Aerotropolis Atlanta ADS Demonstration

Submitted By:
Metropolitan Atlanta Rapid Transit Authority

In Response To:

U.S. Department of Transportation
NOFO Number 693JJ319NF00001
"Automated Driving System Demonstration Grants"

March 2019

Part 1 – Project Narrative and Technical Approach

PART 1 – PROJECT NARRATIVE AND TECHNICAL APPROACH

a. Introduction

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March 21, 2019

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

Acting Director Aimee Drewry
Acting Director, Office of Acquisition and Grants Management
Federal Highway Administration
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Dear Secretary Chao and Acting Director Drewry:

The Metropolitan Atlanta Rapid Transit Authority (MARTA) is pleased to submit this application in response to U.S. Department of Transportation (DOT) Notice of Funding Opportunity (NOFO) for Automated Driving System (ADS) Demonstration Grants (NOFO Number 693JJ319NF00001). The assembled team, which includes the Aerotropolis Atlanta Community Improvement Districts, the Center for Transportation and the Environment, Georgia Power, New Flyer of America, Inc., Robotic Research, ABM Industries, and the Society of Automotive Engineers' (SAE) Office of Automation represents public, private, and non-profit regional partners that possess the skills and expertise necessary to implement a demonstration of this magnitude. In addition to the named team members, the proposed project has garnered widespread support within the state from organizations including the City of Atlanta and Hartsfield-Jackson Atlanta International Airport, the Georgia Department of Transportation, Delta Air Lines, the Atlanta Regional Commission, Fulton and Clayton Counties, the Cities of College Park, Hapeville, and East Point, the ATL Airport Chamber, and Alliance Bus Group. Furthermore, the Atlanta-Region Transit Link Authority (The ATL), which was established to provide coordinated transit planning for the metropolitan Atlanta region, has offered their support to the project. Please see Part 4 of the application for letters of commitment and support.

The opportunity to integrate ADS into the transportation network serving one of the Atlanta region's most vital activity centers is particularly appealing to MARTA for many reasons. Integrating ADS technology on a battery electric transit bus to demonstrate SAE Level 3 automation will provide valuable insight and operational data that could significantly influence transit operations of the future. We believe this technology can complement the skills of well-trained human operators to improve road safety, increase energy efficiency, and boost labor retention by reducing driver stress. ADS technology can also support yard operations and our planned network of bus rapid transit routes through more precise maneuvering in more controlled environments.

Georgia signaled its intent to lead the nation in development of ADS technology with the enactment of SB 219 in 2017, legislation that legalized ADS operations on public roads and welcomed the sort of demonstrations MARTA and its partners are proposing in this application. However, without support

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from grant programs such as this one, the resource constraints of public transit agencies in research and development would limit our pursuit of these emerging transportation technologies.

MARTA is requesting $7,807,472 of federal funds to support this effort, with a contribution of cost share in the amount of $1,945,303.

On behalf of MARTA, our team members, and supporters from throughout the state, I would like to thank you for your consideration of our application for funding under the Automated Driving System Demonstration Grants. We appreciate the US DOT's commitment to advancing the integration of ADS into the nation's transportation system. We strongly believe this project will provide a wealth of data to inform policymakers, educate the public, and advance priorities for transit bus automation established by the Federal Transit Administration (FTA) in its Strategic Transit Automation Research (STAR) Plan.

If you have any questions regarding MARTA's application, please contact Melissa Mullinax, Chief of Staff, at (404) 848-5169.

Sincerely,

Jeffrey A. Parker
General Manager/CEO

Summary Table

Summary Table	
Project Name/Title	Aerotropolis Atlanta ADS Demonstration
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	Metropolitan Atlanta Rapid Transit Authority
Point of Contact (Name/Title; Email; Phone Number)	Michael Bradley, Grant Program Analyst mbradley1@itsmarta.com 404-848-5232
Proposed Location (State(s) and Municipalities) for the Demonstration	Atlanta, GA; College Park, GA; East Point, GA; Hapeville, GA
Proposed Technologies for the Demonstration (briefly list)	Level 3 Automated Driving Systems, Electric Transit Bus Platforms, Vehicle-to-Infrastructure Communications
Proposed duration of the Demonstration (period of performance)	July 1, 2019-December 31, 2022
Federal Funding Amount Requested	$7,807,472
Non-Federal Cost Share Amount Proposed	$1,945,303
Total Project Cost (Federal Share + Non-Federal Cost Share)	$9,752,775

Table of Contents

Listing of Tables/Figures

Project Narrative and Technical Approach

1. Executive Summary

a. Vision, goals, and objectives

The Metropolitan Atlanta Rapid Transit Authority (MARTA) and its project partners are proposing a first-of-its-kind demonstration program that will test and deploy two automated zero-emission battery electric transit buses on public roads serving Aerotropolis Atlanta (Aerotropolis), a district comprising Hartsfield-Jackson Atlanta International Airport (the Airport) and multiple communities around it. The demonstration will test the operation and safety of these automated buses between MARTA's College Park rail station and the Airport's International Terminal, providing pilot service to employees, travelers, and residents alike.

MARTA and its partners see this proposed demonstration not only as a fulfillment of the United States Department of Transportation's (USDOT) Automated Driving Systems (ADS) Demonstration Grants, but as a bold step forward for transit automation globally. The grant program justifiably emphasizes demonstration of ADS technology safety and data collection to further those ends, and the project team is fully committed to supporting those aims. However, MARTA and its partners, which include public, private, and non-profit entities, *additionally* seek to demonstrate ADS technology that can offer significant value for transit operations in Georgia and across the United States.

This is why the project team, informed by local planning studies, selected a demonstration route serving a clearly-identified transit service gap. This demonstration brings together key local stakeholders, leading transportation technology developers, and experienced integrators to ensure the vehicles deployed simultaneously provide the safety research value for federal policymakers and serve regional mobility needs.

Moreover, the project exemplifies the Atlanta region's role as global leader in transportation and intermodal logistics, with the planned route serving the world's busiest and most efficient airport and the corporate headquarters of the world's second-largest airline, Delta Air Lines. From outside the Atlanta region, it brings in New Flyer, North America's largest supplier of transit buses, Robotic Research, the largest supplier of ground autonomy systems for the US military, and the SAE International Office of Automation to provide the significant technical expertise necessary to successfully demonstrate automated 40-foot battery electric transit buses on public roads.

This demonstration project leverages an existing ADS development partnership between New Flyer and Robotic Research, which will produce New Flyer's first automated electric bus prototype in 2019. Robotic Research's track record in proving its ADS development and deployment capabilities, and its experience working with New Flyer on bus automation, set this project apart from any proposed initiative to date.

This project's ultimately aims to fulfill the following main objectives:

1. Successfully demonstrate advanced Level 3 ADS technology (SAE 2018) on heavy-duty transit buses on public roads and evaluate benefits and challenges of those operations
2. Collect relevant safety data regarding ADS vehicle performance, and report that data to inform future policymaking around the technology
3. Advance the development of ADS-integrated transit vehicles to accelerate commercialization of the technology

The MARTA-led team is capable of achieving these objectives and exceeding USDOT's expectations for demonstrating ADS technology within its defined project period.

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

As the prime recipient and administrator of the grant, MARTA will serve as the reporting agent to USDOT and oversee all funds disbursed to other project partners. MARTA will also offer its transit operations expertise to assist planning and management of the service proposed in this demonstration, and support marketing, stakeholder engagement, and other project activities.

The Atlanta-based Center for Transportation and the Environment (CTE) will serve as project manager and technical consultant, bringing 26 years of experience successfully executing federally-funded transportation technology demonstration projects and deploying zero-emission vehicles. CTE will also provide third-party oversight of data collection and provision to USDOT, and work with MARTA to develop both its quarterly and final project reports to USDOT.

The Aerotropolis Atlanta Community Improvement Districts (AACIDs) will lead all stakeholder engagement for the project, coordinate local governmental entities that have committed to support the demonstration, and assist with route and service planning prior to its demonstration phase. It will also facilitate professional surveys of demonstration participants.

