CONNECTICUT AUTONOMOUS MICROSHUTTLE DEMONSTRATION INITIATIVE

UCONN

Sarah E Tarpgaard
Contracting Officer
DOT Federal Highway Administration
Federal Highway Administration

Dear Ms. Tarpgaard:

The University of Connecticut respectfully requests a grant of $7,237,006 for our Connecticut Autonomous Microshuttle Demonstration Initiative (CAMDI).

The proposed CAMDI is committed to the safe and effective deployment of automated vehicles (AVs) on our nation's roadways. CAMDI will establish an automated vehicle microtransit program that can serve as a national model for service, research, and education. CAMDI has two main goals:

1. Build a cohesive model for deploying autonomous microshuttle technologies that can be replicated within all fifty states.
2. Document the change in public opinion that occurs from exposure to autonomous vehicles operating within the transit systems.

To achieve these goals, CAMDI will safely and effectively execute a four-phase autonomous microshuttle deployment in rural, micro-urban, and urban environments. CAMDI will focus on systematic operational data collection, analysis, and dissemination, AV technology research efforts to support the development of and best practices for AV deployments nationwide, and an extensive public engagement effort to ensure that the effort is successful and to chart changes in public opinion resulting from the AV deployment. The development of a Standard Operation Procedure based on the experiences of the autonomous micro-vehicle demonstration will facilitate safe adoption and deployment of AVs in communities nationwide.

UConn has a diverse research team that consists of faculty from philosophy, computer science, transportation, business, geography, electrical and mechanical engineering to name a few. The University provides a significant resource of knowledge and expertise to evaluate a wide range of topics related to autonomous and connected vehicles.

Thank you for your consideration of our request. Should you have any questions, please feel free to contact Dr. Eric Jackson, Associate Professor and Director, CTSRC at (860) 486-8426, or eric.d.jackson@uconn.edu

Sincerely,

Eric Jackson, PhD

Summary Table

Project Title	Connecticut Automated Microshuttle Demonstration Initiative
Eligible Entity Applying to Receive Funding	University of Connecticut Sponsored Program Services 438 Whitney Road Ext., Unit 1133 Storrs, CT 06269-1133
Point of Contact	Laura Kozma, Executive Director 860-486-3622 preaward@uconn.edu
Proposed Location for the Demonstration	Storrs, Connecticut Mansfield, Connecticut Stamford, Connecticut
Proposed Technologies for the Demonstration	Autonomous Microshuttles
Proposed Duration of the Demonstration	09/01/219-08/31/2022
Federal Funding Amount Requested	$7,237,006
Non-Federal Cost Share Amount Proposed	$1,087,439
Total Project Cost	$8,324,445

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1. Executive Summary

1.A Vision

The proposed Connecticut Automated Microshuttle Demonstration Initiative (CAMDI) is committed to the safe and effective deployment of automated vehicles (AVs) on our nation's roadways. CAMDI will establish an automated vehicle microtransit program that can serve as a national model for service, research, and education. CAMDI offers a four-phase strategic demonstration approach designed to test and evaluate automated microshuttles in increasingly complex scenarios, from rural to urban geographies and from fixed route to on-demand service. Vehicles will run under varied, and often adverse, New England weather conditions. This staged deployment and testing strategy will provide data and information to the USDOT on a spectrum of deployment challenges. We aspire to ensure that AVs achieve the maximum possible benefit to our citizens in terms of increased mobility, sustainability, and access to technology.

1.B Key Partners, Stakeholders, and Team Members

CAMDI is a public/ private partnership committed to promoting adoption of AVs on our nation's roadways. Team members represent transportation, research, municipal, and public safety interests to facilitate engagement by the many stakeholder groups affected by AV technologies. Our multi-sector engagement approach ensures that demonstration outcomes can impact not only the transportation community, but also technology researchers and developers, policy makers, community outreach professionals, and the educational community.

Our partners and stakeholders are listed below. Details on partner roles, qualifications, and responsibilities can be found in Part 2, Management Plan:

Research and Education

University of Connecticut:

- CT Transportation Safety Institute
- Transportation Services
- Division of Public Safety
- Transportation Safety and Technology Research Group
- School of Engineering

Private Sector

EasyMile (vehicle manufacturer)

FirstTransit (vehicle operator)

Transportation Community

CT Department of Transportation

CT State Police

Municipalities

Town of Mansfield

Town of Stamford

1.C Goals

CAMDI has two main goals:

3. Build a cohesive model for deploying autonomous microshuttle technologies that can be replicated within all fifty states.
4. Document the change in public opinion that occurs from exposure to autonomous vehicles operating within the transit systems.

To achieve these goals, CAMDI will safely and effectively execute a four-phase autonomous microshuttle capability in rural, micro-urban, and urban environments. CAMDI will focus on systematic operational data collection, analysis, and dissemination and multi-pronged AV technology research efforts to support the development of and best practices for AV deployments nationwide.

1.D Geographic Area of Demonstration

CAMDI proposes a four-phase deployment that leverages three distinct geographies, as illustrated in Figure 1. The UConn Depot Campus and the UConn Storrs campus are 3 miles apart and nearly contiguous but have different physical characteristics. Situated on 350 acres of land, the Depot Campus is an easily-isolated, low building and low population density environment with existing road infrastructure. The 5.6 mi2 UConn main campus has an academic year population of over 60,000 students, staff, and faculty, making it a high density, micro-urban community environment. These two campuses offer easy access to vehicles and to rural and urban shuttle routes by the deployment team and researchers. The UConn Stamford campus, located 40 miles from New York City, is in one the most heavily congested travel regions in the country. A Phase IV in this urban transit hub will demonstrate the efficacy of the CAMDI deployment model in a challenging urban scenario.

The four phases of the demonstration and their locations are as follows:

Rural: Phase 1: Establish an autonomous vehicle test facility on the UConn Depot Campus to evaluate vehicle performance on property that can be isolated for safe autonomous microshuttle testing. Phase I will also document all the necessary infrastructure, hardware, software, policy, and regulatory steps required to deploy AVs. Following a successful demonstration in this low-density environment, further testing will be conducted on UConn's main campus in Storrs, CT.

Micro-Urban: Phase 2: Deployment of a fixed route microshuttle transit system, providing first and last mile connectivity for students, staff, and visitors on a variety of roads with varying levels of vehicle and non-motorist activities. This system will provide connectivity between multiple destinations on campus including parking lots, academic buildings, residence halls, and the Mansfield Town Center.

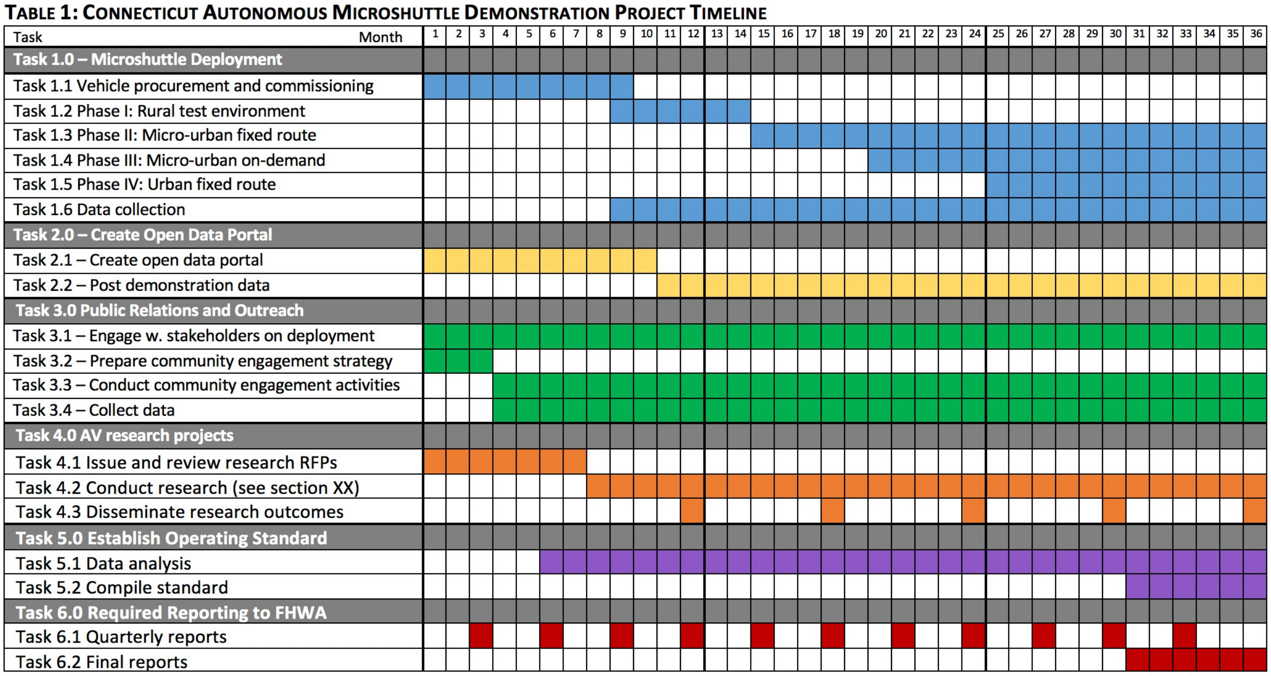
Micro-Urban: Phase 3: Introduce demand-responsive capabilities along a fixed route. Users will be able to input their origin and destination into a mobile app to request a ride, and microshuttle vehicles will dynamically deploy according to demand.

