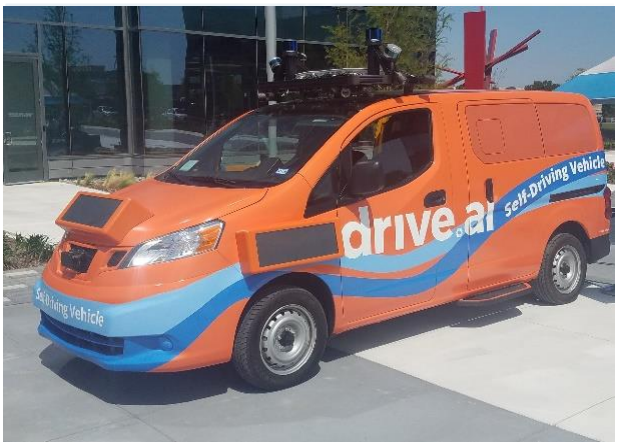
United States Department of Transportation

NOFO Number 693JJ319NF00001

Automated Driving System Demonstration Grants



ON-DEMAND SERVICES IN URBAN CORE

HIGH-SPEED FREIGHT

LOW-SPEED TRANSIT SHUTTLES

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Texas A&M Transportation Institute,
The Texas A&M University System

Texas ADS Research Team

UT Austin Center for Transportation Research
Texas Southern University
Southwest Research Institute

Demonstration Partners:

City of Arlington, Texas
City of Frisco, Texas
Denton County Transportation Authority (DCTA)
City of Fort Worth
City of Dallas
City of Grand Prairie
North Central Texas Council of Governments (NCTCOG)
City of Bryan, Texas
City of College Station, Texas
Bryan-College Station Metropolitan Planning Organization (BCSMPO)
Capital Metro
Houston METRO
City of Houston, Texas
Houston-Galveston Area Council (HGAC)
VIA Metropolitan Transit
Brooks Community
City of San Antonio
Texas Department of Transportation (TxDOT)

COVER LETTER

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March 19, 2019

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

Re: NOFO # 693JJ319NF00001
Automated Driving System (ADS) Demonstration Grants
SRS # 1905386

Dear Ms. Tarpgaard:

The attached documents represent the official submission for the Texas A&M Transportation Institute (TTI).

The Principal Investigator, Karen Dixon, will be pleased to offer additional technical or scientific detail and may be reached at 979-317-2143 or k-dixon@tti.tamu.edu. Please contact Chris Slape (979-845-6280 or srs-awards@tamu.edu) Senior Negotiator II, for fiscal or administrative information.

The research team can confidently state that it will approach this research project with absolute objectivity in its endeavor to satisfy the research objective. None of the team members have ownership in any legal entities nor do they receive remuneration of any kind from organizations that would constitute (or be perceived as constituting) a conflict of interest to this research project. Similarly, the research team members do not have properties, patents, or interests that would benefit in any way from the findings of this research.

The Texas A&M Transportation Institute heartily endorses Karen Dixon and the research team in this proposal. I am confident their abilities will help accomplish this project in a timely, thorough, and capable manner. We greatly appreciate your attention and consideration and look forward to producing useful and informative results for you.

Sincerely,

Gregory D. Winfree
Agency Director

TTI | Office of the Director

SUMMARY TABLE

NOFO Number 693JJ319NF00001 - Automated Driving System Demonstration Grant

Proposing Agency:	Texas A&M Transportation Institute (TTI) The Texas A&M University System 400 Harvey Mitchell Parkway South, Suite 300 College Station, TX 77845-4375 Tel. (979) 862-6777 | Fax (979) 862-3250 REF: SRS #1905386
Amendment 1	TTI acknowledges receipt of Amendment 1 (3/11/2019)
Point of Contact:	Karen Dixon, Ph.D., P.E., RSP, Senior Research Engineer Tel. (979) 317-2143 | k-dixon@tti.tamu.edu
Proposed Locations:	Texas – Houston, San Antonio, Arlington, Frisco, Bryan-College Station, and I-30 between Dallas and Fort Worth.
Proposed Technologies:	Automated driving systems, vehicle controls, advanced driver assist systems, connected braking systems, data management systems, advanced communication systems for vehicle-to-infrastructure (V2I) data sharing, and data collection systems.
Project Period:	October 1, 2019 – March 31, 2023 (42 months)
Federal Funding Amount:	$8,000,000
Non-Federal Cost Share:	$2,003,331
Total Project Amount:	$10,003,331

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PART 1 - PROJECT NARRATIVE AND TECHNICAL APPROACH

Executive Summary

The future of automated driving systems (ADS), though uncertain, offers great potential. The next ten to twenty years in transportation will likely bring more change than the last one hundred. The Texas Innovation Alliance – a network of government, research, industry, and community stakeholders – stands ready to partner with United States Department of Transportation (USDOT). Led by the Texas A&M Transportation Institute (TTI), the Texas ADS Deployment Data for Safety Project (Texas ADDS Project) proposes a collaborative statewide application, for an $8 million UDSOT investment over 3-½ years (matched by over $2 million), to safely advance ADS, harness the data to inform future policy decisions, and maximize the impact for all communities.

TEXAS ADDS PROJECT STRENGTHS

- Texas ADS portfolio of projects includes 4 active with 3 planned low-speed shuttles, on-demand service, and high-speed trucks
- Clear legislative path for ADS
- Existing institutional alliances in place for years
- Experience with outreach and data
- Pre-grant investment exceeds $3.2M

The Challenge. Every day companies, cities, states, and nations are exploring and deploying automated vehicles (AVs) on public roads without a full understanding of the true safety benefits or data exchange opportunities. Without a secure and collaborative environment, deployments remain uncoordinated and stakeholders hesitate to share information that could put their market advantage at risk. Texas has recognized the transformational impact that AVs could have on lives and businesses and has been forging a new model of deployment that convenes diverse stakeholders – local, regional, state, research, industry, and community – to accelerate statewide knowledge and action. These Texas partners seek to collaborate with the USDOT to advance ADS across the country.

The Vision. Texas envisions a best-case future where AVs become part of a safe and seamless mobility ecosystem: one where parents no longer worry about their teenagers getting into a car crash, a businesswoman shares her commute with a coffee shop owner and then takes transit to pick up groceries on the way home, a homebound grandparent easily accesses his medical appointments and visits the community center in the evenings, and a small business expands operations with automated package delivery. More than a technology, AVs can be tools to address the country's most pressing mobility challenges. Texas welcomes the opportunity to chart a course forward with USDOT to advance safe deployment of AVs, gather additional data, and form collaborative partnerships to guide the nation's future policy, regulatory, and investment activities. Together, Texas and USDOT will be prepared to readily adapt to and navigate the coming era of rapid change. Key to this partnership is the Texas Innovation Alliance.

Texas Innovation Alliance. Texas has outpaced its 20th century transportation systems. Facing rapid growth, rising congestion, and more traffic fatalities than any other state, the Texas Department of Transportation (TxDOT) issued a call to action in December 2016 and metropolitan regions stepped forward to form the Texas Innovation Alliance. The Alliance is a partnership of cities, transportation agencies, and research institutions who seek to safely

integrate and take full advantage of the latest technology advancements and prepare their shared transportation system to meet the future mobility needs of Texas residents and businesses. The Alliance is a force multiplier for USDOT – leveraging collective resources, expertise, and solutions to enable USDOT to maximize value and minimize risk.

- **An Alliance of Experienced Partners**. Texas already has an established network of partners – local, regional, state, national, research, industry, and community – in place who are committed to the safe deployment of AVs. The Alliance will enable USDOT to rapidly align local, state, and federal goals, achieve consensus around priorities such as data sharing, and streamline coordination across stakeholders.
- **Clear Legislative Path.** In 2017, the Texas Legislature passed a leading AV bill – Senate Bill 2205 – that defined, clarified, and made legal the operation of an ADS-equipped vehicle on public roads. The bill has signaled to auto manufacturers and AV developers that Texas is open for innovation, leading to an influx of AV investment and sparking interest from the Governor's Office and the public.
- **A Pipeline of Locally-Funded Diverse Use Cases.** With active, locally-funded deployments – in Arlington, Frisco, Houston, Bryan-College Station, the I-30 corridor between Dallas and Fort Worth – and planned deployments in the pipeline – in San Antonio and Corpus Christi – USDOT can leverage the significant support, diversity in use cases, and investment being made at the local level.
- **Secure Data Environment for Safety Analysis and Rulemaking.** The Texas Advanced Computing Center (TACC) at the University of Texas at Austin will collect, store, secure, and manage the data for the Texas ADDS Project, enabling USDOT to access safety-critical information and compare performance metrics across deployments. The system also includes a user interface – the Texas ADS Portal – where USDOT, policymakers, and the public can access robust data for rulemaking and to learn more about AV performance.
- **Scaling and Sustainability Mechanisms.** Texas supports ongoing knowledge sharing and technology transfer opportunities that will maximize the reach of USDOT's efforts. The Alliance supports bi-weekly Team Lead calls, partners with a non-profit to deliver monthly community of practice calls, and organizes the annual Texas Mobility Summit. By engaging the Alliance, USDOT can develop best practices from on-the-ground deployments and enable AV deployments to learn from one another in peer-to-peer settings.