New Flyer will supply two 40-foot battery electric Xcelsior Charge buses—which it has been delivering in scaled production to major transit agencies across the United States since 2017—and integrate the ADS hardware supplied by Robotic Research into those vehicles. It will also provide service for advanced powertrain and ADS systems on the vehicles while in operation during the closed course testing and demonstration phases, and assist with maintenance and safety driver training. For this project, New Flyer and Robotic Research will advance an existing partnership and integration development to deploy ADS buses in pilot transit service.

Robotic Research will supply all hardware and software required to enable ADS capabilities on the demonstration vehicles, configure and maintain the ADS technology throughout the project period, and collect and securely store all data generated. The data it configures and collects with input from CTE will be made available to USDOT through secure server access. Robotic Research will also work with New Flyer to deliver safety driver training for vehicle operators during the demonstration.

The SAE International Office of Automation (SAE) will support Robotic Research as a technical consultant and leverage data provided to inform its standards development for *J3018: Safety-Relevant Guidance for On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving System (ADS)-Operated Vehicles*. This Office of Automation also intends to use demonstration data to inform other SAE councils as appropriate.

Georgia Power will install, maintain, and service any charging infrastructure at the vehicle storage facility during the demonstration. It will also coordinate power supply with the local utility, managed by the City of College Park.

ABM, which currently operates multiple fleets serving the Airport and surrounding area, will fulfill operations and maintenance requirements during the Aerotropolis demonstration. It will hire safety drivers, provide vehicle storage, and perform routine maintenance, all the while supporting local workforce development initiatives.

Other local, regional, and state partners have offered their support to the project. The Airport is supporting the project and will help coordinate service for its passengers and employees at its International Terminal frontage. Delta Air Lines has also offered support and will work with the Aerotropolis on route and service planning to increase the demonstration's transportation utility to employees and guests of its global headquarters. The Georgia Department of Transportation (GDOT) has committed to installing roadside units and software capable of broadcasting traffic signal states to the ADS vehicles during the project's demonstration. The Atlanta-Region Transit Link Authority (The ATL), which was established to coordinate transit planning and funding for the metropolitan Atlanta region, is supporting the project, as is the Atlanta region's metropolitan planning organization, the Atlanta Regional Commission (ARC). The cities of Atlanta, College Park, East Point, and Hapeville, which own the roads serving the demonstration route, have pledged their support to the project. Finally, Fulton County, Clayton County, the ATL Airport Chamber, and Alliance Bus Group, a Board member of the Aerotropolis CIDs and local bus distributor, have all provided their support for the proposed project.

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

Public transit systems differ from other transportation modes in that riders often depend on their operation in any and all road conditions. Moreover, barring congestion or mechanical failure, riders expect them to operate with consistent and reliable headways. Public agencies must exercise a more conservative approach to technology adoption due to budget constraints, procurement requirements, and operational limitations. Therefore, the pathway to ADS commercialization on transit buses will ultimately demand a higher degree of confidence in the technology's safety and general capabilities than in the private sector. Maneuvering a 40-foot bus along a diverse range of roadway and traffic characteristic is more challenging than operations of most other vehicle platforms.

The demonstration site selected will feature narrow residential roads, major arterials, and an airport terminal with a dynamic curbside environment. Each scenario presents different challenges for maneuverability and interacting with vulnerable road users and other motor vehicles, but Robotic Research has the experience necessary to configure its ADS technology to address those challenges. It has successfully deployed its Level 4 ADS technology on vehicles ranging from low-speed shuttles operating in dense urban environments (Local Motors' "Olli"), to heavy-duty US military vehicles operating in combat zones in Afghanistan. Additionally, the existing partnership between Robotic Research and New Flyer will produce a first prototype ADS-equipped bus in 2019, and their experience testing the technology will enable accelerated configuration for this ADS demonstration site.

Robotic Research's ADS technology enhances road safety by automating dynamic driving tasks that may otherwise suffer from the limitations of human attention and responsiveness. It also aims to ease the often-tedious work of bus drivers by assisting in daily operations of their vehicles. The integration of ADS into transit bus may enable a variety of capabilities, including:

- Longitudinal control (automated acceleration and braking)
- Latitudinal control (lane-keeping)
- Automatic emergency braking and lateral collision avoidance
- Automated curbside docking
- Synchronized driving with traffic signal phase and timing (SPaT)

Though safety drivers trained for operations of both buses over the duration of this demonstration will need to remain attentive in case the ADS software disengages and requires human intervention, their manual drive requirements will be substantially reduced. The team will monitor driver attentiveness throughout the demonstration, collecting data on the delay between the system prompting a driver to disengage the system and driver response.

The team expects to see increased precision in lane-keeping and curbside docking, reduced delay between obstacle detection and braking, fewer traffic violations, and improved energy efficiency in the driving task itself.

CTE and New Flyer have extensive experience collaborating on electric bus deployments and evaluations, and are well-equipped to measure and assess the energy requirements introduced by ADS integration into demonstration bus service. Though the ADS technology stack will impose additional power requirements on the bus batteries, more efficient driving could mitigate much of the negative energy impact. Energy consumption will be a secondary focus area for the project team.

d. Geographic area or jurisdiction of demonstration

The demonstration phase will involve deploying the two ADS-equipped buses in pilot service for 12 months within the Aerotropolis (See Figure 1). The Aerotropolis covers multiple jurisdictions surrounding the World's Busiest Airport, Hartsfield-Jackson Atlanta International Airport. The

Aerotropolis is becoming a major focus area for development, redevelopment, transportation infrastructure, workforce development, and education initiatives. The buses will operate between MARTA's College Park Station and the Airport's International Terminal, serving two routes on an identical alignment. The first route, representing the first six months of the Aerotropolis demonstration, will offer direct service between MARTA's station and the terminal in both directions. After six months, the service will add at least one additional stop, the Delta Air Lines global headquarters, and possibly others in between the station and terminal.

*Redevelopment Zones identified in Aerotropolis Atlanta CIDs Master Plan (indicated in blue)

Figure 1: Demonstration Site and Proposed Route Alignment
(Credit: Aerotropolis CIDs; Google)

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

This project period is proposed at 42 months from the time of award, distributed among five primary tasks (See Figure 2 below).

This project plan includes:

- An initial period of six months for grant agreement and subcontracts execution
- A build and test period of the two electric buses, integrating the ADS system, and evaluating performance
- A design/build phase for electric bus charging infrastructure to support the Aerotropolis demonstration
- An ADS testing period at Robotic Research's Maryland test facility
- A demonstration period in the Aerotropolis Atlanta community, including local stakeholder engagement prior to, during, and following the demonstration; and

- A close-out period for final reporting and possible asset disposition

Note: The proposed schedule anticipates USDOT grant agreement execution by June 30. If not feasible, a Letter of No Prejudice is anticipated to be requested in order to maintain the proposed schedule.

		2019				2020				2021				2022			
Task	Task Name/Subtask Name	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	**Vehicle Build, Integration, Testing**																
1.1	Design			■	■	■											
1.2	Major Component Procurement						■										
1.3	Build						■	■	■								
1.4	Integration								■								
1.5	Testing								■								
2	**Electric Bus Charging Infrastructure**																
2.1	Design							■	■								
2.2	Build									■	■						
3	**ADS Engineering at Robotic Research/New Flyer Test Grounds**																
3.1	Use Case Planning							■	■								
3.2	Operation									■	■						
3.3	Maintenance and Support									■	■						
3.4	Data Collection									■	■						
4	**Vehicle Demonstration at Aerotropolis**																
4.1	Aerotropolis Demonstration Route and Service Planning							■	■	■	■						
4.2	Permitting							■	■								
4.3	Operation											■	■	■	■		
4.4	Maintenance and Support											■	■	■	■		
4.5	Data Collection											■	■	■	■		
4.6	Community Meetings							■	■	■	■	■	■	■	■		
4.7	Rider Surveys											■	■	■	■		
4.8	Decomission Vehicles															■	
5	**Project Management**																
5.1	Contracting			■	■												
5.2	Finalize Data Management Plan			■	■												
5.3	Reporting					■	■	■	■	■	■	■	■	■	■		
5.4	Final Reporting															■	■

Figure 2: Aerotropolis Demonstration Workplan

2. Goals

a. Safety

As the fatal 2018 accident involving an automated vehicle in Arizona proved, ADS safety flaws can prove devastating not just for the humans directly impacted, but also for public perception of the entire industry developing this technology. Therefore, the team considers safety its highest priority, and is committed to exercising all caution necessary to ensure the safety of demonstration participants and other road users.

