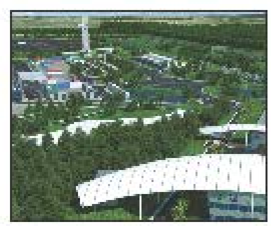
BUS AUTOMATION NEEDS FOR ACCESSIBILITY AND NIMBLE ADOPTION (BANANA)

US DOT Automated Driving System (ADS) Demonstration Grant

NOFO#693JJ319NF00001



LYNX

PROTERRA

EASY MILE

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

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Cover Letter

Central Florida Regional Transportation Authority
455 N. Garland Ave.
Orlando, FL 32801-1518
407.841.LYNX (5969)

Central Florida Regional Transportation Authority - Part 1

LYNX

March 19, 2019

The Honorable Elaine Chao
Secretary of Transportation
United Stated Department of Transportation
1200 New Jersey Avenue, S.E.
Washington D.C. 20590

RE: US DOT Automated Driving System (ADS) Demonstration Grant
LYNX Application Project BANANA (Bus Automation Needs for Accessibility and Nimble Adoption): NOFO#693JJ319NF00001

Dear Secretary Chao:

The Central Florida Regional Transportation Authority, d/b/a LYNX, in collaboration with the City of Orlando, the Orlando Utilities Commission (OUC), the University of Central Florida (UCF), SunTrax, SunStore and industry leading partners, Proterra and EasyMile are pleased to submit our application for US DOT ADS demonstration grant. LYNX is requesting $8,699,390 in federal funding to purchase two autonomous, electric, 40-foot buses to test the safe integration of autonomous driving technologies into the nation's public transit system focusing on individuals with mobility and other impairments that require use of mobility and communications adaptations, and to deliver real-time data sharing for public benefit.

The vision of this project is to demonstrate initial prototype systems that maximize the accessibility of public transit automated vehicles for riders of varying abilities. Solutions will be demonstrated that are designed to meet the needs of the disabled community and replicable to others. LYNX and its partners are interested in identifying and understanding the implications of the ADA requirements to the autonomous vehicle technology and its application to support current and future transit service initiatives and investments. This autonomous vehicle ADA initiative will establish the partnerships, policies, technical, financial, infrastructure and workforce needed for the implementation of safe, autonomous, public transit services in the Orlando metropoltan area. It is proposed that the project be implemented over the period 2019-2023. Phase I will use SunTrax, a Florida test track demonstration. Phase II fixed route demonstration will be the Downtown Orlando BRT system called LYMMO within the urban core, which is a major central business and entertainment destination for residents and visitors.

LYNX is transforming transit in Central Florida with a focus on innovation and technology to provide more frequent, reliable and direct connections. We are committed to technology leadership and to establishing safe mobility solutons that will help build public confidence in the safety of autonomous mass transit. LYNX serves 2.1 million residents and 95.8 million annual visitors in a service span area of approximately 2,850 square

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Central Florida Regional Transportation Authority - Part 1

miles within the three counties of Orange, Osceola and Seminole in the state of Florida, and delivers 24,845,029 million rides per year.

LYNX appreciates the opportunity to be part of a safe quality public transit and advancing US DOT's goals in deploying new technologies through the US DOT ADS program. Thank you for your consideration.

Sincerely,

James E. Harrison, Esq., P.E.
Interim Chief Executive Officer

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Summary Table

Summary Table	
Project Name / Title:	Bus Automation Needs for Accessibility and Nimble Adoption (BANANA)
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address	Central Florida Regional Transportation Authority, dba LYNX 455 N Garland Ave Orlando, FL 32801
Point of Contact (Name/Title; Email; Phone Number)	Project Contact: Doug Jamison, Senior ITS Developer; djamison@goLYNX.com; 407-254-6071 Grant Contact: Belinda Balleras Manager of Grants; bballeras @goLYNX.com;407-254-6115
Proposed Location (State(s) and Municipalities) for the Demonstration	SunTrax Facilities, Lakeland, Florida City of Orlando, Florida
Proposed Technologies for the Demonstration (briefly list)	EZ10 – EasyMile Platform 40' Catalyst Electric Bus- Proterra SunTrax – Test Track Phase 1 SunStore- Data Management and Sharing
Proposed duration of the Demonstration (period of performance)	4 years from project initiation 5 years of Data Sharing
Federal Funding Amount Requested	$8,699,390
Non-Federal Cost Share Amount Proposed, if applicable	$4,225,805
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$12,925,195