Urban: Phase 4: A fixed-route deployment in downtown Stamford will connect one of the nation's busiest train stations to UConn's Stamford Campus, housing, and businesses within 1-mile of the train station.

1.E Proposed Period of Performance

Table 1 summarizes the envisioned 3-year program timeline. See also part 2, Management Plan.

TABLE 1: CONNECTICUT AUTONOMOUS MICROSHUTTLE DEMONSTRATION PROJECT TIMELINE



2. Goals

CAMDI has two main goals:

5. Build a cohesive model for deploying autonomous microshuttle technologies that can be replicated within all fifty states.
6. Document the change in public opinion that occurs from exposure to autonomous vehicles operating within the transit systems.

The proposed project at UConn meets many of the focus areas outlined in the FHWA NOFO. As one of the most densely populated states in the country, Connecticut sees numerous challenges related to congestion, along with the associated impacts on travel time reliability and emissions. While transit is available on UConn's main campus, coordination of first and last mile connectivity is limited. Recently, autonomous microshuttles have emerged as a potential solution to this problem. This project will address the key goals outlined by FHWA.

To achieve these goals, CAMDI will safely and effectively execute a four-phase autonomous microshuttle deployment in rural, micro-urban, and urban environments. CAMDI will focus on systematic operational data collection, analysis, and dissemination, AV technology research efforts to support the development of and best practices for AV deployments nationwide, and an extensive public engagement effort to ensure that the effort is successful and to chart changes in public opinion resulting from the AV deployment. The development of a Standard Operation Procedure based on the experiences of the autonomous micro-vehicle demonstration will facilitate safe adoption and deployment of AVs in communities nationwide.

The tasks required to reach the goals of the demonstration are summarized in Table 2 and are elaborated on in the subsequent sections of the Project Narrative and Technical Approach.

Table 2: CAMDI Tasks Aligned with FOA Goals

Task #	Task Description	FOA Goal(s)
Task 1	Execute a new AV microshuttle deployment in rural and urban environments while documenting: • Procurement Process and Challenges • Contracting and Partnerships in the State • Policy Changes • Permitting Requirements • Required Collaborations and Partnerships for Successful Deployments • Data Collection Planning • Daily Operations • Supplemental Data Collection Required for Safety • Reporting and Operations Requirements	• Safety • Data for Safety Analysis & Rulemaking
Task 2	Create an open data portal for the USDOT and researchers to access data collected	• Data for Safety Analysis & Rulemaking
Task 3	Conduct a public engagement and outreach campaign to ensure a successful deployment and to educate the public on the integration of AVs into our transit system	• Community Engagement
Task 4	Conduct research in both technical and behavioral aspects of AVs in support of safe deployments.	• Safety • Data for Safety Analysis & Rulemaking
Task 5	Establish a Standard Operating Procedure for safety and evaluation of effective daily operations	• Safety • Data for Safety Analysis & Rulemaking

3. Focus Areas

Below each focus area is addressed in this project.

Table 3: CAMDI Tasks Aligned with FOA Focus Areas

Task #	Task Description	FOA Focus Area(s)
Task 1	Execute a new AV microshuttle deployment in rural and urban environments	• Significant Public Benefit • Addressing Market Failure or Other Compelling Public Need • Transportation-Challenged Populations
Task 2	Create an open data portal for the USDOT and researchers to access data collected	• Significant Public Benefit • Addressing Market Failure or Other Compelling Public Need
Task 3	Conduct a public engagement and outreach campaign to ensure a successful deployment and to educate the public on the integration of AVs into our transit system	• Significant Public Benefit • Addressing Market Failure or Other Compelling Public Need • Transportation-Challenged Populations
Task 4	Conduct research in both technical and behavioral aspects of AVs in support of safe deployments.	• Significant Public Benefit • Addressing Market Failure or Other Compelling Public Need • Economic Vitality • Complexity of Technology • Diversity of Projects • Transportation-Challenged Populations • Prototypes
Task 5	Establish a Standard Operating Procedure for safety and evaluation of effective daily operations	• Significant Public Benefit • Addressing Market Failure or Other Compelling Public Need • Economic Vitality

3.1 Significant Public Benefit

UConn, Storrs, and Stamford are being used as a pilot for larger-scale deployments, achieving significant public benefit will occur when the data collected in this pilot are made public for analysis and lessons learned in Connecticut are applied in AV deployments across the country. The benefits to the state of the practice and public, in general, are discussed below.

First and last mile connectivity- Connectivity and access for those with limited mobility has emerged as one of the key transportation challenges throughout the country. Even where dense and well-developed transit networks exist, would-be riders often opt for single occupancy vehicle travel due to the distance between transit stops and their final destinations, as well as the complications involved in making a connection, or the lack of visibility of transit at their origin or destination. Travelers with disabilities and older adults face additional difficulties due to restricted mobility.

The proposed project seeks to mitigate these challenges by connecting transit and remote parking with major employment centers and points of interest using autonomous microshuttle vehicles. Deployments in both urban and rural areas of UConn's Main Campus will offer easy connectivity for workers, residents, and students. By blending traditional transit concepts with the convenience of ride hailing services, this project will encourage mode diversions from single occupancy vehicles.

The introduction of microshuttle service on the UConn campus will provide individuals without cars more choice, particularly when accessing public transportation. In addition, quality service is anticipated to induce some students, faculty, and visitors to get out of their personal vehicles to travel across the campus and to the Mansfield Town Center and potentially beyond via transit. Car ownership costs in Connecticut are higher than the national average in nearly every category, ranking the state the 11^{th} highest, according to a study conducted in 2016 [1]. According to AAA, annual auto costs range from \$5,500 to more than \$7,000 nationally, depending on miles driven. If even 1 percent of students who currently have a car were able to avoid purchasing and maintaining a personal vehicle, annual costs of auto ownership would decrease \$625,000 annually, assuming annual costs of \$6,250. If 5 percent of students did not own a vehicle, vehicle operating costs would be reduced by more than \$3 million annually.

Safety, Mobility, and Environmental Benefits- Deployment of the microshuttle technology on the UConn main campus and in Stamford is expected to improve access between transportation facilities, providing increased modal choice to area residents, students, employers, and visitors. UConn students and faculty can use the shuttle service to access the Mansfield Transportation Center. Aged and or disabled individuals/students who rely heavily on public transportation or assistance from others to travel may also benefit from the microshuttle service, which offers enhanced human-independent mobility. First and last mile connectivity is also essential in connecting underserved communities to healthcare and other public services.

Safety Benefit- Human error is responsible for an estimated 94 percent of crashes in the United States according to NHTSA. Microsimulation modeling has been conducted that estimates an 85 percent penetration rate of autonomous vehicles leads to a 50 percent reduction in crashes [2].