The autonomy platform proposed for this grant is an evolution of the many programs Robotic Research has deployed for the Department of Defense (DoD), and commercially with Local Motors' Olli vehicle. Although past performance does not guarantee future results, it will provide insights into how the bus are expected to operate. The demonstration preparation will progress as follows:

Initially, trained safety drivers will manually operate the buses. Since the ADS will not be engaged, there will be essentially no difference between driving a traditional bus and the ADS-equipped bus. The ADS will collect data in the background, but will not control the vehicle. Robotic Research will compare and analyze operations data from the human-driven system and the “shadow” ADS system’s actions to prove that the system would have operated safely. After all project partners are comfortable with the ADS performance, true demonstration will begin. Operators will remain in the driver’s seat; however, the ADS is engaged and controlling all driving tasks along the demonstration route. Operators are prepared to take control of the vehicle should the ADS prompt them to do, referred to as a disengagement. The ADS will include control of the throttle, braking system, and steering to follow the designated route.

For demonstration cybersecurity, Robotic Research takes several steps to protect the safety-critical vehicle control system from malicious agents. Network security is achieved by using Virtual Private Networks (VPN) and firewalls to ensure that only authorized personnel can access the shuttle’s control system network. The control software itself is a read-only file system that cannot be modified during service operation. Where applicable, Robotic Research leverages devices with integrated military-grade encryption to mitigate further cyber threats. On-board network security is enforced by using different networks to silo the sensor network from command and control network via virtual local area network and a managed switch.

The Aerotropolis demonstration will utilize Altoona-tested, production build buses as the base vehicles for ADS integration, ensuring roadworthiness and compliance with all federal motor vehicle safety standards (FMVSS).

Finally, Robotic Research has designed robust protocols for training safety drivers through its prior ADS development programs, and will work with both New Flyer and ABM to ensure all are well-equipped to execute their responsibilities throughout the demonstration period. SAE will oversee and advise this process, and will use any lessons learned to inform further J3018 (SAE 2018) guidelines development.

b. Data for safety analysis and rulemaking

Robotic Research’s nSight™ platform provides a comprehensive suite for studying ADS safety, through data collection and automated performance analysis of the systems demonstrated. The nSight suite is composed of the Onboard Data Recorder, Data Storage Server, and the After-Action Review (AAR) tool. The AAR tool will be available to the project team and relevant USDOT personnel for anytime access to all data collected during the demonstration. Users will be able to generate reports on-demand, with demonstration data uploaded to Robotic Research’s secure cloud daily. nSight provides ADS performance feedback to developers, end-users, researchers, and regulators on the performance and safety compliance of the ADS. This includes all hardware and software elements that comprise the on-board automation system. nSight was created in partnership with US Army TARDEC Ground Vehicle Robotics to measure ADS performance in their automated vehicle pilot programs. Examples of how nSight is used:

1. *Drive Performance Accuracy* - Comparing commanded vs. actual values for drive elements such as speed and path accuracy. E.g. Measure the accuracy and consistency of the ADS at

stop signs and crosswalks. If the data shows deviation or inconsistent performance, nSight provides analytics and supporting data to understand the root cause whether the cause is internal to the vehicle systems or external/environmental.

2. *Sensor Performance* - nSight has a unique ability to measure sensor performance and predict degradation. LIDAR and other sensor manufacturers define a range of acceptable performance for their products. As these sensors are used, degradation from wear and tear require developers to regularly verify performance. nSight can flag sensor issues daily, automatically monitor performance, and plot degradation trajectories. This analysis enables developers and even regulators to build predictive models and provide increases measure of operational safety.

3. *Near Miss* – An increasingly common term in ADS evaluations, "near misses" represent situations where the vehicle did not remain within programmed limits, and came too close to an obstacle. Near misses can alarm passengers, and illustrate potentially dangerous deviations from the programmed behavior of the AV. nSight can flag, filter and report on all near misses, and then use its analytics engine to find root causes and potential patterns that caused the deviation. The issues may be internal to the AV or external (e.g. environmental).

MARTA shall negotiate and sign a mutually agreeable data sharing agreement with USDOT ensuring at a minimum the NOFO-required data accessibility for at least the minimum defined period.

AAACIDs will lead qualitative data collection and analysis, primarily perception and preference survey responses from employees, airport passengers, and residents of the area. Surveys will target riders of the service, both before and after their trips, and will emphasize perception of ADS safety, and evaluate the AACIDs' marketing strategies; however, general feedback will also be conducted throughout the Aerotropolis to raise awareness of the demonstration. This data collected will help determine future outreach and education by informing the project team, USDOT and others how to inform the public of the safety benefits of ADS. The surveys will also solicit feedback on the marketing strategies for advertising the service. This feedback will inform on necessary adjustments to market ADS to target populations.

c. Collaboration

The MARTA-led project brings together a diverse group of public, private, and non-profit partners for the purposes of executing a successful ADS technology demonstration, collecting and disseminating useful data to inform policymakers, and engaging local stakeholders to promote awareness of ADS technology. The project was set up with a significant collaboration network in mind, leveraging existing relationships between key project partners

MARTA, CTE, and New Flyer have collaborated on previous demonstration programs for bus transit, including a Reduced Engine Idle Load project funded through the FTA's Bus Efficiency Enhancements Research and Demonstration (BEERD) program. CTE and New Flyer are currently working together on five additional projects supported by USDOT grants, ranging from technology demonstration programs to zero-emission bus deployments.

New Flyer and Robotic Research recently partnered to develop New Flyer's first prototype of an ADS-integrated battery electric bus in 2019. This demonstration leverages the existing partnership, and will benefit from lessons learned during that initial prototype development. Dr. Edward Straub from SAE's Office of Automation will use lessons learned from this demonstration to inform J3018 standards development and other SAE councils.

AACIDs will assume the role of marketing and outreach lead, and focus efforts in three key areas: education, outreach, and feedback. MARTA has also allocated significant planning and communications resources to the project to work with AACIDs on these marketing and outreach functions. While these tasks will, at many times, occur concurrently; each will have a primary role before, during, and after the demonstration. Prior to launching the demonstration, AACIDs will focus on ADS education for stakeholders and the wider public. Additionally, they will begin marketing the pilot service and communicating vehicle testing progress. Key strategies for education include creating a project website, coordinating with local jurisdictions to create pop-up events, establishing and maintaining MARTA Station and Airport project information kiosks, and providing regular updates at local city council and county commission meetings

Strategies for Marketing including:

- Advertising the new services on through various media
- Demonstrating the service through virtual reality or virtual augmentation;
- Designing and installing a branded wrap for each of the vehicles
- Deploying signage at the College Park MARTA Station and Airport
- Coordinating press coverage with MARTA and other relevant jurisdictions

During the demonstration period, AACIDs will focus on continuing outreach to stakeholders and the public, with AACIDs leading efforts on collecting qualitative data from participants. They will target riders before and after their experience to understand if and how perceptions of ADS changed. AACIDs will also solicit feedback regarding how they learned about the service, why they wanted to try it, and if they felt it was marketed accurately and appropriately. AACIDs will continue communication efforts through the same means outlined for the pre-demonstration period. Following the demonstration, they will obtain feedback from stakeholders, elected officials, and the public. Specifically, they will solicit best practices and lessons learned, and compile this information to create a best practices manual for USDOT and project partners.

