USDOT NOFO 693JJ319NF00001

TAMPA HILLSBOROUGH EXPRESSWAY AUTHORITY
DOWNTOWN MERIDIAN CONNECTOR

AUTOMATED DRIVING SYSTEM DEMONSTRATION

PART 1

Project Narrative and Technical Approach

TAMPA-HILLSBOROUGH EXPRESSWAY AUTHORITY

March 15, 2019

Secretary Elaine L. Chao
U.S. Department of Transportation
1200 New Jersey Ave, SE
Washington, DC 20590

Dear Secretary Chao:

The Tampa Hillsborough Expressway Authority (THEA) appreciates the opportunity to continue our relationship with the USDOT as we collectively demonstrate Automated Driving System (ADS) technologies. We are excited to utilize the significant lessons-learned from the Connected Vehicle (CV) Pilot to show CV technologies' ability to enhance ADS safety. THEA's ADS proposal is a practical demonstration of ADS's potential role as not only a viable "last-mile" Mobility as a Service (MaaS) option, but our proposed Downtown Meridian Connector (DMC) system can also provide a rich data source to be openly shared with the USDOT and our industry to enable the detailed safety analysis and rulemaking that is critical to safely advancing these transformational transportation technologies.

As further detailed in Part 1 of our application, the concept for the USDOT THEA DMC ADS involves Society of Automotive Engineers (SAE) Level 3 or greater (L3+) Automated Vehicles (AVs) providing transportation services to/from THEA-owned parking facilities in the vicinity of the Lee Roy Selmon Expressway to downtown Tampa destinations. The user (THEA toll customers and others) will request a connected, automated vehicle (with safety attendant/driver) via a specially developed, full-featured web and smartphone-based application that will allow users to customize their trip and process fares.

As customers enjoy their automated mobility experience to/from their downtown destination or THEA parking facility, the AV will be in constant communication with Roadside Units (RSUs) deployed through the USDOT THEA CV Pilot, as well as those deployed by the City of Tampa as part of their ongoing ATMS expansion in cooperation with FDOT. The DMC will demonstrate safety benefits resulting from integration of CV and ADS technologies and will be comprehensively evaluated through specific use-cases that address known safety issues related to AV crashes over the past several years.

THEA is confident in the DMC ADS demonstration's ability to generate valuable data to help advance research and inform policy-making. To this end, and as more fully described in the Draft Data Management Plan (Application Part 3), the demonstration will provide access to DMC data via uploads to the USDOT's Secure Data Commons (SDC) and ITS Data Hub. The two platforms are developed with specific system structures and the ability to support different data formats. A joint letter from our partners is attached as part of this cover letter to show our team commitment to providing USDOT open sharing of all project data.

In closing, THEA is dedicated to supporting the USDOT's goals of the ADS Demonstration Grant Program by:

- developing a project designed for safe integration in mixed-traffic;
- building upon collaborative public and private partnerships;
- sharing data and lessons learned for industry development and potential rulemaking;
- maintaining and growing a permanent ADS deployment site and USDOT Affiliated Testbed; and
- providing data for institutional and financial models that may be able to support long-term sustainable growth without the need for dedicated federal funding.

On behalf of our team and public agency partners THEA is excited for the opportunity to implement the DMC ADS demonstration to further leverage previous investments in emerging transportation technology to spur innovation and advancements in future mobility.

Sincerely,

Joe Waggoner
Executive Director
Tampa Hillsborough Expressway Authority

Tampa-Hillsborough County Expressway Authority
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March 15, 2019
Secretary Elaine L. Chao
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Subject: Data Sharing for USDOT ADS Demonstration, NOFO #693JJ319F00001

Dear Secretary Chao:

The Tampa-Hillsborough County Expressway Authority (hereinafter referred to as THEA) and their undersigned team members for the subject USDOT Automated Driving System Demonstration Grant affirm that all data collected during this demonstration will be made available to the USDOT and others as specified by the USDOT for research and evaluation for a minimum of five years after the award of performance expires. The THEA team will not retain any ownership to any of the data specifically generated for this demonstration. Our team may retain copies of the data for its archives and shall not otherwise license or market the data without the prior written consent of the USDOT.

The THEA team also understands that details relating to sharing data with the USDOT will be specified in a forthcoming mutually agreeable data sharing agreement per the subject NOFO Amendment 1 dated March 11, 2019.

Sincerely

Joe Waggoner
Executive Director, THEA

John A. Barton, P.E.

John Barton, PE
Senior Vice President, HNTB

Marcus Welz
CEO, Siemens Mobility, Inc.

Sisinnio Concas
Director, CUTR

Regina Marini Cargill
COO, Evolve

SUMMARY TABLE

Project Name/Title	Downtown Meridian Connector ADS Demonstration
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	Tampa-Hillsborough Expressway Authority (THEA) 1104 East Twiggs Street Tampa, Florida 33602
Point of Contact (Name/Title; Email; Phone Number)	Joseph Waggoner Executive Director joe@tampa-xway.com (813) 272-6740
Proposed Location (State(s) and Municipalities) for the Demonstration	Florida, Tampa
Proposed Technologies for the Demonstration (briefly list)	• SAE Int'l Level 3 or greater ADS • Smart Device Application • Smart City and Connected Vehicle Technologies • SCMS Certificates • Live connections to USDOT ITS Data Hub, OTA Data Exchange
Proposed duration of the Demonstration (period of performance)	4 years
Federal Funding Amount Requested	$9,999,815
Non-Federal Cost Share Amount Proposed, if applicable	$2,750,172
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$12,749,987

CONTENTS

TABLES

FIGURES

PART 1

PROJECT NARRATIVE and TECHNICAL APPROACH

1 EXECUTIVE SUMMARY

The Tampa Hillsborough Expressway Authority (THEA) Downtown Meridian Connector (DMC) is an innovative, visionary Mobility as a Service (MaaS) initiative that will demonstrate Automated Driving System (ADS) technologies. It Involves Society of Automotive Engineers International (SAE) Level 3 or greater (L3+) Automated Vehicles (AVs) providing transportation services to/from THEA-owned parking facilities in the vicinity of the Lee Roy Selmon Expressway to downtown Tampa destinations. As presented in **Figure 1-1** and in a specially developed video found at (*https://www.tampa-xway.com/dmc/*), the user will request a connected AV (with safety attendant) via a specially developed, full-featured web and smartphone-based application that will allow users to customize their trip and process payment of fares.

