Proposal submitted to U.S. Department of Transportation

Notice of Funding Opportunity (NOFO) Number 693JJ319NF00001
“Automated Driving System Demonstration Grants”

Due Date: March 21, 2019

AVA: Automated Vehicles for All

Submitted by John L. Walker

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March 21, 2019

Subject: Submission of "AVA: Automated Vehicles for All" to U.S. Department of Transportation Notice of Funding Opportunity (NOFO) Number 693JJ319NF00001

Dear Proposal Review Committee,

We are very pleased to submit our proposal "AVA: Automated Vehicles for All" to U.S. Department of Transportation Notice of Funding Opportunity (NOFO) Number 693JJ319NF00001. Researchers from Texas A&M University, George Washington University, and the University of California Davis are proposing an extensive data collection effort using L4 automated vehicles in Texas, Washington D.C. and Northern Virginia. The proposal team is partnering with General Motors, NVIDIA, National Instruments, and Washington D.C. Department of Transportation to conduct these tests.

These tests are targeting the challenges of the current deployment efforts. These deployments have focused on large cities (excluding more than 80% of Americans from access to the safety benefits of this technology) and have overlooked the multimodal interactions (where the safety benefits of ADS can be quickly realized). Accordingly, this study will focus on rural roads as well as multimodal driving environments

I will serve as the main point of contact for this proposal. Please do not hesitate to contact me if additional information is required.

Best regards,

Alireza Talebpour, Ph.D.
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http://smartct.tamu.edu/

Summary Table

Project Name/Title	AVA: Automated Vehicles for All
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	Texas A&M Engineering Experiment Station (TEES)
Point of Contact (Name/Title; Email; Phone Number)	Alireza Talebpour, Ph.D.; Assistant Professor; Email: atalebpour@tamu.edu; Phone: 979.845.0875
Proposed Location (State(s) and Municipalities) for the Demonstration	College Station, TX Northern Virginia Washington D.C.
Proposed Technologies for the Demonstration (briefly list)	L4 automated passenger vehicles in rural and urban environments CARMA 2.0 based V2X Communications
Proposed duration of the Demonstration (period of performance)	Four years
Federal Funding Amount Requested	$ 7,063,787
Non-Federal Cost Share Amount Proposed, if applicable	$0
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$7,063,787

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1. EXECUTIVE SUMMARY

1.1. Vision

Our vision is to bring the safety benefits of autonomous driving to all Americans. Automated Driving Systems (ADS) has the potential to improve safety throughout the roadway system. However, the current deployment efforts have focused on large cities (excluding more than 80% of Americans fropm access to the safety benefits of this technology) and have overlooked the multimodal interactions (where the safety benefits of ADS can be quickly realized). Accordingly, this study will focus on rural roads as well as multimodal driving environments.

1.2. Goals and Objectives

Our goal is to develop a systematic and scalable approach to the safe integration of cooperative automated vehicles (CAVs) into the nation's transportation system. Towards realizing this goal, our objectives are threefold:

I. Develop and test strategies for safe integration of CAV operations into the transportation system with a focus on rural roads and multimodal roadway environment with pedestrians, and cyclists.
    a. Develop and test ADS for rural roads to operate without high-definition maps and with no or low-quality road signs and marking.
    b. Develop and test ADS based on safe interactions among non-motorized modes of transportation and CAVs.

II. Develop a comprehensive dataset for CAV safety analysis and rulemaking.
    a. Develop a systematic approach to assess the safety of CAVs as an improvement to the state-of-the-practice in CAV safety analysis.
        i. identifying risk factors that contribute to crashes and near-crashes involving CAVs and humans.
        ii. Identifying measures to assess CAV safety in rural areas.
        iii. Identifying measures to assess CAV safety in mix multimodal traffic environments with non-motorized modes of transportation.
        iv. Identify a baseline for the safety of CAV operations within these environments.
    b. Develop a framework for near real-time sharing of the collected data.

III. Develop a meaningful collaboration among the project team, project industry partners, and stakeholders to enable a safe integration of CAVs into the transportation system.
    a. Work with various transportation agencies, research institutions, CAV industry, and non-governmental organizations (NGOs) to develop integration strategies that fit their needs and limitations/concerns.
    b. Engage with the CAV industry early on in the project to better understand their challenges towards expanding their operations to rural areas and

dealing with non-motorized modes of transportation. Addressing these challenges within this project can bring this technology to all Americans.

1.3. Key Partners, Stakeholders, Team Members, and Other Participants

The proposal team consists of faculty and researchers from Texas A&M University, George Washington University, and the University of California Davis. The Texas A&M University team consists of experts in autonomous driving, computing, and control. The George Washington team consists of human factors and safety experts. The University of California Davis team consists of vehicle dynamics experts.

I. *Key Texas A&M University Personnel:* Dr. Alireza Talebpour will lead the project. He is currently leading the Texas A&M team in SAE/GM AutoDrive Challenge. Dr. Dilma DaSilva is the department head for Computer Science and is an expert in cloud computing. She will lead the data collection and analysis efforts. Dr. Reza Langari is the department head for Engineering Technology and Industrial Distribution and is an expert in control theory and autonomous driving. He will lead the field tests at the RELLIS campus.

II. *Key George Washington University Personnel:* Dr. Samer Hamdar will lead the George Washington team and is an expert in safety modeling and assessment.

III. *Key University of California Davis Personnel:* Dr. Francis F. Assadian will lead the University of California Davis team and is an expert in vehicle dynamics.

Key industry partners: General Motors, NVIDIA, and National Instruments support this proposal by providing hardware and software as well as consulting in all project phases, including planning, data collection, and data analysis.

Key public agency partners: The District of Columbia DOT (DDOT) will facilitate the testing process in Washington D.C. Moreover, the proposal team has permission to operate on public roads in the State of Texas.

Stakeholders: The stakeholders will be selected from public transportation agencies, law enforcement officials, private transportation companies, private CAV developers (among technology sector and automotive OEMs), and research institutions (including universities and US national laboratories). The stakeholder selection and engagement will be coordinated with USDOT.

1.4. Issues and Challenges to Be Addressed

The following issues and challenges will be addressed in this project:

1.4.1. Measuring Safety

The state-of-the-practice in AV safety analysis is focused on actual and simulated miles driven and the majority of companies compare their safety records based on the total miles driven and the number of crashes and disengagements events. In a recent study, Intel/Mobileye showed the infeasibility of such an approach (Shalev-Shwartz et al., 2017). Accordingly, measuring CAV safety faces the following key questions:

I. What are the risk factors that contribute to crashes and near-crashes involving CAVs?

II. How to assess the safety of artificial intelligence and dynamic learning algorithms?

III. What are the measures to assess CAV safety in rural areas?
IV. What are the measures to assess CAV safety in mix multimodal traffic environments with motorized and non-motorized modes of transportation?
V. What is the safety baseline for the safety of CAV operations within these environments?
VI. What data should be collected and shared with public agencies for CAV safety events? And how can public agencies and CAV operators mitigate safety risks?

1.4.2. Infrastructure

The current ADS deployments are aimed at operating alongside the existing infrastructure. However, modifying and/or upgrading the existing infrastructure, including the addition of roadside communication units and better signs/markings, can significantly improve the safety of CAV operations. Two key questions need to be addressed:

I. What infrastructure is needed to support CAV operations?
II. How to measure and predict the impact of improving/adding infrastructure elements on CAV safety?

1.4.3. Equity and access

The main goal of this proposal is to bring the safety benefits of autonomous driving to all Americans. Ensuring equity and access is the key towards realizing this goal. Accordingly, this project focuses on rural areas and addresses the following question:

I. How can CAVs serve aging populations and populations with disabilities?

1.4.4. Human factors and user acceptance

The safety benefits of CAVs can be most realized at high market penetration rates. Accordingly, human factors and user acceptance becomes critical factors:

I. When do people feel safe inside and outside of a CAV?
II. When would public agencies allow the removal of the “safety operator”?

1.4.5. Human-machine interface

A reliable ADS should be able to communicate with people inside and outside of the vehicle. This is critical to communicate intent to ensure the safety of roadway users. Moreover, an interactive interface can facilitate the adaptation process. The key questions are:

I. What is a reliable approach to communicating with users inside of CAVs?
II. What is a reliable approach to communicating with roadway users outside of CAVs?