CTE will hold weekly or biweekly team calls to ensure all project partners are engaged and in alignment on completing project tasks. CTE will also complete all necessary reporting and hold review meetings to ensure that project sponsors and stakeholders are informed.

3. Focus Areas

a. Significant Public Benefit(s)

Most automated vehicle deployments to date have generated little performance data for public consumption, as developers have considered those data competitive and highly proprietary. California requires ADS developers testing on public roads to report system disengagements, but informal reporting standards have resulted in little data of value. The data collected and reported to USDOT during the Aerotropolis demonstration is intended to inform future National Highway Traffic Safety Administration (NHTSA) policymaking, including through Federal Motor Vehicle Safety Standards (FMVSS). The SAE International Office of Automation will lead the project team's efforts to disseminate findings through those channels.

Though the USDOT ADS Demonstration Grants program is funded and administered by the Federal Highway Administration (FHWA), this project will also serve the broader multimodal USDOT agenda for advancing research and development of ADS technology. The Federal Transit Administration (FTA) released its Strategic Automation Research (STAR) Plan in January 2018, identifying multiple research and demonstration priorities for transit bus automation. The use of heavy-duty transit buses as the demonstration's vehicle platform provides an opportunity to address many of the FTA's research priorities and stimulate ADS technology implementation among other transit agencies. Moreover, the project will demonstrate ADS operations in airport landside transportation service, offering research value to the Federal Aviation Administration (FAA) as well. This project is unique in that it offers value to four discrete agencies (FHWA, NHTSA, FTA, FAA) within USDOT.

Finally, this project will also support the continued deployment of battery electric transit buses and the environmental benefits realized by their replacing conventional fuel buses. As transit agencies across the country transition to zero-emission buses, the testing and integration of ADS technology may accelerate the commercialization of specific capabilities enabled by the onboard equipment including the driver assistance features. ADS features, including electrified accessories, drive by wire capability, and automated charging would also support complementary transitions for both transit bus automation and electrification.

b. Addressing Market Failure and Other Compelling Public Needs

Over the past several years, billions of dollars in private commercial investment have flowed into developing automation for light-duty vehicles and heavy-duty trucks. However, transit use cases, particularly on the heavy-duty side, have not seen anywhere near that level of investment. Though some private capital has financed development of low-speed shuttles or transit vans for last-mile transit use cases, heavy-duty buses have yet to receive investment at levels necessary to advance commercialization of the technology.

Development of a commercially-ready ADS Level 3 or greater transit bus is a significant task. Transit bus OEMs are characteristically smaller companies with limited engineering capacity and annual sales totaling less than $2.5 billion. In addition, commercial benefits are not well defined, due to the more limited, primarily public sector customer base. The final production cost of ADS features, the price customers would be willing to pay, and market acceptance and uptake are uncertain. New Flyer encountered a similar situation with the development of electric transit buses. It developed its first proof-of-concept bus in 2011, and began an initial five-year demonstration project in 2012 with four buses in service at a cost of approximately $8 million. The proof-of-concept and demonstration project costs were partially offset by government funding. Between 2015 and 2017, encouraged by the success of its demonstration and the growth of the electric bus market, New Flyer invested approximately $25 million of its own funds into production capacity. With that investment, it was able to begin scaled production of electric buses in December 2017.

Integration of high-level automation into transit buses for financially self-sustaining commercial production is likely to have a similar, if not more difficult and riskier, development pathway. Government assistance at this early stage can accelerate technology development in the transit bus industry. Given potential benefits of transit bus automation, including—but not limited to—improved road safety, cost savings from operational efficiencies, increased energy efficiency, and reduced driver stress, the lack of investment represents a significant market failure. Advancements in ADS capabilities for transit buses could translate to other medium- and heavy-duty vehicles for people and package movement, including coaches and school buses, and accelerate the technology's spread to those platforms.

c. Economic Vitality

This project will ensure federal funds are used to support the US industrial base and the southeast region in particular. New Flyer's Buy America-compliant electric transit buses will be built in Anniston, Alabama. In 2018, New Flyer invested $25 million to expand manufacturing capability at the Anniston facility to enable it to completely build buses on that campus, including full welding of the structural frame of the bus. The lithium battery cells and modules will be built in Michigan by Xalt Energy. The Siemens electric drive inverters and control system are built in New Kensington, Pennsylvania with engineering development in Alpharetta, Georgia. Though not the focus of this grant, this project also supports the transit bus industry's continued transition to zero-emission vehicles. The ADS system development and testing by Maryland-based Robotic Research will be completed at its facilities in that state. Due to the components' origins and final assembly sites, the team will satisfy Buy American requirements.

CTE is headquartered in Atlanta and will accomplish all management work out of its Midtown office. The team will procure depot charging infrastructure for the Aerotropolis demonstration from Siemens, which has a facility in the Atlanta metro area. Georgia Power, a wholly-owned subsidiary of Atlanta-based Southern Company, will provide infrastructure installation and maintenance services. ABM will support local workforce development initiatives by hiring local labor to fulfill safety driver and vehicle maintenance roles during the demonstration.

d. Complexity of Technology

This demonstration proposes to deploy and collect data on level 3 ADS per SAE J3016 recommended classification practices. The hardware and software integrated into New Flyer's Xcelsior Charge battery-electric 40-foot buses will enable ADS operations along the entire demonstration route, with few operational design domain (ODD) restrictions. GDOT's commitment to install SPaT roadside units (RSU) at all signalized intersections along the demonstrate route will provide a necessary redundancy to ensure vehicle acceleration and braking coordinates with those signals.

To responsibly advance development and eventual commercialization of ADS in transit buses, the team has taken a conservative approach to classifying and communicating the technology's capabilities and complexity. The ADS technology demonstrated may reach a maturity level to justify SAE's level 4 classification during the project period, as Robotic Research has already developed and deployed level 4 systems on multiple other vehicle platforms. However, certain "edge case" limitations, including possible extreme weather conditions, emergency response, and necessary wheelchair recognition for automated ramp deployment, may restrict the demonstration to an advanced level 3 system. The project team is sensitive to these considerations, and the need for an on-board safety driver who can assume manual control of the bus should any ADS-related challenge threaten reliability.

e. Diversity of Projects

We believe this project is unique among any carried out to date, committing to deploy the first automated transit bus on public roads anywhere in the United States, and possibly the world. Though many cities have deployed low speed automated vehicles (LSAV) in their urban cores and entertainment districts, no municipal or state agency has invested in automating high capacity bus transit. MARTA and its project partners are committed to putting the country's first L3 automated buses on public roads, and will do so in an especially compelling environment at speeds up to 40 miles per hour.

Beyond the vehicle platform itself, this Aerotropolis demonstration will be the first airport landside AV service to transport passengers on public roads—at the world's *busiest and most efficient* airport. It will provide scheduled service on an alignment between a heavy rail station, a Fortune 500 corporate headquarters, and the airport terminal. This last-mile service will fill a significant transit gap for tens of thousands of employees and other area residents. The multi-jurisdictional demonstration will also cross four cities, two counties, and two community improvement districts. If proven successful, the route and similar service could serve other local establishments, including Porsche's North American headquarters, Hapeville downtown business districts, area hotels and restaurants, among others.

f. Transportation-challenged Populations

The Aerotropolis area is known for having a disproportionate percentage of disadvantaged populations compared to the Atlanta Metropolitan Statistical Area (MSA). The Atlanta Regional Commission has analyzed populations across the region and has identified the Aerotropolis as an Equitable Target Area, which identify a high concentration of minority or low-income populations. This guides regional transportation and land use planning needs and related investments, which have lacked in the area historically. Table 1 compares key demographics between the Aerotropolis and the Atlanta MSA.

