Demonstration of Campus Multimodal Automated Driving Systems

Part 1

Project Narrative and Technical Approach

A Proposal in Response to
USDOT Automated Driving System Demonstration Grant
Notice of Funding Opportunity (NOFO) Number 693JJ319NF00001

Prepared For
Federal Highway Administration

U.S. Department of Transportation
Federal Highway Administration

March 21, 2019

March 21, 2019

U.S. Department of Transportation (USDOT)
Federal Highway Administration (FHWA)
1200 New Jersey Avenue, SE; Mail Drop: E62-204
Washington, DC 20590
Attn: Sarah Tarpgaard, HCFA-32

RE: Automated Driving System Demonstration Grants (693JJ319NF00001)
Requested Amount: $1,810,915.45
Principal Investigator: Dr. Pei-Sung Lin

Dear Ms. Tarpgaard,

It is with great pleasure that the project team led by the Center for Urban Transportation Research (CUTR) at the University of South Florida (USF) submits our application for an Automated Driving System Demonstration Grant. Our proposed project title is "Demonstration of Campus Multimodal Automated Driving Systems," and enclosed is the project narrative, technical approach, and subsequent sections of the grant application. In the event that the project is awarded, we agree to carry out the contract and grant administration policies and responsibilities.

Under my leadership, we have assembled an outstanding team with extensive experience and expertise in system automation, automated vehicles, electronic design automation, traffic operations analysis, traffic "big" data, intelligent transportation systems, cybersecurity, advanced statistical analysis and traffic simulation, and software development. Safety is the top priority of our demonstration, and we firmly believe in the value of integrating automated vehicle technologies in low-speed environments.

Please contact me with any questions regarding the technical/scientific aspect of this proposal at 813-974-4910 or via email at lin@cutr.usf.edu. Any administrative questions can be referred to Takara Waller, USF Sponsored Research Administrator, at 813-974-1914 or via email at waller1@usf.edu.

Sincerely,

Pei-Sung Lin, Ph.D., P.E., PTOE, FITE
Program Director
ITS, Traffic Operations and Safety

CENTER FOR URBAN TRANSPORTATION RESEARCH
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Summary Table

Project Name/Title	Demonstration of Campus Multimodal Automated Driving Systems
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	University of South Florida 4202 E Fowler Ave, Tampa, Florida 33620
Point of Contact (Name/Title; Email; Phone Number)	Ms. Takara Waller Sponsored Research Administrator, USF Sponsored Research waller1@usf.edu / 813-974-1914
Proposed Location (State(s) and Municipalities) for the Demonstration	Tampa, Florida
Proposed Technologies for the Demonstration (briefly list)	Level 3 Automated Vehicle, Level 4 Automated Shuttle, Level 4 Automated Golf Cart, Disabled Population Technologies, Data Sharing platform for USDOT, and public
Proposed duration of the Demonstration (period of performance)	3 Years
Federal Funding Amount Requested	$1,810,915.45
Non-Federal Cost Share Amount Proposed, if applicable	$291,350.88
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$2,102,266.33

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Project Narrative and Technical Approach

1. EXECUTIVE SUMMARY

Transportation safety and mobility have been major challenges of U.S. transportation systems and affect everyone's life every day. Emerging automotive and transportation technologies such as automated vehicles (AVs) have created revolutionary possibilities for future travel. Given the rapidly-evolving state of road-vehicle automation, government agencies at the federal, regional, state, and local levels are envisioning a future with these technologies in use in multimodal transportation systems ranging from private passenger cars and transit shuttles. Our entrenchment in the driving culture, fueled by prevalent inefficiencies in the current transit system, make a pressing argument for a more sustainable future with the shared use of resources in an automated, multimodal, and connected transportation system. Recent experiences with and discussions and discourse about automated technologies have emphasized the need to focus on safety as the top priority.

The project team of the Center for Urban Transportation Research (CUTR) at the University of South Florida (USF) and its partner COAST Automated envision that an importation application of vehicle automation technologies will be a multimodal automated driving system (ADS) in low-speed environments such as college/university campuses, corporate parks, industrial parks, retirement communities, hospitals, and theme parks. We believe equity is important for future ADS.

The proposed demonstration will focus on showcasing the automated capabilities of passenger cars, shuttles, and golf carts for transporting passengers, people with disabilities (those using wheelchairs), and freight across low-speed environments by means of multimodal AVs. The proposed demonstration site will be on the USF-Tampa campus. The proposed AVs for the demonstration include one automated car, three automated shuttles, and three automated golf carts. The initial build of these proposed multimodal AVs is shown in Figure 1. Most important, CUTR and COAST will focus on obtaining and sharing with USDOT and the public valuable data generated and processed from AVs during the proposed demonstration period through the project for safety analysis and future rulemaking.

Automated low-speed shuttle/bus systems will play an important role in a low-speed environment. Several iterations of low-speed automated shuttle/bus systems have been designed or are under development by peer high-tech companies (e.g., EasyMile, NAVYA, COAST, May Mobility) to cover short distances and predefined routes. These advanced technology vehicles have found applications (in the testing phase) as potential circulators and as first/last mile solutions across campuses and communities in the U.S. and Europe.

Figure 1 – Initial build of proposed automated shuttle, golf cart, and passenger car for demonstrations

The CUTR Team has exceptional experience in the research and development in the field of automated vehicles. COAST, a self-driving mobility company, has demonstrated automated technology through 65 demo projects across seven countries, carrying close to 130,000 passengers. CUTR and COAST possess the needed qualifications, experience, and passion to conduct a successful campus multimodal ADS demonstration and gather and share important demonstration data with USDOT and the public.

a. Vision, Goals, and Objectives

Our vision is to use a successful ADS demonstration on the USF-Tampa campus to inspire more multimodal ADS demonstrations and implementation in low-speed environments.

The goals of our proposed demonstration are as follows:

1. Demonstrate multimodal automated driving systems by safely operating a fleet of SAE L3 (Level 3) and L4 (Level 4) automated vehicles for transporting passengers (including transportation-challenged populations) and goods in a low-speed campus environment.
2. Ensure significant data gathering and sharing of the project data with USDOT and the public throughout the project in real-time to assist policy and rulemaking needed to remove governmental barriers for the safe integration of ADS technologies on U.S. roads.