While this analysis focuses on system-wide performance, it is anticipated that the AV technology being utilized in this program would play a major role in reducing the risk of crashes.

Emission Savings- Emission savings are based on lower carbon dioxide (CO2) releases related to the reductions in fuel consumption. Because the AVs being used for this program are electric, emissions savings are anticipated because less environmentally-friendly vehicles could potentially be removed from the roadway.

3.2 Addressing Market Failure or Other Compelling Public Need

Congestion and Emissions- The implementation of microshuttle service at UConn will reduce the need for single occupancy vehicle trips through high density and heavy pedestrian traffic area by enhancing connectivity options. Fleet management software and a demand-responsive operation, can be used to maximize capacity and system efficiency during peak hours. A vehicle operating at capacity and stopping where requested, will be able to complete its route and return to the pick-up location in approximately 15 minutes. By operating entirely on battery electric power, the microshuttle vehicles will not directly emit pollutants into the air in the local area, having a positive impact on local air quality.

Promote Public Acceptance of AVs- Recent reports by the National Academies of Sciences, Engineering, and Medicine, US DOT, and NSF cite the need for further research, particularly in areas that facilitate innovation, safety, sensor development, artificial intelligence, and safe human-AV interactions which will facilitate public acceptance of AVs. [3-8].

Only if this technology is accepted and implemented by the public will the potential benefits of this technology (e.g., improved mobility, faster deliveries, fewer crashes, reduced congestion and emissions, and better accessibility for the disabled, elderly, young, and economically disadvantaged) be fully realized [4]. However, the need for research and education is critical to understand the potential negative impacts (e.g., increased energy consumption congested city streets, crowded inefficient freight corridors, and an increased widening of the social classes due to one's ability to afford and benefit from this technology) of AV technology. [5, 6].

The Automobile Association of America (AAA) conducts numerous surveys on public perception and fears surrounding automated and autonomous vehicles. Their most recent survey indicated that 40 percent of Americans are misinformed on this technology and fully expect that current partially automated driving systems, have the ability to operate without the input of an operator driver [9]. The misconception of systems like Autopilot, ProPILOT or Pilot Assist, is common and underscores the need to educate the public on current technologies, their true capabilities and future opportunities. Furthermore, AAA reports that three-quarters (73 percent) of American drivers surveyed are too afraid to ride in a fully self-driving vehicle [8]. This was a significant increase from an earlier survey in 2017 where 63 percent surveyed reported to be fearful of these vehicles

[8]. This increase is likely due to recent fatal crashes involving Uber's self-driving vehicle and Tesla's autopilot. AAA also surveyed non-motorists, where two-thirds (63 percent) of responding adults would feel less safe with self-driving vehicles on the road as opposed to human drivers [8]. If AVs vehicles are to be successful and their full benefits to society realized, the public needs to gain confidence in this technology through positive experiences and education. The ability to interact with and utilize an innovative technology will increase adoption for that individual as long as their experience is positive. They will, in turn, share their experience with their peers' thus increasing positive public perception of this new technology. UConn will use these vehicles for research into public perception and outreach to understand and alter public attitude towards self-driving vehicles.

Contributions to technical advancements using these consumer, "off-the-shelf" shuttles might be limited by the proprietary nature of the software and hardware, but the resulting research can still be significant and transformative. These vehicles are a combination of complex systems and sensors that have cybersecurity vulnerabilities in addition to operational challenges. The National Science Foundation has invested heavily in research into intelligent, autonomous systems, including AVs, yet recognizes the need for further advances.

In October of 2018, the US Department of Transportation (DOT) released its latest guidance titled "Preparing for the Future of Transportation: Automated Vehicles 3.0." The USDOT describes their position as purveyors of "voluntary technical standards" as opposed to traditional regulatory methods that might stifle innovation [9]. This essentially leaves manufacturers to self-police and regulate their products. However, the rapid development and deployment of these systems can lead to significant security flaws and limited quality and safety testing. Independent testing and verification of safe operation in all possible weather and operating conditions is the foundation of this proposal. The development of new, innovative sensors, systems and algorithms will be investigated in tandem with the testing and verification of purchased commercial off-the-shelf products.

3.3 Economic Vitality

Economic Opportunity- UConn serves as a major employment center within the very rural town of Mansfield. The UConn Storrs campus has over 5,000 full and part-time staff that serve over 32,000 students. As a land grant university, UConn is surrounded by farmland and residential housing. Redevelopment of the Mansfield downtown area has created a mixed-use commercial center with businesses on the first floor and five upper stories of residential space. This revived city center has created a new urbanist development and highly dense housing that requires frequent and efficient public transit. Enhanced transit connectivity with the transit hub in the new Mansfield center will create regional access to new jobs and education, especially for individuals without personal automobiles and mobility limitations. Recently, UConn like major cities has seen a shortage of surface parking requiring an increase in the price of parking and construction of parking lots further from the center of campus. As the trend of urban redevelopment continues, it is possible that current single occupancy vehicle commuters or those with mobility challenges may soon be required to walk further distances to their destinations after parking or devote more of their income to parking for work or education. Conversely, one anticipated long-term benefit of autonomous vehicles is the ability to convert underutilized parking into higher value land uses. The enhanced first and last mile connectivity created by the proposed project will provide additional options for both transit-based households and choice riders as land use dynamics, and real estate trends continue to shift.

3.4 Complexity of Technology

One of the most advanced vehicles of currently on the market is manufactured by EasyMile. EasyMile's technical design works on a three-pronged approach. The first is perception, allowing the shuttle to understand the surroundings in which it is located, to detect obstacles and to anticipate movement. The second decision, is where the shuttle calculates and determines its route and path. Finally, there is action, where the shuttle carries out the decisions made by the vehicle's computer to the best of its ability. Furthermore, EasyMile's shuttle has an integrated onboard communication system. This system consists of an intercom system, and 360° interior camera to remotely view the vehicle's interior in real-time and answer any questions passengers may have.

EasyMile's EZ10 Driverless Shuttle was specifically designed to meet the needs of an autonomous, driverless vehicle while also optimizing navigation and safety features. With neither a steering wheel nor pedals, the vehicle uses data from Lidar (light detection and ranging) sensors, cameras, global positioning system real-time kinematics, inertial monitoring and odometry sensors which are merged and analyzed using deep learning algorithms. These real-time onboard systems allow the EasyMile shuttle to make decisions and react to its surrounding environment without a driver onboard. The EasyMile shuttle is an electric vehicle that can hold up to 15 passengers, 11 seated and four standing. The shuttle can operate up to 9 hours on a single charge under ideal conditions.

The EZ10 is the most deployed autonomous shuttle in the world. Since 2015, EasyMile has successfully deployed its vehicles over 250 times in over 23 countries on four different continents. Over 300,000 people have traveled on EasyMile, for more than 200,000 miles. They have experienced several environments (city centers, university campuses, corporate campuses, amusement parks,…), traffic conditions (segregated road, mixed traffic with bicycles and pedestrian, mixed traffic with low-speed cars, …), and various weather conditions (hot countries, snow, rain, ...). Thanks to their "Safety First" approach, there have been no collisions involving a vehicle in operation. Their research and development, testing and deployment processes are focused on risk assessment, and management makes their vehicle the safest on the market. As a result of these processes, EasyMile is the first and only shuttle provider in the world to have a commercial service running fully autonomous with no operator onboard.

Autonomous electric shuttles are the most innovative solution to fill existing gaps in transportation coverage. A fleet of EZ10s are well-suited for short trips (0.3 to 3 miles) and can be available on-demand 24 hours a day. EasyMile's experience positions the company to be the strongest partner to create a successful project for UConn. EasyMile has created a scalable process of programming, deployment, and training that allows us to meet quality and safety standards effectively. We are proposing to provide all of the staff support needed in order to ensure the project's success.