1.4.6. Congestion, emissions, and energy consumption

The efficiency of CAVs and their impact on congestion, emissions, and energy consumption has been overlooked by the industry. Accordingly, the key question is:

I. How does designing CAVs for safety impact congestion, emissions, and energy consumption?

1.4.7. Adverse weather and roadway conditions

The majority of the current CAV deployment efforts try to avoid adverse weather and seize operations in such weather and/or roadway conditions. Operating in adverse weather conditions is critical in order to make this technology accessible to all Americans. Two key questions should be addressed:

I. When should CAVs seize operation when dealing with adverse weather/roadway conditions?

II. Are different safety criteria necessary for operating CAVs in adverse weather/roadway conditions?

1.5. Technology Development

This proposal is focused on developing and testing ADS that bring the safety benefits of autonomous driving to all Americans. Accordingly, the following two key areas are targeted:

I. *Rural and suburban roadway environment:* The current development and deployment efforts do not focus on rural roads due to the challenges associated with operating CAVs in such an environment without high-definition maps, with no or low-quality road signs and marking, and possibly limited GPS signal. Such driving environments require specialized perception systems and any decision-making mechanism should consider vehicle dynamics and roadway condition (something that is largely ignored in the current deployments). Developing reliable ADS for rural roads is essential to bring this technology to all Americans. Unfortunately, such ADS technologies do not currently exist, and industry is not focused on developing them. The key technical questions to address from the development perspective are:

   a) How should the current perception systems be updated to function in such environments?

   b) How critical is the role of vehicle dynamics in these semi-structured environments?

   c) How can communication be integrated into the ADS in these remote rural areas with limited coverage?

II. Multimodal roadway environment: The behavior of non-motorized modes of transportation (e.g., pedestrians, cyclists, etc.) can significantly influence CAVs decision-making and can result in high-risk safety-critical scenarios. Unfortunately, the current CAV development efforts are mainly focused on enhancing in-vehicle safety and they treat pedestrians, cyclists, etc. as moving objects to be avoided. Moreover, these development efforts largely ignore the communication element and potential safety benefits from utilizing V2X communications. Developing ADS that goes beyond treating roadway users as moving objects and considers the dynamic interactions among CAVs and other roadway users can significantly enhance roadway safety in a mixed driving environment. The key technical questions to address from the development perspective are:

a) How can we go beyond treating roadway users as moving objects? That is how we can integrate the decision-making logic of other modes of transportation into the CAV decision-making framework to improve the safety of these transportation system users that are more exposed and prone to collisions than vehicle drivers and passengers.

b) How we can incorporate V2X communications into the decision-making logic of CAVs to develop safe and efficient cooperation among all transportation system users and not just CAVs.

The data collected from the above deployments will be utilized to address the above issues related to measuring safety, infrastructure needs, ensuring equity and access, developing a reliable human-machine interface, capturing the impact of "safe design" on efficiency, and identifying safe operating conditions.

1.6. Quantifiable Performance Improvements

The successful completion of this project will result in:

I. A comprehensive dataset from ADS operations in rural and urban environments.

II. The generation of new measures to assess the safety impacts of ADS.

III. The development of perception, decision-making, and control algorithms for the same operation of CAVs in rural driving environment.

IV. The development of novel approaches to communicate the intent of CAVs to other roadway users.

1.7. Geographic Area of Demonstrations

This project will be conducted in three locations across the United States:

1.7.1. College Station, TX

College Station is the home to Texas A&M University RELLIS Campus. RELLIS Campus is a 2,000-acre campus being transformed into a high-tech, multi-institutional research, testing, education, and workforce development campus. These proving grounds have long been a place where Texas A&M has conducted world-class research, technology development, and workforce training in a variety of areas such as vehicle safety, traffic engineering, law enforcement training, robotics, connected and autonomous vehicles, and unmanned aerial systems. All the development activities and initial tests will be performed at RELLIS campus. Moreover, College Station offers several hundred miles of challenging rural roads within 2 hours of driving that will be used for data collection.

1.7.2. Washington D.C. and Northern Virginia

Washington D.C. is the home to George Washington (GW) University Foggy-Bottom (FB) Washington D.C. Campus. This campus offers a challenging multimodal roadway environment with pedestrians, cyclists, and scooters. Through collaboration with the District of Columbia DOT (DDOT), the proposal team will collect data from ADS operations within 1 mile of the GW FB campus. Note that all the development activities and initial tests will be conducted at the GW Virginia Science and Technology Campus (VSTC) that offers a semi-controlled environment.

1.8. Proposed Period of Performance

The requested period of performance is four years starting January 1, 2020.

2. GOALS

Our goal in this project is to develop a systematic and scalable approach to safe integration of cooperative automated vehicles (CAVs) into the nation's transportation system. Towards realizing this goal, our objectives are formulated as follows:

I. Develop and test strategies for the safe integration of CAV operations into the transportation system with a focus on rural roads and Multimodal roadway environment with pedestrians, cyclists, and scooters.

II. Develop a comprehensive dataset for CAV safety analysis and rulemaking.

III. Develop a meaningful collaboration among stakeholders to enable a safe integration of CAVs into the transportation system.

A discussion on how these objectives are aligned with the NOFO goals is provided in the following sections.

2.1. Safety

The majority of current CAV deployments efforts are focused on city environments with high population density. Moreover, these deployments do not include Vehicle-to-Everything (V2X) communications. Such an approach results in two key issues: (1) it limits the access of more than 80% of Americans (that mostly live in suburban and rural areas) to this technology, (2) it precludes significant safety benefits that can be provided (particularly to pedestrians, bikes, etc.) through real-time low latency V2X communications. Towards addressing these limitations, our first objective is to develop and test strategies for the safe integration of CAV operations into the transportation system with a focus on rural roads and Multimodal roadway environment with pedestrians, cyclists, and scooters. Several key challenges will be addressed to realize this objective:

2.1.1. ADS Technology

Operating CAVs in rural areas is challenging and algorithms should be able to operate safely without high-definition maps, with no or low-quality road signs and marking, and possibly limited GPS signal. The need for specialized perception systems and complex decision-making logics (that should include roadway condition, vehicle dynamics, etc.) adds to the complexity of the system. Developing a robust ADS system for such an environment is critical to the safe integration of ADS into life in rural areas.

In a multimodal roadway environment, incorporating the behavior of transportation system users into the CAVs' decision-making logic is critical for the safe integration of this technology. Moreover, if planned accordingly, the addition of V2X communications can further benefit safety and facilitate the integration process.

2.1.2. Infrastructure

The current ADS deployments are aimed at operating alongside the existing infrastructure. However, modifying and/or upgrading the existing infrastructure, including the addition of roadside communication units and better signs/markings, can significantly improve the safety of CAV operations. An accurate characterization of the potential benefits from investment in this area can help speed up the integration process.

2.1.3. Human factors and user acceptance

The safety benefits of CAVs can be most realized at high market penetration rates. Accordingly, human factors and user acceptance become critical factors. Particularly, a reliable and effective human-machine interface (inside and outside) that can also use V2X to communicate intent, can facilitate the adoption process. Understanding when people feel safe inside and outside of a CAV and when they are willing to use one or feel comfortable interacting with one can significantly facilitate the integration process.

2.2. Data for Safety Analysis and Rulemaking

This project will collect extensive data from various autonomous driving scenarios. Data will contain information from vehicles, sensors (processed and raw), other connected transportation system users (e.g., connected pedestrians and bikes), weather condition, roadway condition, traffic data, and safety incidents (historical and real-time collected data). The developed comprehensive dataset will be shared with the public in near real-time and can be utilized for CAV safety analysis and rulemaking. A key contribution of this proposal is to develop a scalable data-sharing platform for rural areas with limited 4G LTE coverage. Several key challenges will be addressed to realize this proposal objective:

2.2.1. Measuring Safety

The state-of-the-practice in AV safety analysis is focused on actual and simulated miles driven and the majority of companies compare their safety records based on the total miles driven and the number of crashes and disengagements events. The collected dataset will be utilized by the project team to develop a systematic approach to assess the safety of CAVs as an improvement to the state-of-the-practice in CAV safety analysis. The dataset will be used to identify the risk factors that contribute to crashes and near-crashes involving CAVs, develop methods for assessing the safety of artificial intelligence and dynamic learning algorithms, and identify the safety baseline for the safety of CAV operations.