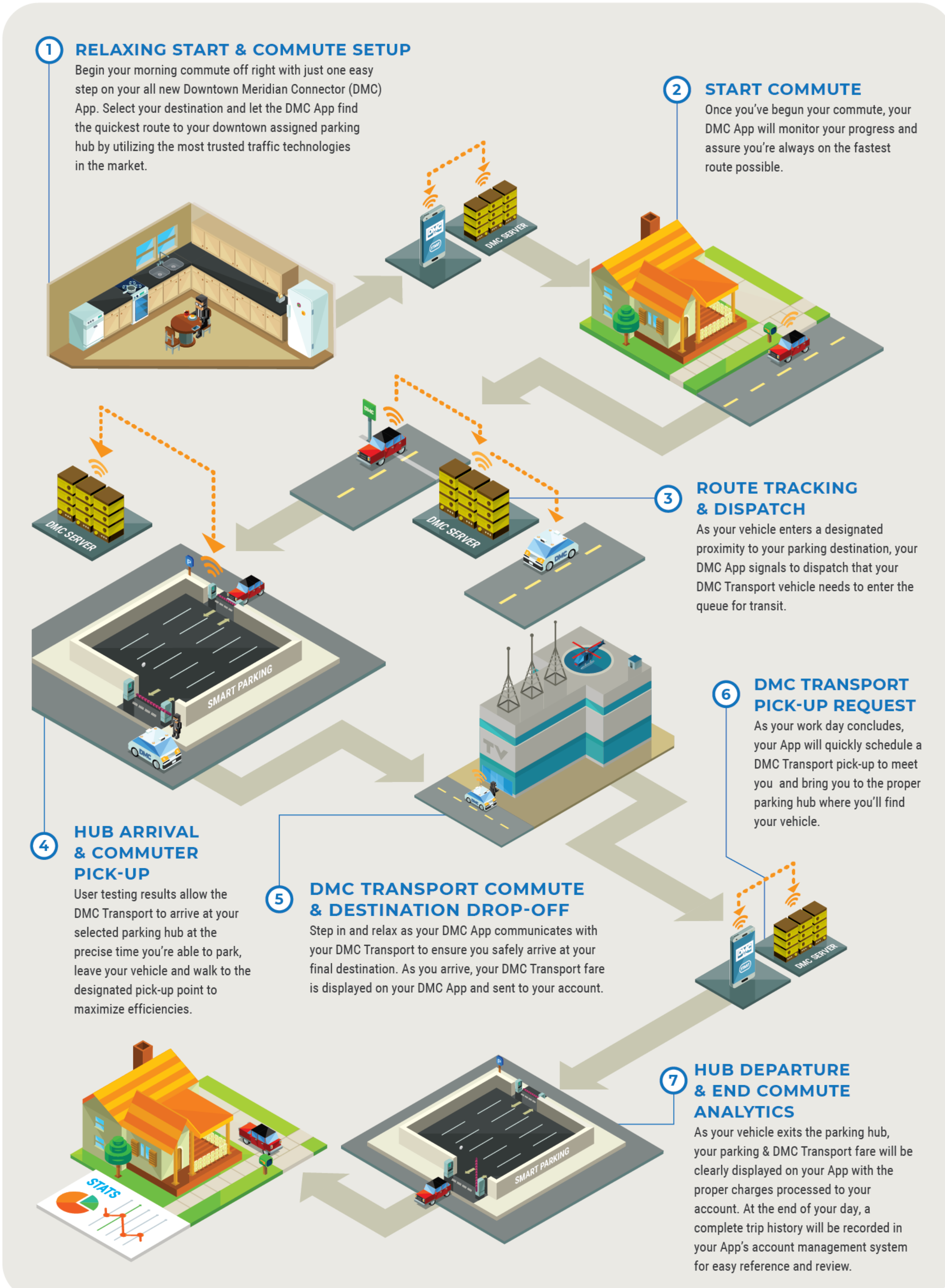
As customers enjoy their automated mobility experience to/from their downtown destination or THEA parking facility, the connected AV will be in constant communication with Roadside Units (RSUs) deployed through the US Department of Transportation (USDOT) THEA CV Pilot, as well as those deployed by the City of Tampa as part of their ongoing Advanced Traffic Management System (ATMS) expansion in cooperation with the Florida Department of Transportation (FDOT). The DMC will demonstrate safety benefits resulting from integration of connected vehicle (CV) and ADS technologies and will be comprehensively evaluated through specific use-cases that address known safety issues related to AV crashes over the past several years. The THEA team will conduct modeling and simulation prior to the physical demonstration to validate findings from National Transportation Safety Board (NTSB) investigations of these crashes. NTSB recommends that:

"Fusing V2V communication-based technology with vehicle-resident systems can enhance the safety benefits of vehicle automation systems. Such technology might have affected the outcome of the Williston crash."[1]

The THEA DMC ADS demonstration will generate data to help advance research and inform policy-making. The project will also provide access to valuable DMC data via uploads to the USDOT Secure Data Commons (SDC) and Intelligent Traffic Systems (ITS) Data Hub as more fully described in the Draft Data Management Plan presented in Part 3 of this submittal document.

[1] https://www.ntsb.gov/investigations/AccidentReports/Reports/HAR1702.pdf, Section 2.8.

FIGURE 1-1: THEA DMC ADS FUNCTIONAL ARCHITECTURE



Through the DMC Demonstration, THEA is also excited to potentially establish a model whereby public agency-owned CV infrastructure is leveraged to help attract private enterprise investment in and implementation of safe ADS, MaaS, and related transportation systems on public roadways.

1a Vision, goals, and objectives

THEA brings to the USDOT ADS Demonstration Program a culture of innovation that has made them a successful, award-winning global transportation agency. The DMC is a multi-faceted vision for smart transportation that will create the ultimate commuter experience while simultaneously addressing Tampa Regional goals of meeting growing transportation demands - all in a manner that is safe, efficient, effective, reliable, and financially sustainable.

Our ultimate DMC vision is a journey with a fundamental first objective of demonstrating safe operation of connected ADS-equipped vehicles on Tampa's existing downtown roadway network. The funding opportunity and USDOT partnership made possible through the ADS Demonstration Program is critical to achieving this important first step. Equally important however are the USDOT's goals and focus areas for the Program. Therefore, the THEA team has thoughtfully crafted our approach to ensure a successful outcome that addresses the goals of both agencies.

To summarize, the THEA DMC ADS Demonstration will address a real need to help alleviate rapidly growing downtown congestion by reducing the amount of traffic searching for parking. Additionally:

- **Safety** will be enhanced by leveraging prior investments in connected vehicle infrastructure and integrating into ADS-equipped AVs;
- **Data for Safety Analysis and Rulemaking** (and Evaluation) will be collected and shared with the USDOT as described in the Data Management Plan and forthcoming Data Sharing Agreement; and
- An environment of **Collaboration** will be sustained, building off the longstanding USDOT- THEA CV Pilot partnership and extending to our DMC public agency partners of the City of Tampa, Hillsborough Area Regional Transit Authority (HART), the Tampa Downtown Partnership, and Port Tampa Bay, as well as the private and academic entities that make up the THEA team.

1b Partners and organization

As the applicant of the USDOT ADS Demonstration Grant, THEA owns and operates one of the most unique, award-winning toll roads in the world, the Lee Roy Selmon Expressway Reversible Express Lanes (REL). THEA also manages/maintains several connector surface streets and covered surface parking throughout downtown Tampa, providing an ideal deployment site for a demonstration of AV technology. With THEA as a CV Pilot Deployment Site, existing infrastructure is already in place to observe the interaction, coexistence and potential improvements of applying connected capability to AVs. The existing infrastructure provides an established and tested interface for providing live data and analysis to USDOT and the ITS Data Hub for sharing with the research community at large.

The THEA team leverages key staff and partnerships from the USDOT-THEA CV Pilot Team. As demonstrated during the CV Pilot, THEA recognizes the entire USDOT team including its consultants and partners as equally important members of the collaborative partnership required to fully create meaningful research outcomes and recognize public benefit.

THEA's Planning Director, Robert Frey will be the overall Project Manager, THEA's General Engineering Consultant, HNTB will provide program management support, and returning CV Partners Siemens, Center for Urban Transportation Research (CUTR) at the University of South Florida (USF) and the Evolve Design Group will continue to work together as a proven, synergistic team to leverage their extensive collaborative work experience from the CV Pilot and other projects. A more detailed description of the THEA team's organization for the demonstration is provided in our application's Part 2 – Management Approach, Staffing Approach and Capabilities.

In addition to the project team, THEA has an established working relationship with SAE who will play an important role as a key stakeholder to guide application of existing and emerging AV standards. SAE resources will also be utilized to ensure consistency with market and technological trends, to ensure public survey development meets the needs of the sector, and to collaborate in conducting public demonstration events to be scheduled throughout the project.