3.5 Diversity of Projects

The University of Connecticut is proposing a number of research topics that will be explored using the vehicles purchased, operated, maintained, and deployed using a four-phase approach. Table 4 outlines the diversity of the UConn staff that will be involved in these research projects. Faculty from across campus will be asked to propose unique, innovative research and data collection projects with the requirement that the data collected are shared and added to the open data portal. UConn will contribute over $1 Million dollars in cost share to support research projects using these vehicles. Cash from UConn will support ten graduate research assistants in year two and three of this project for a total of at least 20 students engaged in active research over the three-year project. Faculty with expertise in the areas below will advise these students and be required to contribute 10% of their salary as in-kind cost share. The internal grant completion will allow UConn to select the best research ideas from across many disciplines to produce a very diverse research effort.

Table 4: Faculty and Diversity of Projects proposed for CAMDI Tasks

Focus Area	Faculty	Title	Department
Public Perception and Adoption	Kerry Marsh	Professor	Psychological Sciences
	Carol Atkinson-Palombo	Associate Professor	Geography
	Norman Garrick	Professor	Civil and Environmental Engineering
	Sara C. Bronin	Professor	Law Instruction and Research
	Thomas F. Gallivan	Professor	Law
	Peter Kochenburger	Assistant Clinical Professor	Law Instruction and Research
	Joseph MacDougald	Assistant Clinical Professor	Law
Human and Machine Interaction	Kerry Marsh	Professor	Psychological Sciences
	Alexandra Paxton	Assistant Professor	Psychological Sciences
	Kristine Nowak	Professor	Communication
	Carol Atkinson-Palombo	Associate Professor	Geography
	Sara C. Bronin	Professor	Law Instruction and Research
	Thomas F. Gallivan	Professor	Law
	Peter Kochenburger	Assistant Clinical Professor	Law Instruction and Research
	Joseph MacDougald	Assistant Clinical Professor	Law
	John Ivan	Professor	Civil and Environmental Engineering
Cyber Security	Marten van Dijk	Professor	Electrical and Computer Engineering
	Bing Wang	Dept. Head and Professor	Computer Science Engineering
	Ben Fuller	Assistant Professor	Computer Science Engineering
	Michael Laurent	Professor	Computer Science Engineering
	John Chandy	Department Head & Professor	Electrical and Computer Engineering
Sensing and Connectivity	Song Han	Assistant Professor	Computer Science Engineering
	Sung Yeul Park	Associate Professor	Electrical and Computer Engineering
	Abhishek Dutta	Assistant Professor	Electrical and Computer Engineering
Machine Learning and Decision Making	Krishna R. Pattipati	Distinguished Professor	Electrical and Computer Engineering
	Abhishek Dutta	Assistant Professor	Electrical and Computer Engineering
	Fei Miao	Assistant Professor	Electrical and Computer Engineering
	Jin Zhu	Assistant Professor	Civil and Environmental Engineering

3.6 Transportation-Challenged Populations

UConn has a long history of campus improvements to help mobility-challenged populations. In 1967 UConn established the Program for the Physically Handicapped under Public Health Services. The goal of this group was to improve access to the University for students with disabilities. This center was key for improving access to buildings and reviewing plans to ensure accessibility to UConn's Student Union, Life Sciences, Administration, Jorgensen, School of Education, Beach Hall, and School of Business buildings. To further improve access on campus, UConn enacted Section 504 of the Rehabilitation Act of 1973, in June of 1977. This program required that students with disabilities have equal opportunities and access across campus. In 1992 that program was formalized and the "Center for Students with Disabilities (CDS)" was created. Renovations and upgrades to UConn's campus resulted in modified ramps, doors, lavatories, sidewalks and installed elevators in inaccessible buildings. As a result, in 1999, New Mobility Magazine voted UConn one of the Top Ten Disability-Friendly Colleges. As of June 2018, the CSD provides services for over 4,300 students with disabilities at UConn. Today, the CSD consists of over 20 professional staff members and a number of graduate and undergraduate student employees. From August 2017 to May 2018, CSD celebrated their 50th anniversary by hosting campus-wide events including speakers, conferences, exhibits, movies, aimed to educate the campus community on including disability as diversity, and explored the history of the disability rights movement.

The CDS at UConn provides an amazing opportunity to collaborate and involve proactive students, faculty, and staff, with a wide range of disabilities into the evaluation of automated vehicle technologies. One of the designed deployment routes will have a stop just outside the Wilbur Cross building which houses the CDS. Students, faculty, and staff affiliated with the CDS will be asked to participate in this pilot program and provide critical feedback on current limitations and how this technology may improve their transportation options in the future.

3.7 Prototypes

UConn currently does not have the capability to manufacture a full vehicle for testing and research. The ability to purchase a fully automated self-driving vehicle will allow researchers to bypass the challenges and delays that come with testing and development of entire systems and focus on the refinement of algorithms and placement, sensitivity, and design of new sensor systems. However, this purchase should not be considered as off-the-shelf or a tried and true technology. EasyMile even states that "Projects like UConn's are at the edge of what the technology is able to provide today, which means that a safety operator will be necessary for at least the next few years." This purchase would facilitate a new innovative research area at UConn, and in the region, that would engage groups across the university and enrich our educational programs.

The majority of research groups across the country have focused on the technical development of autonomous vehicles. UConn has decided to expand our focus and concentrate on the societal challenges and impacts that result from deploying these vehicles while exploring the technical challenges. Furthermore, we will also develop outreach and education activities utilizing the vehicles purchased and the technology in development. To provide the capabilities needed to support the research described above, UConn will purchase commercially available autonomous vehicles. Given the inherent proprietary nature of the systems and sensors on these vehicles, UConn will work with vehicle manufacturers to execute the necessary non-disclosure agreements and in addition attach new and innovative sensors to the vehicles to collect data, refine algorithms and verify real-time operations against the vehicles onboard sensors.

4. Requirements

As one of the most densely populated states in the country, Connecticut sees numerous challenges related to congestion, along with the associated impacts on travel time reliability and emissions. Recently, autonomous microshuttles have emerged as a potential solution to this problem. The following section outlines how the proposed deployment will address each of the required focus areas as outlined by FHWA. Following award and agreement with U.S. DOT, the project team will initiate project management and systems engineering activities which will establish a baseline for successful project delivery. The deployment will then occur using a phased approach, with a preliminary test and learn phase followed by three multi-year projects. The objective of the applicant team is to sustain and grow service beyond the grant period.

Table 5: NOFO Requirements and Associated CAMDI Project Tasks

Requirement	Associated Task	Section
A. Research and development of automation and ADS technology with a preference for demonstrating L3 or greater automation technologies;	Task 4: Conduct research in both technical and behavioral aspects of AVs in support of safe deployments.	4.1
B. Each demonstration must include a physical demonstration;	Task 1: Execute a new AV microshuttle deployment in rural and urban environments	4.2
C. Gathering and sharing of all relevant and required data with the USDOT throughout the project, in near real time.	Task 2: Create an open data portal for the USDOT and researchers to access data collected	4.3
D. Include input/output user interfaces and allow users with varied abilities to input a new destination or communicate route information and to access information generated by the ADS	Task 3: Conduct a public engagement and outreach campaign to ensure a successful deployment and to educate the public on the integration of AVs into our transit system	4.4
E. Address how the demonstration can be scaled to be applicable across the Nation in furtherance of technical exchange and knowledge transfer.	Task 5: Establish a Standard Operating Procedure for safety and evaluation of effective daily operations	4.5

4.1 Focus on the Research and Development of ADS Technology

Task 4 of this research effort is devoted to the wide range of research project that will be generated as a result of this deployment. Below each of the potential areas of research at UConn are outlined.