The Path Forward. The USDOT plays a significant role in safely leading the country through this period of dramatic change. USDOT benefits from new partnership models that ensure public safety and create the flexibility to innovate. Texas is developing a collaborative environment where government, industry, and research can work together to safely advance ADS technologies. USDOT can share in this collaborative environment with investments already underway and activities already on the ground.

Goals and Objectives

The future of ADS technology is full of promise. The lifesaving capabilities of these technologies could have significant safety advancements and a wide range of possible benefits, given that all of today's stakeholders within the transportation system carefully coordinate design and implementation. Reflective of the diversity across the state, the Texas ADDS Project proposes to advance the state of knowledge and implementation in numerous domains. The portfolio of

projects will be linked by a comprehensive set of goals and objectives in five major categories: 1) Safety, 2) Mobility, 3) Environmental, 4) Human Factors, and 5) Equity and Access.

Key Team Members, Partners, and Stakeholders

The Texas ADDS Project is a unique partnership to bring multiple ADS deployments together under one effort. The Texas Innovation Alliance has been collaborating for nearly three years, sharing experience on transportation technology. Deployment of ADS has been a big focus of this effort. The Alliance agreed to support the Texas ADS Research team of TTI, UT Austin Center for Transportation Research (UT/CTR), Southwest Research Institute (SwRI), and Texas Southern University (TSU) to lead the Texas ADDS Project. The ADS Research Team will work closely with all the partners that make up the Texas ADDS Team as shown in Figure 1.1, including members of the Texas Innovation Alliance, the Public Sector partners that are leading ADS deployments, the ADS developers for each of those sites (including low-speed shuttles, on-demand services, and high-speed ADS trucks), and the private sector partners that are contributing infrastructure and data collection. The Texas Project will include a number of faculty, researchers, and practitioners that make up the ADS Community of Practice. By providing access to the data, this stakeholder group will be able to conduct analysis and evaluation beyond the Texas ADDS Project.

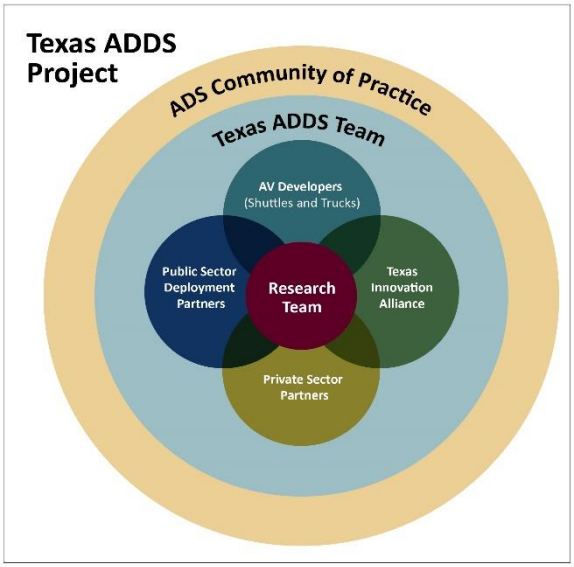


Figure 1.1 Texas ADDS Project

Performance Metric Framework

The assessment of data associated with ADS-enabled vehicles is unchartered territory and can introduce unexpected challenges. To conduct a comprehensive evaluation, there is a need to acquire data associated with the study vehicle, the roadway environment, the user experience, crash history, and additional elements that may be considered as surrogates for safety.

In addition to safety data, the project team will also acquire data that will enable an analysis of the prevailing traffic conditions as well as impacts on environmental considerations. A focused benefit of ADS deployment, particularly for transit or on-demand deployments, is the ability to improve access for all and introduce ways to develop and maintain equitable opportunities.

Technologies to Be Demonstrated to Address the Issues

There are a wide variety of opportunities for enhancing transportation as ADS applications become more widespread. Two critical issues that specifically should be addressed are (1) ways to provide better mobility and equity for system users, and (2) techniques to improve freight operations. For this study, the Texas team proposes three types of deployments that are designed to assist with these two critical issues. These technologies include:

- Low speed AV shuttles in simple environments.

- On-demand services in complex urban environments.
- Automated trucks operating in high-speed, freeway environments.

Geographic Area or Jurisdiction of Demonstration

Texas is a leader in the deployment of AV shuttles with several operational projects representing a variety of use cases and driving environments. As shown in Figure 1.2, there are five active sites – Houston, Arlington, Frisco, Bryan, and I-30, and three planned sites – San Antonio, Corpus Christi, and College Station. In taking a portfolio approach, Texas minimizes the risk to USDOT and maximizes value in deploying a range of use cases in different operational design domains.

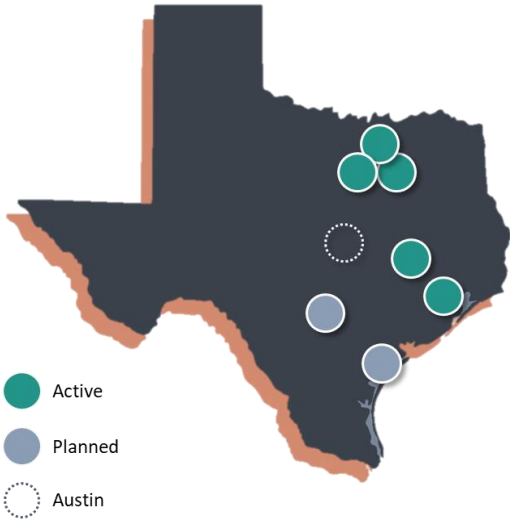


Figure 1.2 Texas Deployment Sites

Quantifiable Performance Measures

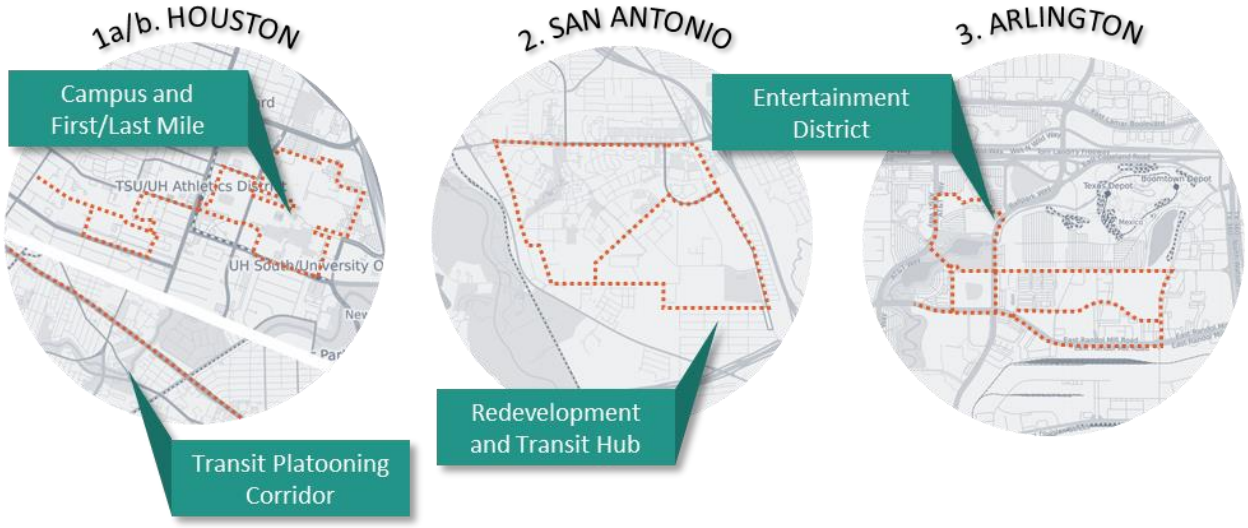
The primary goal for the data collection effort associated with this project is to identify innovative ways to assess safety and related performance measures for ADS deployments in the categories of mobility, environment, human factors, and equity and access. To assess safety performance, the Texas team intends to use a variety of techniques. It is the expectation of the team that the deployment locations will have very few crashes. This means that a crash-based safety assessment approach will not be practical for most of the conditions and creates an opportunity for Texas to formulate new approaches. For this reason, the project team expects to develop a risk-based strategy that will assess vehicle maneuvers and near misses, as well as take into account other contributing factors such as traffic characteristics, road weather conditions, and human behavior.