1c Issues and challenges, technologies, performance improvements

1c.i. ISSUES AND CHALLENGES

Challenges are typically inherent to any new or emerging technology. There are many challenges to fully deploying high-level automated driving systems (ADS). Finding solutions to these challenges are critical to advancing the regular, sustained use of ADS in a mixed traffic environment. **Table 1-1** lists known issues and impediments to advancing ADS development, indicating the technologies or approaches that the DMC ADS will apply to these issues as a demonstration of a full or partial solution.

TABLE 1-1: KNOWN ISSUES AND SOLUTIONS

Challenge	Solution
Current AVs rely only on sensors to advise the vehicle automation. AVs have known functional issues in mixed-traffic based on historic, real-world incidents. AVs still face large safety challenges before widespread deployment, including but not limited to Sun Phantom Red Light Running, Background Contrast Crash, Side Street Crashes, Emergency Vehicles, Pedestrian Crash Warnings, and Lane Departures.	The DMC ADS will deploy AVs that are also equipped with CV Technology. THEA will run multiple experimental protocols to demonstrate quantifiable performance differentials between, AV only, AV with V2V and AV with V2I/X. See Section 5: Approach, for description of the THEA CV Pilot data overlays for analyzing AV response vs AV + CV response to incidents.
Even if existing AVs could communicate, there is no means to establish trust. In fact, even current CV devices have issues with handling misbehavior.	The ADS will utilize CV with Security Credential Management System (SCMS) certificates compatible with the CV Pilots. As part of a controlled experiment, the DMC will utilize a closed location test site within the study area to inject faulty BSMs to assess the AV sensor control response and how both AV & CV attempt to deal with erroneous or fake BSMs.
Private AV developers are not sharing data. Competition limits cooperation and prevents data sharing needed to advance rulemaking and safety improvements.	The DMC project team will leverage the data plan from the THEA CV Pilot Project to develop real-time AV-CV data sharing with USDOT.
Public distrust of AVs. The public remains skeptical of AV technology, hindering widespread adoption of AVs in mixed traffic.	The DMC project will collect and report the changes in public response and opinion from users of the ADS as a first/last mile option with proven safety record
Transportation planners/regulators face challenges in forecasting impacts of AV and CV technologies.	The DMC ADS will include data collection and reporting of origin/destination travel time, safety improvements and other key data to guide planners, regulators and legislators.

1c.ii. TECHNOLOGIES

The DMC ADS will utilize the latest, existing technologies available to provide L3+ AVs. The project will also leverage the existing CV technologies deployed in Tampa by the CV Pilot to produce a fully functional CV-enabled ADS:

- **L3+ ADS** - All existing and developmental AV technologies will be considered and selected based on the needs of the DMC to serve the public and provide significant data for performance measures. This will be solidified during the initial phase of evaluation to ensure vehicle procurement meets research requirements.
- **Smart Device Application** – The application will be user-focused with functionality for reservations, secure payment, account administration and user messaging/alerts.
- **SCMS certificates -** THEA is uniquely able to provide SCMS certificates that are compatible with the three CV Pilots. This ensures that the CV technologies applied to AV can be fully tested/demonstrated in not only general mixed traffic, but also with the 1000 connected vehicles and RSUs deployed in Tampa.
- **Live connection to the ITS Data Hub** – This will augment sharing and collaboration, as demonstrated in the THEA CV Pilot.
- **Over-the-Air (OTA) Data Exchange** – Data logging and OTA updates offer near real-time live stream data accessibility to USDOT.
- **Smart City Infrastructure** – Integrating connectivity to support ADS will include Smart Parking Hubs fully integrated with the DMC ADS App and Smart Poles (Enhanced infrastructure incorporating RSUs, Signal Controllers and advanced sensors for improved, real-time ADS guidance/alerts).

1c.iii. ANTICIPATED PERFORMANCE IMPROVEMENTS

At a high-level the ultimate vision for the DMC is anticipated to:

- Improve the traveler experience for the public at large by providing a last mile MaaS solution;
- Address issues relating to parking and traffic congestion;
- Improve the economic vitality of downtown residents, visitors and businesses by enhancing accessibility and overall downtown travel experience.

More specifically, the DMC ADS demonstration is expected to provide the following quantifiable performance improvements over existing non-connected ADS by applying CV technology and providing significant, real world data.

- Improve the overall safety of ADS by providing CV data such as SPaT and MAP and Traveler Information Messages to supplement the sensor data of the typical non-connected AV.
- Improve overall safety of ADS's by providing CV applications such as Intersection Movement Assist (IMA), Emergency Electronic Brake Light (EEBL), Forward Collision Warning (FCW), Pedestrian Collision Warning (PCW), and Wrong Way

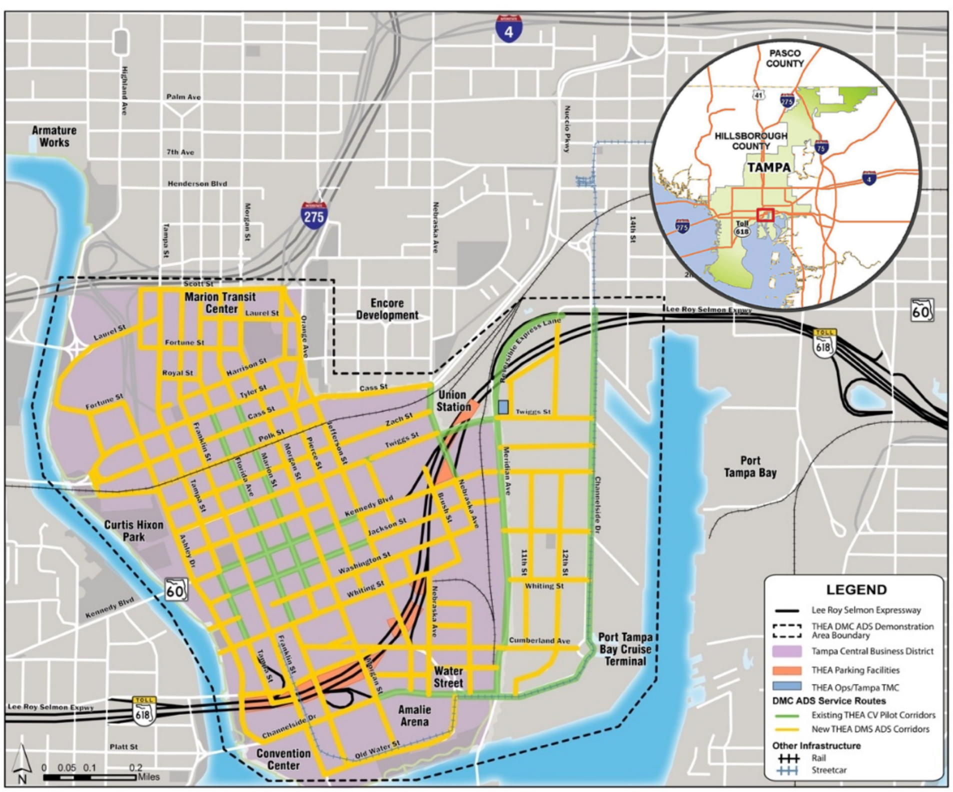
entry (WWE). These CV Apps will provide guidance to the ADSs of the AVs similar to the way they alert drivers in CVs.

- Improve Emergency Vehicle Operations (EVO) efficiency and safety by providing real-time data on work zones, road closures, and interaction with connected ADS. Improve the acceptance and adoption by the public and roadway operators of ADS.
- Improve the ability and efficiency of rulemaking to adopt appropriate policies based on empirical data.
- Improve the ability of state and local agencies to collaborate and utilize demonstration data to better align master plans and work programs based on empirical data including travel times, capacity, trending behaviors and demonstrated benefits of connected AVs and infrastructure as well as identify unique needs for groups such as those that are transportation-challenged.