The objectives of the proposed demonstration are as follows:

1. Demonstrate, gather, and share data from a passenger AV traveling between major hotspots on campus roadways with mixed traffic.
2. Demonstrate an automated shuttle for the transport of users with disabilities and gather and share data from this shuttle traveling on a campus walkway with mixed pedestrians, bicyclists, and skateboarders.
3. Demonstrate, gather, and share data from an automated shuttle for transport of users along a fixed route on campus with mixed traffic.
4. Demonstrate, gather, and share data from an automated shuttle for transport of users as an on-demand service on campus roadways with mixed traffic that can be requested by a smartphone and/or web-application.
5. Demonstrate, gather, and share data from an automated golf cart for the transport of goods along selected sidewalks on campus.
6. Demonstrate, gather, and share data from an automated golf cart traveling along a fixed route on campus.
7. Demonstrate, gather, and share data from an automated golf cart as an on-demand service on campus that can be requested by a smartphone and/or web-application.

b. **Key partners, stakeholders, team members, and others proposed to participate**

The key partner for this project is our proposed subcontractor, COAST Automated. COAST is committed to delivering self-driving solutions that are designed to make cities and campuses more liveable by removing traffic and connecting people with mobility options that put pedestrians first. Its P-1 shuttles and self-driving golf carts are designed to move people and goods efficiently with the maximum amount of flexibility. Its vehicles can navigate in pedestrian areas or in mixed-traffic conditions, either on demand or on fixed routes. Key members from COAST include Chief Technology Officer Pierre Lefevre, Robotics Chief Officer Dr. Cyril Royere, Director of Program Development Aimie Nghiem, and Research and Development Technician Kevin Ferguson. Detailed qualifications and resumes of key COAST members are provided in proposal Part 2 – Management Approach, Staffing Approach, and Capabilities.

CUTR's key stakeholders include major government agencies and Tampa Innovation Partnership in the Tampa Bay area and key internal departments on the USF-Tampa campus. Stakeholders outside USF include Florida Department of Transportation (FDOT) District 7, the City of Tampa, the Hillsborough Metropolitan Planning Organization (MPO), and !p Potential Unleashed. Stakeholders inside USF include Parking and Transportation Services, Facilities Management, Risk Management, Environmental Health and Safety, General Counsel, and Police Department.

The proposed Principal Investigator (PI) for this grant is Dr. Pei-Sung Lin, P.E., PTOE, FITE. He is the Director of the ITS, Traffic Operations and Safety Program at CUTR and Director of the Florida Local Technical Assistance Program (LTAP) Center. He has assembled an outstanding CUTR team that has extensive experience in system automation, connected and automated vehicles (CAV), electronic design automation, traffic operations analysis, traffic "big" data, intelligent transportation systems (ITS), cybersecurity, advanced statistical analysis and traffic simulation, and software development. Key CUTR team members include Dr. Zhenyu Wang and Dr. Cong Chen of CUTR, Dr. Nikhil Menon, Prof. Xiaopeng Li of the USF Department of Civil & Environmental Engineering, and Prof. Srinivas Katkoori of the USF Department of Computer Science Engineering. Detailed qualifications and resumes of key COAST members are provided in Part 2 – Management Approach, Staffing Approach, and Capabilities. Three graduate research assistants will participate in this project if awarded.

We plan to invite USF Student Government officers and College of Engineering faculty to participate and provide input and feedback.

c. **Issues and challenges to be addressed, technology(ies) that will be demonstrated to address the issues, and any quantifiable performance improvements that are anticipated.**

Automated vehicle technologies have been rapidly evolving. Many state, regional, and local governments are slowly grasping their intricacies for safe and smooth integration into the market. Research is essential to addressing policy and decision-making for incorporating these innovative technologies into future transportation systems.

A review of recent advancements and the literature in the field of road-vehicle automation show some gaps in both the state of the art and the state of the world.

A major issue that appears to be unaddressed in this era of high-tech advancement is equity. Current iterations for an automated, connected, electric, shared future consist of an inequitable system in which transportation-challenged populations (specifically persons with disabilities) are least likely to seek the benefits of this future. The CUTR Team considers this to be a major challenge worthy of research and development. Through the proposed demonstration project, the CUTR Team strives to address this shortcoming and demonstrate relevant technology that will focus on the safe access, egress, and transfer of such populations to and from automated vehicles at both origin and destination. Interventions to address this challenge include but are not limited to:

- Design and development of a wheelchair-friendly automated shuttle with facilities for safe access, egress, and transfer of users with disabilities to and from the automated shuttle at both origin and destination
- Provisions for safely strutting wheelchairs inside the automated shuttle

Another challenge to be addressed through this demonstration will involve the design of a seamless multimodal automated transportation system through a fleet of minimum SAE L3 automation technology-enabled vehicles. The project will demonstrate the ability for users to travel from origin A to destination B by using a suite of AVs (automated passenger cars, shuttles, and golf carts). A smartphone/ web-based platform will be designed for users of this multimodal transportation eco-system.

Data gathering from automated vehicles and their subsequent sharing with governments and the public for safety analysis and rulemaking poses challenges. These challenges will be overcome by the CUTR Team to safely and securely transmit data points to USDOT (and relevant data to the public) during the timeline proposed by the Federal Highway Administration (FHWA).

Several quantifiable performance measures can be anticipated from this project:

- Outcomes targeting users with disabilities will be evaluated with assistance from the USF Office of Students with Disabilities Services (SDS). A feedback survey will be initiated among the members of the SDS community to elicit opinion on the ease-to-use of the new technology for access/egress/transfer and on securement systems for the wheelchairs in the automated shuttle. Feedback will also be sought on the smartphone/web-based application, ADS interface regarding user-friendliness, and ease-of-use.

- Rider feedback will be sought during the demonstration period using a stated-*cum*-revealed preference survey to elicit information on their experience using the multimodal fleet of automated vehicles. Information will be obtained from riders on the various aspects of their automated vehicle experience, from booking the ride to transfers, as well as on the integration of the various modes to ease their ride experience.
- The gathering and transfer of the data from AVs during the proposed demonstration will help USDOT assess the performance evaluation of the automated vehicles to investigate the possibility of integrating these technologies onto U.S. roads. The CUTR Team also will investigate the safety benefits of these technologies via the use of various surrogate measures. Information on these surrogate measures is available in Section 5c.

d. **Geographic area or jurisdiction of demonstration**

Various aspects of testing and research will use the campuses of USF and Pinellas Technical College, and the proposed demonstration will be conducted at the USF-Tampa campus. Figure 2 shows the USF-Tampa campus with potential routes for the proposed demonstration. Note that these routes are tentative; final route selection will depend on a high-level analysis of campus activity patterns followed by approvals from USF administrators.