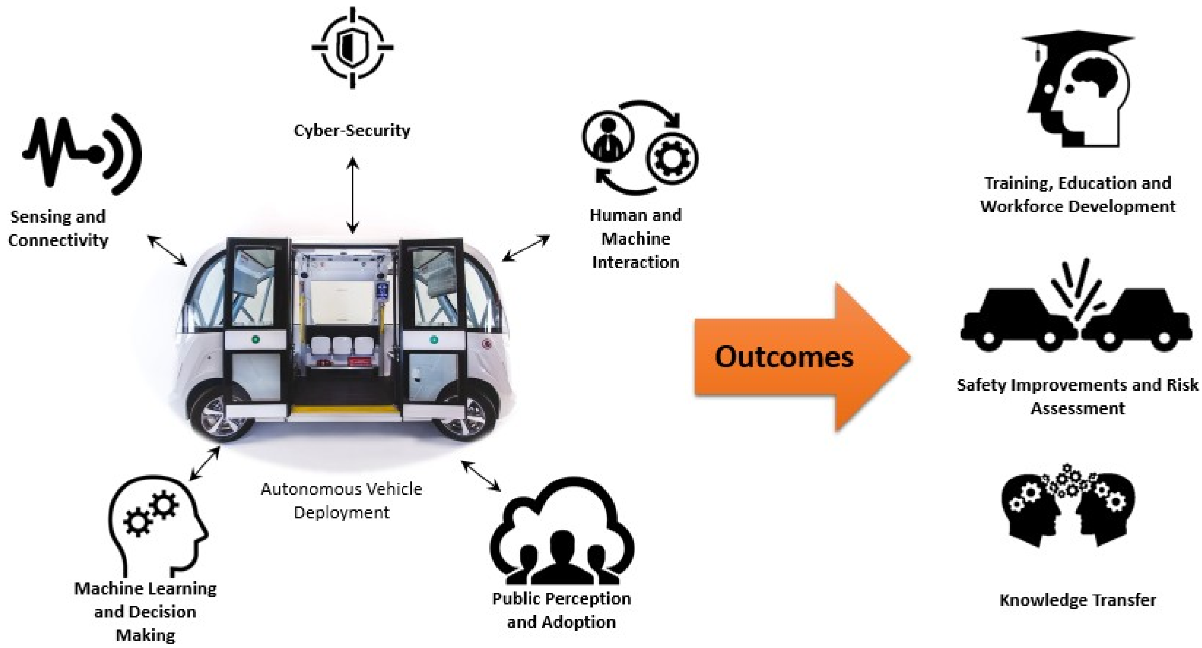
Availability of Microshuttle Evaluation Data- Commercially available shuttle vehicles have undergone various amounts of testing, but little evaluation has been done to compare vehicle operations and capabilities in a controlled environment and along the same course. Communities looking at the future use of these vehicles may not understand the capabilities of each manufacturer or vehicle, and may not know how best to utilize the vehicle in their situation. Testing conducted on UConn's Depot Campus will identify potential barriers and resulting solutions with respect to deployment within Connecticut and beyond. This will be achieved by evaluating the performance of AV shuttles operating under the same conditions across a range of use cases. Potential use cases will include varying pavement conditions, snow testing, and the evaluation of the minimal amount of infrastructure-based technologies required for vehicles to meet their stated performance specifications.

Sensor Data Collection and Development- The project team will follow the U.S. DOT systems engineering process to ensure the project progresses in a consistent and systematic process that can be replicated in future deployments. Following the award, a systems engineering management plan will be developed and updated periodically throughout the project. This plan will describe the information needs to complete the Concept of Operations, Systems Requirements Specification, Architecture Design, and Test Plan deliverables. It is anticipated that the systems engineering task will initiate prior to the Phase 1 Vehicle Evaluation task, with most deliverables developed iteratively during Phase 1. Testing will conclude after the initiation of Phases 2, 3 and 4 to ensure each deployment meets the established requirements.

Mini-Grants for AV Research and Development- the UConn AV deployment project management team will establish a research program, where researcher across campus can propose projects that will use the AVs deployed. Funding for these research projects will be supplied by UConn and will support graduate and undergraduate research assistants over a broad range of disciplines. Below is a list of potential research areas or projects the UConn would expect to fund based on an internal RFP and evaluation process.

UConn has identified researchers across campus who are interested in and actively involved in fields related to AV research. Research focus areas and predicted outcomes are described in detail below. Figure 1 outlines the areas in which these vehicles will inspire and produce innovative research and educational activities at UConn and in the region. Each of these research areas will engage faculty and students from across the University as outlined in Table 4.

Figure 1: CAMDI Focus on the Research and Development of ADS technology



Public Perception and Policy with Respect to Autonomous Vehicles- The regulation of emerging transportation technologies is already the subject of intense debate. Discussions are most intense in cities that are at the cutting edge of technology, such as New York, San Francisco and Boston [5, 12-15]. City streets are being inundated by ride source services such as Uber and Lyft, and more recently by a plethora of devices such as dock-less bikes and scooters that fall under the label of Mobility-as-a-Service (MaaS) [16, 17]. The general approach of companies has been to roll out technologies onto city streets, forcing officials to scramble after the fact to address any problems that arise. This is the exact situation the DOTs in the Northeast are trying to avoid since technology moves much more rapidly than policy and infrastructure investments and updates. The UConn facility and vehicles will allow for real-world testing and research in the northeast while educating the region on the future impacts and demands of these vehicles. Similar uncertainties are evident with the testing of AVs in California. Initially, AVs were allowed to be tested on public roads, but the state later revoked the licenses for Uber's self-driving cars [18]. Uber subsequently shifted its testing to Arizona, only to be at the center of a controversy in which a cyclist was killed by a self-driving car (with a human driver intended to act as a safeguard) [19]. These early lessons highlight the need for researchers to be involved in a controlled testing facility where the public is not being placed a risk. Furthermore, this type of testing facility and commercially available vehicles will permit researchers to document, assess, and understand this fast-changing landscape, to determine how emerging transportation technologies can be implemented in a way that maximizes the benefit and minimizes the cost to all sectors of society.

The UConn Transportation Technology & Society (TTS) Research Group believes that effective regulations will only come from answering questions such as, "What Do We Want from Self-

Driving Cars?" This group would make use of the purchased vehicles to try and answer this question and many others. The first stage of their US DOT funded study consists of evaluating the approaches in different cities towards testing and planning for the wider implementation of AVs to better understand the goals that these cities are trying to achieve. On a more granular level, the TTS Group has a current grant from the Kettering Foundation to probe the question of how individuals view AVs and what are their hopes and fears surrounding its implementation. Having the ability to test hypothesis and findings from other groups across the country at UConn would be a significant advancement of that project and its potential outcomes. The TTS Group plans to use the insights gained through this research to inform the AV implementation policy for the State of Connecticut. Having these vehicles at UConn would allow the state legislature the ability to experience and better understand the impacts and applications of this technology.

Human and Machine Interaction

Researchers are beginning to focus on the issues that pedestrians and drivers of non-autonomous vehicles will face in their interactions with AVs. These include understanding the intent of the AV, the loss of human-based information from drivers, and different underlying motives for drivers when the other drivers around are AVs rather than humans.

***Safe and Civil Interactions of Humans and Autonomous Vehicles*-** Drs. Paxton and Marsh, a cognitive scientist and a social psychologist, in collaboration with graduate students, are interested in studying human-AV interactions from a "joint action" and social "ecological perception-action" perspective [20, 21]. From such a perspective, challenges arise from three areas: *joint perception* ("Does the AV 'see me,' and 'know' that I have seen them 'seeing' me?"), *joint action* ("How do the AV and I behave to achieve some mutual goal, such as ensuring our mutual safety?"), and *direct perception* of AVs ("How do I veridically extract information about an AV's intent from its visible actions like changes in speed, direction, and acceleration?", [22-25].

Basic experimental paradigms propose to involve: a) human pedestrians interacting with AVs (e.g., at a crosswalk or intersection [24]) and b) human drivers interacting with AVs (e.g., following behind an AV on the road). Experimental manipulations will include altering the information available to humans interacting with AVs (e.g., by adding displays, lights, signage, or other graphical elements akin to "social robots", [23, 26-28] or changing the behavior of the AVs themselves (e.g., by implementing "gestures" to indicate intent or asking and giving permission to pass; [28, 29]. Dr. Paxton's expertise in data science, computer vision, and machine learning will be of particular importance for this project, as these studies will involve video that will require large-scale computation and data management of rich datasets.

Such experiments will identify specific types of information and communication that support safe and civil interaction involving human drivers and AVs. In examining such questions, we can diagnose specific "pain points" that may appear during the gradual rollout of AV technology and identify behaviors that an AV could exhibit to make interactions between AVs and human drivers more natural to human drivers.