1d Geographic area

As reflected in the map in **Figure 1-2**, the THEA DMC ADS will be demonstrated on the downtown Tampa roadway network to leverage the CV infrastructure investments made through the USDOT-THEA CV Pilot and City of Tampa Traffic Management Center (TMC) expansion. This location will enable the DMC ADS to service areas with billions of dollars' worth of new development including four community development areas as well as multiple employment and entertainment destinations and transportation facilities such as the Port Tampa Bay.

FIGURE 1-2: THEA DMC ADS DEMONSTRATION SITE MAP



1e Period of performance and schedule

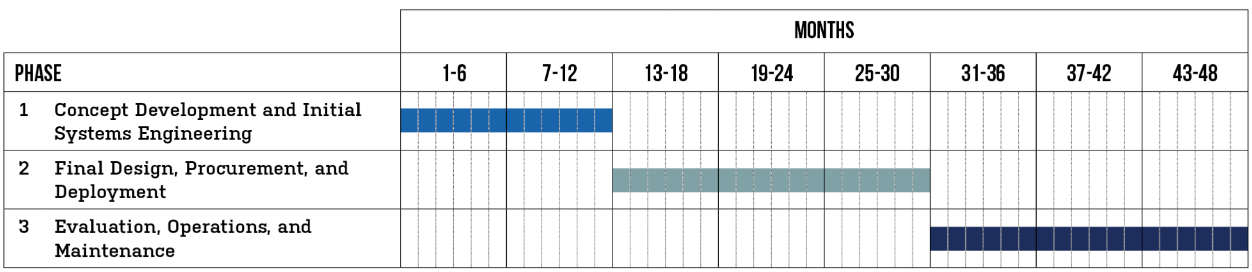
The development, deployment and evaluation of the THEA DMC ADS demonstration program will be conducted in following three (3) phases:

Phase 1 – Concept Development and Initial Systems Engineering
This phase will include specific deliverables such as: Kickoff Meeting; Project Management Plan; Project Evaluation Plan; Concept of Operations; Modeling and Simulation Report; Systems Engineering Plan and Requirements Document; Cybersecurity and SCMS Plan; Data Management Plan; Performance Measurement Plan; and initiation of ongoing Partner/Stakeholder Engagement.

Phase 2 – Final Design, Procurement, and Deployment
Phase 2 deliverables include: System Design Documents; ADS Procurement Plan; ADS Deployment Plan; ADS Operational Readiness and Test Plan; System Construction and Deployment; Application Development & Integration; System Testing; Operational Readiness Demonstration.

Phase 3 – Evaluation, Operations, and Maintenance
The Phase 3 deliverables will include: Data Analytics and Sharing; Performance Measurement; ADS AV Operations and Maintenance; Final Project Evaluation Report; and, Joint THEA/USDOT Cooperative Scientific White Papers.

FIGURE 1-3: PROPOSED SCHEDULE FOR IMPLEMENTATION AND EVALUATION



2 GOALS

This section summarizes how the THEA DMC concept aligns with each of the USDOT ADS Demonstration Program goals.

2a Safety

The DMC will address safety benefits resulting from integration of CV and ADS technologies and will be comprehensively evaluated through specific use-cases that address known safety issues related to AV crashes over the past several years. The THEA team will also conduct modeling and simulation prior to the physical (i.e. in the field) demonstration to validate findings from National Transportation Safety Board investigations of these crashes.

2b Data for safety analysis and rulemaking

Generation of data to help advance research and inform policy-making is a critical goal of the THEA DMC ADS demonstration. As such, the project will provide access to valuable DMC data via uploads to the USDOT Secure Data Commons and ITS Data Hub. Examples of the type of data that will be collected includes THEA CV Pilot data relevant to ADS, plus additional data from vehicle systems including vehicle dynamics, throttle position and brake actuation, plus safety driver after-action reports of ADS anomalies of each trip. A more robust description of ADS data collection, measurement and sharing is provided in the Draft Data Management Plan presented in Part 3 of our application.

2c Collaboration

An environment of collaboration will be sustained, building off the longstanding USDOT-THEA CV Pilot partnership and extending to our DMC public agency partners of the City of Tampa, Hillsborough Area Regional Transit Authority (HART), the Tampa Downtown Partnership, Port Tampa Bay, SAE, and other private and academic entities that make up the THEA team. As part of the USDOT THEA CV Pilot, the Change Control Board (CCB) was established to facilitate collaboration and direct input from partners and stakeholders. The CCB consists of reviewing members that are long-term owner/operators/researchers and the team proposes to sustain this established structure for the DMC ADS. This process is open and can be documented for other jurisdictions concerned with safe deployment of ADS.

3 FOCUS AREAS

3a Significant public benefits

The project provides significant public benefit by developing and deploying a MaaS solution that road operators and jurisdictions can implement to improve efficiency on constricted street networks. Service development, parking, and performance data will be utilized to provide road operator/jurisdiction with data and technology that can ultimately improve deficiencies. The project develops a model for CV and AV integration through a public-private partnership without impacting the existing private rideshare market model with requirements related to connectivity standards and open data sharing.

The metrics captured in this project will also provide relevant data and information to multiple stakeholders in both the public and private sectors leading to additional public benefits including:

- Develop, deploy and monitor AV technology that engages riders throughout their daily commute to calculate future models for the AV marketplace as it relates to safety, cost and communications.

- Utilize the program data to assess the business case for public agencies to make investments in CV infrastructure independently and in partnership with private enterprise.
- Generate CV marketplace data to help mitigate transportation barriers for transportation-challenged individuals such as seniors and those with disabilities.
- Acquire ongoing data to aid in viability assessments for replica programs to be executed in low population / high-need areas as a safe and cost-effective solution to traditional mass transit systems.
- Provide a real world understanding of AV technologies to the public, transportation planners, lawmakers, private industries and others to best serve the evolving demands and needs of the community.

3b Addressing market failure and other compelling public needs

Over the past decade, there have been notable market failures relating to the adoption of CV technology particular relating to safety, cost and access. With first-hand experience and expertise, this team has identified a number of current challenges facing the industry and countered with effective solutions to advance and standardize practices.

TABLE 3-1: THEA DMC ADS SOLUTIONS TO MARKET FAILURES

Market Failure	DMC ADS Project Solution
AV Technology Maturity vs. Public Expectations The public expectations of current and near-term AV technology capabilities are not aligned with today's real AV operational capabilities in mixed-traffic.	Project emphasizes safety of the users and transportation network by utilizing the synergies of AV and CV technologies to provide the greatest amount of data to transportation officials/road operators. The DMC will: 1. Report early findings by overlying Pilot Phase 3 data of driver warnings on known safety issues of AVs operating in mixed traffic. 2. Deploy and operate a fleet of AVs as MaaS. Data collection will measure the effects of adding CV messages to applications as input to supplement AV sensors and autopilot system.

Market Failure	DMC ADS Project Solution
AV is only reactive to situations. Current AV Technology can only respond to situations captured by vehicle sensors in the immediate vicinity/physical space of the vehicle.	The DMC Demonstration uses connected AV to enable predictive analytics to anticipate a necessary action and respond accordingly.
Public MaaS Value Public transportation institutions have not matched the competition from private transportation solutions that provide MaaS. A consumer market is driving the need for customized services and platforms.	This project deploys a connected AV MaaS for THEA customers, enabling researchers to better gauge the service and financial models of the market that is demanding and paying for the service.
Lack of standards While Congress granted USDOT the authority to mandate safety devices in vehicles, no similar authority is granted to mandate roadway-based infrastructure equipment and technology standards to support ADS vehicle systems.	The DMC project supplies USDOT with high-quality data and academic analysis to support regulatory decisions and standards development. The expected long-term outcomes are to standardize connectivity to improve ADS safety.