2.2.2. Adverse weather and roadway conditions

The majority of the current CAV deployment efforts try to avoid adverse weather and seize operations in such weather and/or roadway conditions. Operating in adverse weather conditions is critical in order to make this technology accessible to all Americans. This proposal will include operating in adverse weather condition in Washington D.C. and Northern Virginia as an effort to collect publicly available data from these conditions.

2.2.3. Congestion, emissions, and energy consumption

The efficiency of CAVs and their impact on congestion, emissions, and energy consumption has been largely overlooked by the industry. The collected data will be utilized by the proposal team to identify the impacts of designing CAVs for safety on congestion, emissions, and energy consumption.

2.3. Collaboration

This proposal will develop a meaningful collaboration among stakeholders to enable a safe integration of CAVs into the transportation system. The proposal team will work with various transportation agencies, research institutions, CAV industry, and non-governmental organizations (NGOs) to develop integration strategies that fit their needs and limitations/concerns. Moreover, we will engage with the CAV industry early on in the project to better understand their challenges towards expanding their operations to rural areas and dealing with non-motorized modes of transportation. Addressing these challenges within this project can bring facilitate the safe integration of CAVs into the life of all Americans. Several key challenges will be addressed to realize this proposal objective:

2.3.1. Equity and access

The main goal of this proposal to bring the safety benefits of autonomous driving to all Americans. Ensuring equity and access is the key towards realizing this goal. Accordingly, this project will work with medium and small cities in Texas as well as DDOT to better address the equity and access issues in these driving environments. The focus in rural driving environments will be on addressing the needs of the aging population and people with disabilities.

3. PROPOSALS RELATION TO USDOT FOCUS AREAS

In addition to the overall goals and objectives of this proposal, we will also address the following USDOT focus areas as indicated by the NOFO.

3.1. Significant Public Benefits(s)

The proposed project brings significant public benefits in the following areas:

I. By targeting rural roads and developing ADS to operate in such driving environments, we bring the safety benefits of autonomous driving to more than 80% of Americans that are not being served with the current state of the technology.

II. By targeting the aging population and people with disability in small- and medium-size cities, we bring a means of mobility to a segment of the population that has no other choice of travel, except relying on family members. Accordingly, we expect to significantly improve the quality of life for these people.

III. By incorporating the behavior of pedestrian and cyclists into the decision-making logic of CAVs, we go beyond treating roadway users as moving objects. Accordingly, we expect to significantly enhance the safety of pedestrians and cyclists in mixed driving environments.

IV. By incorporating V2X communications to the CAV operations, we significantly improve the safety of all transportation system users and not just CAV users.

3.2. Addressing Market Failure and Other Compelling Public Needs;

The proposed project is focused on the following market failures and public needs:

I. Rural driving environments are largely overlooked by industry due to the risk and complexity of the operation. We will work closely with our industry partners to address the challenges associated with operating in such environments.

II. Providing mobility service to the elderly and people with disabilities is the key focus of our rural operations. Unfortunately, only a small number of private companies focus on this group and lack of private sector investment is a huge barrier to enhance the quality of life for the elderly and people with disabilities.

III. Developing cooperative multimodal roadway environment requires collaboration among private industry, research institutions, and public agencies. The lack of investment and coordination has slowed the process significantly. This project will bring all these elements together. By utilizing the CARMA platform as the core of the development efforts, we will go beyond cooperative driving to develop cooperation among all transportation system users.

3.3. Economic Vitality

Through collaboration with our industry partners and addressing the current limitations of ADS, we expect to ensure the US lead in the autonomous driving industry for the years to come. Moreover, we expect several patents to emerge from this project and related activities.

3.4. Complexity of Technology

All of the proposed development and testing efforts in this proposal will be based on SAE L4 (for rural roadway environment) and SAE L3 (for multimodal roadway environment). Note the developing L4 CAVs for rural roads, where we address the needs of people with disabilities and elderly, is critical due to the challenges associated with manual override.

3.5. Diversity of Projects

The proposed project will address the challenges associated with CAV operations in urban, suburban, and rural areas. Moreover, in Washington D.C., we will work focus on multimodal driving environment and design an ADS to bring the safety benefits of CAVs to all transportation system users.

3.6. Transportation-challenged Populations

All our testing and development efforts in rural roadway environment will focus on addressing the transportation needs of people with disabilities and elderly.

3.7. Prototypes

Our existing CAVs have been developed based on the GM guidelines for automated vehicle safety and the vehicles are roadway legal. A similar development approach will be taken for the development of additional CAVs for further testing and data collection. Note that, as will be discussed later, the software development efforts will focus on certain elements of ADS that are not being addressed by the industry (e.g., autonomous driving without high-definition maps); thus, the developed technologies will not be ready for a broader deployment right away. However, we will work with our industry partners and stakeholders to disseminate the findings of this study.

4. HOW PROPOSAL MEETS REQUIREMENTS

This proposal meets all the requirements indicated by NOFO.

I. The focus of our development efforts is on L3 vehicles for multimodal roadway environments and L4 vehicles for rural roadway environments.

II. We will conduct extensive testing and data collection using our CAVs. We will also conduct simulation studies during the development phase to ensure the safety and reliability of the design.

III. All the collected data will be shared with USDOT in near real-time and will be kept for public access for at least five years after the end of the project. The data includes vehicle information (i.e., location, speed, heading), sensor data (processed and raw data from camera, LiDAR, radar, and GPS), data from other connected transportation system users (e.g., connected pedestrians and bikes), weather condition, roadway condition, traffic data, and safety incidents (historical and real-time collected data). All the IRB guidelines will be followed for sharing the collected dataset.

IV. All the vehicles will have Input/output user interfaces based on a monitor mounted in the vehicles. Users can input their destination, receive real-time information on about the ride, and execute emergency stop from the monitor. Voice command will be also provided for people with disabilities.

V. Specific guidelines will be developed to explain how the findings of this study can be adopted across the Nation to similar roadway environments. Moreover, through our stakeholders as well as conference presentations, we will conduct outreach activates to disseminate the findings of our study and lessons learning from working with private industry and public agencies.

5. APPROACH

This section presents our approach towards experimental setup, data collection, and data analysis and assessment.

5.1. Technical approach to implement and evaluate the demonstration

Our vision is to bring the safety benefits of autonomous driving to all Americans. Accordingly, to address the limitations of the existing ADS deployments, this study will focus on rural roads, where current deployment efforts have largely overlooked and multimodal roadway environment, where the safety benefits of ADS can be quickly realized. Our goal is to develop a systematic and scalable approach to safe integration of CAVs into the nation’s transportation system. This goal will be achieved through the following tasks. Task-specific deliverable and their due dates are summarized in the proposed deliverables schedule and are presented in the management plan document.

Task 1 - Project Management and Work Plan

The PIs and project manager will prepare a comprehensive project execution plan. The plan will cover issues such as task scheduling, interaction plans (among TAMU, GW, UC Davis, GM, NVIDIA, and NI), and data collection methodology. The team will prepare a Gantt chart summarizing tasks and deadlines as well as deliverables over the duration of the project. This Gantt chart will be utilized to keep track of the project progress and might be updated based on the input from USDOT staff, our industry partners, and stakeholders. The team will set up a kick-off meeting, where the work plan and charts will be presented. This kick-off meeting will be set to no later than two weeks after the start of the project.

The project manager will schedule bi-weekly meetings with USDOT staff. The proposal team will provide monthly progress reports to USDOT staff. The project manager coordinates with all the team members to complete the deliverables and will submit all the report.

Task 2 – State of Practice Review

The proposal team will conduct a thorough literature review and state of practice review of available datasets as well as CAV safety assessment methods. Any useful dataset identified by this review will be shared (either the data or guidelines to access it) through the project website. The review of safety assessment methods will assist with data analysis tasks in this project. All the findings of this task will be documented in a draft task report.

Task 3 – Stakeholder Interaction

The proposal team will prepare a list of potential stakeholders related to this project across the disciplines. The detailed discussion on the list potential disciplines is provided in the management plan document. The list of stakeholders will be created based on feedback from USDOT.

Once the list is finalized, the proposal team will coordinate webinar logistics. Four webinars will be conducted (one for each year of the project) to share the plans and findings of the project with stakeholders and to receive feedback. All the discussion in these meetings will be documented and the proposal team will share these meeting notes with USDOT and stakeholders for further comments.