Demographic	Aerotropolis Area	Atlanta MSA
Percentage Minority	88.5%	47.1%
Median Income	$38,305	$57,792
Secondary Degree	30.1%	43.4%
Renter Occupied Housing	46.0%	34.0%

Table 1: Aerotropolis Demographics
(Source: US Census, American Community Survey, 2016)

The Aerotropolis hosts more than 207,000 jobs, which is 8.9% of the Atlanta region's total employment. However, only 39,000 (18.8%) of those employees live in the area, and the others commute in from elsewhere within the region. The majority are coming from south of the Airport. The Aerotropolis Transit Feasibility Study (2018) was conducted by the AACIDs and included feedback from local cities, counties, private sector stakeholders and the public. The study reviewed all trips within the Aerotropolis, finding that 40% of all trips were outside of single occupancy vehicles, with 7% using existing transit (US Census, American Community Survey, 2017). Further analysis determined that the transit ridership increases to 38% for household with zero cars. Current transit options in the Aerotropolis include a rail line with its southern terminus at the Airport and several local bus routes through the rest of the district.

g. Prototypes

The vehicle is a heavy-duty New Flyer Xcelsior Charge 40-foot (XE40) transit bus. Following initial pilots in 2014 to 2016, New Flyer began delivering production models built on its standard production line with deliveries in late 2017 to New York City's Metropolitan Transit Authority (MTA). Subsequent orders for other transit customers entered production shortly thereafter. Altoona testing for the XE40 was completed in 2015. The Xcelsior Charge is not a prototype, but is the only electric bus in full production in a manufacturing facility certified to ISO 9001 (quality), ISO 14001 (environmental) and OSAHA 18001 (safety).

Furthermore, New Flyer and Robotic Research will complete their first prototype ADS transit bus in 2019, and will use that vehicle to inform the manufacture and testing of both demonstration vehicles procured under this project. Having a mature, extensively-tested base vehicle will significantly reduce risks to public safety during the demonstration phase, and to project execution. The ADS hardware components will be track-tested and evaluated prior to the public demonstration, and trained safety drivers will have the ability to disengage their vehicle's ADS during the demonstration either through braking (akin to cruise control disengagement) or pushing a disengage button.

4. Requirements

a. Research and Development of automation and ADS Technology

As discussed in Sections 1(a) and 3(d), this project would support the development of ADS capabilities aimed at reaching level 4 under SAE's taxonomy, but more appropriately would classify under the level 3 definition. The demonstration buses will be able to operate on their designated route without human intervention under the vast majority of circumstances.

However, certain conditions may require the vehicles' trained safety drivers to disengage the ADS—or take control when prompted by the system—these will be rare per Robotic Research's prior experience deploying level 3-4 systems on other vehicle platforms, and in other ODDs. This project represents a continuation of an existing partnership between New Flyer and Robotic Research, aimed at eventual commercialization of ADS technology on transit buses.

b. Physical Demonstration

Of the 42 months scheduled in this proposal, 12 of those will involve a physical demonstration on public roads. Prior to deploying the ADS-equipped battery-electric transit buses on public roads, New Flyer and Robotic Research will spend six months testing the two demonstration vehicles on closed courses. These tests will be designed to evaluate capabilities required for ADS operations on the Aerotropolis demonstration route.

c. Gathering and Sharing of Data

Robotic Research will collect and store data per USDOT's NOFO request, in a capacity that satisfies all requirements for the ADS grant. All data will be labeled with date and time stamps, and individual sensor data will be labeled with the location of that specific sensor on the vehicle. Each vehicle will be equipped with a nSight Recorder™, which ties into the communication bus of the vehicle to retrieve raw data streams (e.g., sensor data) and processed data streams (e.g., command/status messages). The raw data is mostly captured in the industry standard pcap format. This is used for data communicated across Ethernet, but it also used for serial data, like CAN, USB, RS-232. The processed data is outputted in ROS bag format, which was selected because it is a common format familiar to commercial and academic institutions. Robotic Research used these formats specifically to provide an open interface for data sharing. Data will come primarily in three forms: pcap, daq, and bag files. The following table provides a list of all data types collected by sensors onboard each bus:

Data Type Descriptions	
Sensor Files	Radar (front and side), LIDAR (front and rear), camera
Objects Detections	Speed and Location of objects (vehicles, humans, etc)
Platform control and feedback	Steering, brake, throttle, other vehicle control and feedback signals
Localization	Logs of GPS and IMU location data
Planning	Planned Trajectory of bus
Tagged Event (i.e. ADS brake tap-out)	Event or time tagged essential data of platform

Table 2: nSight Data Type Descriptions

After raw data is collected and processed, nSight will automatically generate reports based on specifications defined by the project team in coordination with USDOT. As all data will also be geotagged, the team may also isolate event locations to focus in on specific domain conditions prompting repeated events. Reports automatically generated from raw data processed by the nSight system will include, at minimum:

- "Near misses" with pedestrians and other vulnerable road users, with object details
- "Near misses" with other motorized vehicles, with object details
- Other failures to detect and appropriately respond to road users
- Failure to properly respond to road signage or signals, with object details
- Safety driver takeover time during vehicle disengagements
- Lane-keeping precision and deviations
- Docking precision for curbside pickup/alighting

An inward-facing camera will also capture the actions of safety drivers, and will be directed at their hands and feet to omit facial details from the raw camera data. This, plus the captured timestamps of disengagements, will allow the team to assess safety driver responsiveness to ADS cues. SAE can use this data to further inform its J3018 guidelines.

Robotic Research will own responsibility for raw data storage and availability to USDOT during and after the project, making its After Action Review (AAR) Tool available to the agency's assigned personnel. This will allow any user to access data on demand and generate the aforementioned reports. The team can provide USDOT biweekly or monthly reports, or more frequently if requested. All data will be stored on Robotic Research's secure cloud server. Because the data collected may reach quantities that are uneconomical for long-term storage, Robotic Research proposes to store identified event data, defined by parameters agreed to by USDOT, for a period of at least five years following the project's period of performance. If USDOT finds that approach unsatisfactory, the team will discuss alternatives with USDOT that satisfy its requirements. There are no proprietary concerns from Robotic Research.

d. User Interfaces

The proposed demonstration involves Americans with Disabilities Act (ADA)-compliant transit buses operating on fixed routes with scheduled service. When the demonstration buses dock at designated stops, they will automatically open their doors and kneel for passenger pickup. Both buses will be equipped with ramps for handicapped passengers, however, the safety driver will deploy them without ADS input. Wheelchair recognition and automated ramp deployment were considered as development components but were not included in this project scope and will be accomplished as future development. The buses have voice annunciation technology integrated, and will announce stops as they arrive. Passengers can also signal that they want to alight in a traditional manner, as "stop request" buttons are located throughout the vehicles, including at wheel chair securement locations. Beyond automated ramp deployment, the team considered several automation capabilities for this demonstration, but schedule and budget considerations necessitated retaining those functions as human tasks reserved for future development.

Finally, each bus will have an onboard display monitor that shows the safety driver and passengers exactly how the ADS sensors are processing road and environment data. This will further educate riders on the efficacy and safety of ADS technology operating the demonstration vehicles.

e. Scalability

The technology developed and demonstrated in this project, and lessons learned from it, can be applied to other transit buses and other routes across the country. In 2017, U.S. transit agencies collectively operated more than 65,000 buses (APTA 2017). Moreover, state and municipal agencies operated more than 470,000 school buses in the 2016-2017 school year (School Bus Fleet 2017). Integrating the ADS technology demonstrated in the Aerotropolis district into these other transit and school buses will accelerate the realization of automation benefits discussed in section 1(c). Intercity and tourist motor coaches, heavy-duty trucks, and other medium- and heavy-duty vehicles that serve the nation's on-road transportation network could also leverage the ADS technology developed in this demonstration.

SAE International's Office of Automation (SAE) has committed to the project to inform data collection and assist with dissemination of demonstration findings. SAE will report safety-relevant operational findings to the On-Road Automated Driving (ORAD) committee task force revising the standard: *SAE J3018 Safety-Relevant Guidance for On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving System (ADS)-Operated Vehicles*. SAE will also conduct a gap analysis identifying areas where standards are needed, and introduce suggested courses of action to the organization's Motor Vehicle Council (MVC) and Truck/Bus Council, as appropriate. Finally, SAE will identify research issues that may inform a review of FMVSS with a recommended project outline with estimated tasks, resources, and timeline (as a separate, follow-on project).