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Project Narrative and Technical Approach

Executive Summary

This project called ***BANANA*** (Bus Automation Needs for Accessibility and Nimble Adoption) involves the application of advanced automated driving system integration, test track deployment, fixed route circulator bus deployment and big data analytics to demonstrate the safety integration of Automated Driving System (ADS) into public transportation while also addressing the unique public transit's obligation under the Americans with Disabilities Act (ADA). LYNX is requesting $8,699,390 under the Notice of Funding Opportunity from the US Department of Transportation for "Automated Driving System (ADS) Demonstration Grants" for the overall project duration of four (4) years, and additional 5 years for data sharing.

LYNX is the regional transportation authority providing and coordinating mass transit services within the three counties of Orange, Osceola and Seminole. Services span an area of approximately 2,850 square miles to service a population of 2.1 million residents and 95.8 million annual visitors. In addition, LYNX provides transit services under contract to the neighboring counties of Polk and Lake.

LYNX has collaborated with a consortium of industry leading public and private partners that will enable our region to develop solutions in transit automation adaptable to the ADA rider needs. These partners include:

- City of Orlando – Recently adopted a Community Action Plan for Sustainability and Resilience with a vision to transform Orlando into one of the most environmentally-friendly, economically and socially vibrant communities in the nation
- Orlando Utilities Commission (OUC) –The second largest municipal utility in Florida with a primary goal to encourage the conversion of the transportation sector from internal combustion engines to battery electric.
- University of Central Florida (UCF) – Has a nationally recognized Center for Advanced Transportation Systems Simulation, which conducts research in the area of traffic safety, ITS, traffic simulation, transportation demand analysis and transportation planning concepts and methods.
- SunTrax – A 400-acre research facility located in Lakeland, Florida and dedicated to AV testing will provide a controlled and safe environment for Phase I testing.
- SunStore – An ongoing FDOT initiative to connect and integrate the many data sources created and utilized by the FDOT. SunStore includes Master Data Management, Data Fusion, and Sensor Fusion for increased data quality. SunStore interfaces with Florida's Data Integration and Video Aggregation System to make transportation data available to universities, research institutions, and businesses to encourage and support innovation.
- Proterra - A leader in the design and manufacture of zero-emission vehicles that enable bus fleet operators to eliminate the dependency on fossil fuels and to significantly reduce operating costs while delivering clean, quiet transportation to the community.
- EasyMile - A leader in autonomous vehicle technology currently at Level 4 according to the SAE definition of Driving Automation Systems for On-Road Motor

Vehicles. A Level 4 system is an ADS that can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances.

Our vision is a two phased implementation: Phase 1 deployment will utilize the test track, dubbed SunTrax, a 2.25-mile oval track on a 400-acre site in Auburndale, Florida and will test autonomous vehicles in simulated situations such as rain, fog and smoke; Phase II of the project will intend to demonstrate SAE Level 3 autonomy on a 40 foot electric bus on the LYMMO Orange Line. LYMMO is the Downtown Orlando Bus Rapid Transit (BRT) system within the urban core, that connects major central business and entertainment destination for residents and millions of tourists. The Orange Line opened in 1997 and is first BRT in the US. The line totals 2.58 miles, contains 14 stations and offers 5-7-minute peak service frequency and 15 minutes off peak frequency. Annual ridership on the Orange LYMMO Line totals 625,344 passengers.

The Goals of the ADS Project BANANA	Objectives of Project BANANA
To develop a transit system that does not have systemic barriers that unintentionally block members of our community from free movement. We are creating a frictionless transportation system. Understand the impacts of AV vehicles and technologies on the transit ecosystem and from the passenger perspective. Improve transportation efficiency by promoting agile, responsive, accessible, and seamless multimodal service inclusiveness for transit through enabling technologies and innovative partnerships.	Through two-phased demonstrations and data analytics, this project seeks to improve agility and responsiveness of dynamic automation technologies to the critical needs of ADA, seniors and physically challenged riders. Design and test AV technology on the mainstay vehicle platform for public transit; the 40' bus.
Increase transportation effectiveness by ensuring that transit is fully integrated and a vital element of a regional transport network that provides safe, consistent, reliable and accessible service to every traveler.	The project is designed as a stand-alone demonstration but also represents a step towards regional integration with respect to the use of demonstration data and analytics. With a focus on vulnerable passengers, the project also promotes consistent, reliable and accessible service to all passengers as an emerging technology.