Changing Attitudes Toward Autonomous Vehicles- Community test-beds for AVs have experienced different reactions from residents, with one extreme involving Arizonans attacking Waymo driverless cars with rocks and knives [30]. Drs. Nowak and Paxton propose studying the crucial research question of how individual attitudes and trust in AVs change over time, motivated in part by diffusion of innovation perspective [31, 32]. A longitudinal study would examine changes in acceptance of AVs from before their arrival in the community, to initial exposure to AVs, and after repeated encounters with AVs. Such conventional approaches could be augmented by dynamical modeling approaches, yielding mixed data sources that capitalize on Dr. Paxton's expertise in data science and computationally-rich and data-intensive techniques (natural language analysis, and Twitter scraping, [33, 34]. The goal would be to understand the key variables at the individual level (past experience with technology, dispositional variables), relationship level (density and strength of linkages in small networks), and community level (presence/absence of stakeholder groups) work against or support AV adoption [35]. In addition to describing naturalistic changes in attitudes in the community, potential lab experiments could use established attitude change techniques [36, 37] to examine at a more molecular level what specific approaches lead participants' attitudes toward AVs to change in positive or negative ways.

Public Perception and Policy with Respect to Autonomous Vehicles- The earliest versions of AVs on the nation's roadways require a human driver to be present in the vehicle to take over the driving in the event of a malfunction. A crucially important question that pertains to this "switching" is: "what are the moment-to-moment dynamics of how individuals in vehicles will manage the serious attention challenges of being only occasionally called to operate the vehicle?" Our new $250,000 driving simulator at UConn is an important tool to better understand how various levels of distraction might affect these dynamics. The integration of simulation and real-world testing will allow the TTS group to validate simulation models and construct simulations that may be too risky to test in the field. UConn has also secured and developed simulation software to test autonomous vehicle operation in a virtual environment, but without a real-world vehicle, the dynamics and decisions of those decisions cannot be validated.

Dr. Kerry Marsh, who is a social psychologist specializing in human-environment transactions, is working with a doctoral student to examine attentional challenges in a simulated autonomous vehicle [38]. This work was spurred by a pilot project sponsored by Travelers Insurance in which the team is reviewing the literature on distracted driving interventions (such as phone apps). Guided by that literature, the TTS group is providing support for experiments to test hypotheses regarding factors predicted to slow driver's response time at switching when driving a simulator in autonomous mode (e.g., cell phone versus passenger conversations, e.g., [39-40]. The researchers are also developing experiments to test whether augmented reality (visual perception) could be used to increase engagement during what otherwise would be long periods of ignoring the road, and to use simple action devices (akin to "fidget spinners") for that purpose as well (cf. [41-43].

Interactions Between Pedestrians and Autonomous Vehicles- Vehicle crashes involving pedestrians are thankfully rare, but are on the increase in recent years in the USA, especially as a percentage of total fatalities. Dr. Ivan has proposed interactions between pedestrians and motor vehicles, especially severe conflicts, are more frequent than crashes and can be used to assess pedestrian safety in conditions with low pedestrian or vehicular volumes. Driver and pedestrian inattention has been identified as a likely cause for these recent increases in fatalities. Removing the element of driver inattention and error by introducing autonomous vehicles to the traffic stream could potentially reduce the occurrence of severe conflicts and crashes between pedestrians and vehicles. The proposed autonomous campus shuttle demonstration will provide an opportunity to explore this possibility by observing interactions between pedestrians and both the autonomous shuttle and manual vehicles and identify differences in the severity of these interactions between each combination of road users.

Sensing and Connectivity: Sensor and Communication System Evaluation for Autonomous Vehicle Operations- Although designed to sustain long life, autonomous vehicle systems have yet to be tested over time. New sensors that have not been time tested are prone to degrade in performance due to weather, corrosion, manufacturing anomalies and unanticipated faults and hazards. Systems to check, alert and maintain these sensors need to be developed. Dr. Pattipati seeks to develop robust analytical tools, based on an information ensemble generated from integrated sensor-based (also referred to as data-driven), model-based and knowledge-based approaches, which enable early diagnosis and prognosis (D&P) of incipient faults in and hazards induced by autonomous vehicles. Dr. Javidi plans to apply turbidity mitigation and integral imaging techniques to facilitate information optics and related technologies for imaging in degraded environments. These methods are expected to reduce the effect of degraded environments and improve object visualization, detection, and classification. These are of particular importance to autonomous vehicle operations in harsh winter scenarios.

Furthermore, Dr. Park has proposed to study and analyze battery energy storage and performance under various roadway and weather conditions, specifically: summer and winter weather testing where batteries are placed under high demand by heating and air conditioning systems. Proposed testing would entail the measurement of voltage, current, and temperature in three different scenarios: 1) only battery terminal voltage measurement, 2) battery voltage, current, temperature while charging, and 3) all measurement data available during charging and discharging cycles. Battery life, health, and efficiency will be monitored and optimized to prevent critical failures and vehicle downtime. With regard to AV connectivity research, Dr. Han and Dr. Zhou are designing a software-defined radio (SDR) based configurable high-speed communication module and dynamic real-time traffic scheduling framework to support agile resource management in vehicular networks. These procured autonomous vehicles provide an ideal experimental platform to test out relevant design principles and develop a flexible SDR based communication framework for pursuing future autonomous vehicular networking research.

Machine Learning and Decision Making-The problem of integrating both shared infrastructure information and the AV's sensor information in order to model the environment also remains poorly defined. Hence, UConn will address these two challenges. Dr. Dutta's expertise in model-based and non-model-based learning control techniques would be leveraged to address the above challenges that would make the AVs much more accessible and road-worthy. Dr. Miao plans to build a probabilistic model to predict how a human driver's behavior is affected by increasing numbers of autonomous vehicles on roadways. Using collected simulation data, we will define a hybrid model of a human driving vehicle in different scenarios ("modes"), such as passing through an intersection, driving during rush hour with numerous autonomous vehicles on streets, and waiting for pedestrians. Dr. Zhu is exploring how to understand the emergent behaviors of different entities in a mixed traffic road environment that includes traditional vehicles, autonomous vehicles, drivers, pedestrians, and traffic lights as a complex sociotechnical system. The AV equipment will help researchers capture information to abstract the complex sociotechnical system (e.g., what are the entities and how these different entities are connected), collection data regarding the dynamic behaviors and interactions from a real system during operation using different tools (e.g., sensors, cameras), and build computational models to test and evaluate different attributes, decision rules, and strategies in simulation environments.

Cybersecurity: The Learning Experience and Unauthorized Access- Electronic and cyber systems are crucial components in all modern automobiles. The security and assurance of these components are critical because of the potentially disastrous consequences of unsafe and insecure automobiles. Each of these systems and components becomes a potential door for unauthorized access and sensor input. While systems engineering is a mature discipline, security is considered an afterthought and not a core design tenet. The availability of an autonomous vehicle and the associated infrastructure will greatly enhance the ability for researchers to explore these security risks through hacking challenges called "Hack-a-Thons." These events provide students with real-world experience interacting with the technology of the future and a challenge to attack its weak spots. Potential weaknesses are inherent when technology is rapidly deployed with limited testing and time-proven rigidity. These events are a great learning experience for students and manufacturers.

Secure systems engineering entails bringing security into the systems engineering process including security requirements, security verification, penetration testing, and defensive measures at deployment. As a first step, the security of the established communication protocols needs to be investigated. In particular, the composition of all used protocols needs to be examined. This can be done by applying the Universal Composability (UC) framework, which is used for proving the security of cryptosystems involving multiple protocols and can be used to prove the security of the overall communication (V2V and V2I, where the components that communicate together are assumed to be "ideal" in terms of correctness and security). A next step is to analyze the communication between systems and components in a vehicle, e.g., are bus protocols (CAN and LIN) used in such a way that overall security can again be proven in the UC framework? Expanding the framework to the context beyond a single vehicle, e.g., in the context of V2V and V2I communication is even more challenging, as it involves the protocols that typically operate over the wireless medium, which is even more vulnerable to various attacks.

4.2 Physical Demonstration

The primary objective of this proposal is the physical deployment. This is Task 1, Execute a new AV microshuttle deployment in rural and urban environments. A description of the physical demonstration can be found in Section 5: Approach.