3c Economic vitality

The THEA team understands and will fully comply with the Buy American Executive Order 13788. The DMC project will impact the economic vitality of downtown Tampa and the Tampa Bay region – for workers, visitors, and residents. The study area and area of economic influence includes four certified community redevelopment areas, and the service will support mobility needs of the Central Business District (CBD), regional attractions, and major development underway in the downtown area.

3d Complexity of technology

The DMC ADS will be the first live demonstration of the integration of complex CV and AV technologies with near real-time data capture and delivery. The DMC ADS will utilize and integrate the latest, existing technologies including L3+ADS, Smart Device Application, SCMS certification, live connection to the USDOT ITS Data Hub, OTA Data Exchange, and Smart City Infrastructure.

3e Diversity of projects

The DMC is a strong contributor to the USDOT's focus area of diversifying ADS demonstrations. As the USDOT chooses among a diverse array of projects to demonstrate safe ADS deployment, the DMC provides a unique integration of technology that impacts technological advancements and policymaking. Additionally, the easy transferability of the DMC to a wide range of geographies, technologies and modes will augment the usefulness of this project as a resource tool to USDOT and the transportation industry.

3f Transportation-challenged populations

Understanding how the automated vehicle industry can address the needs of transportation-challenged individuals, such as the elderly and those with disabilities, is of paramount importance. The Tampa region provides a valuable wealth of information and opportunities to study the needs and interactions of this population through this demonstration both in terms of age and disability. In 2016, Florida ranked 5th in the nation for the highest median age[2], and as the US population ages, the percentage of people with disabilities increases.[3]

According to Pew Research Center, Americans with disabilities have a lower technology adoption rate. As the pilot program explores the physical parameters for transportation such as entry, egress, options for easy transfer, accessibility, usability, safety, restraints and more, consideration will also be given to the user's personal interaction with the technology. How users utilize the DMC ADS demonstration's mobile application, understanding waiting and boarding time thresholds and technology acceptance are just a few examples of additional information to be gathered beyond the physical use of the vehicles. This information will ultimately enable the DMC to service transportation-challenged populations in future deployment expansion.

3g Prototypes

This project will provide a true ADS prototype for a connected automated vehicle and service model for operation in mixed traffic on existing roadways.

FIGURE 3-1: DMC VEHICLE PROTOTYPE

[2] Source: American Community Survey
[3] Source: Institute of Disability/UCED

4 REQUIREMENTS

The THEA team fully understands and will comply with the requirements of the ADS NOFO. The requirement matrix (see **Table 4-1**) summarizes the approach to fulfilling each requirement.

TABLE 4-1: REQUIREMENTS TRACEABILITY MATRIX

Requirement statement	Requirement response
REQUIREMENT 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.	THEA will deploy an ADS that leverages existing technology as a baseline. The team will advance development of ADS by enhancing the system with CV technologies to better inform the ADS guidance system as opposed to relying on AV sensor data alone. The THEA ADS will use Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and additional infrastructure sensor data for these improvements to provide a safer, trustworthy ADS that can operate in mixed traffic.
REQUIREMENT B	
Each demonstration must include a physical demonstration.	THEA will deploy a live, ongoing deployment of a L3+ ADS. The demonstration will be an important first step in the ultimate THEA vision of mobility.
REQUIREMENT 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.	THEA will leverage its existing data connection to the USDOT ITS Data Hub and Secure Data Commons to provide near real-time uploads per the NOFO requirements. THEA is already doing this under the CV Pilot and will continue to provide not only data from the ADS but also for the existing CV data available.

Requirement statement	**Requirement response**
REQUIREMENT 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.	THEA will provide a fully operational, user-friendly mobile application that complies with accessibility standards for ADA requirements. This application will also interact with an AV safety attendant device to interface with the system.
REQUIREMENT 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 system development, financial and service model, and MaaS deployment will provide a transferable application of safe ADS service to other communities, large and small. Similar to the USDOT THEA CV Pilot, the THEA DMC team will provide outreach and lessons learned on status, results, and important "how to" insights throughout the three phases of the project.

5 APPROACH

The DMC ADS technical approach follows the systems engineering process and utilizes multiple phases to simulate and demonstrate technology and specified use cases. Another key component to our approach will be public engagement, education, and industry sharing. In addition to a robust internal capacity to engage participants, stakeholders, and the public; THEA will utilize their already established relationship with SAE to ensure technical compatibility with industry standards, enhance the applicability of user surveys, and provide awareness and education in any public events.

5a Technical approach

The DMC ADS Approach will utilize systems engineering to develop, design, deploy, test and demonstrate AV L3+ technology combined with connectivity to address known AV safety issues, along with smart infrastructure and connected devices to deploy a seamless MaaS option for downtown Tampa.

The project will build upon existing investments from the USDOT funded THEA CV Pilot Project and the City of Tampa ATMS project. Utilizing an established, data rich and connected environment with RSU saturation, the DMC will determine if connectivity can address the real-world problems of AVs by integrating connected AV into a mixed traffic environment that already includes over 1000 connected vehicles deployed under

USDOT THEA CV Pilot. The DMC ADS demonstration will use the proven method of applying the theorized solutions to real world, documented use cases or problem statements. The team will apply a combination of experimental design, pre/post treatment, and subjective survey categories of performance measurement data to evaluate outcomes. The data and analysis will support USDOT and others in addressing regulatory decisions and policies.

5a.i. PROJECT DEMONSTRATION

As a precursor to the actual physical DMC ADS demonstration, modeling/simulation will be performed by the THEA team to validate NTSB findings on how CV technology may have prevented six (6) AV crashes. The physical demonstration will operate in mixed traffic in Tampa's CBD. A seventh specialized use case will simulate the AV response to CV misbehavior on a closed roadway to monitor and ensure safety.

The DMC ADS project will leverage data collected during Phase 3 of the USDOT THEA CV Pilot to investigate and evaluate the seven Use Cases provided in **Table 5-1**. All the data generated during the demonstration will be archived and shared with USDOT as detailed in the Draft Data Management Plan (DMP).

TABLE 5-1: USE CASE AV/CV MITIGATIONS

UC	Documented AV Issue	AV Issue	CV App	Description
1	Sun phantom	AV shuttle runs red lights, sun phantoms	RLV	Red light violation warning
2	Background contrast	Original equipment manufacturer (OEM) AV strikes white truck, cloud contrast	IMA	Intersection movement assist
3	Side street crash	AV shuttle crashes with delivery truck	IMA	Intersection movement assist
4	Emergency vehicle violations	OEM AV crash, emergency vehicle	EVA	Emergency vehicle alert
5	Vulnerable road user crash	AV crashes with walking cyclist crossing street	PCW	Pedestrian collision warning
6	Lane departure/ revoked lane	OEM AV departs lane, strikes barrier	MAP	MAP lane location and rules
7	AV response to misbehavior	AV Sensor Control over/under response	All	Report out-of-range data