The Goals of the ADS Project BANANA	Objectives of Project BANANA
Incorporate accessibility in the front-end of development to allow autonomous vehicles to be designed for all populations including the underserved.	The project leverages federal and state investments in management systems, advanced technologies and proving ground facilities that can demonstrate and replicate a real world environment for initial testing with input from the target population.

SunTrax, a testing ground for Phase 1, is a long-term partnership between the Florida Department of Transportation, Florida's Turnpike and Florida Polytechnic University and a high-tech hub for the research, development, and testing of emerging transportation technologies related to tolling, intelligent transportation systems and other advanced transportation concepts. Construction on the oval track is scheduled to be completed in spring 2019 and construction will begin in fall 2018 on the track's 200-acre infield which will include a simulated urban environment complete with buildings, pedestrians and more for automated and connected vehicle testing.

Project BANANA comprises building two 40-foot electric Catalyst Proterra buses with EasyMile's proven ADS technology and testing them in the controlled and safe environment of SunTrax proving ground while trying to address major accessibility issues such as visual, mobility and cognitive impairments. With the project utilizing EasyMile's vehicle technology, it includes a sensor software that has been designed to know the vehicle's exact position with centimeter-level precision, at all times. The software can obtain a level of precision utilizing: (1) Laser scanning the environment (2) Cameras (3) Differential GPS (4) Visual location (5) Estimation using an Inertial Measurement Unit (IMU) (6) Odometry estimation. The Proterra buses for this demonstration will be built to the same standards with the development of the hardware and software adapting Easymile's shuttle platform to the Proterra bus through a combination of possible solutions, such as including a phone app, buttons on the bus and/or bus stop and auditory announcements among other options, to address the need of providing accessible trips from origin to destination.

In addition to our robust public-private partners, the project will engage various stakeholders from the disable community and passengers from multiple socio-economic and ethnic backgrounds to seek input, guidance and feedback through-out the period of performance. This will include focus groups from Metroplan Orlando's Local Coordinating Board and Disability Quality Assurance Task Force.

Issues and Challenges to be addressed: Like most agencies aggressively pursuing the full potential of automated driving technology, LYNX is facing the dilemma of selecting the appropriate technology that addresses the needs of persons with disabilities as well as the greater population. Because of the cost of development and the risks associated with the burden of financial investment, there is very little information on the implementation implications of automated technology. This project seeks to address those issues when considering the introduction of automated technology, evaluate the full impact of the equipment and systems throughout the demonstration, including the entire passage community, to ensure the optimal use is not compromised, and effectiveness is adequately tested and measured. In delivering transit services, LYNX must fulfill the ADA requirements of making public transit accessible to all. The cost-effectiveness of the communication technology or techniques must be measured relative to the benefits of all riders, not just those with identified disabilities.

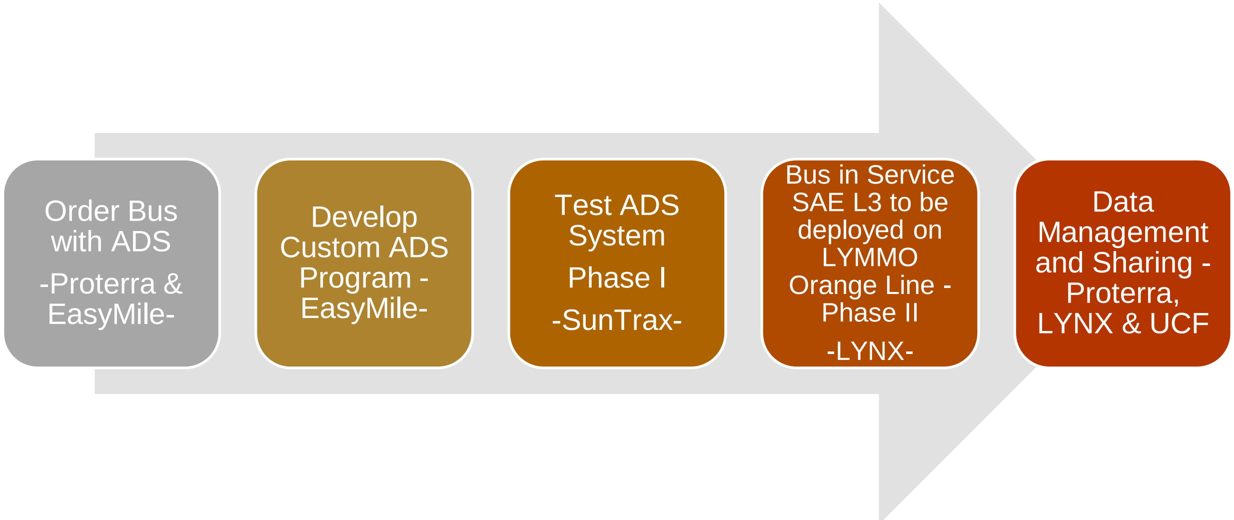
The proposed Phase1 and 2 deployments will have quantifiable benefits addressing safety:

1. The system solution proposed for this project has multiple layers of redundancy in order to maximize the safety of the passengers, other road users and the vehicle itself:
    - Redundant coverage by sensors
    - Independent obstacle detection function
    - Fail-safe and redundant braking system
    - Redundant industry-grade emergency buttons
2. Big data on safety will be generated and collected by fusing and interpreting data from the systems. This data is collected and can be presented in numerous forms to allow for analysis. This data can be generated daily for reports for Key Performance Indicators (KPIs) and also provided real time feed through our APIs.
3. LYNX and UCF will collaborate on analysis of data and input from passengers and users
4. Safety performance modeling will evaluate the occurrence and count of disengagements, utilizing econometric models to identify the various parameters affecting the results.
5. Benchmark metrics will be obtained prior to ADS installation, based on current infrastructure. After adding ADS, the same metrics will be recompiled to compare performance across two systems. The comprehensive analysis will include multivariate models from statistics, econometrics and machines learning.

To assess and communicate performance, SunStore has open data standards using Application Programming Interfaces (APIs). These standards are portable and can be supported by third-party users. This project has the data management tools in place to commit system and performance evaluations of safety.

Geographic areas of demonstrations: SunTrax, Auburndale Florida and LYNX LYMMO Orange Line, Downtown Circulator Orlando, Florida.

The following provides schematic diagram of the project concept:



Project Goals

EasyMile will work with Proterra to install Automated Vehicle technology already in service on its EZ10 platform to two a Proterra 40-foot buses. This will involve the two partners working together to understand how to integrate the technology into the systems on the bus. At the same time, EasyMile will be developing new technical solutions to meet the needs of all users, including disadvantaged individuals and individuals with disabilities. This will result in solutions with multiple interfaces which that will provide the same interaction with passengers but in different forms. Passengers will be able to use the interface which that is easiest and most comfortable for them. EasyMile will work with LYNX on behalf of the two vendors for input from a transit agency perspective and will seek input from the disabled community to ensure that the solutions are developed with all passengers in mind.

Proterra will work with the Orlando Utilities Commission (OUC) and LYNX during the development of the automated bus to ensure that the required charging infrastructure is in place prior to the vehicle delivery. Proterra and EasyMile will also work with LYNX and the City of Orlando to prepare the new automated bus for service on the exiting bus rapid transit lines, LYMMO Orange and Grapefruit lines. Training will be provided to LYNX bus operators on how to control the bus during driver operations, such as deadhead to and from the depot, and how other bus operators in the lanes interact with the Autonomous Vehicle. LYNX, Proterra, EasyMile OUC, and the City of Orlando will work together to prepare to assist and educate the transit service riders passengers and those in the City of Orlando for interaction with the Automated Vehicle.

Initial testing of the vehicles will occur at the SunTrax testing facility by EasyMile and Proterra. This will also involve LYNX and the University of Central Florida learning about the operation of the vehicle, the capabilities of the automation, and an understanding of the operation of the vehicle.

As the vehicles moves from testing into physical demonstrations outside of the test track, Proterra will provide data on the operation of the vehicles and of the automation to LYNX, OUC and to the University of Central Florida for analysis. This data will be stored in an account in the Florida Department of Transportation SunStore system. Access to data will be made available to each of the partners, to the USDOT, and to interested third parties.