4.3 Sharing of Data with USDOT

As part of Task 2, UConn will create an open data portal for the USDOT and researchers to access data collected. All data collected as part of this project will be collected and stored on the Universities SQL server core. UConn will develop a user interface and data visualization tools to allow the USDOT and authorized users to view the video footage, sensor data, user interfaces, EasyMile's EZFleet system compiles thousands of data points throughout the EZ10s' operations and, as such, can be quite informative for reporting purposes. EasyMile can share many of these data points with the City via its APIs in addition to training the City's Customer Service Ambassadors on how to collect useful operating data throughout the service. More details of the data collected and shared can be found in the Data Management Plan.

4.4 Demonstration and Documentation of User Input and Output Interfaces

Task 3 of this project address the user interface and experience. UConn will conduct a public engagement and outreach campaign to ensure a successful deployment and to educate the public on the integration of AVs into our transit system. User interfaces on the shuttles will be captured and made available as part of the open data portal. A wireframe mockup of the user interface will be developed and posted to the data portal such that researchers can experience what users of the transit system would experience. Any apps that are created will also be made available in a virtual environment for testing and experience. Users of the transit system will be surveyed to evaluate their experience, and the ease of use and utility of these interfaces will be a major part of the user experience survey. Draft survey questions can be found in the Data Management section of this proposal.

4.5 How this demonstration can be scaled up to a national model or approach

One of the key tasks of this project is to document all the process of deploying AVs through this process. Tasks 5 involves establishing and refining standard operating procedures for safe and effective deployment and daily operations. More information regarding this task can be found in the next section.

5. Approach

The proposed project seeks to initiate an autonomous vehicle pilot program on the UConn Storrs campus. This program will purchase four microtransit shuttles to connect remote parking lots with major employment centers and points of interest on UConn's Storrs campus using autonomous microshuttle vehicles. Deployments will offer easy connectivity for workers, residents, and students in both urban and rural settings. Deployment on UConn's campus would take place in three phases.

The following phases are proposed:
Rural: Phase 1: Establish an autonomous vehicle test facility on the UConn Depot Campus to evaluate vehicle performance on property that can be isolated for safe autonomous microshuttle testing. Phase I will also document all the necessary infrastructure, hardware, software, policy, and regulatory steps required to deploy AVs. Following a successful demonstration in this low-density environment, further testing will be conducted on UConn's main campus in Storrs, CT.

Micro-Urban: Phase 2: Deployment of a fixed route microshuttle transit system, providing first and last mile connectivity for students, staff, and visitors on a variety of roads with varying levels of vehicle and non-motorist activities. This system will provide connectivity between multiple destinations on campus including parking lots, academic buildings, residence halls, and the Mansfield Town Center.

Micro-Urban: Phase 3: Introduce demand-responsive capabilities along a fixed route. Users will be able to input their origin and destination into a mobile app to request a ride, and microshuttle vehicles will dynamically deploy according to demand.

Urban: Phase 4: A fixed-route deployment in downtown Stamford will connect one of the nation's busiest train stations to UConn's Stamford Campus, housing, and businesses within 1-mile of the train station.

5.1 Pre-Deployment Details and Approach to Regulations

Federal Level- EasyMile is required to get a federal exemption from the National Highway Traffic Safety Administration (NHTSA) to operate on public roads (as no autonomous shuttle complies with the current Federal Motor Vehicle Safety Standards). Furthermore, UConn and EasyMile will need to apply for an exemption from the terms of the NOFO clause in Section F, Paragraph 2.J, of the Buy America Act. There is not a US-based manufacturer that is currently permitted to operate on public US roads, where the final assembly of vehicles occurs in the United States. In October 2018, NHTSA updated their process for granting these approvals and EasyMile was the first to apply and be approved for projects via this new process.

EasyMile was at the forefront of this change with the federal government during this process. This is a testament to the level of experience that EasyMile has gained deploying the autonomous technology around the world, resulting in us being recognized as the leader in this space. EasyMile continues to work closely with NHTSA, Federal Transit Administration (FTA), Federal Highway Administration (FHWA), Volpe, and other branches of the federal government, and continue to work with California, Colorado, and other states as driverless regulations are developed and refined. The updated federal process requires the importer to submit vehicle and project-specific information. Once the application is submitted, the process is estimated to take less than 60 days. To date, EasyMile has successfully imported all vehicles (around 20 vehicles) and received approvals for all funded projects (over 30 project-specific approvals).

State Level- As of today, EasyMile's understanding is that there is nothing in the existing or proposed new regulations that prohibit this project from proceeding. As EasyMile has done in other States, we value our government partnerships, and we will work with the Department of Transportation, and other stakeholders to ensure current and future legislation is aligned with EasyMile's driverless technology.

Comprehensive Site Assessment Report- Before the vehicles have arrived on-site, one of EasyMile's experienced deployment engineers will identify and document all potential risks and mitigation strategies along the proposed route. Based on these findings, the EasyMile team will develop a Site Assessment Report, which summarizes EasyMile's requirements and recommendations for the site, and gives the scope and conditions of the operations on this specific site. The team will then review the findings with UConn, assess the feasibility of the proposed routes, and ensure that all of these recommendations are appropriately addressed prior to finalizing the vehicles' route location and operating assignment.

5.2 Deployment Details

Non-federal cost share- UConn's commitment of over $1 Million dollars is outlined in detail in section 3.5 where 20 graduate research assistants and an internal request for proposals will generate a number of research projects looking at the impacts on mobility challenged individuals, sensor development, public perception and adoption, and data collection and visualization.

Vehicle Validation- The EasyMile team will ensure that a staff person is on-site to unload the vehicles and validate the vehicle and all associated technology have shipped safely and is assembled appropriately. The EasyMile staff person will ensure the latest software updates have been installed and confirm that the vehicle is ready for operations.

Vehicle Setup and Reference Map Creation- Once on site, a trained EasyMile deployment engineer will manually drive the EZ10 on the agreed-upon routes with the purpose of "pre-learning" its possible routes and operating environment. Over the following days, the vehicle creates a "reference map" that represents all the routes and site environment. Every intersection and station is defined in this map, speed limitations and the use of bell/indicators are programmed, so the EZ10 knows what to do and where. This process enables the vehicle to know its exact position by comparing its perceived environment to the "reference map." Once the map and trajectories have been validated with one EZ10, the deployment engineer is able to transfer the information to the rest of the fleet and test with all the vehicles. The graphic below provides a sample reference map.

Training Program- EasyMile's strategy is to transfer the skills needed to conduct the 'day to day' operations of the shuttle and the knowledge on how to deploy and maintain the Z10. For this project, we understand that UConn is working with a private transport company (e.g., First, Transdev, RATP Dev) for operations. The goal is to provide tools customers are comfortable using to be fully self-sufficient. During the training process, EasyMile team makes sure that the skills of the trainees fulfill our high expectancies by having an exam at the end of the curriculum to have documented evidence of "fit for operation."

Daily Operations- EasyMile can work with UConn staff to design an operations schedule that best meets the City's needs.

5.3 Phase Details

Rural: Phase 1: UConn is located in the Town of Mansfield Connecticut. The Depot Campus is the home of the former Bergin Correctional Institution, a 35-acre site, opened in 1989 and decommissioned by the state in 2011. Furthermore, the Depot campus housed the Mansfield training school, a 350-acre campus which at the height of its use, housed over 1,800 residents and featured over 50 buildings, including a hospital devoted to patient treatment. The training school was closed in 1993, and the land was granted to UConn. Many of the buildings are now uninhabitable, but the infrastructure of a small city remains. As the campus currently sits underutilized, it is ideal for safe and effective initial deployment of autonomous vehicles without the safety concerns related to a heavily populated city. Ultimately, testing on the UConn Depot Campus will be conducted to evaluate the safe and effective operational characteristics and conditions of the UConn Main Campus.

Figure 2 outlines the roadways on the UConn Depot Campus that might be used for testing and research. These roadways add up to approximately 4.5 total miles. Some or all of these roadways will be utilized for Phase 1 testing and deployment of AVs. Most of the roads on the UConn Depot Campus are surrounded by buildings, some of which are utilized by UConn faculty and students, but most buildings are abandoned and boarded up to prevent unauthorized access.