The CUTR Team envisions that the demonstration will cater to a wide campus audience. Previous studies show the major activity hubs around the USF-Tampa campus to be:

- USF library
- Juniper Poplar Housing
- Campus Recreation
- Marshall Student Center
- Hub (dining area and Publix)
- Yuengling Center
- remote parking lot (Lot 18 North)

Tentative demonstration plans have been made keeping in mind the need to cater to the previously-determined hotspots of campus activity. Further investigations will be initiated during the project's initial phases, and discussions will be conducted with key stakeholders and USF administrators before determining the final route selections. It is also worth noting that these route selections are relevant only for fixed-route operations. The CUTR Team aspires to create an on-demand service that will be able to transport users to most parts of the USF-Tampa campus.

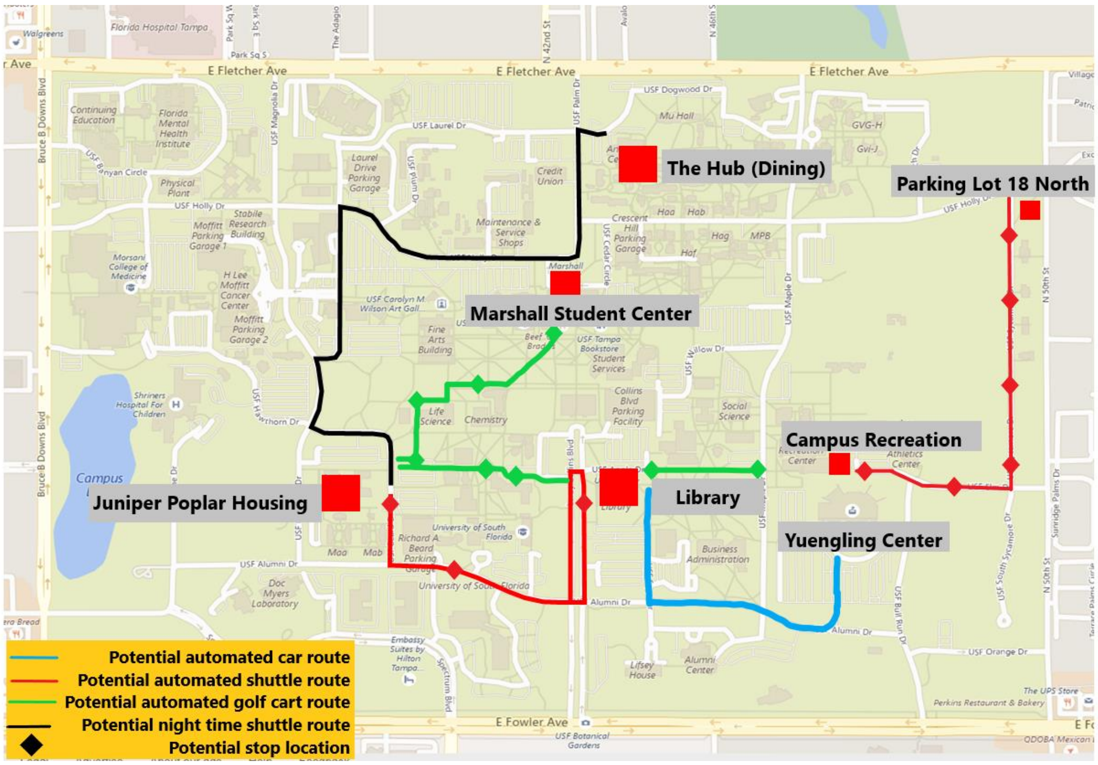

Figure 2 – Potential route selections for the campus automated driving system demonstration

e. **Proposed period of performance including a schedule for implementation and evaluation of the demonstration.**

The total period of performance will be 36 months from the start date of the project (06/01/2019). The project has been sub-divided into nine tasks:

Task 1 – Demonstration Planning
Task 2 – Research and Development
Task 3 – Mapping and Route Programming
Task 4 – Data Transformation and Integration Development
Task 5 – Setup and Testing
Task 6 – Operator Training
Task 7 – Automated Driving System Demonstration
Task 8 – Data Collection and Processing
Task 9 – Demonstration Evaluation

A full schedule for implementation and evaluation of the demonstration is as shown in Figure 3.

Tasks			Task 1: Demonstration Planning	Task 2: Research and Development	Task 3: Mapping and Route programming	Task 4: Data Transformation and Integration Development	Task 5: Setup and Testing	Task 6: Operator Training	Task 7: Automated Driving System Demonstration	Task 8: Data Collection and Processing	Task 9: Demonstration Evaluation
Y1	Q1	06/19-08/19									
	Q2	09/19-11/19									
	Q3	12/19-02/20									
	Q4	03/20-05/20									
Y2	Q1	06/20-08/20									
	Q2	09/20-11/20									
	Q3	12/20-02/21									
	Q4	03/21-05/21									
Y3	Q1	06/21-08/21									
	Q2	09/21-11/21									
	Q3	12/21-02/22									
	Q4	03/21-05/22									

Figure 3 – Full project schedule

2. GOALS

a. Safety

Safety has consistently been USDOT's top strategic and organizational goal and is the top priority for the CUTR Team with the proposed demonstration. We will seek to safely integrate a multimodal fleet of AVs in a low-speed campus environment with other road users (human-driven vehicles, pedestrians, bicyclists, skateboarders). Results from this effort will address the challenges associated with the safe integration of a multimodal automated driving system in a low-speed environment in conjunction with today's transportation systems via a proposed three-month demonstration and subsequent data analyses and demonstration evaluation.

b. Data for Safety Analysis and Rulemaking

The comprehensive data generated and collected from three COAST automated shuttles, three COAST golf carts, and a customized automated passenger car from this proposed demonstration will be shared with USDOT for safety analysis and rulemaking.

The CUTR Team will extract safety measures and assist USDOT with conducting a safety analysis. The safety measures will be based on the relative trajectories between moving objects (such as vehicles, bicyclists, pedestrians) and infrastructure barriers (such as road curbs, lane markers, medians, etc.). These measures will be evaluated and compared with peer measures for human-driven vehicles. Safety advantages and risks of automated shuttles will be quantified. Based on these results, recommendations for policy and rulemaking to enhance AV safety benefits and mitigate any safety risks will be made and evaluated with stakeholders.

c. **Collaboration**

The proposed demonstration will involve collaboration from a host of partners, stakeholders, and supporters of the project. The CUTR Team will build on our previous collaboration during a week-long automated vehicle demonstration on the USF-Tampa campus in February 2019. If awarded, within days of the award of this proposed grant the CUTR Team will develop a stakeholder engagement/ collaboration plan and meet with the key partners and stakeholders to pave the path for the impending demonstration and successful completion of the project. To accomplish this, we will first coordinate with USF and its constituent offices (Vice President, General Counsel, Risk Management, Environmental Health & Safety, Facilities Management, Parking & Transportation Services, USF Police, and Students with Disabilities Services) to bring everyone up to speed with the tasks involved in the project and obtain feedback/ suggestions from all parties concerned.