Proposed Period of Performance

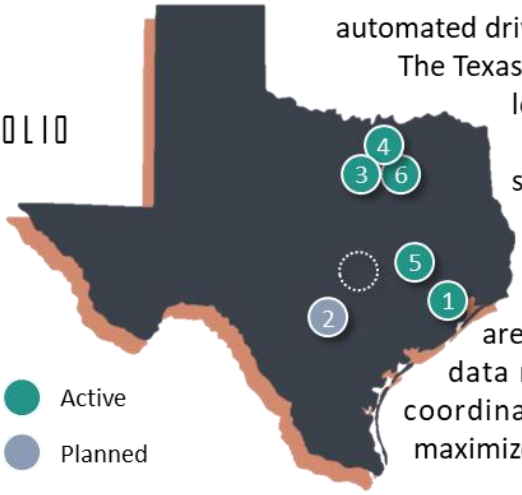
The proposed period of performance for the Texas ADDS Project is from October 1, 2019 to March 31, 2023, a 42-month project. This schedule is based on a contract award in the spring of 2019. Because the Texas ADDS Project builds on existing deployments, the Team will be able to complete the Planning Task (Task 1) and the Deployment Task (Task 2) in 18 months. With the deployment sites operating and the data collection platform in place, this schedule then accommodates a full operation year to collect data followed by a full year to analyze the data and complete the evaluation and final report. Figure 1.3 highlights the high-level schedule.

Texas ADDS Project Schedule													
CY19	CY20				CY21				CY22				CY23
Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Planning Task													
			Deployment Task										
						Operational Period							
										Analysis & Evaluation			

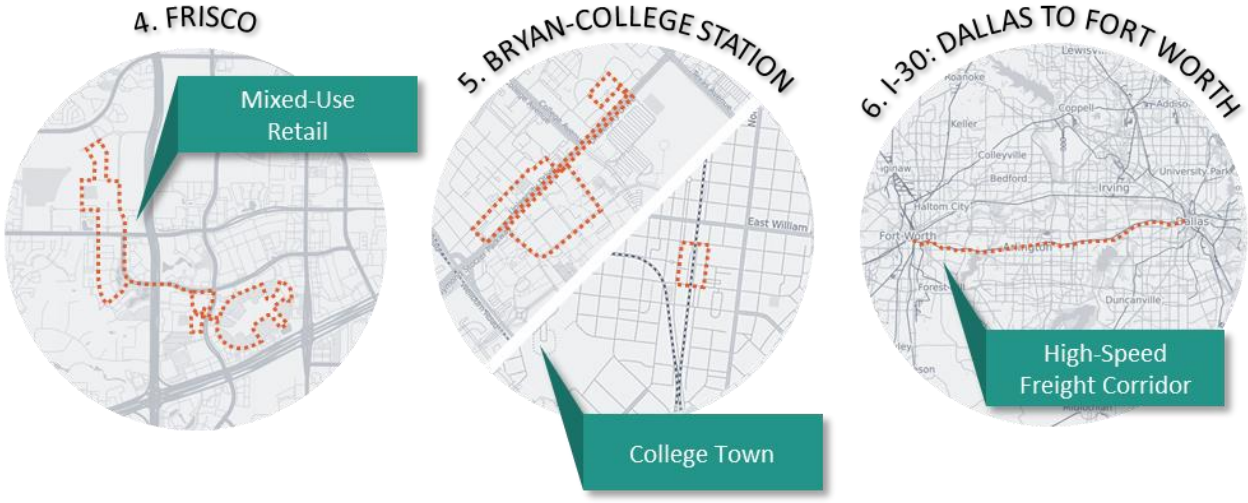
Figure 1.3 High-Level Project Schedule



TEXAS ★ AUTOMATED PORTFOLIO



Texas is investing in a portfolio of automated driving system (ADS) projects. The Texas Automated Portfolio (TAP) leverages resources to offer USDOT a collaborative and safe environment for diverse deployments. While each demonstration is locally-tailored, the deployments are harmonized with a unified data management system and coordinated to minimize risk and maximize impact.



LOW-SPEED TRANSIT

1a HOUSTON

Environment: University campus and mixed-traffic roads that navigate work zones and link to light rail

A multi-phase project enabling students and nearby Cuney Homes residents to traverse TSU's campus, make transit/light rail connections, and access medical centers.

>> Characterize safety risk of ADS integration in closed campus, mixed-traffic, and complex work zone and transit environments

1b HOUSTON & AUSTIN

Environment: Dedicated high-occupancy vehicle lane in the Houston METRO network

Small fleet of platooning transit shuttles that begin in the research phase, progress to a demonstration in a real-world setting on the Houston METRO network, and are transferred to the Capital Metro network in Austin.

>> Develop bus platooning to enhance throughput in constrained corridors and assess workforce impacts.

2 SAN ANTONIO

Environment: Redeveloped community with office, retail, and residential linking into major transit hub

Small fleet integrating with public transit to provide employees, residents, and visitors service around the Brooks campus to office, retail, residential, and the new Brooks Transit Center hub.

>> Guide FTA transit automation research by integrating automated vehicles with the public transit fleet and assessing interoperability needs.

ON-DEMAND URBAN SERVICES

3 ARLINGTON

Environment: Mixed-traffic operations in the Entertainment District with special events

Service for residents and visitors of all abilities to access on-demand, automated and non-automated wheelchair accessible options in the Entertainment District to retail, concerts, and major sports events.

>> Enhance experience for mobility-challenged populations by dispatching vehicles with wheelchair ramps and prototyping accessible pick-up/drop-off

4 FRISCO

Environment: Mixed-traffic operations in the North Platinum Corridor with mixed use, office, and retail facilities

On-demand passenger pickup for employees, residents and visitors in the North Platinum Corridor accessing several mixed-use developments and other urban centers.

>> Set a baseline for safe ADS operation and assess the navigation of complex intersections, right-of-way decisions, and behaviors of cyclists and pedestrians.

5 BRYAN-COLLEGE STATION

Environment: Mixed-traffic operations in downtown and on university campus, highway, and arterials integrated with special events

Shuttle service for students, residents, and visitors in central business district and to connect between Texas A&M University campus, Kyle Field football games, apartments, and local businesses.

>> Provide detailed vehicle data to define the leading indicators for safety analysis across a range of operational design domains.

HIGH-SPEED FREIGHT

>> Provide data to define safety equivalency for light duty and heavy-duty vehicles,

>> Inform motor vehicle fuel economy standards

>> Guide law enforcement interactions

6 I-30: Dallas to Fort Worth

Environment: High-speed urban freight corridor with dedicated lane and mixed-traffic configurations

Twelve-mile managed lane facility enabling freight vehicles to test in a dedicated lane, mixed-traffic, and teleoperations scenarios with both DSRC and 5G Cellular-V2X capabilities.

Alignment with USDOT Goals

The Texas ADDS team is a strong partner for USDOT because together the two can build upon the momentum of ongoing activities. Texas' existing network of partners aligns with the USDOT goals of the ADS Demonstration Program. Texas offers diverse deployments to assess a variety of safety factors, harness data to inform policy and regulatory activities, and collaborate across an alliance of partners who share lessons learned and develop best practices in real-time.

Safety. Texas is investing in a portfolio of projects that demonstrate how to address challenges for the safe integration of ADS for on-road transportation systems. Texas will conduct a safety risk assessment for each deployment that addresses the safety of the vehicle, operational design domain, cybersecurity concerns, education and training, and policy guidance.

Vehicle safety encompasses technologies along the automated and connected continuum. Included will be an assessment of the vehicle's ability to perform core functionalities including: object and event detection and response (OEDR), fallback into minimal risk conditions, and synergize with connected vehicle applications (i.e., vehicle-to-vehicle and vehicle-to-infrastructure). The vehicle safety assessment will enable USDOT to identify areas where Federal Motor Vehicle Safety Standards (FMVSS) may need to be clarified or updated.

Operational design domains (ODDs) will consider roadway types, traffic characteristics, road weather conditions, and other domain parameters. Texas will provide insights into three major environments – low-speed campuses, complex urban cores, and high-speed freight corridors. The output from this effort will inform USDOT and state regulatory agencies who are developing ODD frameworks and exploring paths to ODD certification.

Cybersecurity includes developing data management plans with security by design principles that 1) protect personally identifiable information (PII) and confidential business information (CBI), 2) identify cyber vulnerabilities, and 3) establish cyber incident response strategies. As a partner, Texas will provide guidance to USDOT on best data governance practices and access policies to securely manage local, state, federal, research, and private sector partners.

Education and training programs will be developed to build awareness of AV safety among several target users, guide safe behavior in and around an AVs in operation, and include demonstrations where the public may test ride and become familiar with the technology, its safety features, and benefits. The Texas experiences will enable USDOT to provide guidance to states on how to modernize driver education and training programs to safely operate and be in traffic with AV technology.

Policy guidance will bring the Federal, State, and local stakeholders together to identify areas of the law that may require further clarification and/or adaptation, manage compliance and enforcement of the law, and develop a flexible framework that ensures public safety while encouraging innovation. Texas policymakers will work with the USDOT to inform policy, standards, and regulatory activities at all levels of government.

Texas' major contributions to safety research and implementation include the following:

- **Arlington, Frisco,** and **San Antonio** will assess safety performance for a variety of users,

including older adults and travelers with disabilities, to understand when it is safe to transition from a safety driver, to safety chaperone, and finally to remote monitoring.