UC 1 – UC 6 INTEGRATION OF CV DATA TO EVALUATE KNOWN AV SAFETY ISSUES

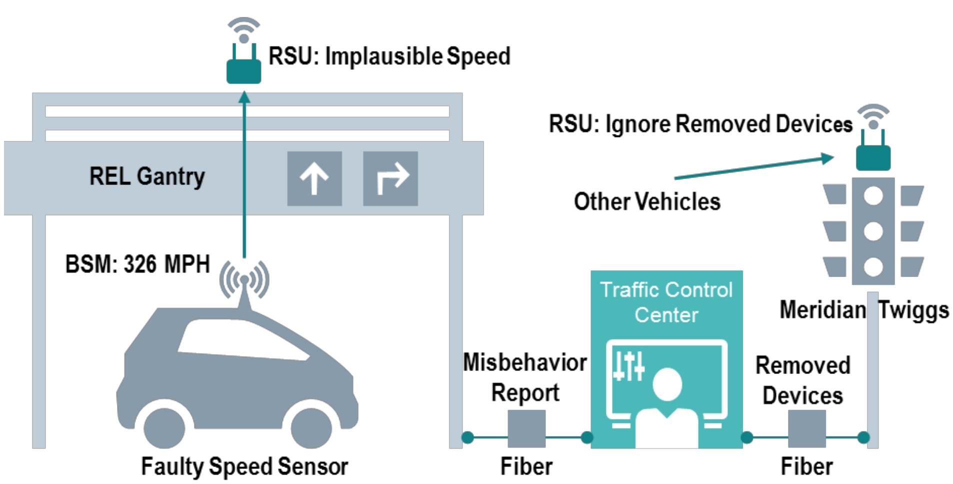
The goal of the modeling/simulation activity is to validate and build upon the NTSB's investigative work and recommendations of these six use cases. This will pre-evaluate the effectiveness of integrating AVs with CV technologies to assess current safety issues involving AVs operating in mixed traffic, as detailed in **Table 5-1**. The modeling/simulation will utilize CV data from the existing safety applications of the USDOT THEA Pilot which will be overlaid on to the AVs in referenced incidents. The evaluation will consider the impact on avoiding crash or conflicts by comparing the expected AV response to these conflicts if CV had been implemented. This will occur during phase 1 and be deployed and demonstrated physically during phases 2 and 3.

UC 7 ASSESSING AV RESPONSE TO OBU MISBHAVIOR

UC 7 focuses on assessing and measuring potential issues introduced by relying on CV technologies. Successful CV deployment hinges on the safe, secure, and reliable transmission of Basic Safety Messages (BSMs) between vehicles and infrastructure. BSM reliability can be threatened from faulty sensors or internal on-board unit (OBU) components producing erroneous data transmitted and received by vehicles. Relevant fields in a BSM can host faulty information, such as vehicle coordinates, speed, acceleration, heading and brake status as shown in **Figure 5-1**.

Other threats could be imposed by malicious third-party system hackings feeding misleading data while posing as a trusted vehicle or RSU. Failure to recognize these anomalies can lead to wrong actions by an AV operating with data support from connected vehicle equipment. While simulation can provide relevant insight on misbehavior detection, a preferable setting for testing algorithm is provided by scenarios that are closer to a real-world environment. The DMC ADS Project will provide this real-world testing environment via a closed track utilizing the AVs in mixed traffic consisting of non-CV team fleet vehicles, and CV equipped team vehicles to analyze processing and response of CV and AV to valid, erroneous, and fake BSMs and Traveler Information Messages (TIM).

FIGURE 5-1: MISBEHAVIOR DIRECTION



UC7 builds upon current groundbreaking work performed by USDOT on misbehavior detection and will focus on assessing the impact of OBU misbehavior on AV operations. Using a controlled experiment, the research team will develop and implement an approach to assess the AV Sensor Control algorithm response to anomalous BSMs by the following process:

- Select appropriate location within study area for safe injection of faulty BSMs
- Utilize available tools and algorithms for faulty BSM detection, such as the most up-to-date version of the recently developed Faulty BSM Generator (*https://github.com/Noblis/Faulty-BSM-Generator/commit/7d730563693b3e110d2f5ec06161819d1de38e28*)
- Collect, archive, and share faulty BSM data
- Evaluate and report on the change in response by the System Control sensor algorithm under the presence of BSM misbehavior.

5a.ii. PROCUREMENT

Availability of data will drive the AV vendor procurement decision-making process. There will be two potential options to evaluate during Phase 1 for vehicle procurement:

- Select auto manufacturer L3+ vehicle that meets National Highway Traffic Safety Administration (NHTSA) requirements, or
- Utilize unique project team experience to build a connected, L3+ vehicle, using after-market components on a commercially available vehicle.

The DMC ADS team will work alongside the USDOT to evaluate which scenario is the most appropriate to ensure open data collection. Phase 1 of the DMC ADS project will include the development of Procurement Requirements and Specifications, and an evaluation of risks/reward. Considerations will include:

- Commercially available vehicle
- DSRC OBU integrated into the vehicle system
- Autopilot system features integrated into the vehicle system
- Final vehicle assembly in the USA per terms of the NOFO

5a.iii. COMMISSIONING

Deployment of the AV fleet adheres to proven control theory practices, system engineering and methodologies used for safe startup of computer-control of hazardous industrial processes, such as factory automation. The trained process operator starting up a hazardous factory process is replicated by a trained AV safety attendant overseeing the startup of the AV fleet in safe, incremental steps shown in **Table 5-2**.

TABLE 5-2: HAZARDOUS PROCESS COMMISSIONING STEPS

#	Factory Operator Duties	Trained AV Driver Duties
1	Manually operates equipment	[L2]: Engaged at all times
2	Takes control for critical alarms	[L3]: Takes control with notice
3	Controls critical process steps	[L4]: Takes control in certain conditions
4	None, fully-automated process	[L5]: None, automated in all conditions

The ultimate levels of automation achieved depend upon the performance available on commercially available vehicles during the procurement task of the project schedule.

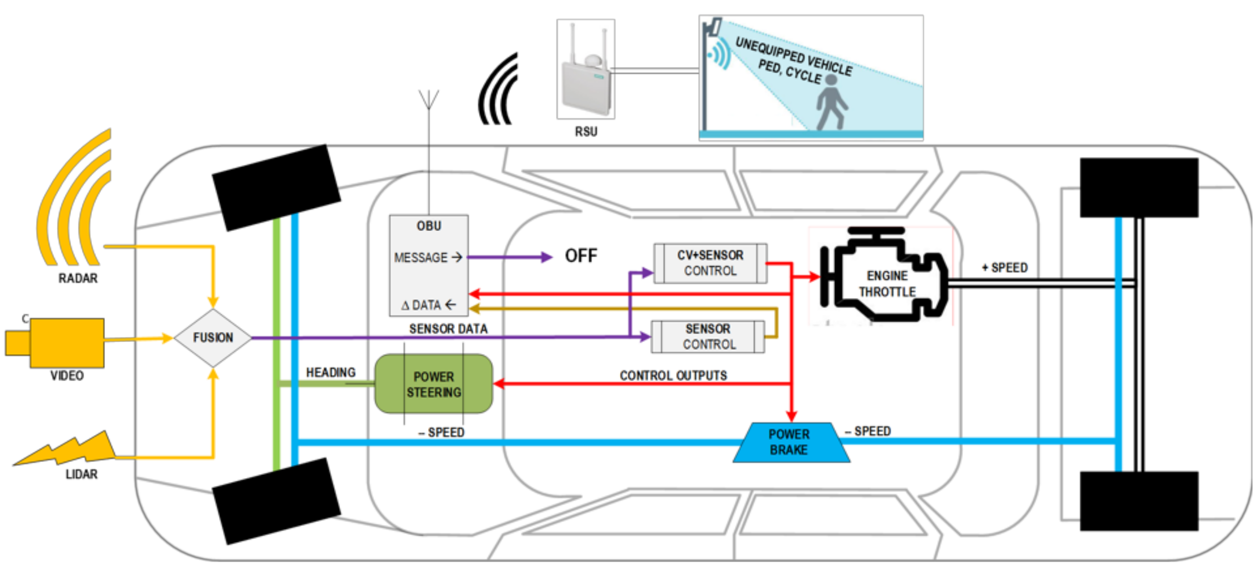
5a.iv. DEMONSTRATION EVALUATION

The demonstration evaluation will deploy a data-driven and statistically robust approach. This approach is applicable to all UCs considered. The evaluation will consist of two continuous phases of data collection, archiving, sharing, and evaluation: 1) AV fleet operating and solely relying on vehicle sensors, 2) AV fleet operating and relying on vehicle sensors augmented with OBU/RSU transmitted/received data. These data collection stages will allow conducting a pre-treatment vs. post-treatment data collection and assessment. The processes below are applied for UCs 1-6