Feedback will be sought from all partners, stakeholders, and supporters along the various stages of the project to ensure that the outcomes of the demonstration are in line with the vision set forth by the CUTR Team. SDS will play a key role in the research and development stages of this project. The project team will seek detailed feedback and suggestions from SDS regarding the challenges faced by transportation users with disabilities and seek their feedback on the proposed products from this project.

The CUTR Team and COAST will visit potential sites for the demonstration, study them thoroughly, and work with USF authorities to seek approvals and choose candidate areas, campus roadways, wide sidewalks for golf carts, and walkways for the demonstration. The Team will then present these findings to the other stakeholders (City of Tampa, FDOT District 7, Hillsborough MPO, Tampa Innovation Partnership) to seek their feedback on the project tasks and the demonstration plan at various stages of the project.

3. FOCUS AREAS

a. **Significant public benefit(s)**

The CUTR Team foresees significant public benefit from the proposed demonstration. This effort will highlight the safe and successful operation of a multimodal fleet of low-speed automated vehicles on U.S. roadways. This project will serve a variety of transportation markets, including shared mobility and freight in a low-speed ecosystem. Results from a successful demonstration of this magnitude will have significant applications such as busy downtown districts, campuses (both academic and commercial), retirement homes, hospitals, and theme parks. Additionally, and more importantly, this demonstration will be the first of its kind in showcasing the application of AV technology for safely transporting users with disabilities. Safety is the key focus of this demonstration, and the technologies we design for transporting users with disabilities will serve as an important benchmark in making a more inclusive, equitable transportation system for the future.

b. **Addressing market failure and other compelling public needs**

With safety as the primary priority of the demonstration, the current effort will be unique in its detailed investigation into the mobility problems encountered by transportation users with disabilities. Private sector investment to date has been insufficient to support innovations in mobility solutions for this demographic. The CUTR Team will focus on delivering a proof-of-concept from an automated shuttle for the safe access, egress, and transfer of transportation users with disabilities from their origins to destinations.

c. **Economic vitality**

The COAST P-1 shuttle is manufactured and assembled in the U.S., and the COAST AV golf cart is a Textron EZ-GO golf cart manufactured in the U.S. and converted for automated operation by fitting it with sensors and electronics; the conversion process also takes place in the U.S. Further, the L3 passenger car AV is built on an American brand vehicle Lincoln MKZ hybrid, and its sensor, computing and control hardware are supplied by a U.S. company AutonomouStuff. This proposed demonstration will be an excellent demonstration of the success of the domestic industrial base. The CUTR Team will work with COAST to promote the domestic industrial base by meeting Buy America requirements. The proposed demonstration also strives to support economic vitality at the regional and national levels by advancing domestic industry and development of U.S.-based intellectual property.

d. **Complexity of technology**

The proposed demonstration aligns with complexity of technology. CUTR and COAST will demonstrate a fleet of low-speed automated vehicles that meet the requirements of SAE L3 or greater. The USF passenger car AV has integrated the AutonomouStuff AV platform and a customized high-level L3 AV control software platform developed by Dr. Li's team. The software platform has been validated with field experiments involving complex maneuvers such as car-following, lane changing, and coordination with signal lights in mixed traffic containing human driven vehicles. With this, the USF AV is able to complete a route in the pure automated mode in nominal conditions with an in-vehicle driver monitoring and prepared to take over in the event of emergency, which satisfies the SAE L3 definition: *The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene*. It will use an automated passenger car, three automated shuttles, and three golf carts to demonstrate the complex operations of AVs under the following different scenarios:

1. Automated passenger car traveling on roadways in mixed traffic conditions with different traffic control devices such as a traffic light, two-way stop sign, and/or four-way stop sign.
2. Automated shuttle transporting passengers with disabilities traveling on a campus walkway with mixed pedestrians, bicyclists, and skateboarders.
3. Automated shuttle transporting passengers along a fixed route on a campus with mixed traffic.
4. Automated shuttle transporting passengers as an on-demand service on campus roadways with mixed traffic that can be requested by a smartphone and/or web-application.
5. Automated golf cart delivering goods along selected sidewalks on a campus.
6. Automated golf cart traveling along a fixed route of sidewalks on a campus.
7. Automated golf cart transporting passengers as an on-demand service on a campus that can be requested by a smartphone and/or web-application.

e. **Diversity of projects**

The CUTR Team proposes to prepare and demonstrate a fleet of multimodal automated vehicles that will show the capabilities to safely navigate and integrate into campus roadways, sidewalks, and walkways. This project will serve across a variety of transportation markets, including personal mobility via an automated passenger car, freight via automated golf cart, and public transportation via automated shuttles in a low-speed environment. The proposed demonstration will cover the above-mentioned scenarios and aligns with the focus area of Diversity of Projects.

Results of the proposed demonstration will highlight the capabilities of a multimodal fleet of AVs that could be deployed safely in a variety of communities such as busy downtown districts, hospitals, campuses (both academic and commercial), theme parks, and retirement communities. As the operations will be in a low-speed environment, public acceptance of these technologies would be much higher than other cases and is set to revolutionize the possibilities of deploying these technologies safely across candidate environments.

f. **Transportation-challenged populations**

The proposed demonstration will cater significantly to transportation-challenged populations. The CUTR Team will focus its efforts on developing mobility solutions not just for older adults (as evidenced by the possibility of operating such technologies in retirement communities or hospitals) but also work on using these technologies for improving the mobility of transportation users with disabilities. In this regard, the CUTR Team will coordinate with COAST to provide a demonstration that enables the safe access, egress, and ease of transfer process to/from an automated shuttle at origins and destinations. The proposed demonstration is aligned with the focus area of Transportation-challenged Populations.

A current challenge with transporting users with disabilities is focused around securement and restraint systems for wheelchairs and the development of AVs that are capable of transporting users confined to wheelchairs. The CUTR Team proposes to focus efforts on solving this issue to arrive at a proof-of-concept that displays safe and easy transport of users with wheelchairs through the proposed demonstration.

g. **Prototypes**

The CUTR Team already has a level 3 AV (see Figure 1) integrating a commercial AV hardware platform (from Autonomoustuff) and a customized software platform (developed by Dr. Li's group based on opensource AV software Autoware). The software platform has been tested with field experiments in complex signalized mixed traffic environment for both longitudinal and latitudinal control, as illustrated in Figure 4 below.