- **Bryan** and **Houston** will assess how AVs safely operate in high-pedestrian areas, integrate with mixed traffic, navigate construction zones, and interface with light rail.
- **I-30** will assess how freight vehicles safely operate at high-speeds in a dedicated lane as well as alongside other passenger and freight vehicles in mixed traffic, interact with law enforcement officers, and tele-operate where the vehicle is being monitored remotely.
- **Bus Automation/Platooning** will assess how ADS technology can improve the safety of bus operations operating on a managed lane in Houston.

Data for Safety Analysis and Rulemaking. The Texas Data Management Plan follows a system of systems approach. At the center of the plan, Texas has established a Data Lake at the University of Texas at Austin Texas Advanced Computing Center (TACC) that will store and manage the data for all Texas deployments. The Data Lake consists of two components: a public datastore for non-sensitive data, and a secure datastore for data that contains PII and/or CBI. Major inputs and data consumers are managed by a secure access layer through a user-interface – the Texas ADS Portal – to enable USDOT, local deployment partners, state agencies, a research community of practice, and the public to access information in a secure and convenient way.

The Unified Data Framework will tie all Texas deployments together. It is a voluntary consensus data framework that establishes common definitions, safety and technical criteria, and performance metrics. The Unified Data Framework maps research questions to use cases and enables one deployment to be readily compared with another while still providing the flexibility for a local approach. A standard language will guide a rapidly evolving market and position USDOT to advance the national and global interoperability of ADS technologies.

Collaboration. Partnerships are a core tenet of the Texas model for innovation. Texas has forged a network of partners – the Texas Innovation Alliance – to harness the collective expertise, ingenuity, and knowledge of multiple stakeholders who share the common challenges of rapid growth, rising congestion, and limited mobility options. The Alliance reflects the diversity and comradery of the state, recognizing there is no one-size-fits-all solution but capitalizing on every opportunity for collective action. Texas maintains several forums to facilitate knowledge transfer and technology exchange at the state and national levels. Based on successes in-state, Texas seeks to partner with USDOT peers to establish a nationwide collaborative model and share the data and information learned from the Texas Innovation Alliance deployments. Texas' major contributions to collaboration include the following:

- **Texas Innovation Alliance** is a network of local, regional, state, and research partners who have been actively collaborating, sharing lessons learned, and developing best practices since 2016 on a number of priority mobility challenges. The Alliance is committed to the safe deployment of AVs and will enable USDOT to magnify its impact on a statewide and national level.
- **Research Community of Practice** includes leading experts from research institutions in Texas who are committed to using the data collected from the Texas deployments to study and contribute to social science and technical fields such as transportation safety, human factors, public policy, computer science, and urban planning. These experts

partner across academic institutions for interdisciplinary research and maintain open dialogue with public agencies to apply their talent to pressing mobility and policy needs.

- **Governor's Connected and Automated Vehicle (CAV) Task Force** was announced in January 2019 and will serve as a public-private forum to convene diverse stakeholders on core CAV issues: policy development, licensing, enforcement, liability, and more. In addition, the Task Force will function as an advisory body to the Governor's Office, Texas Legislature, and other state agencies as well as engage with other states and USDOT to translate findings and lessons learned from state-level regulatory and policy issues to federal interests. The Texas ADDS Project will inform this task force of its findings.

USDOT Focus Areas

American ingenuity holds the potential to once again transform mobility. Automated technologies promise significant benefits for the American people and economy. Along with potential benefits, however, automation brings new challenges and potentially unintended consequences that need to be addressed. Texas provides a collaborative environment where diverse stakeholders can work closely together to ensure safety without stifling innovation. Texas addresses the USDOT focus areas in the following sections:

Significant Public Benefits. Determining how autonomous vehicles will impact the transportation system in different environments and use cases will form the basis for public policymaking that facilitates the safe development and adoption of AVs. Expected public benefits include reducing incidents and fatalities, improved traffic congestion, reduced CO_2 emissions, expanding transportation accessibility and opportunities, and reducing parking requirements thereby freeing up real estate for alternative uses.

Texas is also committed to mitigating unintended consequences. The public has genuine concerns about the safety, security, privacy, and accessibility of AV technology. Texas will proactively address these concerns. The Texas ADS project will use data from its six deployments to determine public impacts and quantify them in the realms of safety, mobility, environment, human factors, and equity and access.

Addressing Market Failure and Other Compelling Public Needs. AVs could provide first/last-mile services that connect commuters to public transportation with demand responsive, real-time routing capabilities. Urban areas have long faced challenges in providing adequate public transportation with limited resources and while competing with new mobility services such as ride-hailing and microtransit. Transit agencies, especially medium-sized cities in Texas that have little-to-no fixed transit infrastructure, may currently find that their limited resources are best spent focusing on high-capacity corridors to meet the needs of their residents. This longstanding tradeoff between service coverage and frequency is driven by high operating costs, especially labor that could be alleviated by automated services that reduce labor costs. AV deployments in strategic partnership with transit agencies could supplement public transport, solving first- and last-mile, dynamic demand, and other challenges.

The trucking industry and the economy are inextricably linked. Trucking is the primary U.S. mode for goods movement by both tonnage and value. However, a shortage of truck drivers threatens the future of the country's economy. Under continuing trends in the explosive growth in online

shopping and other market forces, the labor shortage could grow to 60,000 drivers in 2026. The Texas ADDS grant will deploy and evaluate CAV trucking technologies in long-haul and urban environments and include teleoperations backed by a cellular network in the DFW region.

Economic Vitality. Texas has the tenth largest economy in the world. The overall automotive market could expand as automobiles become accessible to a broader scope of users, including transportation-challenged populations, who are enabled by autonomous driving to enjoy the convenience of automobiles without physically driving them. The trucking and freight industry will likely be among the earliest adopters of automotive driving as companies seek to improve transport efficiency. Autonomous driving systems will free drivers from the task of driving, and to sustain economic vitality Texas will cultivate new skill sets and vocational training for those whose jobs may be replaced by automation to ensure all are included in the new economy. This will enable trucking companies to transport larger quantities of freight at lower costs, resulting in an increase in economic benefits.

Complexity of Technology. The Texas ADDS project includes multiple projects with levels 3 and 4 automation, including DSRC and cellular connectivity, and teleoperations. Project deployments will be geographically diverse in urban and suburban, and across closed, controlled, and open environments.

Diversity of Projects. Texas is investing in a portfolio of projects that represent diverse use cases in three environments: 1) Next-Generation Transit Shuttles, 2) On-Demand Services in the Urban Core, and 3) High-Speed Freight. The portfolio serves a variety of urban and suburban communities, a range of transportation markets including freight, personal mobility, and public transportation, and users across all abilities including the elderly and disabled.

Transportation-Challenged Populations. Many seniors and people with disabilities have limited or no capability to drive, even with vehicle modifications that help others drive safely. AVs with specially tailored services or equipment could provide many more Americans transportation access and personal freedom. Automated driving systems should also be adapted to the needs of elderly and disabled individuals. The Texas ADDS Project will prioritize deployments that ease ridership barriers from the various transportation-challenged populations by following these design principles:

Design vehicles and hardware with adaptive uses in mind including lower floors to accommodate wheelchairs; ramps or aftermarket modifications; and accessible door handles, securement options, and storage spaces

Create accessible user interfaces for trip planning and booking including voice-controlled systems; visual displays with adjustable size and contrast options; audio and visual information about the environment surrounding the vehicle; directions on exiting using available adaptive features; information on first- and last-mile directions to their destination including orientation landmarks

Ensure ride-hailing technology and mobile apps are accessible including enhanced audio and visual options; offering navigation cues for visually impaired riders to help with boarding and exiting a vehicle; built-in intelligence to vehicles to ensure that it aligns with wheelchair accessible pick-up and drop-off points.

Prototypes. Texas is investing in projects that have achieved a minimum prototype level of technology readiness. All demonstrations will meet applicable safety standards or apply for any necessary exemptions. The portfolio includes projects that will be launching as well as more mature deployments that have over one year of experience. Experience from the leading projects is shared with others, enabling projects to accelerate to launch or scale deployment.

How Proposal Meets Requirements

The ADS Demonstration Grant notice listed six specific project requirements. Table 1.1 provides a summary of how the project proposal will meet these requirements.