PRE-TREATMENT AV OPERATION – NO INPUT FROM CV TECHNOLOGY BUT COLLECTING DATA FROM ONBOARD CV

During the first stage of implementation, AVs will be operating in mixed traffic without relying on input from CV technologies to generate a baseline AV operating behavior. The AVs will have OBUs installed and completely functional, collecting and transmitting messages from other OBUs and RSUs. This data will not be routed to augment sensor-provided data flowing to the AV automated control system, as shown in **Figure 5-2**.

FIGURE 5-2: AV GUIDANCE SYSTEM



The input to the Sensor Control algorithm consists of sensor data, such as Light Detection and Ranging (LiDAR), radar, lane marking cameras, location service and other sensors. The Sensor Control algorithm constantly:

- Scans the sensor data as input to the Sensor Control algorithm
- Computes the error between the current location/speed and planned
- Adjusts the Control Outputs to reduce the error by increasing the:
  - Engine Throttle input when the error includes under speed
  - Power Brake input when the error includes overspeed
  - Left yaw to Power Steering motor when error includes over-right location
  - Right yaw to Power Steering motor when error includes over-left location

This stage of deployment will establish a baseline for each proposed UC. For this purpose, the research team will analyze historical data generated during Phase 3 of the Tampa CV Pilot Deployment to produce historical conflict and accident statistics and to identify hotspots along the AV operating route.

Data Output: CV Pilot Phase 3 data and AV Sensor Control data will be collected, stored and processed by the research team for analysis and shared with USDOT. These data will be complemented with non-CV data to control for confounding factors, such as localized weather conditions and factors affecting travel patterns in the study area. These data will be timestamped for matching with the CV-generated data.

POST-TREATMENT AV OPERATION – INPUT FROM CV TECHNOLOGY IS SENT TO AV CONTROL SYSTEM

In this stage, AVs will be operating in mixed traffic with the automated control system relying on data from the vehicle sensors and data from the OBU. The OBU provides oversight by redirecting alerts and warnings data to the Sensor Control algorithm (**Figure 5-3**). The Sensor Control responds by avoiding the incident as would a Phase 3 CV driver receiving the same warning. The research team will analyze the response difference between the AV decision undertaken by solely relying on Sensor Control data (running in parallel and logging data) versus the AV decision taken by relying on integrating Sensor Control data with OBU data.

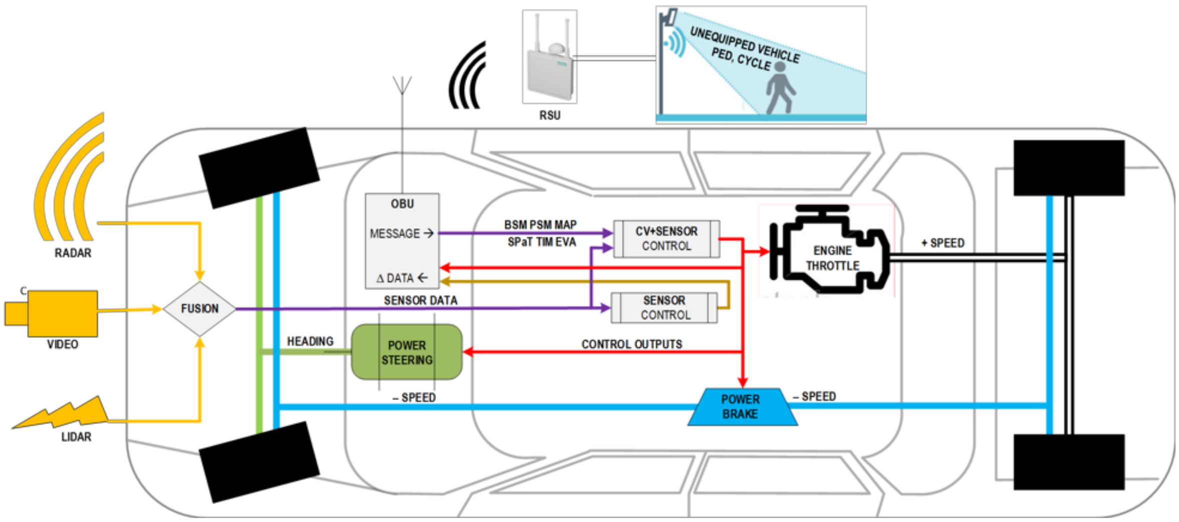
Data Output: AV Sensor Control data and AV OBU data will be collected, stored and processed by the research team for analysis and shared with USDOT. Data and sources are provided in

Table 5-3.

TABLE 5-3: AV OBU AND SENSOR CONTROL DATA

Data Source	Data
AV OBU	Sent/received warnings, received MAP and SpaT, host and remote vehicle location, direction, speed, heading (before and after warnings are issued)
AV Sensor Control	Engine throttle, power brake, power steering

FIGURE 5-3: SENSOR CONTROL WITH CV TECHNOLOGY GUIDANCE



SAFETY EVALUATION DATA AND METRICS

At a minimum, the research team will consider the following safety measures to evaluate the overall contribution of the demonstration to improve the safety of the transportation system. These metrics will be applied to each of the use cases at intersection travel segment levels:

- Number, type and severity of potential crashes/crash rate. The types of crashes to be considered include rear end, and sideswipe/angle crashes due to sudden lane change maneuvers.
- Number, type and severity of potential conflicts / near misses from OBU data logs analysis. The types of conflicts are the same as the types of crashes, i.e. rear end conflicts, and sideswipe/angle conflicts due to sudden lane change maneuvers.
- Number of alerts (warnings) from ERDW, EEBL, and FCW CV apps.
- Comparative assessment of false positives and false negatives generated by AV operation by comparing events generated by the AV decision undertaken by solely relying on Sensor Control data (running in parallel and logging data) versus the AV decision taken by relying on integrating Sensor Control data with OBU data.

CONTROLLING FOR CONFOUNDING FACTORS

The accuracy and effectiveness of performance evaluation depends on the presence of concurrent confounding factors. Confounding factors are any events that might arise during the demonstration, which can be associated with having an apparent effect on some dependent variables of interest (i.e., performance measures). In a design experiment, confounding factors that are not accounted for during design could either understate or overstate the relevance of treatment effects upon treated units. In extreme cases, confounding factors can lead to spurious relationships between explanatory and dependent variables, with the variables having no direct causal connection, while it may be wrongly inferred that they do.

Based on the experience gained during the CV Pilot Phase 3, the research team will focus on the following types of confounding factors that are likely to arise from the pilot implementation:

- Study-area specific factors (e.g., climate, special events)
- Deployment-specific factors (e.g., demonstration-specific, technology-specific)

Factors that can a-priori (i.e., before implementation) be identified, recorded and measured are defined as observed factors. Factors that cannot be directly observed or measured are defined as unobserved factors. During performance measurement and statistical modeling, observed factors can be accounted for by their proper inclusion as explanatory variables and modeling method, while unobserved factors can be accounted for by utilizing appropriate statistical techniques to reduce omitted-variable bias.