Figure 4 – Screenshots of L3 AV experiments in mixed traffic with human-driven vehicles: (a) lane changing, and (b) trajectory smooth at a traffic signal

This AV prototype with advanced hardware and field-validate software provides a prototype vehicle platform for the L3 demonstration on low speed campus environment. We will further this prototype vehicle by enhancing its object identification functions (e.g., fusing both video camera and Lidar information) with deep-learning algorithms and integrating the specific configurations for the campus demonstration environment. Further, we will add DSRC (dedicated short-range communications) units to four intersections to allow the AVs to communicate with signal lights. As such, this proposed demonstration is well aligned with the focus area of Prototypes.

4. REQUIREMENTS

a. **Each demonstration must focus on the research and development of automation and ADS technology (per the SAE definitions), with a preference for demonstrating L3 or greater automation technologies.**

Our automated passenger car has automated car-following, lane changing, turning, and parking functions and can accomplish a complete route in the automated mode in normal conditions. A driver will be seated in vehicle to monitor and prepare to respond while it is running. This satisfies the SAE definition of L3 automation.

The COAST automated vehicles are capable of operating under SAE L4 automation technology in normal conditions. However, an operator will be available at all times in each automated vehicle to monitor its smooth performance and take over operations if necessary. As such, the COAST vehicles will satisfy the minimum SAE L3 requirement.

b. **Each demonstration must include a physical demonstration.**

The CUTR Team proposes to include a three-month physical demonstration in a low-speed ecosystem on the USF-Tampa campus with a multimodal fleet of automated vehicles fitted with automation technologies that satisfy SAE L3 or greater. Although modeling and simulation activities may be used as secondary avenues in the initial research and development stage, the main focus of the demonstration will involve a physical demonstration that spreads over three months in a low-speed campus environment.

c. **Each demonstration must include the gathering and sharing of all relevant and required data with the USDOT throughout the project, in near real time. The Recipient must ensure the appropriate data are accessible to USDOT and/or the public for a minimum of five years after the award period of performance expires.**

The CUTR Team will save all data, including raw data, on local secure storage at the CUTR building. After anonymizing the data, we can directly provide the link for accessing the data on our research websites (CUTR or USF Civil & Environmental Engineering). We will share all relevant and required data with USDOT throughout the project in near real time. We will ensure that appropriate data are accessible to USDOT and/or the public for a minimum of five years after the award period of performance expires.

Further, smaller abstract data with information, such as object trajectory data, safety measure data, and survey data, will be uploaded to the USDOT SDC platform (https://its.dot.gov/data/secure/index.html) to ensure they are is accessible to USDOT for the period of time proposed by the FHWA.

d. **Each demonstration must include input/output user interfaces on the ADS and related applications that are accessible and allow users with varied abilities to input a new destination or communicate route information and to access information generated by the ADS.**

A smartphone/web-accessible application will be developed by the CUTR Team that allows users to select origin and destination and the need for disability assistance (e.g., wheelchair ramp) on any candidate route. The app will be based on a GIS map, and the selection of the locations can be completed by a user-friendly intuitive touchscreen operation. This app can create an account for each user, which allows them fill out a feedback survey in the end and access published data statistics generated based on the ADS data for their benefit. A similar interface will also be present in each automated vehicle that could interact with users of varied abilities to input new destination or communicate route information. The data will be updated daily to achieve near-real time data sharing.

e. **Each demonstration must address how the demonstration can be scaled to be applicable across the Nation to similar types of road environments, and include an outreach task to share demonstration status, results, and lessons learned with other jurisdictions and the public, in furtherance of technical exchange and knowledge transfer.**

The proposed demonstration in a low-speed environment with a fleet of multimodal automated vehicles could be applicable to similar environments such as busy downtown districts, theme parks, campuses (both academic and commercial), hospitals, and resident/retirement communities.

5. APPROACH

a. Technical approach to implement and evaluate the demonstration.

In this section, our four technical approaches are presented followed by a detailed description of the nine supporting tasks for this proposed ADS demonstration. Our technical approaches to implement and evaluate the demonstration include 1) research and development of AV modes, 2) automation function field testing, 3) evaluation of data generation, collection, storage, and sharing, and 4) demonstration safety and operation evaluation.

Technical Approach 1: Research and Development of AV Modes

Three types of automated vehicles will be included in the proposed demonstration: automated passenger car, automated shuttle, and automated golf cart. Before commencement of the three-month physical demonstration on the USF-Tampa campus, the CUTR Team will ensure that all the modes will have at least Level 3 or higher automation functions based on the SAE Automation Definition. The CUTR Team will work on enhancing of the existing L3 automated passenger car to ensure its L3 Automation capability specifically required for the proposed demonstration. In particular, we will upgrade the existing feature-based object identification to deep learning-based identification to improve identification accuracy and the capability of classifying object types (e.g., vehicle types, pedestrians, bicyclists). And the USF team will also work on integrating the HD 3d campus map in an AV compatible format provided by COAST into the automated passenger car navigation system. COAST will be fully dedicated to enhancing and fulfilling L3 or higher Automation on the automated shuttles and golf carts.

Technical Approach 2: Automation Function Field Testing

Based on the requirement of this NOFO and with the R&D effort of on all AV modes, the CUTR Team will conduct repeated tests on different scenarios to ensure the successful fulfillment of L3 or higher automation on all multimodal demonstration vehicles; testing will be conducted regarding the following functions or objects:

1. USF automated passenger car, COAST automated shuttles and golf carts
2. Field communication devices and sensors
3. Communication between USF automated passenger car, COAST automated vehicles, and field devices, especially at signalized intersections
4. Operation of USF automated passenger car between multiple major campus centers
5. Operation of automated shuttles and golf carts on all demonstration routes under various potential scenarios, left and right turns, traffic and/or pedestrian/bicyclist environment, and weather conditions
6. Generation and collection of all specified raw data and their formats
7. Transformation of specified raw data to intermediate data produced from the raw data and final data. Intermediate data will include trajectory data of AV and surrounding objects (other vehicles, pedestrians, bicyclists, etc.); final dataset will include safety measures derived from the intermediate data, including objective indicators

Specifically, the automated vehicles have been assigned the following tasks:

- Automated passenger car traveling on campus roadways with mixed traffic and traffic control devices such as traffic signalized intersections and stop signs
- Automated shuttles traveling on campus roadways with mixed traffic and traffic control devices and stopping at requested stops
- Automated shuttle traveling on walkways with pedestrians, bicyclists, and skateboarders
- Automated shuttle serving people with disabilities using wheelchairs
- Automated golf carts traveling on approved campus sidewalks and stopping at requested stops
- Automated golf cart delivering goods on approved campus sidewalks to specified destinations

During the field-testing procedure, data generation, collection, storage, processing, and sharing will be tested, and data-driven analysis (public opinion and observation surveys will not be collected in field testing) will be conducted in preparation for the demonstration safety and operation evaluation. Communications between AVs and field devices and communications among automated vehicles will also be tested during the data generation and collection testing process. See Evaluation on Data Generation, Collection, Storage, and Sharing and Demonstration Safety and Operation Evaluation sections for detailed evaluation procedures.