All partners in the BANANA Project will be willing to meet with USDOT and with local AV partners (FDOT, Central Florida AV Partnership, UCF and Florida Polytechnic University, City of Orlando, MetroPlan Orlando) to share progress and lessons learned and to gain input throughout the duration of the project.

Safety

The technology proposed to be used for this demonstration was effectively proven on the EZ10 shuttle platform of EasyMile. Adapting the technology to a 40-foot electric bus with the same effectiveness and safety is one of the major goals of this project. Being able to produce a mass transportation vehicle that accurately detects, recognizes, anticipates and responds to the movements of all transportation system users could be the breaking point to develop safer public transportation across the nation. According to the National Safety Council, the state of Florida has had a spike of at least 5.8% in crash fatalities. The Proterra buses built for this demonstration will be built to the same standards as the EZ10 model described below whenever possible.

Safety is not just a goal for EasyMile but is the outcome of a well-trained, well educated, and motivated workforce providing consistently high-quality service. As in any complex system, the risk mitigation approach is at the core of good engineering practices and safe operations. EasyMile's comprehensive approach to safety; and the experience, expertise, tools, training and focus of every employee contribute to the achievement of this objective and will be applied to deployment of the technology on a Proterra 40-foot bus.

Thanks to more than 210 projects rolled out around the world in various weather conditions (winter, tropical and desert) and a variety of operating environments (open road, business park, cycle path, etc.), EasyMile has gained the experience to improve their technology with over 105 EZ10 shuttles deployed to date. Over the 155,000 miles traveled with this advanced shuttle and, with 320,000 passengers transported, EasyMile has had no accidents to report, either in automatic driving mode or during manual use by a trained agent.

Safety is the primary requirement and the key challenge in AV and Automated Transport Systems (ATS). Any accidental failures (safety issue) or intentional attacks (security issue) may result in severe injury or loss of life. Any missing consideration on either failures or attacks may lead to terrible consequence. EasyMile brings this focus on integrating safety into the solution to be developed for this project.

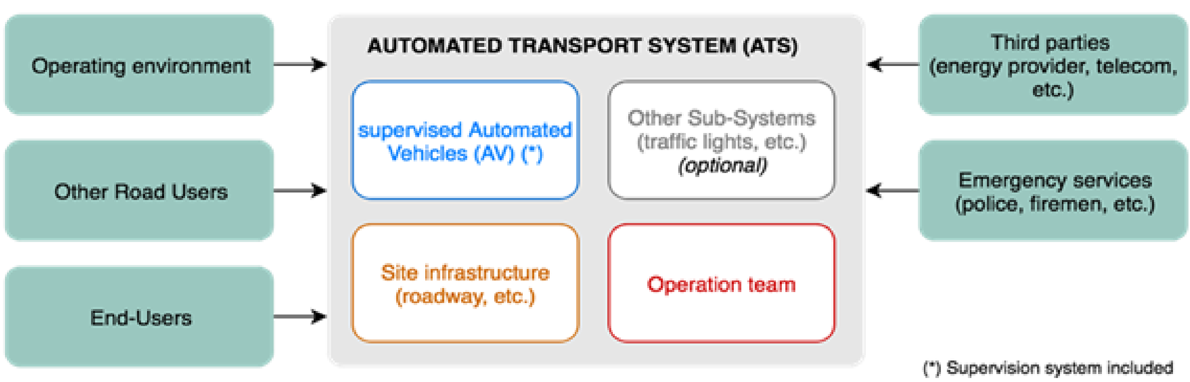
Safety and Security (S&S) are interrelated and, therefore, have to be aligned early in the development process. International standards from the International Organization for

Standardization (ISO 26262, and Society of Automotive Engineers (SAE J3061) will be followed for Safety and Security.

These standards do not address all the aspects of AV as these standards rely on a human driver controlling the vehicle, while EasyMile's ADS is fully responsible for driving the vehicles. Additionally, the standards do not consider all aspects of the ecosystem of ATS. Beyond the vehicle, the technology must be able to operate and interact with systems that are related to specific transit agency sites characteristics, to other subsystems (in addition to the AV), and to a human-based organization responsible for the daily operation.