Task 4 – Draft Data Collection Plan

The proposal team will create a draft data collection plan. This document will provide the details of the data collection plan based on the discussions provided in this document. This document will be shared with USDOT and stakeholders and will be updated, refine, and finalize based on the comments received. This document includes:

I. Detailed data collection plan schedule, including dates, times of the day, and location. Note that data collection tours will be designed for the rural driving environment to cover various types of roads and to not impose any limits on the data collection by only covering the roadways in the vicinity of College Station, TX.

II. Detailed information on collected data, their sources, their format, and estimated size.

III. Detailed information on the data sharing process and frequency of uploading the data.

Task 5 – Vehicle Development

The PIs currently have three automated vehicles, one Chevy Bolt EV, one Kia Soul, and one Ford F-150 (See Figure 1). These vehicles will be utilized in this project for data collection. Moreover, the proposal team in collaboration with our industry partners (GM, NVIDIA, and NI) will develop another four vehicles. An overview of the hardware and software utilized in these vehicles is provided below. Note that all the development efforts will take place at Texas A&M RELLIS Campus (see below for more information).

Figure 1: Automated Vehicle Platforms at Texas A&M.

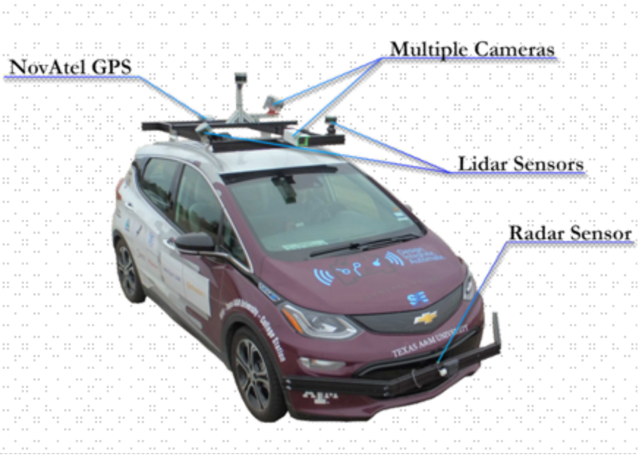
Vehicle design

The Vehicle development process will follow the SAE/GM AutoDrive Challenge guidelines. AutoDrive is a competition among eight North American universities to develop a L4 Chevy Bolt EV. The competition is sponsored by SAE International, GM, Intel, Velodyne, Bosch, Continental, ZF, On-Semiconductors, NoVatel, etc. The PI Talebpour is leading the Texas A&M's team in this competition. As part of the competition, safe, reliable, and comprehensive hardware and software solutions are developed.

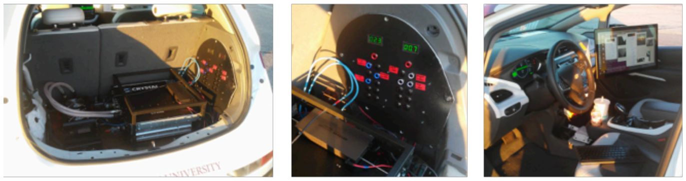
Hardware Design

We have designed and developed robust Autonomous Driving Systems based on the Chevrolet Bolt EV (see Figure 2). These systems include Global Positioning System sensors, LiDAR sensors, and visible light cameras which comprise our perception system. The perception system is securely mounted onto a custom rack that was designed and built in-house and is securely attached at multiple points to the roof of the vehicle.

Acting as the central computational core of our Autonomous Driving Systems is a Crystal Rugged computing platform that is securely harnessed into the trunk of the vehicle. Next to the computer harness, we have created a control panel that acts as the on, off, and reset switch for our implemented perception systems. Our perception



Vehicle Sensor System



Computing Unit Control Panel Human-Machine Interface

Figure 2: Perception system, computing unit, control panel, and human-machine interface.

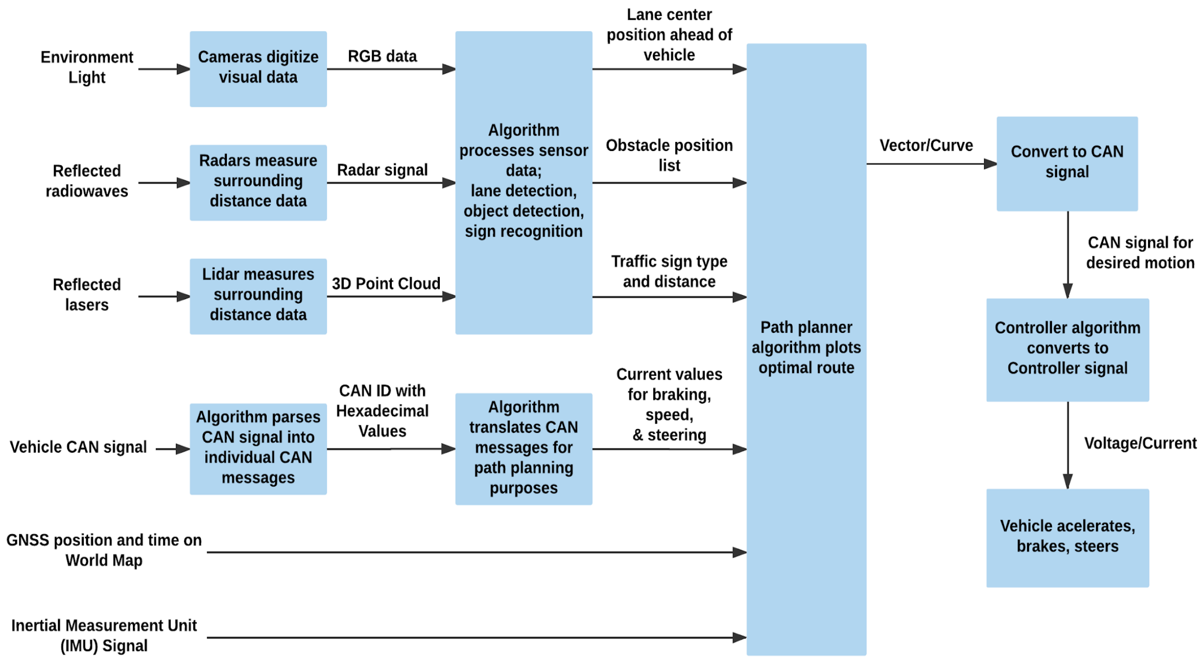


Figure 3: Functional Model of our ADS.

systems feed into the computer to provide information for our state-analyzer and controls systems to manipulate the real-time behavior of the vehicle. A display, with a keyboard and touchpad, is built into the front passenger dash to allow the front passenger to act as a co-pilot for the vehicle. This co-pilot can then program at any level specific behaviors into the car, monitor any system vitals, view the real-time output of the perception systems, etc.

Software Design

A functional model of the software system is shown in Figure 3. This process aided in breaking down each function for better visualization and understanding. Furthermore, each function's input and output were considered to verify the system functionality. Figure 4 demonstrates how the functional model evolved into the software breakdown. Each color demonstrates one of the major sub-tasks utilized to execute the autonomous driving. The blue Sensing Block was made up of perception modules that developed systems for object, lane, and sign detection. Following the figure, the data then was sent to the green Sensor Fusion module that worked on data synchronization and verification along with ranking the incoming data. This module is also responsible for vehicle localization. This information was then sent to the yellow Trajectory and Waypoint module to determine the course forward. Next the red Control block, which consisted of lateral and longitudinal controls interpreted the data to send messages controlling the vehicle movements. Finally, the purple Execution module read the CAN messages to execute the Control messages. Note that all the communications are based on the Robot Operating System (ROS).

It is important to note that the Local Health Monitoring System (LHM) is in place as a redundancy to verify healthy and safe behavior. The Global Health Monitor (GHM) and the state machine represented in Figure 4 take on the task of receiving the information from the local health monitors and using that information to react based on any failures or changes of state. The global health monitor is a central module that cyclically receives status data informing about system boundary crossings from all monitoring components and thus has the overview of all preconditions for operating. As for the state machine, the Team has defined the state machine as a reactive function which receives information from the global health monitor and uses this information to decide if a change in driving condition has occurred. The interaction of the state machine with the state enforcer addresses the step to be taken when driving conditions change. Internally or externally imposed driving conditions will be dealt with as the state enforcer updates the prioritization of processing steps in the system architecture. For instance, during normal driving conditions, the system architecture will Sense-Plan-Act in a predefined manner. However, in a low energy state, the state enforcer may adjust the limitations of the maximum torque engagement to promote energy conservative driving. Another example is during a state of high alert such as a school zone, the state enforcer may reduce the functional boundaries of the lateral/longitudinal control and spend additional energy on the Analysis function in the Sensor Fusion block to detect and track items of interest (i.e., children).