Technical Approach 3: Evaluation of Data Generation, Collection, Storage, and Sharing

It is critical to ensure smooth data generation and transmission as well as data collection, storage, and sharing in a near real-time basis during the demonstration. The CUTR Team will follow the data management plan and actively monitor data generation and collection from the equipped AVs, archive these collected data on a CUTR local server and/or at the USDOT SDC (Secure Data Commons Portal) to ease direct access by USDOT. The CUTR Team will actively examine the rate and stability of data generation, transmission, and processing as well as data server available storage space and data redundancy and will identify any technical issues and develop feasible solutions to ensuring effective data management.

Technical Approach 4: Demonstration Safety and Operation Evaluation

Demonstration safety and operations will be evaluated using two different approaches: survey evaluation and data-driven analysis. During the evaluation, two surveys will be designed—a public opinion survey and an observation survey. The public opinion survey will be designed to collect the opinions of campus faculty, staff, and students regarding the functionality and convenience of the demonstrated automated vehicles and will include the following topics:

- Experience riding AV(s)
- Experience transferring through modes
- Opinion on adoption of technologies for future use

Observations surveys will be collected on AVs of three different modes to examine their automation functionality, focusing on:

- Automated vehicle starting, stopping, and parking smoothly
- Vehicle responses to contingent or regular traffic events, including but not limited to traffic signals and signs, potential conflict, and other complications (pedestrians, bicyclists, human driving vehicles, other automated vehicles, jump-in animals, etc.).

Three levels of data will be collected during the demonstration: 1) raw sensor data including Lidar, video, and GPS data; 2) AV and other identified objects surrounding the AV trajectory data, with geometries, locations, and kinematic states recorded; and 3) process data, including safety measures as well as mobility and fuel efficiency measures.

In addition to survey evaluations, data-driven demonstration safety and operation evaluation will be conducted on different demonstration scenarios through statistical modeling and traffic simulations, and various measurements of effectiveness will be used. For safety, based on the relative locations and speeds between the subject AVs and other detected surrounding objects, a series of surrogate measures will be constructed, including:

- Gap Time (GT) – time lapse between completion of encroachment by turning vehicle and arrival time of crossing vehicle if they continue with same speed and path
- Encroachment Time (ET) – time duration during which turning vehicle infringes upon right-of-way of through vehicle
- Deceleration Rate (DR) – rate at which crossing vehicle must decelerate to avoid collision.
- Proportion of Stopping Distance (PSD) – ratio of distance available to maneuver to distance remaining to projected location of collision
- Post-Encroachment Time (PET) – time lapse between end of encroachment of turning vehicle and time that through vehicle actually arrives at potential point of collision.
- Initially Attempted Post-Encroachment Time (IAPT) – time lapse between commencement of encroachment by turning vehicle plus expected time for through vehicle to reach point of collision and completion time of encroachment by turning vehicle
- Time to Collision (TTC) – expected time for two vehicles to collide if they remain at present speed and on same path

Other safety measures may be used, including:

- DR distributions
- Required braking power distributions
- Gap-acceptance distributions
- Number of vehicles caught in dilemma zones
- Speed differential between crossing movements
- Speed variance
- Red- and yellow-light violations by phase
- Time-integrated and time-exposed TTC measures (TET and TIT – duration of time that TTC is less than threshold and integrated total TTC summation during

that time, respectively)

These safety surrogate measures will provide rich information on the safety performance of the AVs interacting with different types of surrounding objects. Further, the associated mobility (e.g., throughput, travel delay) and environment data (fuel consumption and emissions) can be easily extracted with object trajectory data.

The detailed description of our supporting project task to successful accomplish the goal and project objectives of this proposed campus multimodal ADS demonstration is provided below.

Task 1: Demonstration Planning

This task will plan tasks for supporting CUTR to conduct a successful demonstration on the USF-Tampa campus, deliver required data to USDOT, and complete all project tasks. CUTR will conduct a kick-off meeting with USDOT at a mutually-agreed-upon location. The meeting may be virtual or in-person based on mutual agreement of the parties. Thereafter, CUTR will conduct a stakeholder meeting including but not being limited to USF stakeholders; representatives of the Florida Department of Transportation (FDOT), the Hillsborough Metropolitan Organization (MPO), the City of Tampa, !p Potential Unleashed, and Coast Automation, LLC to plan and obtain input for the demonstration of campus multimodal automated driving systems on the USF Tampa campus.

CUTR will conduct site visits with subcontractor Coast and selected USF stakeholders to determine and select the demonstration areas and routes. CUTR will develop a detailed 1) Project Management Plan (PMP), 2) Data Management Plan (DMP), and 3) Project Evaluation Plan. The PMP will include a statement of work, major project milestones, a staffing table, and a project budget. The DMP will comprise a description of how data will be managed during and after the project and delivery of data and associated documentation as outlined in the DMP. The Project Evaluation Plan will include a statement of project objectives, a list of evaluation criteria, a description of data-collection procedures tailored to these criteria, an outline of the evaluation report, and a description of the data system where evaluation data will be stored and analyzed. In addition, a Project Demonstration Plan will be developed.

Deliverable 1: Kick-off meeting minutes, Project Management Plan, Data Management Plan, Project Evaluation Plan, and Project Demonstration Plan.

Task 2: Research & Development

Based on the PMP developed in Task 1, this task will focus on all needed research and development (R&D) and application development for an automated driving system demonstration on the USF-Tampa campus. The R&D of automation and ADS technology (per SAE definitions) will support the demonstration of Level 3 or greater automation technologies on a passenger car, three shuttles, and three golf carts.