5. Approach

a. Technical Approach

<u>Vehicle Design, Build, Testing</u>

New Flyer and Robotic Research will collaborate to design the two demonstration ADS buses. During the design phase, the joint team will create safe drive-by-wire (DBW) hardware to allow a computer to control steering, braking, and throttle autonomously. The team will determine the best way to actuate the bus and optimally position sensors.

New Flyer has scheduled production for two heavy-duty New Flyer Xcelsior Charge transit buses in the second quarter of 2020, to be confirmed upon grant award and contracting. After New Flyer fully manufactures both buses, with provisions for the Autonomy Kit (A-Kit) and DBW (B-Kit), at its Anniston facility, the buses will then ship to Robotic Research's Maryland facilities for the installation of remaining A-Kit and B-Kit components, including computing hardware and communications equipment (see Figure 3 below). Then Robotic Research will install its proprietary ADS software and conduct component testing on both vehicles. Once the team is satisfied that all components are working correctly, full system testing will proceed at the Robotic Research proving grounds. Validation testing will follow verification testing.

The buses will have two modes: Human Mode and ADS Engaged Mode, which safety drivers can select using a toggle switch. A pull-to-unlock toggle lever prevents accidental switching of modes, and LED lamps will indicate when the system is under "Human" or "ADS" control. An LED also indicates when the E-Stop is engaged, and when the A/B-kit is powered. In both modes of operation, a safety driver will always be present. To aid safety drivers during operations, they will have access to a tablet-based operator control unit (OCU), which provides diagnostic information about vehicle status and feedback about current and planned vehicle behaviors.

Before any vehicle system leaves the Robotic Research Proving Grounds, it will undergo strict capability and safety verification testing. This is the first phase of the technology evaluation prior to on-site testing. Robotic Research has a proven track record of delivering capable autonomy systems to the Department of Defense, and it will maintain those same high standards when testing and deploying the New Flyer ADS vehicles.

Robotic Research's validation testing is intended to exercise ADS capabilities in preparation for operations on-site at Atlanta. The following tests will be conducted:

- Mechanical Evaluation: Stress test all of the physical and mechanical parts such as brakes, lighting, sensors, etc
- Vehicle Characteristics: Determine minimum stopping distance ADS mode.
- Rules of the Road: Ensure the ADS bus follows rules of the road, including identifying road markings, signals, and signage
- Object(s) Detection and Response: Ensure the ADS bus accurately identifies known and unknown objects, both stationary and moving, and determine how the prototype bus responds. Also, determine the average, median, maximum, minimum distance the vehicle comes to an object(s)
- Object(s) Detection and Trajectory Prediction: Ensure the ADS bus accurately predicts potential trajectories of identified objects, and determine how the ADS bus responds
- Pedestrian Reaction: Determine how the ADS bus reacts when it encounters pedestrians. Determine the average, median, maximum, minimum distance at which the vehicle initiates a response to stationary and moving pedestrians. Ensure the resulting response maintains a safe and appropriate distance (not too close or too far)
- Intersection Negotiation: Determine how the ADS bus handles intersections. Determine the average, median, maximum, minimum distance and estimated time to intersect oncoming traffic when the bus enters the intersection, and ensure the resulting response maintains a safe distance from other moving objects in the intersection
- Critical Path Selection: Ensure that the bus enters a designated "clear" area if an obstacle forces it to stop in an unsafe location, such as while crossing a road
- Human Intervention: Determine the frequency and circumstances when a human took control of the bus with ADS engaged. Account for driver and passenger comfort level
- Additional parameters will be identified. As data accumulates, patterns will emerge that will warrant deeper investigation of performance variance

The B-Kit hardware allows electronic steering, brake and throttle actuation. Robotic Research and New Flyer are working together to develop the actuation and electronics to safely control a bus. Robotic Research' past experience includes providing vehicle control systems for these heavy-duty vehicles: Oshkosh PLS (M1075A1), M1126 Stryker Infantry Carrier Vehicle, M113 Armored Personnel Carrier, and LMTV cargo truck.

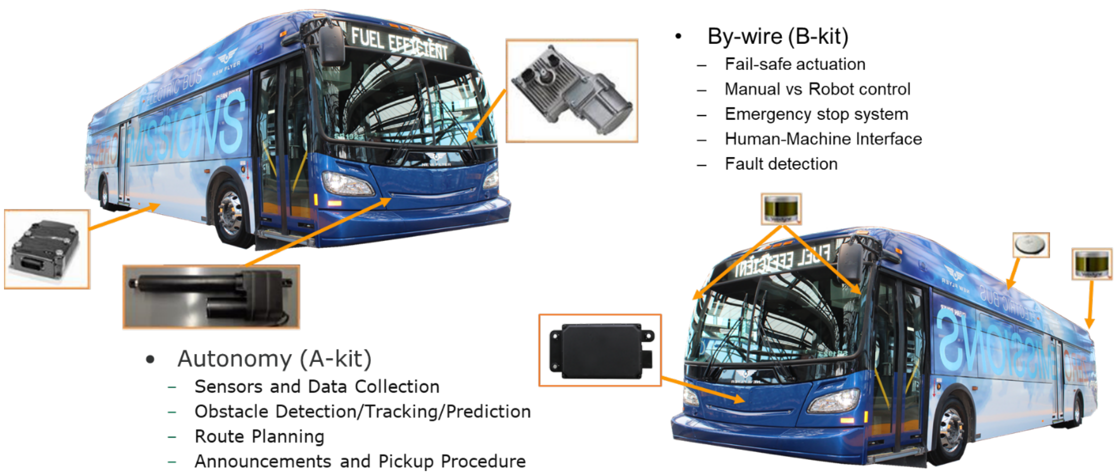

Figure 3: Robotic Research-New Flyer ADS Architecture (A-Kit below, B-Kit above)

The A-Kit enables automation capabilities. It includes sensor hardware, but mostly software modules, such as obstacle detection, prediction, and route planning. It operates at SAE Level 3 autonomy, and will allow the ADS bus to safely operate along its route without issues. Robotic Research uses radar and LIDAR as its primary obstacle detection sensors. The ADS can detect and track discrete entities such as vehicles, pedestrians, and static obstacles, and automatically plan safe trajectories to avoid obstacles and predict trajectories of other vehicles. The system requires a safety driver to be present.

<u>ADS Enabling Hardware</u>

Robotic Research's core ADS technology stack includes the following:

- *Robotic Research RR-N-140 Navigation Unit* – Hardware unit comprised of global positioning systems (GPS) and inertial measurement units (IMU) that provides a stable and robust localization and heading. Provides centimeter-level accuracy in horizontal positioning and heading accuracy within .1 degrees. Robotic Research's localization technology is far more robust and reliable than standalone GPS, and uses landmark-based registration via LIDAR to detect and reference vertical poles for positioning. It can also operate without the GPS component should that lose signal entirely.
- *LIDAR* – Sensors used for precise range, bearing resolution, and object definition, allowing the ADS to create an accurate three-dimensional sampling of the environment. Sample LIDAR sample is shown in Figure 4**.**
- *Radar* – Sensors used to measure speed, approximate location, and approximate heading, but require LIDAR augmentation for precise positioning and heading.
- *Cameras* – Used for traffic signal recognition and road lane detection. Camera-based lane detection improves intra-lane localization and alignment by calculating vehicle offset from the lane center. A sample Robotic Research camera detection is shown in

Figure 5. Cameras also provide redundancy to the V2I communications for traffic signal detection.

- *Vehicle-to-infrastructure (V2I) communications* – Each vehicle has dedicated short range communications (DSRC) onboard units (OBU) to receive signal phase and timing (SPaT) data from equipped traffic signals. This allows the ADS buses to synchronize longitudinal movement with intersection signals.