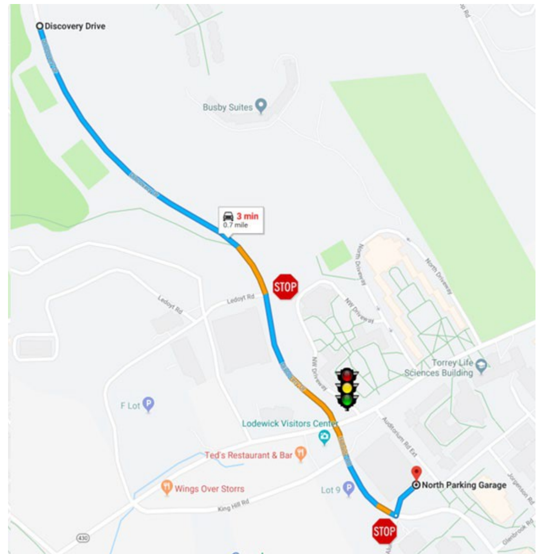
Figure 2: UConn Depot Campus

Upgrades to the Depot campus will be necessary and will include the installation of cellular equipment and/or dedicated short-range communication (DSRC) road-side units (RSUs) along the route(s) and/or at traffic signal(s) so that the AVs equipped with corresponding onboard units (OBUs) can talk to traffic signals and other infrastructure along the route. Additional power upgrades, signal controller hardware, signal system software and backhaul communication improvements may be necessary to make these upgrades function properly and for research to be conducted.

Micro-Urban: Phase 2: Following a successful demonstration in the low-density environment of the UConn Depot Campus, testing and deployment routes will be established on the UConn Main Campus to evaluate vehicle performance in pedestrian and mixed traffic environments with significantly more activity and vehicle interactions. UConn's main campus in Storrs, as a land grant agricultural college UConn is set in a rural setting with a dense urban infrastructure surrounded by farms and cattle fields. The University has a summertime population of over 15,000 in 5.6 mi^2. The University's main campus at the height of the semester will provide an urban setting with significant foot traffic and heavy traffic volumes at peak. Since the majority of people inhabiting the UConn campus would be students, faculty or staff, the research team would have access to emails and mailing addresses which will be used for stated preference surveys regarding perceptions of safety, adoption of new technology, experiences with this technology, and potential obstacles to deployment.

The exact route(s) and pick-up and drop-off locations selected for service will be redefined as the limits of the technology are defined in Phase 1. The route(s) and pick-up and drop-off locations to be selected will connect a variety of locations on campus including parking lots, visitor attractions, academic buildings, resident halls, and the Mansfield Town Center, which also includes frequent CTtransit express service to and from Hartford.

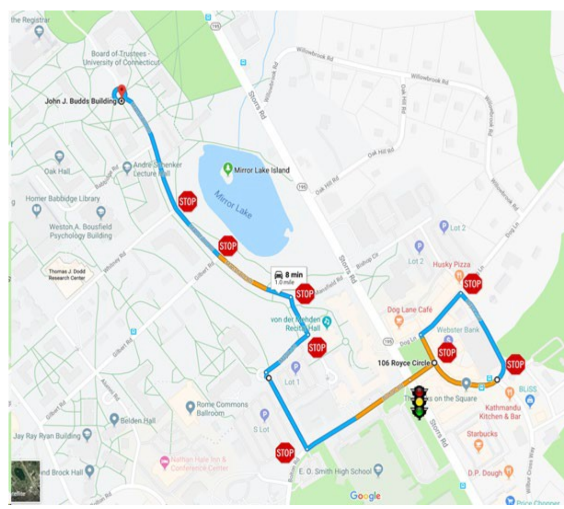
Figure 3: UConn Route Option 1



One potential route (see Figure 3), provides an AV microshuttle service between the north parking garage the newly constructed technology park located on Discovery Drive. On this potential route, an AV microshuttle would run less than 1 mile in length between J lot near the Technology park and drop commuters off near the Student Union on Hillside Road. The connection to UConn's Technology Park would also promote visibility of the AV shuttle and research here at UConn.

The second route option (Figure 4) for testing includes access to Mansfield Center and the Center of UConn's campus. Mansfield Center consists of shops, restaurants housing and public roads maintained by the Town of Mansfield. At the Mansfield Town Center, there is also access to regional transit service operated by the Wyndham Regional Transit District (WRTD), access to express bus service to and from Hartford operated by CTtransit as well as access to inter-city bus service operated by Peter Pan Bus Lines. This shuttle would provide connectivity between the Transit Hub and central campus, as well as access to the Mansfield downtown shops and residences.

Figure 4: UConn Route Option 2

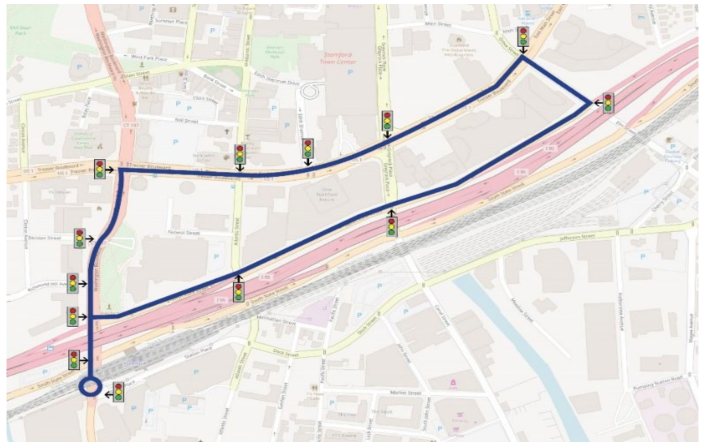


Micro-Urban: Phase 3: This phase will introduce an on-demand AV shuttle service where riders will have the ability to track and hail an AV shuttle. The shuttles will travel on the same routes as in Phase 3, but there will be more options for riders to interact with the transit system. User interfaces will be captured, and riders will be surveyed to gain feedback on the system and upgrades.

Urban: Phase 4:

Following the successful conclusion of Phase 3, the project team will select a route (Proposed route in Figure 5) in Downtown Stamford, CT to deploy the shuttles. A proposed 1.65 mile Downtown Stamford route will connect the Stamford Transit Center (STC) with 2 million square feet of office space, providing first and last mile connectivity with numerous transit services. In addition to local and regional bus service, the STC includes the busiest commuter rail corridor with connectivity to New York City via Metro-North and to Eastern Connecticut via Shore Line East. The nation's busiest inter-city and commuter passenger rail corridor also stops at this station, served by both Acela Express and Northeast Regional trains throughout the day. As a transit center of regional significance, this presents the opportunity for one of the highest impact first and last mile connectivity solutions in the nation.

Figure 5: Stamford Preliminary Route Option



The Stamford Transportation Center (STC) generates a substantial number of trips, with an annual ridership of over 8.4 million on Metro-North and 410,600 passengers on Amtrak. The Stamford station is the second busiest station in the entire Metro-North Railroad network after Grand Central Terminal (GCT) in Manhattan, making up 21% of ridership on the New Haven Line. The congestion in and around the STC is considerable due in large part to passenger pick-up and drop-off. Beyond single occupancy vehicles and taxis, shuttles exist to connect passengers with their destination. However, a recent study by Western Connecticut Council of Governments (WestCOG) indicates that the average shuttle leaving the STC is only 40% full. The combination of arriving, departing, and idling cars in and around the STC also creates significant emissions and air quality concerns.

In conclusion, UConn has a diverse research team that consists of faculty from philosophy, computer science, transportation, business, geography, electrical and mechanical engineering to name a few. The University provides a significant resource of knowledge and expertise to evaluate a wide range of topics related to autonomous and connected vehicles. The college campus and City of Stamford provide an ideal opportunity for interactions between the public and technology. The fact that the research team will have access to emails, addresses, and phone numbers of nearly every student, staff and faculty on campus provides the opportunity to conduct pre and post-deployment surveys to gain an understanding of adoption and perception changes as a result of these interactions.