Table 1.1 How the Texas ADDS Project Meets Requirements

Requirement	Texas ADDS Project
1. Must focus Level 3+ ADS technology	Focuses on Level 4 automation. The four active deployments all have Level 4 vehicles serving the public. In addition, the high-speed truck automation test bed will bring together five different Level 4 automated truck partners to be demonstrated and share data. The project will also demonstrate a bus automation use case with bus platooning where the first bus is driven by a bus operator and the second bus follows with Level 3 automation.
2. Must include a physical demonstration	The Texas ADDS Project will demonstrate: • High-speed truck automation with four private companies and one university on I-30 • High-speed bus automation on a Houston managed lane The project will include five deployments that are beyond demonstration stage: • Low-speed AV Shuttles in Houston and Bryan, Texas • On-demand AV Service in Arlington, Frisco, and San Antonio
3. Must include the sharing of data	The project will expand on existing Texas Data Lake efforts and build a unified data platform to include all relevant data from the ADS deployments to share with USDOT.
4. Must include user interfaces	The project will study the user interfaces. The Houston and Bryan deployments will examine user access and accessibility of low-speed shuttles. The on-demand AV service in Frisco and Arlington will look at the user's application used to request rides.
5. Must address scalability	The project is focused on scalability across Texas by looking at four existing deployments, three expansions of those existing deployments, and two new deployments in new regions of Texas.
6. Must include outreach task	The project is supported by the Texas Innovation Alliance which is an existing network of stakeholders focused on outreach. The Innovation Alliance current holds regular meetings, hosts an annual conference, and maintains an active website for the purpose of sharing experiences, lessons learns, and best practices.

Vision

Texas is a force multiplier for innovation. Faced with pressing needs for improved safety, congestion relief, and increased accessibility, Texas' metropolitan regions have stepped forward to develop shared solutions for common mobility challenges. Automation has significant potential to transform the future of transportation. Many questions, however, remain. Texas' vision is to share knowledge, experience, lessons learned, and data on how AVs and ADSs can help overcome these transportation challenges.

Texas is investing in a portfolio of ADS projects. The Texas ADDS Project leverages these deployments to offer a diverse and collaborative environment to study the safety of ADS. The portfolio includes six deployments across three operational environments that range in complexity, route type, service model, infrastructure readiness, and user community. By collecting data from this portfolio of projects, Texas can learn from a range of use cases and offer a significantly robust database to the USDOT to further the national effort on ADS safety analysis, guidance, and possible rule making.

Goals and Objectives

The future of ADS technology is full of promise. The lifesaving capabilities of these technologies could have significant safety advancements and an even wider range of possible benefits, given that all today's stakeholders within the transportation system carefully coordinate design and implementation. The Texas ADDS Project is focused on defining safety, collecting data, and conducting analysis to measure the safety performance of all Texas deployments. The goal is to ensure the safest, most efficient deployments as ADS technology expands across Texas.

Reflective of the diversity across the state, the Texas ADS Grant proposes to advance the state of knowledge and implementation in numerous domains. The portfolio of projects will be tied together by a comprehensive set of goals and objectives in five major categories:

TEXAS ADS GOALS

Safety
Integrating, measuring and comparing ADS in diverse testing environments

Mobility
Enhancing traffic operations, V2I/V2V communications, and resiliency

Environment
Reducing impact on environment and improving public health

Human Factors
Understanding how the public interacts with, perceives, and uses the technology

Equity & Access
Connecting all communities to jobs, medical care, and other critical services

While each deployment is locally tailored, several coordinated elements harmonize the deployments with one another:

- **Unified Data Management Strategy** – Projects within the portfolio will generate and share data based on a Unified Data Framework of consensus definitions, standards, and metrics. Within the framework, each deployment will establish a baseline, compare

performance, and measure progress towards the portfolio goals. Data will be made available through a secure data system to USDOT, participating partners, and a consortium of researchers.

- **Stakeholder Engagement Tools** – Texas mobility is community-driven. To include all communities as part of the innovation process, participating partners will have access to a set of stakeholder engagement tools to assist with public outreach; guide policy development; cultivate industry relationships; and include traditionally disadvantaged populations. Examples of tools include informational resources on connected and AVs, digital equity and inclusion principles, and blueprints for planning workshops and user focus groups.
- **Community of Practice** – Texas is pioneering peer-to-peer learning, and as part of this collaborative effort will continue sharing lessons learned, developing best practices, and fostering meaningful partnerships. Through the network, partners will stay abreast of the latest advancements and benefit from the success of others.

Key Team Members, Partners, and Stakeholders

Texas is the leading marketplace for safely developing, launching, and sustaining a portfolio of ADS projects. There are currently five different ADS deployments active in Texas – Arlington, Bryan, Frisco, Houston, and along the I-30 corridor between Dallas and Fort Worth, with three more planned in College Station, Corpus Christi, and San Antonio, Texas.

Table 1.2 Texas ADDS Team

PUBLIC AGENCIES		INDUSTRY
City of Arlington, Texas	Capital Metro	Drive.ai
City of Frisco, Texas	Houston METRO	First Transit, contracting with EasyMile
Denton County Transportation Authority (DCTA)	City of Houston, Texas	Ike
City of Fort Worth	Houston-Galveston Area Council (HGAC)	Kodiak Robotics
City of Dallas	VIA Metropolitan Transit	Starksy Robotics
City of Grand Prairie	Brooks Community	TuSimple
North Central Texas Council of Governments (NCTCOG)	City of San Antonio	INRIX
City of Bryan, Texas	Texas Department of Transportation (TxDOT)	Cisco
City of College Station, Texas	Coalition of Texans with Disabilities (CTD)	
Bryan-College Station Metropolitan Planning Organization (BCSMPO)		
RESEARCH		
TTI, CTR, SwRI, TSU		

The Texas stakeholders interested in transportation technology have formed the Texas Innovation Alliance. The Alliance is an action network of local, regional, and state agencies and research institutions who are committed to addressing community mobility challenges by

creating a platform for innovation. The vision of the Alliance is a seamless mobility system. The Alliance is dedicated to improving the lives, safety, and economic prospects of Texans through innovative mobility solutions. The Texas Innovation Alliance has supported the Texas ADS Research Team to lead the Texas ADDS Project.

The Texas ADS Research Team is led by TTI in collaboration with UT/CTR, SwRI, and TSU. These research entities all have experience with AV research, testing, and deployment. The Texas ADS Research Team is supporting the larger Texas ADS Team which is made up of the ADS Research Team, the Texas Innovation Alliance members, the public sector partners leading AV deployments (all of which are members of the Texas Innovation Alliance), the AV Developers (including low-speed AV shuttle developers, on-demand AV developers, AV Truck developers, and university AV developers), and private sector partners assisting with infrastructure and data collection.

Overview of Deployment Sites – The Texas AV Deployment Portfolio

Texas is investing in a portfolio of ADS projects. The Texas AV portfolio of projects leverages resources to offer USDOT a safe and collaborative environment for diverse deployments. While each deployment is locally tailored, the deployments are harmonized by a unified Data Management Plan, have access to common stakeholder engagement tools, and leverage the collective knowledge of a national Community of Practice. The portfolio includes deployments across three primary operational environments: 1) Low-Speed Transit Shuttles, 2) On-Demand Services in the Urban Core, and 3) High-Speed Freight. The use cases range in complexity, route type, service model, infrastructure readiness, and user community and are outlined in the following sections.

Next-Generation Transit Shuttles

With a booming population, Texas public transit is evolving to serve a growing demand for mobility among a diverse group of riders. Autonomous vehicles have an opportunity to address first/last-mile gaps, connect suburban commuters to jobs, and provide low-income, elderly and disabled riders with accessibility to critical services.

DEMONSTRATION HIGHLIGHTS

- Integrating with public transit to address first/last mile gaps
- Operating in construction/work zone and light rail environments
- Serving transportation-challenged users

HOUSTON | University District AV Transit Circulator
Partners: Houston METRO, Texas Southern University
Service Type: On-Demand, Fixed Route
Environmental Characteristics: Texas Southern University, METRO Light Rail, Surrounding Neighborhoods

As the 4th largest city in the U.S., Houston is a major metropolitan area with a majority minority population of varying socioeconomic levels. The multi-phase University District AV Transit Circulator Project will reflect the diversity of its population's needs by locating its test sites near low-income or transportation disadvantaged populations and serve diverse use cases ranging from first/last mile gaps, multi-modal connections, and service near campuses and medical centers. Furthermore, the project will test automated technology on complex and previously unseen environments including work zones and a light rail crossing on public roads. Phase I of the project will operate at TSU and deploy an EasyMile shuttle along TSU's pedestrian mall, the Tiger Walk. The University of Houston and low-income housing development known as Cuney Homes are nearby. Cuney Homes has a large elderly population with high need for access to medical care. This grant will help catalyze Phase II, which transitions to public mixed-traffic streets adjacent to TSU, operates in construction zones, and integrates into Houston METRO's light rail system. Future phases include implementation of a district-wide, multi-campus transit system and strategic connections with nearby high capacity public transit stations.