Obstacle Detection and Tracking

Robotic Research's obstacle detector and tracker suite aggregates LIDAR points into discrete entities, such as vehicles, pedestrians, and static obstacles, and then fuses them with radar data. By tracking these objects over time, the ADS sensors can compute precise heading and velocity. This enables the planner to avoid obstacles and predict trajectories of vehicles. Figure 8 illustrates the ADS tracking pedestrian across the street with the system's tracking software.

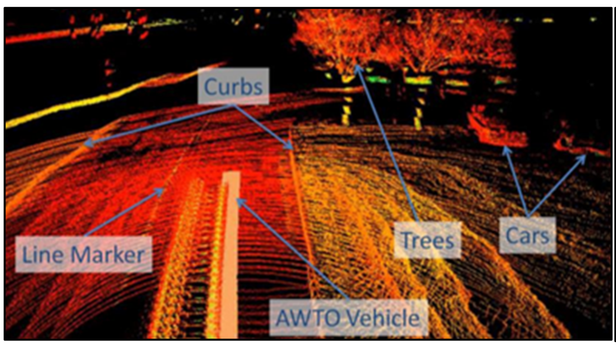

Figure 4 (Left): LIDAR sensors providing detailed 3D point information for imaging
Figure 5 (Right): Camera-based computer vision methods for lane detection.

Prediction and Planning

To operate in a dynamic urban environment, the ADS not only detects and tracks vehicles and pedestrians, but also predicts their movements (see Figure 6 below). Traffic rules apply to the future course of dynamic objects in the world just as it does with the robotic vehicle. Likewise, a pedestrian walking along the sidewalk adjacent to the road has a non-zero probability of jumping into traffic, but most likely will follow traffic rules. If these rules are not accounted for, the ADS bus would have to slow down significantly to pedestrians on sidewalks and vehicles in adjacent lanes.

At intersections, the ADS must track other vehicles to determine right-of- way. Furthermore, use of zero-sum game theory improves prediction accuracy by accounting for how other traffic interacts with the robot's location and behavior. The Traffic Route Planner then searches in the x, y, and time domain to generate the optimal route that avoids obstacles, but follows rules of the road. The bus is constrained to operate on the virtual "rail road track" to help ensure predictability and the comfort of the passengers. The route planner is allowed to deviate from these tracks in designated lane changing areas, but otherwise constrained to a specific lane.

Figure 6: The three images from left to right show a pedestrian (green dot) walking across the street. The heading of the pedestrian is indicated by the blue arrow.

Site Scoping and Demonstration Preparation

Prior to introducing any ADS-enabled vehicles onto the Aerotropolis demonstration site, Robotic Research and New Flyer will work with MARTA, CTE, and AACIDs to evaluate the alignment. AACIDs with engage other local stakeholders, including the Airport, Delta Air Lines, and all other municipalities to finalize route and service planning with MARTA's guidance. At the same time, New Flyer and Robotic Research will assess the proposed alignment for a detailed understanding of key features specific to the geography, terrain, surrounding infrastructure, signaling, traffic behavior, etc. Key features to document include:

- Total distance of route
- Number of total pickup/drop-off locations
- Number of potential riders
- Number of intersections
- Number of stop signs
- Number of traffic lights
- Number of traffic circles/roundabouts
- Type of roads to traverse, paved road, sidewalk, dirt path
- Severity of vehicular traffic
- Severity of pedestrian traffic

Robotic Research will document the route stop locations, as well as the key features listed above, including information about multiple routes. Robotic Research will identify relevant characteristics including construction, school zones, high pedestrian crosswalks without signage, and areas that require human directing flow of traffic. Robotic Research will then create a video of the route and annotate road segments, intersections, loading zones, signs, trees, and other applicable key features. For each route, Robotic Research will document alternate street or direction options, repeat these steps as necessary to fully document each segment of all routes and route options (see Figure 7 below).

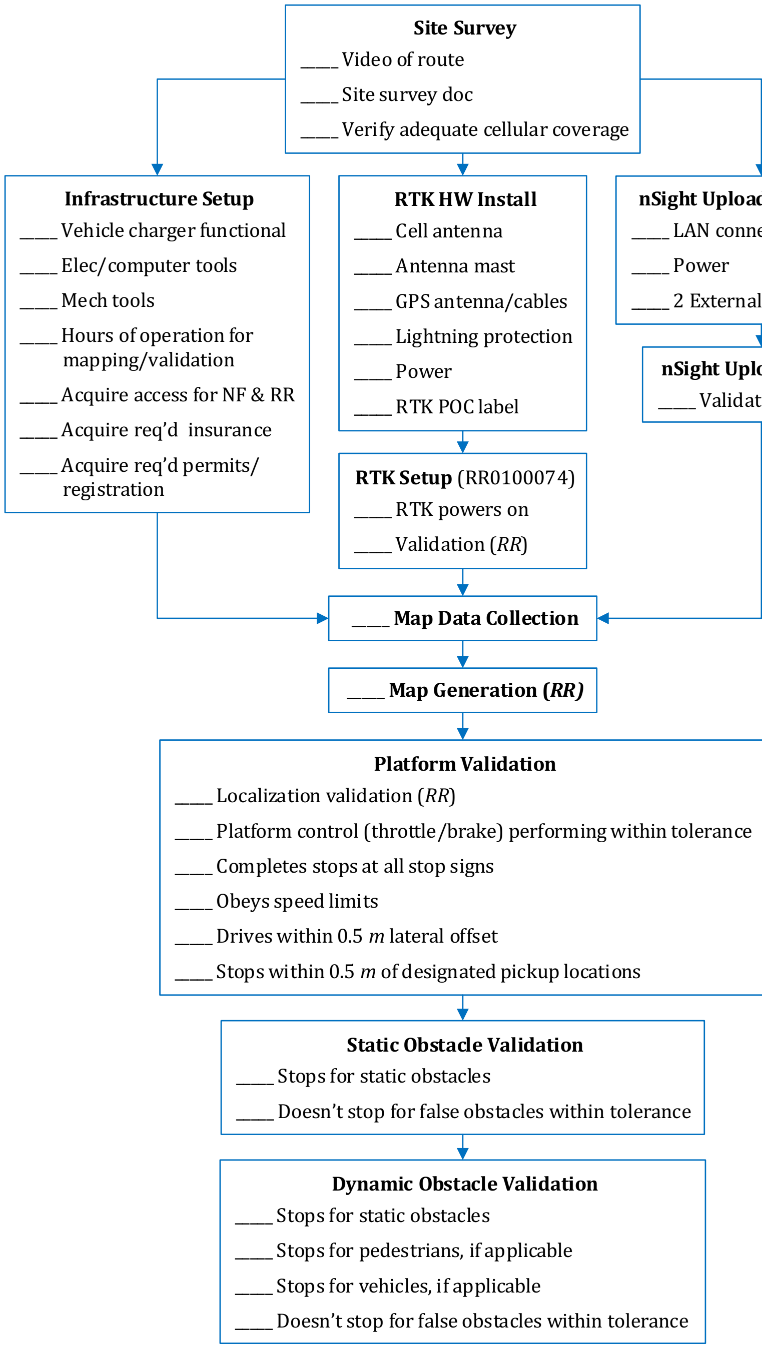

Figure 7: Robotic Research Approach to ADS Demonstration Preparation

Once this phase is complete, Robotic Research will begin its dry runs at the Aerotropolis demonstration site. These will continue for a short period prior to the demonstration's launch, until all project partners are comfortable with proceeding to formally deploy the pilot service.

Over the course of the demonstration, the ADS-equipped vehicles will be collecting, storing, and processing data as described in Sections 2b and 4c. In addition to serving as the data stream informing the team's reporting after processing and analysis, these raw data will also inform Robotic Research's further configuration of the deployed ADS. As the systems encounter edge cases, the Robotic Research team will evaluate those events and use them to program new behaviors, in the instance the ADS encounters that same scenario again.

CTE will lead charging infrastructure activities by working with Georgia Power to supply make-ready power from the utility and install two Siemens depot chargers (supplied by New Flyer) at the Alliance Bus Facility at Hyannis Court in College Park. Georgia Power work will include all necessary design and permitting, a new service point, switchgear, panel, all sitework for electrical and concrete pads for mounting chargers, and installation/connection of circuits.

b. Legal, Regulatory, Environmental, and/or Other Obstacles

The project team does not expect to require any waivers or exemptions for the project.