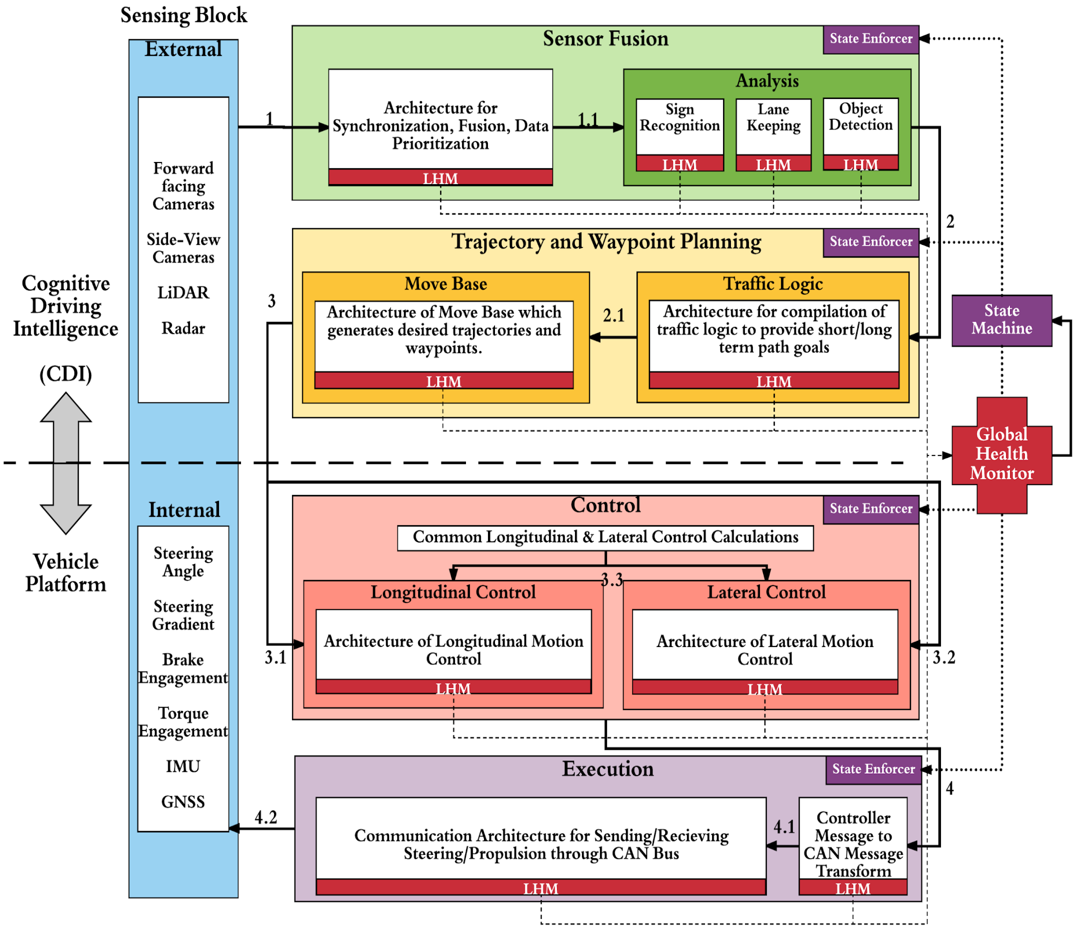


Figure 4: System architecture.

As seen in the architecture, information flows through solid-black, dashed-black, and dotted-black lines. The solid-black lines represent the flow of data that is transformed and utilized to perceive its surroundings and act in the world in which the driving intelligence operates. The dashed-black line represents health information. However, since the functional health monitoring system should be able to find faults and adapt faster than the normal flow of information, the frequency of the information sent through the dashed-black lines is a magnitude faster than the solid-black. In other words, since our goal is to catch a mistake found in the normal flow of information before the car acts on faulty information, then the health monitoring system must detect, send, and act at a much faster rate than the regular flow of information.

Task 6 – Data Collection

This task is the core of this project and spans across its entire duration. Below the details of data collection is provided for rural roadway environment and multimodal roadway environment.

Rural roadway environment experimental setup

The rural experiments will take place mainly within 2 hours of the TAMU College Station Campus and TAMU RELLIS Campus. The complexity of the rural driving environment is much less than the urban environment if we only consider the roadway users (i.e., vehicles, pedestrians, cyclists, etc.). In fact, in such a driving environment, the CAV is more likely to deal with only vehicles (passenger cars and trucks). However, the complexity of rural driving arises when considering the state-of-the-art in ADS. The existing systems rely heavily on HD-maps and known driving environment with often clear markings and roadway signs. Unfortunately, developing and maintaining an HD-map for remote rural areas is impossible and cost prohibitive. Moreover, considering the lack of unique elements on the road (e.g., lack of building edges and similarities in the LiDAR data from a location to another), localization based on HD-maps is extremely challenging. Accordingly, another localization approach needs to be utilized. Note that perfecting such a localization technique through data collection in this study can encourage the industry to test and deploy in rural environments as it eliminates the cost of operating off of HD-maps.

In addition to the localization issue, the quality of pavement is often poor in rural roads (some rural roads are not even paved). Moreover, the roadways elements (e.g., curves, lane-width, etc.) might not be standard. Accordingly, considering vehicle dynamics in the decision-making is of utmost importance to prevent the loss of vehicle control (that can result in single-vehicle crashes). The proposal team will develop and test such a decision-making logic to ensure vehicle safety in a rural environment.

Moreover, these roads usually do not have high quality signs and markings. Accordingly, the perception systems should be updated to identify the safe drivable area. Moreover, due to the usually uneven pavement, the vehicle movements are not smooth, and the sensors do not stay parallel to the roadway (see Figure 5). Accordingly, the deep learning based perception system should be retrained to be able to identify roadway elements under these circumstances.

Finally, wild animals pose a significant safety concern in rural roads. The ADS should be able to detect and identify wild animals and react accordingly. The perception system and decision-making logic should be updated to be able to detect the animal, predict its behavior, and react in the safest possible way to avoid any collision with the animal.

Figure 5: **Rotation of Camera with respect to the roadway surface due to an uneven roadway surface.**

All the experiment in the rural environment will focus on addressing the above challenges, while collecting data from the ADS operation for safety assessment. Challenging roadways will be selected by the proposal team based on an initial data collection. Once the roadways are selected, CAVs will travel through them regularly under various roadway and weather conditions to ensure collecting a comprehensive dataset from rural areas. Such a dataset can facilitate the development of ADS for rural areas and can provide the necessary information to assess the safety of autonomous driving in such driving environments.

Note that the main purpose of tests in rural areas is to bring the safety benefits of ADS to the elderly and people with disabilities. Accordingly, a mechanism will be built into the vehicles to facilitate the process of riding in the CAV (including getting into and out of the vehicle). In the last year of the project, the proposal team will provide rides to this population in the vicinity of College Station.

Multimodal roadway environment experimental setup

The multimodal experiments will take place mainly at the GW DC and Virginia Campus. The experiments will be based on data collected from students/staff/faculty members and up to 100 hired human subjects per year during the second and third year of the project. The first step of every experiment will constitute of controlled environment experiments that will be first implemented and tested at the Virginia Science and Technology Campus (VSTC). The main focus remains the safety impact of ADS systems on vulnerable travelers especially pedestrians and cyclists. Accordingly, there will be a total of 27 scenarios where three variables will be modified: *1)* The Infrastructure Type (the *I*); *2)* the Mode (the *M*); and *3)* the Control Type (the *C*). Since the experiments tested in the controlled environment will be then translated to the non-controlled GW DC environment, the following types of infrastructure will be focused on: *I1*: 4-Way Intersection; *I2*: Mid-Link Crossing; and *I3*: Shared Space Environment. In the Shared Space Environment, the travelers (driver(s), pedestrians and cyclists) will be instructed to head to pre-defined destinations while being alert of the presence of different types of modes through different messaging/control (Stop or Signal). The right of way is always given to the pedestrians and cyclists.