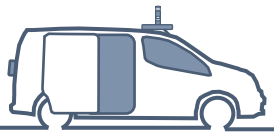
SAN ANTONIO | Brooks Automated Shuttle Service
Partners: VIA Metropolitan Transit, Brooks
Service Type: On-Demand, Fixed Route
Environmental Characteristics: Brooks Innovation Zone, 1308 acres of mixed-use development, VIA Brooks Transit Center, Military Primo Bus Rapid Transit Line

In 2018, San Antonio was the fastest growing city in the nation by sheer population and there is no indication the growth will subside. As such, VIA Metropolitan Transit is embarking on an initiative to bring a small autonomous fleet of two vehicles to the former Brooks Air Force Base now designated as the state's first Opportunity Zone. The Brooks Development Authority (BDA) has invested more than $35 million in infrastructure since 2004 and has secured significant private investment. The redevelopment houses employers, schools, commercial, and residential, and is the site for the new Brooks Transit Center slated to open in Fall 2019. The center will serve as an anchor for a new frequent Primo Military bus rapid transit line and express route to downtown San Antonio. The autonomous shuttle will address the missing link, connecting people from the Brooks Transit Center to the growing Brooks campus along lower-speed, mixed traffic roadways. AVs are expected to integrate with VIA's bus fleet and dispatching systems. In addition, the project will build on mobile applications for fare payment, multi-modal trip planning, and upcoming mobility-on-demand service.

HOUSTON | Bus Platooning
Partners: Houston METRO, Capital Metro, TTI
Service Type: On-Demand, Fixed Route
Environmental Characteristics: Houston Managed Lane

One use case of interest to the transit agencies is bus automation for platooning. Bus platooning offers three potential benefits to transit agencies. The first is added safety by providing ADS to assist existing drivers. The second benefit is the ability to add additional buses to form bus consists that allow "right-sizing" the transit capacity to serve demand at different times of the day. The third benefit is by allowing following buses in the platoon to be highly-AVs, thereby reducing the need for additional drivers and reducing labor costs. The Texas ADDS

Project proposes to demonstrate this use case on a managed lane in the Houston METRO Managed Lane network.



On-Demand Services in the Urban Core

Over half of vehicle trips in the U.S. are four miles or less in length, often taking place around core activity centers. In reimagining personal mobility, autonomous vehicles present the opportunity to improve connectivity and commerce by enabling travelers to access the urban core without relying on vehicle ownership.

DEMONSTRATION HIGHLIGHTS

- Operating in complex environments with pedestrians, bicyclists, scooters, etc.
- Managing a fleet with automated and non-automated vehicles
- Assessing safe transitions

ARLINGTON | Automated and Non-Automated Fleet Management
Partners: City of Arlington, Drive.ai, Via
Service Type: On-Demand, Fixed Route, Crashworthy Passenger Vans
Environmental Characteristics: Entertainment District, University of Texas at Arlington Campus

Arlington has taken great strides to shed its reputation for being the most populous city in the U.S. to lack public transit. Arlington has gained experience deploying a low-speed automated shuttle and has taken to the streets in partnering with Drive.ai and Via by operating both automated and non-automated microtransit services. As Arlington has the longest AV operating experience in the state, they have shared invaluable best practices with other cities around the nation and are primed to continue their leadership in AV testing and deployment. In this project, Arlington seeks to manage a mixed fleet of automated and non-automated vehicles to serve travelers in its Entertainment District and surrounding areas. Now that Arlington has executed upon its own portfolio of AV deployments, they are focusing on transitioning from technology demonstration to critical use cases. Building on its active partnerships, Arlington will explore the feasibility of seamless booking for Drive.ai and Via services, optimizing the City's ability to serve the needs of diverse populations. In particular, Arlington seeks to improve the experience and expand mobility options for disabled riders by dispatching vehicles with wheelchair ramps and prototyping pick-up/drop-off sites suitable for disabled users.

FRISCO | On-Demand Passenger Service
Partners: City of Frisco, DCTA, Frisco Station Partners, HALL Group, and The Star
Service Type: On-Demand, Fixed Route, Crashworthy Passenger Vans
Environmental Characteristics: Office Park, Entertainment District, & Residential Area

Frisco topped the nation from 2016-17 as the fastest-growing city in the nation. To address the increasing demand for mobility, Frisco formed a unique partnership – the Frisco Transportation Management Association (TMA) – to improve connectivity between several mixed-use developments in Frisco's North Platinum Corridor. The TMA partnered with Drive.ai to launch an on-demand passenger service and has been logging real-world miles since July 2018. For this effort, Frisco is interested in expanding its service area to Stonebriar Centre Mall, City Hall, and

the old downtown. Frisco will leverage its experience to provide key safety insights into complex intersection navigation, right-of-way decisions, and cyclists and pedestrians behavior.

BRYAN-COLLEGE STATION | Automated Shuttle On-Campus and On-Street
Partners: City of Bryan, Bryan-College Station MPO, City of College Station, Texas A&M
Service Type: Fixed Route
Environmental Characteristics: One-mile loop in downtown Bryan and three-mile route in College Station, with state highway, university campus, and residential

Bryan-College Station is a rapidly growing region with numerous students, faculty, staff, and local businesses around the Texas A&M University campus and the historic Downtown Bryan region. Unfortunately, the transportation infrastructure has been challenged to keep pace with this growth and is particularly congested during special events such as home football games. Both deployment phases will serve a diverse ridership population, including students, the mobility challenged and areas of economic impact. Phase 1 of the region's deployment focused on a dining, entertainment, office and merchant district within historic Downtown Bryan with a one-mile loop route from the central parking garage to the heart of Downtown. The existing pilot route will be extended to other downtown locations and upgraded to tele-driving capability for more expansive service and hours. Phase 2 of the regional deployment will operate in College Station using two to four AVs linking Texas A&M University, the Northgate entertainment district, and the Century Square mixed-use development. Vehicles will operate along a three-mile route on University Drive (a state highway) as well as on city and campus streets. In addition, the project will connect to the A&M Transit System (the state's 7th largest with 7.5 million rides last year), coordinate with smart intersection enhancements and integrate with the traffic management center to improve operations during game day and everyday operations.

High-Speed Freight

Freight represents the lifeblood for the Texas economy. In 2016, over 745,000 daily truck trips occurred on Texas' roadways. With daily truck trips and truck-miles on the rise, autonomous freight has the opportunity to reduce traffic accidents involving large trucks, optimize fuel consumption, and address changing workforce needs.

DEMONSTRATION HIGHLIGHTS

- Evaluating physical and digital infrastructure quality
- Reducing fuel consumption and greenhouse gas emissions
- Coordinating with law enforcement

I-30 between Dallas and Fort Worth | Connected and Automated Freight Corridor
Partners: NCTCOG, Starsky Robotics, Ike, TuSimple, Kodiak Robotics
Service Type: Fixed Route, Freight Vehicles
Environmental Characteristics: 12-mile managed lane facility, high-speed traffic conditions

I-30 is an ideal test environment for AV truck operations in urban areas. The corridor contains a 12-mile managed lane facility that can be closed and utilized for early stage testing. It passes through four municipalities that have signed on to be part of NCTCOG's Automated Vehicle 2.0

program and two TxDOT Districts that have invested in roadway cameras and other sensors on the corridor. In addition, I-30 is part of the Texas Connected Freight Corridors project that will instrument the roadway with both DSRC and Cellular-V2X capabilities that can be leveraged under this ADS grant. Data from a group of automated freight industry partners will be shared to conduct the following five safety assessments:

1) Data describing the **quality of physical infrastructure elements** will be shared to provide input to TxDOT maintenance regarding areas where improvements can be made to striping, signage, and pavement conditions.
2) Data comparing the **capabilities of V2I technologies** will be used to assess the reliability of the communications network to support tele-operations.
3) Data describing **traffic patterns and mix of vehicular traffic** will contribute towards assessing behavioral risk and making recommendations for optimal hours and designated lanes of travel.
4) Data characterizing **roadway and weather conditions** will be used to inform freight operators about the impact of the angle of the sun, rain, flooding, ice, etc. relative to normal operations.
5) Data identifying **disruptive events** – traffic crashes, construction, dangerous obstacles, etc. – with consistent definitions will assist with effectively comparing disengagements.

Evaluation and Safety Analysis

The USDOT has estimated that 94 percent of motor vehicle crashes occur due to human error. One path towards reducing these crashes is the wide-scale application of evolving technology. Vehicles equipped with ADS features are one potential source for reducing driver-related errors and resulting crashes. A first step towards ADS deployment is to assess how to effectively integrate ADS equipped vehicles into the transportation system with a focused assessment on how this implementation may impact safety. To assess expected safety performance, there is a need to define the elements that collectively contribute to system safety and identify ways to directly or indirectly evaluate their performance as part of the Texas ADS Project.

Definition of Safety and Performance

Safety. While cars are becoming safer, traffic fatalities have been on the rise for the past decade – coinciding with a growing economy, cheaper gas, and increasing vehicle miles traveled. Since November 7, 2000, at least one person has died on Texas roadways every single day – totaling more than 66,000 traffic fatalities.

