<table>
<tr><td colspan="4">Request for Research Funding for FY 2023-2024</td></tr>
<tr><td colspan="4">Project Number (Research Center Use Only): TEO-24-08</td></tr>
<tr><td>Requesting Office</td><td>State Traffic Engineering and Operations and District 5</td><td>Priority: High</td><td>8 of 11</td></tr>
<tr><td>Proposed Title</td><td colspan="3">Roadside Sensor Simulation Using Digital Twin for Connected Vehicles Applications</td></tr>
<tr><td>Justification</td><td colspan="3">Across the state, various new technologies are being deployed along the roadways. Before and after studies are carried out to understand the impact of the new sensors (LiDARs, cameras, RADARs, roadside units (RSUs), etc.) that are intended to support the implementation of CAV and ITS applications. This can often be a lengthy process spanning several years, which also includes the uncertainty regarding construction delays. An effective way would be to carry out sensor simulation and application in a digital twin (DT). Unlike microsimulation, digital twin enables virtual sensor deployment in a simulation environment that synchronizes with the real world. As such, the performance metrics of the sensors at the object location can be measured. Thus, it is able to evaluate the before-after conditions for sensor deployment rapidly and accurately, mimicking that of the field studies. In addition, the high installation and maintenance costs associated with the new roadside technologies make the optimal placement and coverage analysis essential to use available resources fully. It would be beneficial to develop a DT tool where the performance (coverage, range, blind spots, etc.) of the sensors could be simulated and analyzed before deploying in the field location. Thus, in addition to understanding the impact and benefits of CAV technologies, the developed digital twin sensor simulation can also be used to understand the best position to place the sensors for optimum accuracy and cost efficiency.</td></tr>
<tr><td>Impact</td><td colspan="3">The results of this research will be practice ready with expectations to provide a methodology to 1) identify the benefits of ITS and CAV technology based on certain sensors in roadways, 2) analyze the optimal sensor placement in the simulator before implementing it in the real scenario. The optimum sensor location will be based on their accuracy, range, and cost factors. The expected time savings and safety would be substantial. In addition, the visualization capabilities of DT would greatly help decision makers in their pursuit of the best options.</td></tr>
<tr><td>Affected Offices</td><td colspan="3">State Traffic Engineering and Operations. Technology and data relevant offices. Various district 5 offices will be involved primarily TSM&O.</td></tr>
<tr><td>Existing Work</td><td colspan="3">Florida has been at the forefront of deploying several sensing techniques. Connected Vehicles demonstrations by Central Office, Seminole County, and District 5 have been pioneers. The ATCMTD I-4 FRAME project underway at the I-4 corridor is also expected to deploy an integrated traffic management system with various sensor capabilities, including OBU-RSUs. As part of the FDOT's ATTAIN Central Florida program, smart transportation technologies are being implemented on the region's public roadways to enhance safety, lower the incidence of traffic jams, and maximize convenience and mobility. PedSafe is a cutting-edge technology for preventing collisions between pedestrians and bicycles using CV technologies such as LiDARs and cameras. LiDARs help detect objects in real-time, even in severe weather conditions using lasers to scan the surroundings and accurately capture the 3D point cloud data. The City of Orlando is also experimenting in their SODA Federal grant, ATSPM, ASCT, and passive pedestrian detection technologies at several intersections in downtown Orlando.

A comprehensive evaluation of these technologies could be carried out in a digital twin (DT) environment. DT is a new concept; therefore, no projects have attempted to develop the proposed sensor simulation tool. FDOT and UCF will be at the forefront of this field. A search at google scholar for the below-mentioned keywords leads to the following results:

1. UCF SST CitySim: A Drone-Based Vehicle Trajectory Dataset for Safety Oriented Research and Digital Twins
https://doi.org/10.48550/arxiv.2208.11036
https://github.com/ozheng1993/UCF-SST-CitySim-Dataset</td></tr>
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	2. CARLA: Open-source simulator for autonomous driving research. Carla.org 3. BlenSor: Blender sensor simulation toolbox. https://link.springer.com/chapter/10.1007/978-3-642-24031-7_20 4. Shader-based sensor simulation for autonomous car testing https://doi.org/10.1109/ITSC.2012.6338904 5. Traffic3D: A New Traffic Simulation Paradigm https://publications.aston.ac.uk/id/eprint/39573/		
Keywords Used in Existing Work Search **(Cannot leave blank)**	CV implementation, Sensor Simulation, Digital Twin, 3D Traffic Sensor Simulator		
Related Contracts (Give contract numbers)			
Funding Request	$490,000	**Anticipated Duration**	30 months
Project Manager	Jeremy Dilmore, PE Dist 5 TSMO Engineer Co-PMs: Edith Wong, PE	**Contracting Method**	Direct contract with the University of Central Florida (Dr. Aty and Dr. Agarwal)
Equipment	None	Comments* (understanding leases are preferred, include the proposed use of the equipment, whether lease options are feasible, whether work to be done with equipment could instead be procured through service expenditure, etc.)	
Urgency	Score - 1	The advent of CAV demands that roadside sensors are widely deployed along the state. Various projects lead to before-after evaluation of these technologies, which may lead to the conclusion that certain technologies are not feasible. Digital twin simulation and placement analysis tool can provide concrete evidence of the performance of these technologies in real-life scenarios and aid in saving the state time and money during pre-deployment.	
Implementability	Score - 1	Through coordination and collaboration with FDOT, enough data could be accessed regarding the installation of various sensors in existing studies. Virtual sensor simulation can be implemented at those same locations and compared to the before-after evaluation based on realdata, thereby proving the reliability of the digital twin sensor simulation framework.	