In each of the *I* scenario types, there will be three types of controls looked at: *C1*: No Control; *C2*: Stop Control; and *C3*: Signal Control. As mentioned earlier, in the “No Control Scenario”, the right of way is given to pedestrians, then cyclists, then cars. It should be noted that each experiment will include an automated vehicle with the corresponding ADS system implemented. For example, when dealing with a mid-link crossing, a car will be travelling on the main lane. In a minor road or a side-walk, there will be either another car, bike or pedestrian waiting to cross the main lane. A no-control scenario indicates that the car/pedestrian/bike are instructed to cross while the ADS being programmed to give priority to the crossing traveler (driver, pedestrian or cyclist) without an explicit control (signal or stop sign). In other words, the main aspect to be tested is the responsiveness of the pedestrians/cyclists/drivers to the presence of an autonomous vehicle when performing a crossing maneuver (i.e. risk-taking tendencies). Such aspect will directly feed into the training of the autonomous vehicles' drivers when deploying the systems proposed in suburban Virginia and the urban DC environments. Figure 6 offers a more detailed illustration of the multimodal system experimental design.

The controlled experiments results will be stored and analyzed. Given the performed analysis, the professional drivers will be able to perform daily driving tasks especially after making the needed arrangements with DDOT. Special attention will be given to absolute and relative trajectory data.

In terms of subject participation, a factorial design will be performed in order to guarantee the highest number of data points while reducing the number of participants. A total of 9 variables. The variables will be classified as "Within-Subjects Variables" and "Between-Subjects Variables" and a subject might be experiencing different scenarios. The main hypotheses to be tested are:

Hypothesis 1: The provision of control measures fosters improved behavior and reduces traffic near-collision events and disturbances (fewer collisions and less travel time).

Hypothesis 2: drivers will allow the automated driving system to control the vehicle movement for "T" duration of time without interfering.

Each of the hypothesis will be tested again for the different types of modes and the different types of infrastructures/control levels as presented in Figure 6. Specific attention will be given to the following aspects:

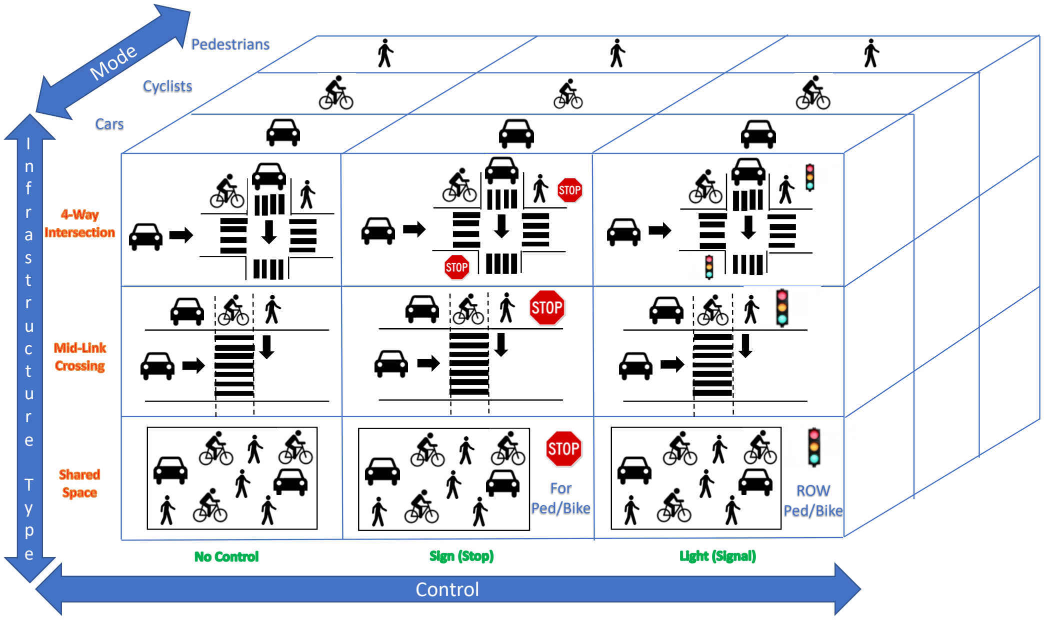


Figure 6: Experimental Set-Up for Urban ADS Scenarios architecture.

I. Robustness of the ADS tested especially in terms of resiliency to errors in measurements and delay in communication and the corresponding reliability. This will be performed after performing the experiments with added simulation sensitivity analysis.
II. The responsiveness of the human subjects in particular and the public in general - especially vulnerable DC travelers – to the ADS if integrated on public US roadway segments.

A note on V2X communications

All the vehicles will be equipped with onboard DSRC and 4G LTE units. The data collections efforts will utilize V2X for communicating information to various roadway users. This is particularly critical in the multimodal urban environment. USDOT's CARMA 2.0 platform will be utilized to handle the V2X communications in this project. The PI is currently using this platform to test merge coordination application for an FHWA project. Moreover, the PI is assisting the CARMA 3.0 localization team in an unofficial capacity.

Task 7 – Data Analysis and Safety Assessment

While improving roadway safety has been at the core of all the above efforts, to date, no reliable approach has been offered to assess the safety of autonomous driving. Several key factors contribute to this lack of reliable safety assessment methods, including:

I. *Perceived safety vs. technical safety:* It is essential to distinguish between how the public (including governmental entities) perceive CAV safety and what is technologically feasible. A CAV might not be able to provide a required level of safety even though it might seem safe based on some measures (e.g., number of disengagements per miles driven, as reported in California). Therefore, to develop reliable CAV safety assessment methods, it is critical to consider what current technologies can offer from the safety standpoint and what are the limitations. Through data collection from inside and outside of the vehicle as well as surveys, the proposal team will explore how perceived safety and technical safety are related. Understanding this relationship can help develop guidelines to ensure consumer safety and comfort.
II. *Performance measures:* It is not clear what should be used as the performance measure to assess CAV safety. All of the companies (even traditional automotive OEMs) compare their safety records based on the total miles driven and the number of crashes and disengagements events (any interference in the vehicle decision-making and/or maneuver by the safety driver can be considered a disengagement event). In a recent study, Intel/Mobileye showed the infeasibility of such an approach and the need for 10^9 hours of testing to reach human-level driving safety after each software/hardware update (Shalev-Shwartz et al., 2017). Considering the CAV development goal to develop better than human drivers, the overall testing time should be much higher to ensure reliable and safe driving-related decisions (Shalev-Shwartz et al., 2017). Moreover, field experience to date has shown crash frequency can increase after each software/hardware update. Unfortunately, the current measures of safety (i.e., miles driven and crashes/disengagement events) do not provide any insight into the nature of these high-risk events; thus, developing preventive measures and design guidelines

require another approach. Utilizing the collected data from ADS operation, the proposal team will identify risk factors that contribute to crashes and near-crashes involving CAVs. Accordingly, new measures for safety assessment is expected to be developed to better reflect the safety of ADS.

III. *Trusting black box learning methods:* CAVs rely heavily on dynamic learning (DL) algorithms (e.g., reinforcement learning and inverse reinforcement learning) based on neural networks (NNs). Accordingly, the behavior of the vehicle changes quickly based on the learning process. Moreover, the black box nature of NNs can result in considerable safety assessment issues. The key questions are “what is required for trusting NNs and DL algorithms?” and “how can we validate NNs and algorithms?”. Three key aspects should be considered:
    a) Trusting the data: It is important to have confidence in the data being used to train NNs and DL algorithms. Data should cover the entire domain of interest to ensure a reliable calibration. Any bias can result in unexpected behavior. Accordingly, the key challenge, in the context of CAV design, is capturing enough data from edge cases (i.e., rare driving scenarios that do not occur often but can result in significant safety challenges).
    b) Trusting the algorithms: NNs try to approximate complicated functions and DL algorithms try to learn to function within complex environments using these NN-based approximations of the functions governing the environment. In other words, our NNs and DL algorithms should work for rare safety-critical cases.
    c) Implementation challenges: A reliable implementation of the algorithms can significantly facilitate the assessment process. The role of hardware-software interactions can be critical in this context as a robust software demands minimum hardware requirements. This is particularly critical considering the variety of the algorithms utilized in autonomous driving.