The term safety can be defined in a variety of ways. The Merriam-Webster dictionary notes that safety is the "condition of being safe from undergoing or causing hurt, injury, or loss." The AASHTO Highway Safety Manual (HSM), when referring to the safety focus within the manual, indicates that the HSM has a "universal objective to reduce the number and severity of crashes within the limits of available resources, science, and technology, while meeting legislatively mandated priorities." The FHWA Office of Safety focuses on providing assistance to help achieve the vision of zero deaths and serious injuries on our Nation's roadways. NHTSA uses the phrase "Safe cars save lives" as an indicator of their safety initiative. As part of this NHTSA focus, in October 2018 NHTSA issued Federal guidance for AVs titled Automated Vehicles 3.0: Preparing for the Future of Transportation 3.0. Included in this NHTSA

document is a list of safety elements that should be considered when deploying and monitoring ADS systems. Ultimately, it is clear that safety, as it applies to the USDOT ADS Demonstration Grants, must focus on minimizing risk and eliminating contributing factors and resulting crashes related to ADS deployments. The ADS-related safety performance assessment must be evaluated from a variety of perspectives including crash history, vehicle characteristics and disengagements, physical roadway characteristics, roadway traffic operations, driver behavior, and supplemental measures that collectively can represent potential levels of risk.

***>> Action Item**: The Texas ADDS Team will work with the USDOT to clearly define safety at the beginning of the Texas ADDS Project. This definition and the associated safety performance measures will drive the data collection, analysis, and evaluation for the rest of the project.*

Mobility. As vehicle fleets slowly progress from limited vehicle infiltration to more substantial ADS integration, the traditional infrastructure and operational characteristics can be expected to change. Currently roadway design, for example, relies heavily on the provision of stopping sight distance. This critical sight distance dimension consists of braking time plus a driver's perception reaction time (ranging from one to 2.5 seconds). Fully automated vehicles will no longer be based on the driver's perception and reaction time. This simple example demonstrates that today's mandatory design characteristics can be expected to change as ADS deployment and market penetration also changes. For the Texas ADS project, the team expects to document the road characteristics of the recurring routes and assess how the vehicle responses differ based on traditional infrastructure considerations. Additional infrastructure elements that may warrant consideration in these largely urban locations may include bus stops, driveways, pedestrian and bicycle accommodations, and re-assessment of other curbside assets.

Traffic operations can also be optimized for automated corridors. The use of strategic corridor progression, for example, can help improve the traffic flow of ADS-equipped vehicles. The vehicle mix is also an important consideration in the evaluation of how a corridor can efficiently accommodate all prospective users.

***>> Action Item**: The Texas team will document the infrastructure characteristics through the use of aerial photographs, site visitation, and video information (either provided by the local city, acquired from a portable camera, or captured by in-vehicle cameras). Included in the project plan is the development of secondary after-market devices that will include forward video information as well as supplemental position and speed data. These devices will be installed in the next-generation transit shuttles and the on-demand urban core service vehicles.*

Environment. Each AV deployment will be uniquely designed to optimize positive environmental influences. For example, the introduction of bus platooning in the Houston initiative can be expected to introduce consistent driving speeds with a reduced number of hard stop conditions. This enhancement will result in reduced vehicle emissions. Similarly, the high speed freight corridor will help optimize the placement and operation of heavy vehicles on an interstate and contribute to reduced fuel consumption and greenhouse gas emissions.

***>> Action Item**: The Texas team will assess the improved performance of vehicle behavior for corridors with enhanced vehicle flow characteristics such as platooning. Though the direct*

measurement of these factors can present a challenge when there is not a fixed-route corridor, the team will identify locations where platooning has been implemented, conduct observational studies, and utilize microsimulation to assess improved flow and reduced fuel consumption for these locations. The simulations can also be used to assess operating speed differentials for other vehicles as a safety performance measure.

Human Factors. Human factors issues can include improved human-machine interfaces for users as they board, ride, and exit AVs. This issue can be particularly important for transit users who need to be able to efficiently and safely access the vehicles.

***>> Action Item**: To assess human factors and associated acceptance levels, the Texas team will conduct observational studies that will monitor user demand for the individual deployments. In some cases, such as the on-demand vehicles, the observational study may be conducted by the assigned reserve driver. In other cases, such as shuttle services, the observational studies could be conducted as part of a ride-along effort.*

In addition to observational studies, the Texas team proposes the use of questionnaires for known users as well as for regional travelers who have the option of utilizing the vehicles. The goal of these tools will be to assess the specific factors that influence the decisions by prospective riders.

Equity and Access. Roadway crashes tend to be disproportionately distributed with underserved and low-income areas being particularly vulnerable as they are often characterized by more pedestrian, cyclist, and transit users than in the higher income regions. In addition to financial equity challenges, there is a need to consider potential age, race, and gender biases.

The inclusion of shuttle services and on-demand ADS vehicles can assist with equity and access challenges by careful consideration of these needs as part of the deployment strategies and physical route choices. The traditional vehicle fleet characteristics and location can represent baseline conditions by which the potential impact of ADS equipped vehicles can be contrasted. Ultimately, shuttle and on-demand services can offer enhanced mobility for travelers with disabilities and renew independent travel opportunities for many of these system users.

***>> Action Item**: For the Texas ADDS Project, one proposed study site will utilize a self-driving shuttle in low-income areas of South Houston. After evaluating the travel patterns and utilization rate of the self-driving shuttles in these areas, the Texas team will use the results of the safety assessment study conducted at earlier pre-deployment stages to explore the equity outcomes of ADS vehicles in these socioeconomically diverse areas.*

In addition to the above economic assessment, the Texas team will monitor the use of the system by persons with disabilities to determine expected ridership by potential users with travel constraints.

Safety-Oriented Data

A wide variety of candidate data elements can be acquired to collectively assess the safety of individual ADS deployments. In many cases, such as the Bryan low-speed shuttle, the entire ADS-generated data set will be available for analysis and data sharing. For other

deployments, the proprietary data elements could be limited to a subset of the entire data set. In addition, the Texas team may post-process data that cannot otherwise be provided. For example, members of the team are not authorized to re-distribute crash data from the Texas system. Therefore, crash records cannot be included in the open database. In the event a crash should occur, however, team members should be able to evaluate the crash conditions and provide some limited documentation about the nature of the collision. Overall, the data platform described in detail in the data management plan will be generated from a variety of potential data sources including information related to vehicle data, roadway data, crash and crash rate data, surrogate safety data, and user experience data. Collectively, these individual data sources can be used to assess the overall system safety for individual ADS deployment strategies.

Vehicle Data

As noted above, vehicle data will serve as a critical element in assessing system safety. Data characteristics that are important to safety but that may not explicitly be acquired as part of these deployments include vehicle crashworthiness and vehicle cybersecurity.

Roadway, Infrastructure, & Operations (RIO) Data

TxDOT provides a roadway inventory database that is freely available for download on their website. This database includes a wide variety of road characteristics. Currently, TxDOT is enhancing this database to include additional geometric elements. In addition to information available from this roadway inventory, the Texas team intends to use aerial photographs and site inspections to enhance the roadway data that will be included for each deployment. Example roadway data will include road geometry, traffic control (signs, signals, and markings), and presence of parking, crosswalks, bike paths, and transit stops.

User Data

User data will be collected from the operators and riders of the ADS-equipped vehicles, as well as other road users. These data will provide insight into more subjective evaluation of the vehicles, including comfort levels of riding in the vehicles, perceived level of safe and "human-like" operation, and acceptance of the technology, among others.

Safety Data

As previously noted, the project team is not authorized to re-distribute Texas crash data; however, team members will work with TxDOT to conduct an analysis of crash conditions at the study sites. Summary information from this analysis can be included for the study sites. The analysis will focus on the number, severity, and type of crashes. At locations with similar vehicle exposures, crash rates may also be selectively assessed. Example information that will be included in the crash summary includes:

In many instances, conditions may contribute to a potential safety issue even if a crash has not been recorded. When this occurs, there are often indicators that would suggest elevated risk to facility users. For example, if a vehicle strays from the designated lane, this maneuver could have resulted in a sideswipe crash if another vehicle had been present in that lane. For the purposes of this study, example surrogate safety metrics include:

Trip-Level Data

Trip information for the deployments in various environments may contain information about travel purposes and other details from the trip such as origin-destination, trip length, and trip purpose to help inform service planning and quality analysis.

Other External Data

The way humans will interact with the vehicle can vary depending on their role. In the case of the reserve driver, any exchange directly with the vehicle must facilitate straightforward driver response. This human-machine interface should be assessed to ensure that the driver can easily take over the driving task if needed.

For riders, there is a need to know what challenges should be overcome to make the use of the vehicle a viable option. As an example, if a shuttle vehicle departs from the bus stop quickly, the rider may not have sufficient time to safely board the vehicle. While on the vehicle, any abrupt maneuvers could make the rider experience uncomfortable and diminish the likelihood that the user will continue to use the service. Data that will capture this rider experience will be acquired through the use of observational studies or user questionnaires. All personally identifiable information will be removed from this data source before it is provided for analysis as part of the larger data share effort.