New Flyer buses are certified to meet all applicable Federal Motor Vehicle Safety Standards (FMVSS) and Federal Motor Carrier Safety Regulations (FMCSR) that are applicable to bus manufacturers. Integrating ADS hardware and software is not expected to affect either standards compliance. Addition of ADS equipment its relation to safety and effect on regulations will be carefully reviewed using FMEA protocols. ABM, which will operate the demonstration vehicles, is registered and compliant with the Federal Motor Carrier Safety Administration (FMCSA).

Both buses will meet Buy America requirements, which by the 2020 manufacture date will require that more than 70% of materials and components—and all steel and iron—are sourced from within the United States and that final assembly occur in the United States. The entirety of Robotic Research's ADS hardware is manufactured in the United States, and all equipment commissioning will take place at its Maryland facilities. The Siemens plug-in charging equipment will meet Buy America requirements for manufactured goods, which require 100% of components be sourced from within the United States.

The demonstration vehicles will also be fully compliant with all state regulations, which pre-empt local considerations. Georgia's SB 219 (2017) defines ADS and regulates their operation on public roads. CTE will hold title to the demonstration vehicles, and will therefore both register and insure the vehicles in compliance with Georgia law, which on or after January 1, 2020 requires coverage at levels consistent with non-ADS vehicles. As this demonstration does not intend to operate the ADS vehicles on public roads without a safety driver behind the wheel, certain provisions relating to "fully autonomous vehicles" in Georgia Code Section 40-8-11 will not apply. Per the legislation, no additional permissions are required to operate ADS-enabled vehicles on public roads, however, MARTA nonetheless sought and received support from every jurisdiction in the Aerotropolis demonstration area, as well as GDOT.

c. Data Commitment and Evaluation Participation

Robotic Research has committed to providing all ADS data collected by its nSight™ platform over the course of this demonstration, both in their raw format and in reports generated to capture pre-defined characteristics. Furthermore, the project team as a whole is committed to providing as much value as it can to USDOT and the public through collection and reporting of ADS safety data. The data classifications identified in this proposal represent initial recommendations for collection and reporting, but discussions between USDOT and the project team are likely to identify additional requirements.

Moreover, AACIDs is committed to providing all the qualitative data collected prior, during, and after the demonstration. All raw data pertaining to surveys will be provided in an appendix to reports submitted and/or published. Reporting will be documented within an agreed upon format between USDOT, MARTA, CTE and AACIDs.

d. Risk Identification, Mitigation, and Management

CTE will guide the entire project by the control and risk management procedures detailed below. CTE's centralized management of the work program will enable team members to concentrate on exceeding project goals and ensure production of deliverables in a clear and well-coordinated manner. CTE's processes for ensuring the efficient accomplishment of these tasks include development of and adherence to:

- *Online Collaboration Tools*
- *Communications Plan*
- *Reporting Plan (includes spending/progress versus budget tracking)*
- *Schedule Control Plan*

CTE provides strong and engaged oversight of project progress through the suite of management controls and tasks above. CTE's management method ensures quick recognition of any project risks that arise. Further, CTE's extensive experience managing projects allows for identification and development of clear mitigation strategies that address the needs of all stakeholders. The project approach includes identifying, documenting, and tracking issues. Issues are assigned to project team members for research, analysis, and resolution. Issues and related tasks are prioritized to ensure that project team members remain focused on the right activities at the right time. Critical issues that remain unresolved and that impact project timeline, scope, budget or resources are escalated to MARTA and USDOT management, along with proposed solutions, for immediate attention. Throughout development of this project and proposal, the team identified and prepared for the following potential risks that are specific to this project.

1) *Route development* – The project team reviewed, visited, selected, and modeled the proposed demonstration route. However, the proposed route is not an existing service with a 40-foot transit bus, particularly under automated guidance, and unforeseen risks may present themselves that are associated with turning requirements, signaling, neighborhood

street clearances, etc. To address this, Robotic Research will accomplish a robust route planning activity including riding the routes and modeling ADS functionality as described in the Technical Approach section. Adjustments to the proposed route may be made accordingly. The team identified multiple alternatives that still serve the proposed route termini and stops. At least four options exist for connecting the College Park MARTA Station to the Virginia Avenue corridor.

2) *Vehicle reliability and availability* – Only the proposed two buses will be serving the route, introducing a risk that vehicle downtime could affect both route service and data collection. To address this, the team chose to utilize new buses for the demonstration. The New Flyer XE40 electric buses and charging infrastructure have already proven reliability in transit service. Additionally, New Flyer will provide warranty service and robust maintenance support, including necessary spare parts. A training program developed and administered by New Flyer and Robotic Research will be provided to ensure that ABM technicians are able to provide routine service and diagnostics. To address component and system failure risks associated with the integrated ADS system, the buses will be designed to operate without the ADS system operational using the on-board safety drivers while issues are being addressed. Most importantly, extensive closed-circuit demonstration for six months has been included in the work scope prior to introduction into public service. This will allow New Flyer and Robotic Research to shake out and address any early-stage design and integration issues.

3) *Energy consumption, range, and charging approach for the electric buses* – While battery electric buses are efficient, their energy consumption and range characteristics are dependent on a number of factors, including duty cycle, environmental conditions, battery size, passenger loads, and auxiliary loads. These characteristics determine how they can be operated and how they should be charged in order to maintain service. If these factors are not well understood, limited range will affect the buses' utility. Further, early stage characterization of ADS energy loads can add a level of risk if they are not accounted for. Given this, the CTE and the project team have utilized their extensive experience to model and provide preliminary simulations for the buses in the proposed automated service. Robotic Research has estimated ADS power loads and these have been considered in the simulations. The team believes that, utilizing a 466-kWh battery as proposed, the buses will be able to provide approximately 10-14 hours of service between full charges depending on how the buses are operated. Therefore, the team is proposing plug-in style depot charging located at ABM facilities for overnight charging of the buses. As the proposed route is a new demonstration service that will primarily serve employees and complement existing transportation modes, the team has some flexibility in defining operational hours. The project team will continue to update and refine the bus simulations throughout the operational planning stage of the project.

4) *Accident or incident involving the demonstration vehicles* – Should an accident or on-board incident occur, whether or not it is due to the automated driving system and project

vehicles, the team must be prepared to address liability concerns and risks. The team plans to accomplish this by keeping a safety driver on-board and behind the wheel at all times the vehicle is in operation, securing an insurance policy, and working with MARTA's police department to establish and prepare protocols in case of any incident. CTE, with partner support, will organize First Responder training. This training will be made available to all first responders from fire and police stations that have jurisdiction along the route alignment. The training will make responders aware that the autonomous electric buses are operating in their area and will cover details about the bus, the service, electrical disconnects, cut points (to avoid for the high voltage wire routing), and any other safety features associated with the buses.

e. Cost-Share Contribution and Management

MARTA is contributing the entirety of its project contribution as cost share, including project administration and reporting, route and service planning support, marketing, communications, and outreach support, and administrative overhead for all project activities. New Flyer is contributing cost-share through its research and development resources and similar contributions from Robotic Research, which will subcontract to New Flyer. New Flyer/Robotic Research cost share also includes the participation of SAE International over the project's duration. The Aerotropolis will supply cost-share in the form of labor throughout the project for its own staff while they perform planning, marketing, communications, stakeholder and community outreach, and other activities in support of the project. It will bill subcontracted services in support of its outreach, engagement, and survey programs.

GDOT has also committed to install and configure roadside units (RSU) with software capable of broadcasting signal phase and timing (SPaT) messages at signalized intersections along the demonstration route. However, as these devices and the software were procured with FHWA funds, they are not considered local match for the purposes of this grant, but will be leveraged to successfully complete the grant.

MARTA will be responsible for securing and managing any promised cost-share committed by project partners.

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