Project Benefits (Succinct, complete explanation)

Exploring the effect of different sensors in various traffic and environmental conditions can aid in understanding the impact of the advanced ITS and CAV technologies on safety and mobility. Hence, it is crucial to investigate this prior to the actual sensor implementation. The most commonly used approach to explore the sensor effect is utilizing virtual simulations, as they can simulate a highly realistic environment. However, merely using simulation is good for testing sensor usage but not sufficient to investigate its role and benefits in the real traffic environment as a pure simulation is independent of real-world activity. The emerging digital twin approach is expected to address this issue.

Digital Twin is a digital replica of a living or non-living physical entity(Figure 1). Digital twin technology paves the way to real-time monitoring and synchronizing real-world activities with virtual counterparts. A digital twin accommodates these modules at a high level of detail while allowing for interactions across these modules. Thus, sensing tools, such as camera, LiDAR, RADAR, OBU-RSU, etc., and traffic flow can be modeled in the digital world. Afterwards, the ITS and CAV applications can be implemented in the virtual world and provide feedback to decision makers, real-world operation, control, and management. In such a way, the impact of the sensors before and after virtual deployment can be tested and compared prior to the field implementation. Potential extensions to add driver(s) and/or pedestrians in the loop could also be possible if needed.

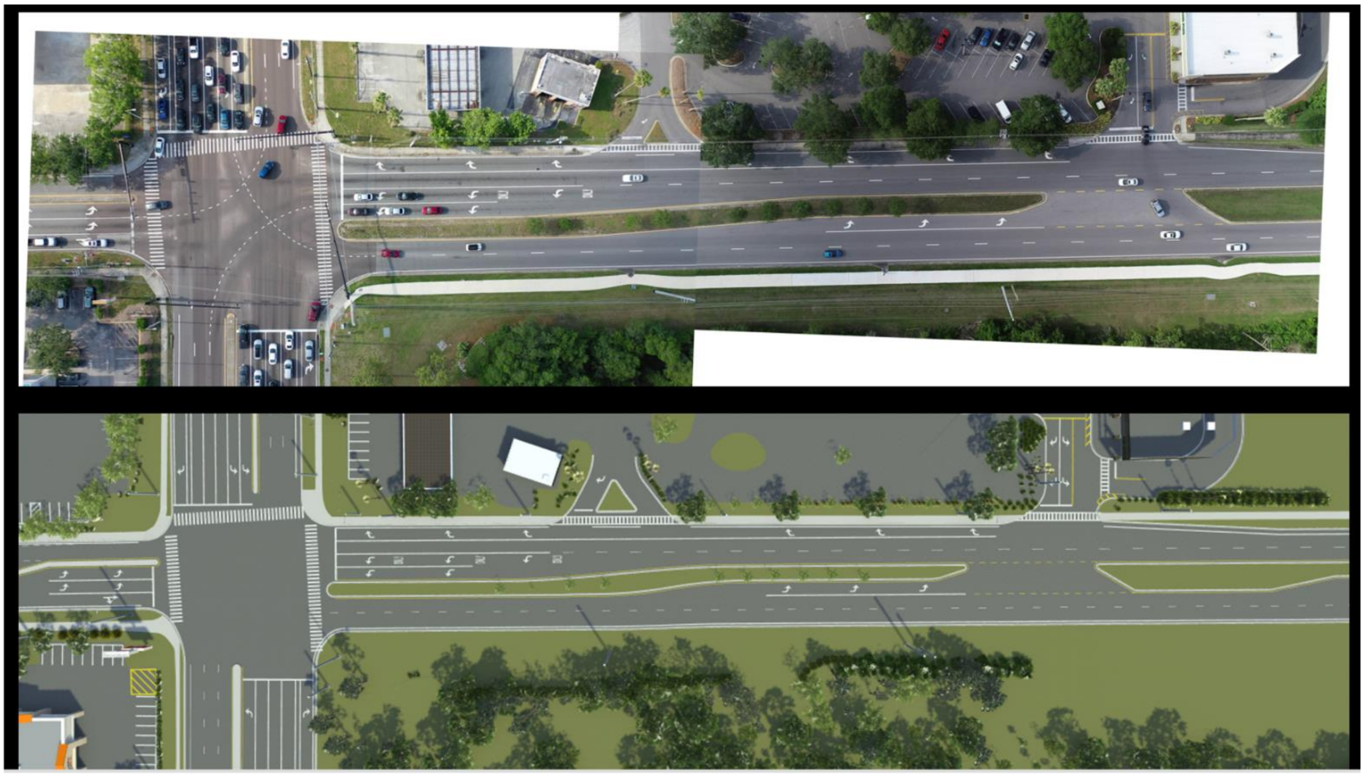

Figure 1: Example of UCF SST CitySim Digital Twin model vs real world drone image of Alafaya@McCulloch

This project will create algorithms to measure sensor accuracy and approximate installation suggestion to obtain the best performance. It will also suggest whether the sensor is suitable to perform the intended functions at a location.

Moreover, the developed DT tool will also enable sensor placement analysis in the simulator before its implementation in the real world. Thus, it will make the deployment easier and more effective for FDOT as the sensor installations are expensive. We are providing some snapshots from our prototype software to give an idea of the functionalities and capabilities. For example Figure 2 illustrates an intersection at the University of Central Florida in the virtual environment and Carla LiDAR simulation. In Figure 3, we place a LiDAR sensor on the sidewalk of the road, then set the vertical field of view (V-FOV) as 45-degree, range as 90 meters, and height as 10 feet. The V-FOV is split equally above and below the horizon. After setting all the attributes, we can visualize the blind zone in the light-yellow conical shape. This zone indicates that the LiDAR will not detect anything from that region. Also, at the far top, we can see the range of the LiDAR.