Utilizing the data collected from the experiments, the proposal team will try to answer the above questions. Note that identifying a reliable approach to evaluate the safety of black box learning methods will result in a breakthrough in ADS safety assessment.

Data Description

This proposal will collect data from the following sources:

I. *Vehicle Data:* Vehicle data contains data from the CAVs as well as other vehicles on the road in the CAVs' vicinity.

II. *Roadway Data:* This data is mainly related to the infrastructure status and quality when designing the CAV maneuvers.

III. *Traffic Data:* This data is in addition to the trajectory data that will be collected by the vehicle. This data includes macroscopic/aggregate characteristics of the traffic.

IV. *Collision Data:* This data is the standard measures normally adopted when analyzing safety by different transportation safety experts.

V. *Surrogate Safety Data:* Since collisions are rare events, at the scale of this project, we don't expect to see any collisions. Accordingly, surrogate safety measures (e.g., Time-to-Collision) should be utilized for an accurate assessment of the impact of CAVs on safety in both rural and urban environments.

VI. *Human Experience and Human Factors Data:* This data relies on observational studies and surveys and is to be translated into human experience and human factors measures.

VII. *Simulation Data:* The PIs Unity-based simulation environment (SAFESim) will be utilized to recreate high-risk driving scenarios observed in the field for further analysis and investigation.

The detailed description of the collected data, its frequency and format, and sharing process is presented in the data management document.

Task 8 – Data Preparation, Storage and Sharing

Data preparation, storage, and sharing the data in a timely fashion (near real-time) is of utmost importance. Data preparation will be an automated process with human oversee. All the software developed by the proposal team for this purpose will be shared under MIT open-source license. The proposal team has developed a solid plan for storage and near real-time sharing of the data through Texas A&M Campus Data Center. The proposal team will work with USDOT to ensure all the requirements for data storage and sharing are met. The detailed description of the data preparation, storage and sharing processes are presented in the data management document.

Task 9 – Simulation

The PIs Unity-based simulation environment (SAFESim) will be utilized to recreate high-risk driving scenarios observed in the field for further analysis and investigation. SAFESim, a comprehensive simulation platform for automated vehicles based on Udacity's simulation platform. While several simulation platforms have been developed for this purpose, SAFESim offers the following novel features:

I. *Realistic models of human drivers and pedestrians:* humans' can make mistakes and create high-risk situations. Moreover, their behavior under these high-risk situations can be fundamentally different from their day-to-day behavior. SAFESim relies on data collected from our automated vehicles and the concepts of traffic flow theory to develop realistic models of human behavior in response to CAVs (particularly, in safety-critical situations).

II. *System failure testing module:* SAFESim simulates all aspects of the vehicle, including CAN Bus communications, sensors, vehicle dynamics, and controllers. Accordingly, various aspects of hardware and software failures can be simulated.

III. *Hardware-in-the-loop testing:* SAFESim is based on the Robot Operating System (ROS) platform and offers direct communications with the physical world through ROS. Accordingly, the automated vehicle can be engaged with the simulation environment for testing algorithms and hardware performance.

Task 10 – Final Report and Data Sharing Platform

The last task of the project will focus on documenting and sharing the findings of the study. Moreover, all the developed software and data sharing platforms will be shared with USDOT for public use.

5.2. Key partners and stakeholders

Key industry partners: General Motors, NVIDIA, and National Instruments support this proposal by providing hardware and software as well as consulting in all project phases, including planning, data collection, and data analysis (please see the letters' support).

Key public agency partners: The District of Columbia DOT (DDOT) will facilitate the testing process in Washington D.C. (please see the letter of support). Moreover, the proposal team has permission to operate on public roads in the State of Texas.

Stakeholders: The stakeholders will be selected from public transportation agencies (including Texas DOT, Virginia DOT, and DDOT), private transportation consulting firms, private CAV developers (among technology sector and automotive OEMs), and research institutions (including universities and US national laboratories). The stakeholder selection and engagement will be coordinate with USDOT.

5.3. Overview of deployment sites

This proposal will focus on the following three geographical locations to conduct testing and data collection.

5.3.1. College Station, TX

All the development and deployment efforts related to the rural roadway environment will be conducted within 2 hours of driving from College Station, TX. The initial development efforts will be performed at the Texas A&M RELLIS Campus. The Texas A&M RELLIS Campus is a 2,000-acre campus being transformed into a high-tech, multi-institutional research, testing, education, and workforce development campus (See Figure 7). The RELLIS Campus is conveniently located adjacent to State Highways 47 and 21, a 15-minute drive from Texas A&M University's main campus. These proving grounds have long been a place where Texas A&M has conducted world-class research, technology development and workforce training in a variety of areas such as vehicle safety, traffic engineering, law enforcement training, robotics, connected and autonomous vehicles, and unmanned aerial systems. ***The existing facilities at the RELLIS Campus include 6-miles of paved runway test tracks and proving grounds, 3 miles of urban grid roadways***, a toll gantry test bed, a roadway safety device test bed and crash test proving ground, pavement marking proving ground, and automated pavement assessment

Figure 7: RELLIS Campus in College Station, TX (top) and rural roads near College Station, TX (bottom).

equipment proving grounds. New improvements underway at the RELLIS Campus include seven new engineering research buildings and test beds that will provide state-of-the-art research and testing capabilities and encourage the development of additional public and private sector research facilities adjacent to the Texas A&M University System's (TAMUS) facilities at the RELLIS Campus. ***The primary research focus areas include robotics, driverless and connected vehicles,*** advanced manufacturing, large-scale testing, as well as smart cities technologies in areas such as smart power grids, water systems, and parking.

The main deployment efforts will be conducted within 2 hours of driving from College Station. The area (as seen in Figure 8) offers several hundred miles of challenging rural roads suitable for data collection. The majority of these roads are poorly maintained two-lane highways (paved or unpaved) with poor visibility and, in many cases, no signs or markings.

5.3.2. Washington D.C.

The second area of deployment and testing is characterized by multimodality and mixed land-used in a highly urbanized environment. This area corresponds to the **George Washington University (GW) Foggy Bottom (FB) Campus** in Washington DC. The campus consists of 43 acres (170,000 m2) and is located a few blocks away from the White House and the National Mall. The boundaries of the campus are mainly defined by Pennsylvania Avenue, 19th Street (NW), E Street (NW), and Virginia Avenue. The GW FB Campus Area contains a very busy transit *metro station* and different *buses/bus stops* operated by the Washington Metropolitan Area Transit Authority (WMATA) (i.e. Foggy Bottom – GWU Station), a *capital bike-share* station with a considerable number of *cyclists*, a significant number of *pedestrians* (students and professionals) and an increasing number of *scooters' users*. Such a unique environment has been created because of the location of GW on a commuter corridor between Maryland, Virginia, and Washington DC (Figure 8). Moreover, within the direct GW FB Campus vicinity, there are *multiple trip generators and attractions* (i.e. The GWU Hospital, the White House/Department of State, The World Bank, the International Monetary Fund – IMF, the nearby memorials,etc.) which increase the travel demand at different durations of the year. Finally, the GW Campus is characterized by major arterials with signalization (i.e. 23rd Street NW, E Street NW, Pennsylvania Avenue, Virginia Avenue) and secondary one-way roadways controlled by signals and stop signs (i.e. 20th Street NW, 21st Street NW and 22nd Street NW) (See Figure 8). This provides the research team with a

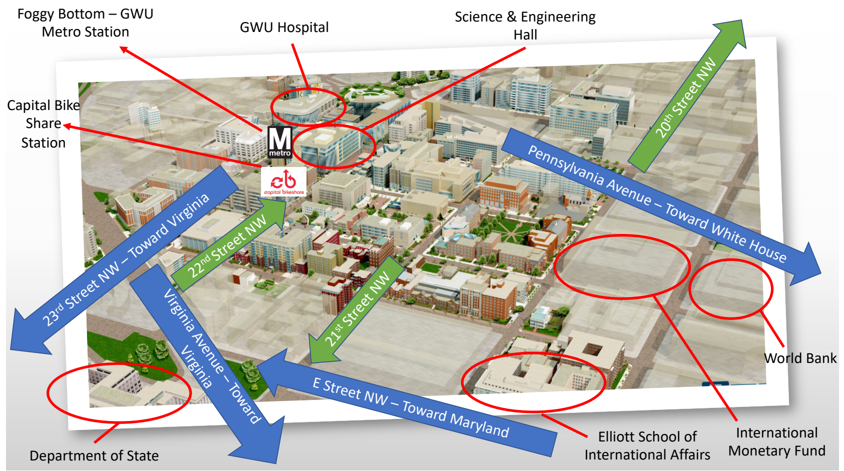


Figure 8: The George Washington University Foggy Bottom Campus – Test Bed 2.

one-of-a-kind environment to test the performance of automated vehicles with different traffic control strategies in a variety of roadway geometric and environmental conditions. The GW Campus will be mainly a deployment site.