R&D efforts and associated subtasks on the automated driving system demonstration will include the following seven scenarios on a campus low-speed environment: 1) an automated passenger car traveling on campus roadways with mixed traffic and traffic control devices such as traffic signalized intersections and stop signs, 2) an automated shuttle traveling on campus roadways with mixed traffic and traffic control on fixed routes, 3) an automated shuttle serving people using wheelchairs and traveling on a walkway with pedestrians, bicyclists, and skateboarders, 4) automated shuttles traveling on campus roadways with mixed traffic and traffic control as on demand services, 5) an automated golf cart traveling on approved campus sidewalks and stopping at requested stops on fixed routes, 6) an automated golf cart traveling on approved campus sidewalks and stopping at requested stops as on demand services, and 7) an automated golf cart delivering goods on approved campus sidewalks to specified destinations.

Based on the experience of the CUTR Team members and the R&D effort, the CUTR Team will equip an automated passenger car for demonstration on the USF-Tampa campus. With assistance from CUTR, Coast will enhance its automated shuttles and golf carts and strengthen its capabilities to successfully perform the specified scenarios during the demonstrations. Advanced communication systems supporting safety and/or mobility, including vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) interoperable communications that benefit ADS integration will also be explored.

Efforts by CUTR will include the development of applications to allow 1) riders of automated shuttles to remotely request rides, 2) riders of automated golf carts to remotely request rides, 3) onboard riders of automated shuttles to manually input designated stops, and 4) onboard riders of automated golf carts to manually input the designated stops.

Deliverable 2: Written report detailing R&D and application development for automated driving system demonstration of an automated passenger car, three automated shuttles, and three automated golf carts.

Task 3: Mapping and Route Programming

This task will conduct needed mapping and route programming of an automated passenger car, three automated shuttles, and three automated golf carts on all selected routes on USF-Tampa campus for the demonstration of campus multimodal automated driving systems. CUTR and Coast will work together to conduct a site visit and schedule and conduct mapping and route programming required for the task. The mapping data for the automated car, shuttles, and golf carts will be viewed and validated for future field testing and demonstration.

Deliverable 3: Written report of mapping and route programming, including mapping data.

Task 4: Data Transformation and Integration Development

This task will focus on the development of all needed tools and software applications to transform and integrate all dynamic sensing data, including raw sensor data from Lidar, video, GPS, and others to SAE Level 3 or higher data representing innovative measures of safety-relevant vehicle behaviors. After the development of initial tools and software applications, the CUTR Team will conduct intensive testing to improve and finalize these tools and applications. CUTR will further enhance these tools and applications based on the results during setup and testing. The final tools and applications will be used during the automated system demonstration in Task 7 to produce innovative measures of safety-relevant vehicle behaviors for submission to USDOT.

The demonstration will include the gathering and sharing of all relevant and required data with the USDOT throughout the project, in near real time. Appropriate data will be accessible to USDOT and/or the public for a minimum of five years after the award period of performance expires. Data demonstrating safety performance will include conventional data regarding safety incidents, operational (vehicle and ecosystem data), exposure measures, and innovative measures of safety-relevant vehicle behaviors that may indicate potential safety problems. The most important and difficult data to produce from the automated driving system demonstration are the innovative measures of safety-relevant vehicle behaviors.

Deliverable 4: Written report detailing data transformation and integration development.

Task 5: Setup and Testing

This task will focus on systems setup and testing before the official demonstration, including 1) field testing of the automated passenger car, shuttles, and golf carts traveling on selected routes, 2) field communication devices and sensors, 3) communication between automated vehicles and field devices, especially at signalized intersections, 4) operation of the automated passenger car, shuttles, and golf carts on all demonstration routes under various scenarios, left and right turns, traffic and/or pedestrian and bicyclist environment, and weather conditions, and 5) generation and collection of all specified raw data and their formats. CUTR and Coast will collaborate closely on the setup and testing to ensure a successful demonstration and data collection. CUTR will coordinate with USF stakeholders in advance of actual system setup and testing of automated vehicles and field devices. USF stakeholders include but are not limited to the USF offices of Parking & Transportation, Facility Management, Risk Management, Police Department, and General Council.

Deliverable 5: Written report detailing system and testing on the USF-Tampa campus before the official demonstration.

Task 6: Operator Training

Operator training is crucial to safely operate automated shuttles and golf carts manually when an emergency occurs during a demonstration. CUTR and Coast will conduct intensive training of all operators of the automated car, shuttles, and golf carts to strictly follow automated vehicle operation protocol developed for this project. All operators will obtain certification from the Coast Chief Technology Officer before operating the automated car, shuttles, and golf carts during the testing and official three-month demonstration on the USF-Tampa Campus. Coast will submit copies of these certifications to CUTR.

Deliverable 6: Written report of operator training and copies of operator training certificates.

Task 7: Automated Driving System Demonstration

This task will execute CUTR's automated driving system demonstration plan. CUTR and Coast will coordinate closely and conduct the multimodal automated demonstration of one automated passenger car, three automated shuttles, and three automated golf carts on selected routes including roadways, walkways, and sidewalks. The automated passenger car will drive on a selected route in the demonstration area on the USF-Tampa campus. The automated shuttles and golf carts will follow either fixed schedules or operate on demand. The CUTR field demonstration manager, Coast project manager, and Coast CTO will supervise the operators and monitor the demonstration to ensure the safety of operations and resolve any issue during the demonstration. Coast mechanics will regularly inspect the automated passenger car, shuttles, and golf carts to ensure a smooth demonstration without mechanical issues. One automated shuttle will focus on providing rides for people using wheelchairs and one automated golf cart will focus on delivering goods to specified destinations.

Deliverable 7: Written report detailing the automated driving demonstration of the passenger car, shuttles, and golf carts.

Task 8: Data Collection and Processing

It will be crucial to ensure significant data gathering and sharing of project data with USDOT and the public throughout the project in near real-time, either by streaming or periodic batch updates, and demonstrate significant commitment to leveraging the demonstration data and results in innovative ways. CUTR and Coast will follow the data collection plan to collect real-time static mapping and dynamic demonstration sending data of all AV operations during the demonstration, including the automated passenger car, shuttles, and golf carts. The mapping data will include low-level physical mapping data and a high-level topological data. The dynamic sensing data will include raw sensor data, safety, and other measured data. The raw sensor data will be direct measurements from Lidar, video, and radar. These real-time raw data will be fused using the tools and applications for data transformation and integration to track all moving objects classified and generate the innovative measures of safety-relevant vehicle behaviors.

CUTR will gather and share all relevant and required data with USDOT throughout the project in near real time. CUTR will deliver conventional data regarding safety incidents, operational (vehicle and ecosystem) data, exposure measures, and innovative measures of safety-relevant vehicle behaviors to USDOT.