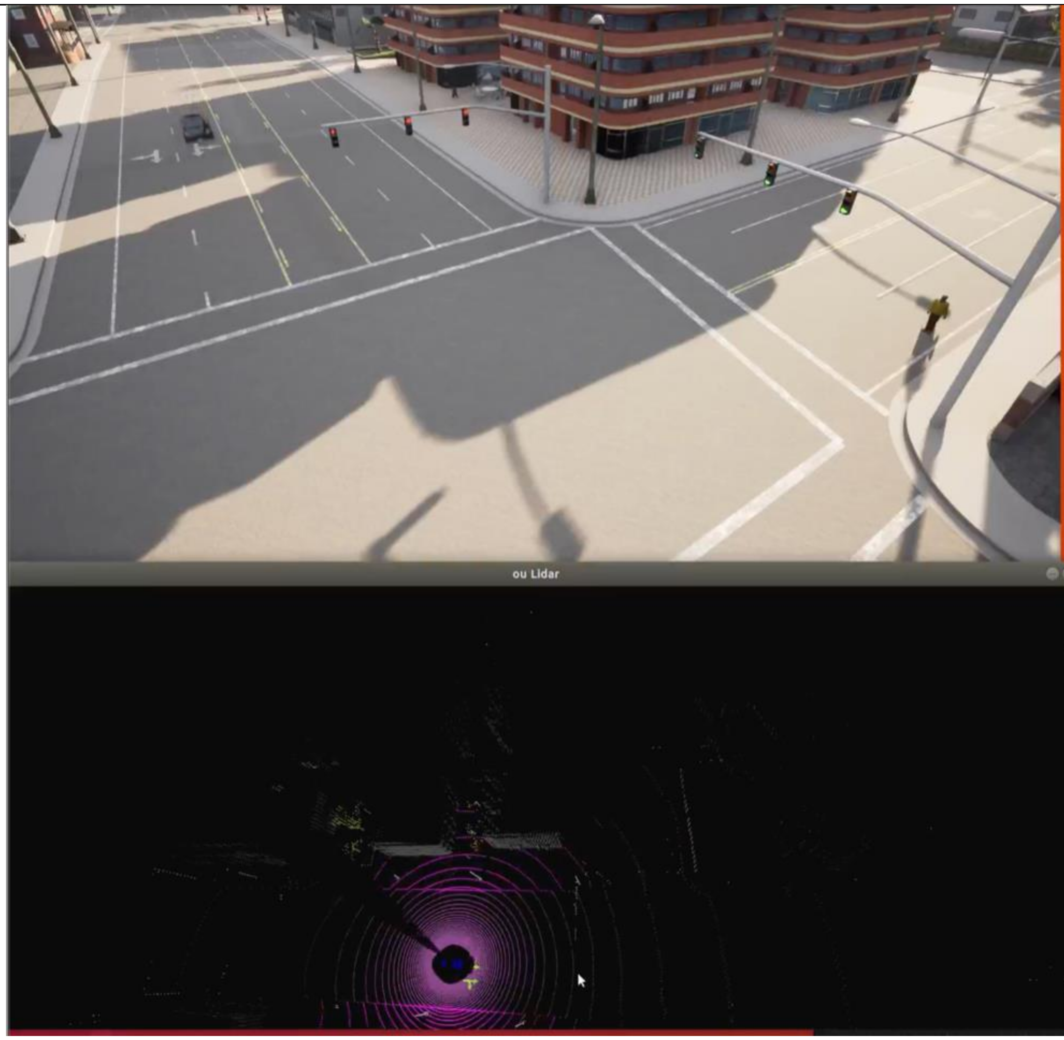

Figure 2: LiDAR simulation base on CARLA

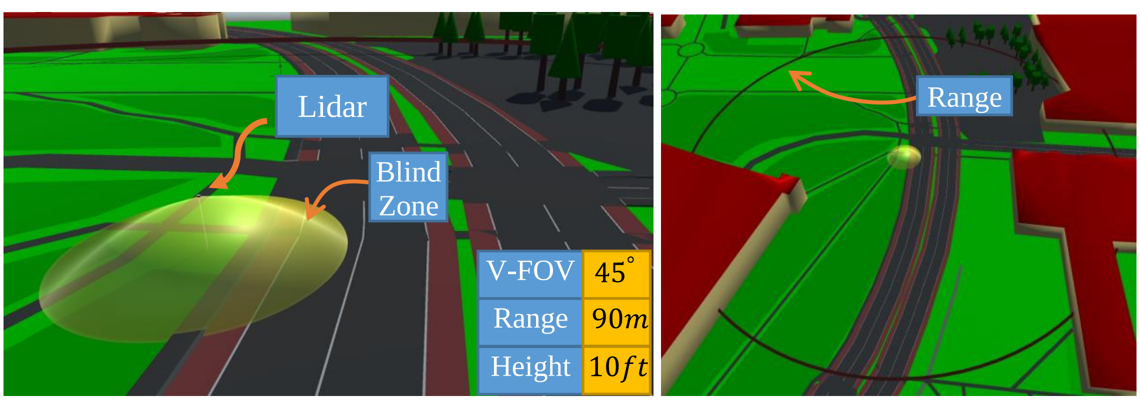

Figure 3: Single LiDAR placement analysis

Figyre 4’s snapshot illustrates a scenario where two LiDAR sensors have been placed on the opposite side of the intersection. The attributes of both the LiDAR sensors are similar to the previous one. From this configuration, we can observe that both sensors have blind zone individually. However, we can combine the sensing data from both sensors, and the integrated 3D point cloud data will not have any blind zone.

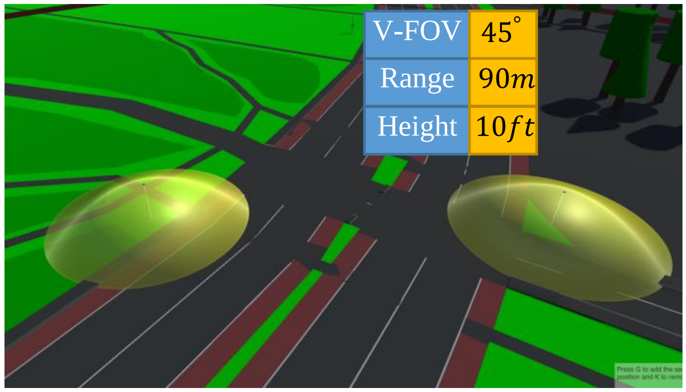

Figure 4: Dual LiDAR placement analysis

Project Benefits **(Select all that apply and explain)**	**Quantifiable Benefits (units, dollars, etc…if applicable)**	**Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits**
○ Materials Enhancement	Sensors	Efficient sensor and CV deployment
○ Materials Savings	Reduced need for traditional field data collection. Optimal deployment of sensors.	Traditionally, studies with field data collection are used. This project proposes a system to replace/reduce the need for field data collection and traditional studies. Moreover, coverage and optimal placement analysis will lead to material savings.
○ Time Savings	Before-After Project	• Avoid construction delays • Quick turnaround than before-after projects • Efficient decision making
○ Lives Saved/Injuries Prevented	Lives and injuries	• Among the benefits of connected vehicles.
○ Other (Explain)	Efficiency and future deployment of CV	• Low-cost implementation of virtual sensing technology and preparing for the advent of CAV • Easier sensor placement analysis – thus increasing productivity for FDOT engineers

*Comments should explain and support urgency, financial benefit, and implementability scores