Given the proposed length of the demonstration, several time-variant factors and events that are specific to the area will be accounted for, spanning from seasonal weather to planned events in the study area main points of attraction, to planned construction development plans, and seasonal cruise line tourism. These factors have the potential to generate confounding information across all Use Cases by influencing individual travel behavior.

5b Legal, regulatory, and environmental obstacles

Florida embraces CV and AV technologies, with strong champions in both houses of the legislature for maintaining a non-restrictive environment to advance and attract innovative economic growth in emerging technologies.

THEA is appreciative of supportive partners and stakeholders in Tampa and the surrounding region who actively participate and collaborate in the advancement of emerging technologies, including CV and AV. Tampa is a data rich environment with substantial existing investment in similar innovations, not the least of which is the USDOT THEA CV Pilot. THEA is not aware of any legal, regulatory or environmental restrictions to successful completion of the proposed project demonstration.

5b.i. FEDERAL MOTOR VEHICLE SAFETY STANDARDS

The project demonstration does not require exemption from Federal Motor Vehicle Safety Standards (FMVSS).

FIGURE 5-4: SIEMENS MANUFACTURING FACILITY IN MARION, KENTUCKY

5b.ii. BUY AMERICAN ACT

The project demonstration does not require exemption to the Buy American Act. Phase 1 project Requirements include provision to procured vehicles manufactured in the USA. Infrastructure equipment, such as additional RSUs and traffic signal controllers are assembled in Siemens manufacturing facilities in Marion Kentucky.[4] Roadside electrical cabinets and roadside signals are manufactured by Siemens distributor Mobotrex manufacturing facilities located in Davenport, Iowa, and Austin, Texas.[5] Project Phase 1 includes a major procurement task to obtain commercially available (made in the USA) vehicles that fulfill project research requirements to generate data for USDOT by vehicles that are or will be available to the driving public within the project timeline.

5c Commitment to provide data

The THEA team is fully committed to providing all data generated by the DMC ADS Project including safety outcomes, measures of effectiveness and other related data, such as mobility data that is already being collected for the USDOT THEA CV Pilot in Tampa, Florida. The existing Master Server, along with related network and security architecture is used with minimal changes to collect the additional vehicle data listed in the Data Management and Performance Measurement sections of this document. As described in our Part 1 cover letter, all THEA team members commit to making this data available to the USDOT and others as specified by the USDOT for research and evaluation for a minimum of five years after the award of performance expires. The THEA team further understands that details relating to sharing data sharing with the USDOT will be specified in a forthcoming mutually agreeable data sharing agreement.

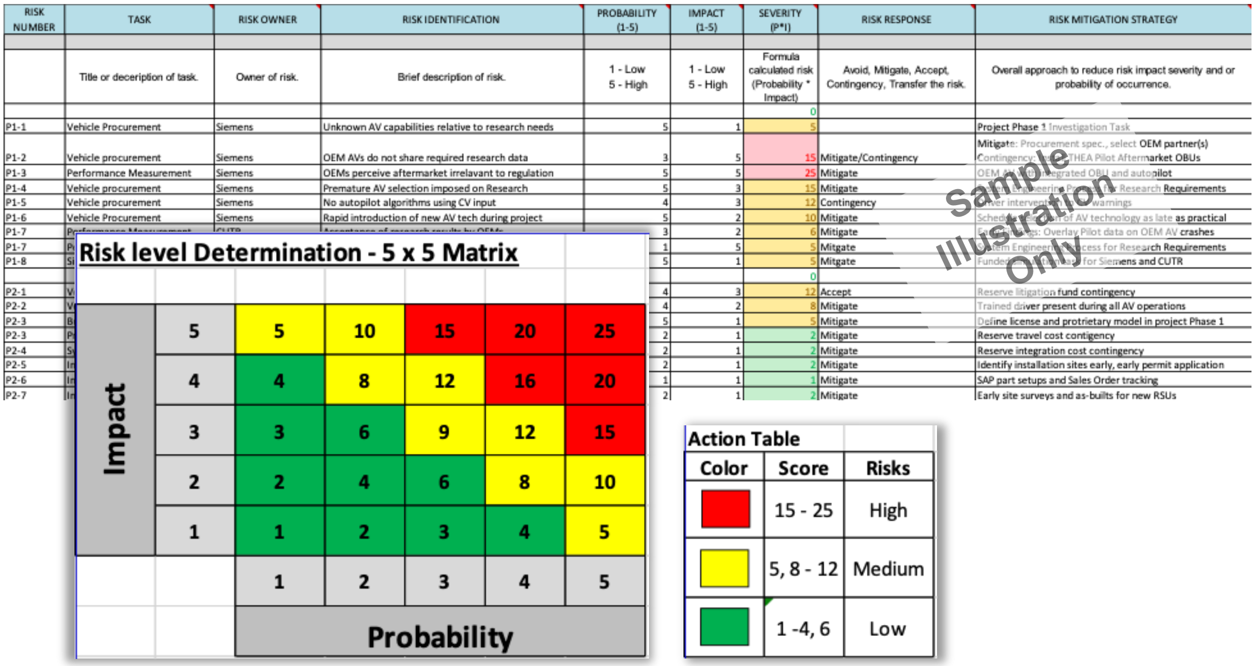
5d Approach to risk identification and management

Project approach to Risk Identification and Management parallels that of the USDOT CV Pilot project in Tampa, Florida. Risks are constantly maintained in a Risk Register as shown in **Figure 5-5**.

[4] https://w3.usa.siemens.com/ mobility/us/en/ pages/factory-locations.aspx

[5] https://www.mobotrexmanufacturing.com

FIGURE 5-5: RISK REGISTER



5e Approach to contribute and manage non-federal resources

While not specifically required, THEA commits a $2.5M hard match to the requested $10M Federal ADS Demonstration grant. Not included in this hard match are THEA's contributed staff hours and associated costs for DMC ADS Demonstration management and oversight. The approach to manage all Federal and non-Federal resources is further described in Part 2 – Management Approach, Staffing Approach, and Capabilities.

FIGURE 5-6: ACRONYM GUIDE

ADS	Automated Driving System
ATMS	Advanced Traffic Management System
AV	Automated Vehicle
BSM	Basic Safety Message
CBD	Central Business District
CCD	Change Control Board
CUTR	Center for Urban Transportation Research
CV	Connected Vehicle
DMC	Downtown Meridian Connector
DMP	Data Management Plan
DSRC	Dedicated Short Range Communications
EEBL	Emergency Electronic Brake Light
ERDW	End of Ramp Deceleration Warning
EVO	Emergency Vehicle Operations
FCW	Forward Collision Warning
FDOT	Florida Department of Transportation
FMVSS	Federal Motor Vehicle Safety Standards
HART	Hillsborough Area Regional Transit Authority
IMA	Intersection Movement Assist
ITS	Intelligent Transportation System
L3+	Level 3 or Greater (SAE J3016 Levels of Driving Automation
LiDAR	Light Detection and Ranging
MaaS	Mobility as a Service
MAP	Map Data Message
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
OBU	On-Board Unit
OEM	Original Equipment Manufacturer
OTA	Over-the-Air
PCW	Pedestrian Collision Warning
REL	Reversible Express Lanes
ROW	Right-of-Way
RSU	Roadside Unit
SAE	Society of Automotive Engineers International
SDC	Secure Data Commons
SPaT	Signal Phase and Timing
THEA	Tampa Hillsborough Expressway Authority
TIM	Traveler Information Messages
TMC	Traffic Management Center
USDOT	United States Department of Transportation
USF	University of South Florida
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
WWE	Wrong-Way Entry