5.3.3. Northern Virginia

The third site of development and deployment is the GW Virginia Science and Technology Campus (VSTC – See Figure 9). The Campus is located in the city of Ashburn, Virginia, around 10 miles north of the Dulles International Airport. It is accessed through four major roads: Route 267 (i.e. Dulles Toll Road - Freeway), Route 28 (i.e. Sully Road – major arterial with most of the segments characterized by controlled access facilities), the Loudon County Parkway (major arterial) and/or Route 7 (i.e. Leesburg Pike – major arterials with a high density of interchanges and signalized intersections). The campus is surrounded by office buildings and residential units but in a less dense suburban environment if compared to the GW FB DC Campus. The campus can be only accessed through one route (i.e. the Loudon County Parkway) with one signalized intersection leading to the George Washington Boulevard: the main Boulevard in the VSTC campus area. The boulevard has bike lanes and multiple bus stops but with limited signalization. The rest of the roadways at the VSTC Campus are secondary roadways with no signalization (i.e. only stop and yield signs). The location and the land-use characteristic of the campus (i.e. access controllability and less dense land-use) makes it ideal to test the vehicles for performing the controlled deployment.

5.4. Legal, regulatory, environmental challenges

Our team currently has all the necessary requirement to perform ADS testing on Texas public roads. As our common practice, before conducting any test on public roadways, we coordinate with local transportation authorities as well as law enforcement officials to ensure the safety of the people living and working in the vicinity of the test areas. We are also working with DDOT (please see the support letter) to meet all the expectations before conducting any tests in Washington D.C.

None of our vehicles are roadway safe and we don't need any exemptions from Federal Motor Vehicle Safety Standards (FMVSS), Federal Motor Carrier Safety Regulations (FMCSR), or any other regulation. Note that all our vehicles are and will be fully insured during the development and testing period.

Recognizing the Buy American Act and Executive Order 13788, through collaboration with our industry partners and

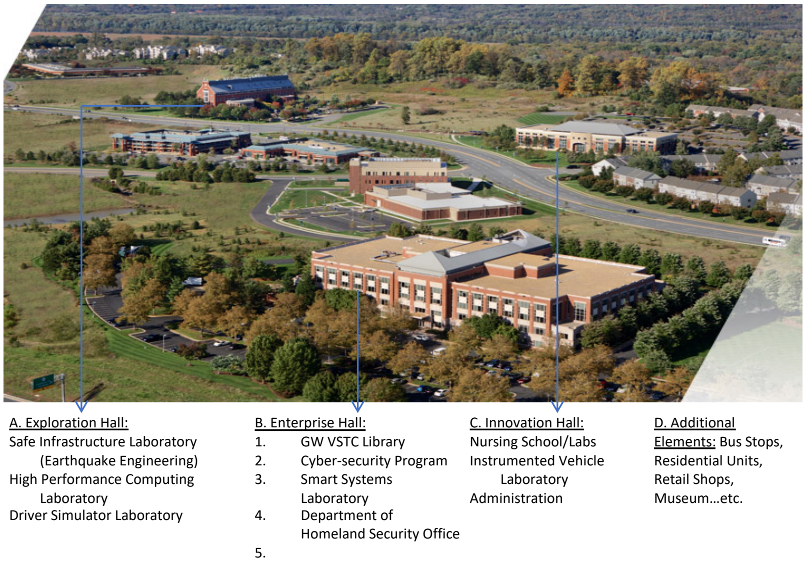


Figure 9: GW VSTC Campus – Development and Suburban Environment Test-Bed.

addressing the current limitations of ADS, we expect to ensure the US lead in the autonomous driving industry for the years to come. Moreover, we expect several patents to emerge from this project and related activities.

5.5. Data management

Our team is fully committed to sharing all the recorded data (raw and processed) with the public. We will develop our own data-sharing portal. However, the sharing process will be further discussed with USDOT and can also happen through the existing portals. All the details regarding data management is provided in the data management document.

5.6. Risk identification, mitigation, and management approach

The critical factors towards the success of this project are 1) safety of the ADS operations, and 2) comprehensive data collection. The proposal team will follow all the GM guidelines for safe CAV operations. The details of these guidelines are provided in the management plan document and include several pre-flight checks. Comprehensive mitigation strategies are also provided in that document based on GM guidelines. The data collection approach will be constantly discussed by USDOT and staff to ensure a comprehensive data is collected. Since the data will be shared in near real-time, stakeholders will have the opportunity to assess the quality of the data.

The project team utilizes “second man” philosophy in all projects. Hence, PI Langari will be a co-PI of the project and while overseeing many technical activities also assume project management activities in the absence of PI Talebpour. Note that the project manager will be heavily involved in all aspects of the project.

Texas A&M has a rigorous cost control mechanism in place by which it tracks and manages all expenditures. The project team will organize bi-weekly check in a conference call with USDOT along with other researchers. This will allow transparent and clear communication between the proposal team and USDOT and avoid any surprises. This also provides USDOT with the mechanism to be engaged in advising and guiding the research team, whenever necessary.

All Go/No-Go decisions will be brought up to USDOT’s attention before their milestone dates. This will allow adequate discussion within the proposal team and USDOT staff. It will give the proposal team the opportunity to make necessary adjustments and modify activities to meet decision criteria for go/no-go decisions.

5.7. Non-Federal resources (cost share) approach

Our team will utilize its existing vehicles, sensors, and vehicle computing units in this project. Moreover, computers, office space, garage space, access to Texas A&M High Performance Computing Center, and access to RELLIS proving ground is provided by Texas A&M University at no cost to USDOT.

5.8. Outreach

The proposal team has been extremely active working with the Connected and Automated Vehicles (CAVs) research community through their membership at the Transportation Research Board (TRB) Traffic Flow Theory and Characteristics Committee (AHB45). This committee has formed the Subcommittee on Traffic Flow Modeling for Connected and Automated Vehicles (AHB45_3) in 2014. PI Hamdar has been the chair of this subcommittee since 2016. Since its creation, the subcommittee has organized four TRB workshops titled:

I. 2019 TRB Workshop: Real and Virtual Data Collection Platforms for Connected and Automated Vehicles Modeling, Calibration and Validation

II. 2018 TRB Workshop: Data Collection, Experiments and Instrumentation in Connected Multimodal Transportation Systems

III. 2017 TRB Workshop: Active Transportation Operation and Demand Management in Connected/Automated Traffic Systems: Data Collection and Analytics, Modeling and Control

IV. 2016 TRB Workshop: Towards Surface Transportation Networks' Automation: Opportunities and Challenges

Furthermore, the AHB45_3 Subcommittee has organized several sessions at the Autonomous Vehicles Symposiums (AVS). The summary of the presentations and the recommendations made by the organizers and panel members resulted in three book chapters (Calvert et al., 2017; Excell et al., 2018, Van Arem et al., 2016). Finally, the subcommittee and its members organized several calls for papers in multiple journals to identify and encourage the highest quality research associated with traffic flow and connected and automated vehicles.

PIs Hamdar and Talebpour will leverage the activities of the AHB45_3 Subcommittee and its network to disseminate this project's findings while learning about new research directions and additional possible improvements. Such dissemination will be ensured through a dedicated website, multiple publications and special calls for papers, posting in multiple newsletters (including the AHB45 Newsletter of which PI Hamdar is the editor), and the addition of the data generated in a "CONnected TRAnsportation DAta Repository (CONTRA - DARE) created by the AHB45_3 Subcommittee with the participation of multiple researchers/contributors from around the world. Finally, through collaborating with our stakeholders and industry partners, the proposal team will disseminate the findings of this study to the related industry.

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