Safety Assessment Analyses

In recent years, safety assessment methods in the U.S. have dramatically changed. Historically, locations where safety improvements were implemented were identified based of site crash history. This approach was particularly problematic for new facilities, new design strategies, or new technologies that did not have associated crash histories. In recent years, safety performance evaluations have shifted to data-driven predictive methods that benefit by using data from larger datasets for similar locations or facility characteristics to estimate safety performance at locations without crash history. In the event that sufficient crash data cannot be identified for this predictive approach, smaller strategic studies that focus on individual safety treatments can be developed. These individual treatments are known as crash modification factors or functions.

For this effort, the Texas team expects to use a variety of safety assessment techniques. It is likely that the deployment locations will have very few crashes. This means that a crash-based safety assessment approach will not be practical for most of the conditions. For this reason, the project team expects to develop a risk-based strategy that will assess vehicle maneuvers and near misses (often acquired using the on-board video). Because the use of on-board equipment for the deployed vehicles will only provide information from the perspective of the ADS vehicle, the project team intends to conduct observational safety studies using supplemental video positioned at strategic locations. Ideally, the use of video from local traffic management centers that focuses on the fixed route deployments will provide effective supplemental information. For locations that do not have camera coverage, the project team will conduct short term studies with additional cameras. Collectively, the team will use the large volume of data to conduct safety assessments while also establishing robust data that others can use for extended safety evaluations.

Table 1.3 Data Sets for Texas ADDS Project

Texas ADS Objectives	Performance Metrics	Data Sets
SAFETY		
▪ Improve Vehicle Safety ▪ Enhance Operational Safety ▪ Design for Cybersecurity ▪ Prepare through Education and Training ▪ Reduce Policy Uncertainty	▪ Near misses ▪ Reason for disengagement ▪ Erratic maneuvers, including rapid acceleration/deceleration ▪ Safety envelope violations ▪ Quality of lane marking and signage ▪ Level of telecommunications service	▪ Vehicle Data ▪ Safety Data ▪ RIO Data
MOBILITY		
▪ Mitigate Congestion ▪ Improve Travel Time Reliability ▪ Strengthen Resiliency	▪ Automated vehicle miles traveled, passenger and freight ▪ Person miles traveled ▪ Automated freight tonnage	▪ Vehicle Data ▪ Safety Data
ENVIRONMENT		
▪ Increase Fuel Efficiency ▪ Improve Air Quality and Public Health ▪ Encourage Alternative Transportation Modes	▪ Fuel efficiency ▪ Greenhouse gas emissions ▪ Number of shared rides	▪ Vehicle Data ▪ Safety Data
HUMAN FACTORS		
▪ Optimize the Driver-Vehicle Interface (DVI) ▪ Develop Vehicle Sociolinguistics ▪ Apply a User-Centered Design Approach	▪ Time to safety operator takeover ▪ Customer satisfaction ▪ Accessibility of service for elderly and disability populations	▪ Vehicle Data ▪ Safety Data ▪ User Data
EQUITY & ACCESS		
▪ Advance Equity and Digital Inclusion ▪ Improve Accessibility ▪ Develop a 21st Century Workforce	▪ Number of wheelchair accessible rides ▪ Number of rides originating in low-income neighborhoods ▪ Rides booked through land line for those without smartphone	▪ User Data ▪ Trip-Level Data ▪ Demographics

In addition to assessing how the ADS vehicles can generally integrate into the traffic stream, the safety assessments will also document the vehicle's ability to perform core functionalities including: object and event detection and response, fallback into minimal risk conditions without driver intervention, vehicle occupants protection in the event of a crash, and connected vehicle application synergies (i.e., vehicle-to-vehicle and vehicle-to-

infrastructure interoperable communications). The vehicle safety assessment will enable Texas and the USDOT to identify areas where Federal Motor Vehicle Safety Standards may need to be clarified or updated.

Legal, regulatory, environmental approach

Texas has the legal framework, the institutional alliances and willingness, the deployment experience, and the research, data and evaluation expertise to build and operate automated driving systems while achieving statewide goals of enhancing safety, improving mobility, ensuring equity, reducing environmental impacts, and understanding and adapting to human interactions.

Texas has a **clear legislative path** for operating AVs on public roads. Historically there has been nothing in the law restricting AVs from operating on Texas roadways. As an example, Google has been testing their vehicles in Austin since 2015.[1] When Google began driving trials, the law in Texas was silent on their operation. To formally address the technology, the Texas legislature approved Senate Bill 2205 in 2017.[2] It specifically required AVs to be capable of complying with all traffic laws, equipped with manufacturer-installed recording devices, and insured like other vehicles. The Senate Bill also requires the vehicle manufacturers or owners to be responsible for broken laws or associated crashes, when applicable. The State of Texas continues to extend this business-friendly legislation in the current 2019 legislative session. The Texas Legislature is currently considering a bill that would clarify that the permission granted in the 2017 law would take precedence over local laws.

Institutional partnerships in Texas are key to current and future successes. An ADS on-demand shuttle deployment in Frisco, Texas is an example of how Texas public sector agencies are working together to expand automated mobility opportunities. This representative partnership includes The Frisco Transportation Management Association, City of Frisco, DCTA, Frisco Station, Blue Star/The Star and HALL Group/HALL Park. This alliance is working with the private sector to provide an ADS shuttle deployment. The letters of support included with this proposal are a further indication of the dedication of Texas public and private agencies to expand team building capabilities related to this proposed effort. Those alliances extend to innovative business and contracting approaches including multi-agency contracts to procure AVs. The Houston-Galveston Area Council of Governments HGACBuy program, in partnership with the NCTCOG and Texas Innovation Alliance, awarded a statewide request for proposals for AVs. This Cooperative Purchasing Program allows public agencies throughout the state to purchase ADS shuttles.[3]

The **Texas deployments will continue to comply with applicable federal standards** including Federal Motor Vehicle Safety Standards, US Department of Transportation Guidance including

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[1] Aman Batheja, A. B. (2015, July 7). Google Puts Self-Driving Vehicle to the Test on Austin Streets. Retrieved March 8, 2019, from https://www.texastribune.org/2015/07/07/google-testing-self-driving-vehicles-austin/

[2] Texas Legislature. (2017, May). Senate Bill 2205. Retrieved March 8, 2019, from https://capitol.texas.gov/BillLookup/Text.aspx?LegSess=85R&Bill=SB2205

[3] HGACBuy. (n.d.). HGACBuy Automated Vehicle Contract Documents. Retrieved March 8, 2019, from https://www.hgacbuy.org/contracts/documents.aspx?contractid=73

the Automated Vehicles 3.0 guiding principles, and Federal Motor Carrier Safety Administration requirements. The HGACBuy Cooperative Purchasing Program AV contract requires vendors to follow applicable federal requirements.

The Texas ADDS Team **has experience with outreach, collection, and analysis of data** associated with AVs. Team members similarly have expertise assessing the operational and safety performance of various facilities based on traditional roadway infrastructure features, mobility characteristics, and crash history. Since 2015, TTI has been collecting data to monitor and track public acceptance of and behavioral responses to AVs. These data include prospective users' perceptions of safety and trust in the technology/software as well as potential personal and societal benefits. Within Texas, team members have collected data from residents of Austin, Dallas, Houston, and Waco. They have acquired similar data from residents of cities outside of Texas (i.e., San Francisco, Phoenix, Las Vegas, and Boston). The data management plan in Part 3 of this proposal provides a comprehensive view of the structure of systems that will aggregate live and external data, distribute data to consumers, persistently store data in a data lake, and provide analyzed output for stakeholders. The Texas ADS Team is committed to providing this data while understanding and protecting the privacy of all users including public and private sector agencies.

Risk Mitigation

In addition to safety, there are other potential risks that the Texas ADS Team recognizes and will address as follows:

- Deployment Risk – mitigated by using existing deployments and identifying alternate deployments, such as Corpus Christi, that can replace a troubled deployment
- Procurement Risk – mitigated by HGACBuy and Texas ADDS Team partners' collaboration through the Texas Innovation Alliance
- Political and Legislative Risk – mitigated by existing legislation in approved Senate Bill 2205 and history of AV testing in Texas since 2015
- Project Risk for Large Multi-agency Team – mitigated by collaboration through the Texas Innovation Alliance as well as engagement of certified project managers in this project
- Technical and Operational Risk – mitigated by multiple sites deploying a variety of technologies in different environments and the AV experience of those sites.

The Path Forward

The USDOT plays a significant role in safely leading the country through this period of dramatic change. To wisely do so, USDOT benefits from new partnership models that ensure public safety and create the flexibility to innovate. Texas is developing a collaborative environment where government, industry, and research can work together to safely advance ADS technologies. USDOT can share in this collaborative environment with investments already underway and activities already on the ground. Texas stands ready to partner with USDOT to deploy multiple use cases and collect the data that is needed to inform national policy, standards, and regulatory action. Through partnerships, the U.S. will be better positioned to make strategic planning and investment decisions for ADS while saving lives, making a positive impact in the lives of millions of Americans, and reaching disadvantaged communities across the nation today.