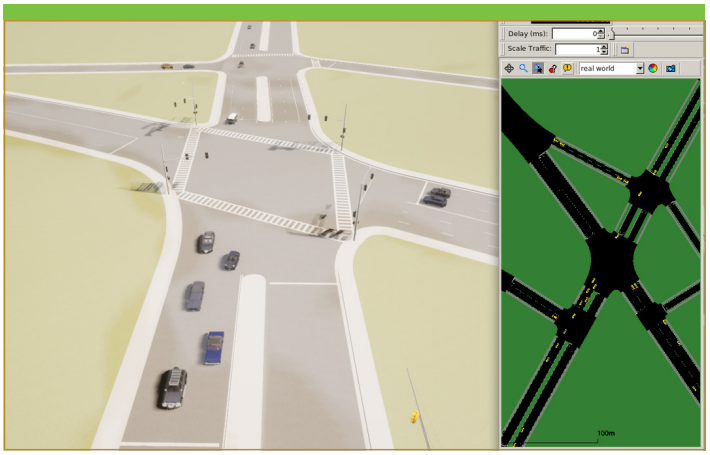
> **"If we can manage the system more effectively, everyone benefits."**
>
> **—Rachel James, Ph.D.**
> **Research Civil Engineer, FHWA Office of Safety and Operations Research and Development.**

By assimilating data acquired from infrastructure and in-vehicle sensors for traffic modeling, prediction, and management, the hybrid-twin system will be able to monitor surrounding traffic, send safety warnings to connected vulnerable users, and provide learning-based controls to traffic lights and automated vehicles. The system thereby can help improve traffic flow and capacity, increase road safety, and reduce emissions.

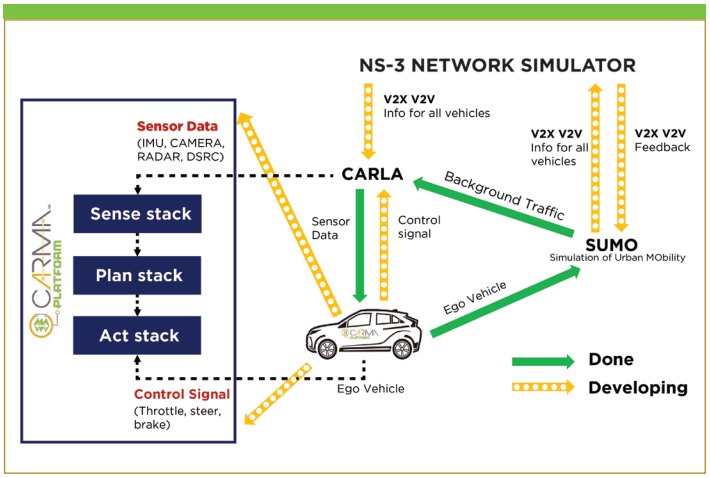
"The vision is that one day we will have a data-driven traffic management center to improve safety, mobility, and reliability. The traffic management center in the research project will have access to data that today's centers do not," said Rachel James of FHWA's Office of Safety and Operations Research and Development. "If we can manage the system more effectively, everyone benefits."

KNOWLEDGE SHARING

The research project includes an education plan to expand underrepresented populations' access to and participation in computer science and engineering programs. The researchers have developed an outreach program to explain transportation concepts to teachers and students in grades K–12 in the New York City Public Schools located in Harlem.



The researchers are integrating CARLA® simulation images and Simulation of Urban MObility™ (SUMO) traffic simulations in the COSMOS testbed.[5,6]



This diagram shows the components of the hybrid twin along with the data flow between the components.

Three different nodes with advanced wireless communications capabilities are being used in the COSMOS testbed.

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In the first 2 yr of the project, the researchers will host students for lab visits, give demonstrations and lectures about the project, and work with teachers to develop educational components for the classroom. In the third year, the researchers will offer internships for underrepresented female middle and high school students to learn about and contribute to the project.

What Is the EAR Program?

The EAR Program supports longer term, higher risk research with the potential for transformative improvements to the U.S. transportation system. The EAR Program seeks to leverage promising expertise and advances in science and engineering to create breakthrough solutions to highway transportation issues.

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CONTACT

For more information about this EAR Program project, contact ***Rachel James***, FHWA Office of Safety and Operations Research and Development, at 202-493-3205 (email: rachel.james@dot.gov).

LEARN MORE

To learn more about the EAR Program, visit https://highways.dot.gov/research/exploratory-advanced-research.

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