In addition, based on the data specified in the PMP, CUTR will collect before/after data, surveys, interviews, system-monitoring data, or other data needed to report on achievement of project objectives.

Deliverable 8: Written report detailing data collection and processing during the three-month demonstration period and submission of all required data from the demonstration.

Task 9: Demonstration Evaluation

CUTR will perform detailed data analysis and conduct a demonstration evaluation based on the evaluation criteria to produce an informative demonstration evaluation report. CUTR will produce and submit a final evaluation report describing the following: 1) how the project met or did not meet the original expectations projected in the PMP; 2) evaluation results of the project according to the Project Evaluation Plan; 3) summary of any complications experienced with the ADS demonstration, specifically outside the ADS including pedestrians, infrastructure, and/or other vehicles; and 4) how to use the demonstration results to help the public interact and better understand the operations of ADS.

Deliverable 9: Written report on final project evaluation detailing data analysis and demonstration evaluation.

b. **Your approach to address any legal, regulatory, environmental, and/or other obstacles to demonstrating the technology(ies), whether those obstacles be caused by Federal, State, or local requirements.**

    i. **Clearly address and explain if your demonstration will or may require**

exemption from the Federal Motor Vehicle Safety Standards (FMVSS), Federal Motor Carrier Safety Regulations (FMCSR), or any other regulation and, if so, your plan for applying for any necessary exemptions.

The proposed demonstration will be conducted on the USF-Tampa campus, not on public roads. As such, the CUTR Team does not anticipate any exemptions to be required from the Federal Motor Vehicle Safety Standards (FMVSS), Federal Motor Carrier Safety Regulations (FMCSR), or any other regulation for the demonstration.

ii. **Clearly address and explain if your demonstration will or may require an exception under the Buy American Act or an exception to the terms of the NOFO Clause at Section F, Paragraph 2.J. entitled BUY AMERICAN AND DOMESTIC VEHICLE PREFERENCES. The clause: (1) requires compliance with the Buy American Act, 41 U.S.C. §§ 8301–8305, as implemented at 48 C.F.R. Subparts 25.1–25.2; and (2) requires that the Recipient not expend grant funds to purchase a motor vehicle unless the final assembly of that vehicle occurred in the United States.**

The fleet of automated vehicles to be used in the proposed demonstration are all manufactured and assembled in the U.S. The COAST P1 shuttle is domestically manufactured, and the COAST automated golf cart is a Textron EZ-GO golf cart manufactured in the U.S. and converted to automated operations by fitting it with sensors and electronics. The conversion process also takes place in the U.S. The proposed automated passenger car is a Lincoln MKZ manufactured in the U.S. and converted to automated operations with hardware from AutonomouStuff (a U.S. company) by the CUTR Team in the U.S.

c. **Commitment to provide data and participate in the evaluation of the safety outcomes of proposed activities, and note measures of effectiveness in other arenas, such as mobility.**

Collected data will include static mapping, dynamic demonstration sending data, and subjective evaluation/survey data. The mapping data will have low-level physical mapping data and high-level topological data, including infrastructure features, road markers, traffic signs, and signal lights. The dynamic sensing data will have raw sensor data, classified object tracking data, and safety and other measure data. The raw sensor data are direct measurements from Lidar, video, and radar. The raw data will be fused to track all moving objects classified as trucks, light duty vehicles (including the AVs themselves), motorcycles, bicyclists, and pedestrians (including those using skateboards and roller skates, not uncommon on campus environments). The tracking trajectory data marked with object geometries and types will be stored in the classified object tracking data. Safety and other measure data will be built on the classified object tracking data.

To address safety, based on the relative locations and speeds between the subject AVs and other detected surrounding objects, the CUTR Team will construct a series of surrogate measures, including Gap Time (GT), Encroachment Time (ET), Deceleration Rate (DR), Proportion of Stopping Distance (PSD), Post-Encroachment Time (PET), Initially Attempted Post-Encroachment Time (IAPT) and Time to Collision (TTC) (see https://www.fhwa.dot.gov/publications/research/safety/ 03050/02.cfm for definitions and formulas). These safety surrogate measures will provide rich information on the safety performance of the AVs interacting with different types of surrounding objects. Further, the associated mobility (e.g., throughput, travel delay) and environment data (fuel consumption and emissions) can be easily extracted with object trajectory data. A team led by Dr. Li has conducted multiple studies using trajectories to extract safety, mobility and environmental data (e.g., Yao et al. 2018; Li et al., 2018; Zhou et al., 2017; Ma et al., 2017).

d. **Approach to risk identification, mitigation, and management**

- The CUTR Team will identify potential possible risks such as unexpected skateboarders with the operation of AVs in low-speed environments and conduct a series of tests on mapping, route planning, and vehicle fleet to minimize any unforeseen risks during the demonstration.
- Coordination among stakeholders, key partners, and supporters will be initiated to ensure that no foreseeable risks are unaccounted for prior to the demonstration.
- The CUTR Team will spend one month training the AV operators to ensure they are fully capable of handling any situations that may arise during the demonstration.
- The CUTR Team will be in constant contact with law enforcement and emergency medical personnel to reduce availability time for assistance during any unforeseen circumstances.
- The CUTR Team will apply for liability insurance for the period of the demonstration to cover any expenditures that could arise during an unforeseen event.

e. **Approach to contribute and manage non-Federal resources (cost share) proposed for the demonstration implementation and evaluation, if applicable.**

USF will contribute a cost share of approximately $75,000 for tuition funding for three graduate research assistants dedicated to this demonstration grant for 2.5 years.

COAST will contribute a cost share of $216,000 for its three automated shuttles and three automated golf carts during at least one month of field testing and three months of demonstration.

References

Yao, H., Cui, J., Li, X., Wang, Y. & An, S. (2018). “A trajectory smoothing method at signalized intersection based on individualized variable speed limits with location optimization.” *Transportation Research Part D*, 62: 456-473.

Li, X., Ghiasi, A., Xu, Z. & Qu, X. (2018). “A piecewise trajectory optimization model for connected automated vehicles: Exact optimization algorithm and queue propagation analysis.” *Transportation Research Part B*, 118: 429-456.

Zhou, F., Li, X. & Ma, J. (2017). “Parsimonious shooting heuristic for trajectory design of connected automated traffic part I: Theoretical analysis with generalized time geography.” *Transportation Research Part B*, 95: 394-420.

Ma, J., Li, X., Zhou, F., Hu, J. & Park, B. (2017). “Parsimonious shooting heuristic for trajectory design of connected automated traffic part II: Computational issues and optimization.” *Transportation Research Part B*, 95: 421-441.