Project partner EasyMile has developed an approach for risk management that it will bring to the BANANA Project that targets to align safety and security lifecycles. This approach is based on SAE J3061, SAE J3016, and ISO 26262 standards at an early development phase of AVs, and then is extended to the project phases of ATS commissioning and operation (i.e. ATS pre-deployment, ATS deployment, ATS agreement to start operation, and finally, ATS operation phase). The approach tries to connect safety failures, security attacks, and the associated countermeasures and risk reduction measures.

EasyMile has experience in projects dealing with systems, in particular with ATS, in which AVs are sub-systems, among others, installed onto a validated road network of a specific site, with dedicated infrastructure components, and managed by a dedicated operation team.



ATS overview and related stakeholders

A comprehensive process for risk management will be implemented for the *BANANA* Project, considering the Safety & Security (S&S) learned from studies related to the AVs themselves, associated with the hazard and threat analysis related to the specific environments, and driving and operating conditions where each ATS is expected to be deployed.

The safety management process has been inspired by two domains of application - **Road vehicles** and **Guided vehicles** (e.g. tramways) - allowing the development team to define S&S objectives and requirements for such a system-oriented approach, not only limited to the vehicles.

Traditional safety tools and analysis will be applied in order to justify how the safety requirements are reached, as well as the limitations of the Operational Design Domains (ODD) and the related residual risks of each ATS.

As this project will be dealing with systems, vehicle design S&S requirements will be associated with additional external mitigation measures that are defined in the development specific to the site according to the project deployment procedures. These would be further designed site-by-site for other development and deployment projects.

The implementation of these external mitigation measures, and the definition of the operating rules will finalize the Definition Stage of the risk management process, by ensuring that each identified residual risks has been mitigated to an acceptable level.

The Operation Stage of the risk management process will then be ensured by LYNX who will provide daily operations the ATS vehicles.

Like complex transportation systems used in commercial aircraft, the solution provided by EasyMile for the Proterra buses has multiple layers of redundancy in order to maximize the safety of the passengers, other road users and the vehicle itself:

- Redundant coverage by sensors
- Independent obstacle detection function
- Fail-safe and redundant braking system
- Redundant industry-grade emergency buttons

<u>Redundant coverage by sensors</u>
No certified LIDAR currently exist on the market today to meet our objectives; thus, our team will implement redundant sensor coverage on each vehicle using a combination of LIDARs from different suppliers. This architecture mitigates risk of single sensor failure.

As an example, on the existing EasyMile's EZ10 vehicle, four LIDARs each covering a 270° range are located at each corner of the vehicle. This offers a redundant 360° perception of the environment around the vehicle. Any obstacle within a 40m distance around the EZ10 will be detected by at least 2 to 3 LIDAR sensors.

Above the four corner LIDARs, the EZ10 also has one VLP16 LIDARs from Velodyne on both the front and rear of the vehicle to have a better awareness of its environment in 3D. These technologies will be adapted to and proven on the Proterra 40' bus.

<u>Independent Obstacle detection function</u>
The processing power needed to run an autonomous vehicle is huge. Today there is not a commercially available certified processing unit with enough computing power to enable

all obstacle detection functions needed. Our solution is to add an independent Safety layer: The Safety Chain. This architecture mitigates the risk of processing unit failure (due to hardware or operating system fault) in the most critical situations.

The architecture that will be used on the Proterra bus consists of:

- An industry-grade computer with a tailor-made version of Linux, enabling better control of processing and cyber-security than commercial Operating Systems. Complex filtering algorithms are embedded on this computer to monitor obstacles around the shuttle, calculate collision probabilities and adapt its behavior accordingly.
- A Safety Chain based on a certified Programmable Logic Controller (PLC) is independent from the main computer. It uses very simple algorithms and can perform emergency stops should the main computer fail to anticipate the potential collision.

Focus on the PLC

The PLC used in Safety Chain implemented by EasyMile is SIL3 certified (according to IEC 61508 Functional Safety standard) and PLe certified (according to ISO 13849 “Safety of machinery - Safety-related parts of control systems” standard).

The PLC performs the following tasks with a high safety level inherent to its certification:

- Continuous monitoring of critical components (such as steering and traction controllers, braking systems, LIDAR sensors, emergency buttons, main computer, etc.).
- Triggering of an emergency stop, in case the Safety Chain fails, the emergency button is manually activated, or a failure is detected by the monitored components. This will ensure that vehicle and its passengers are safe.
- Safe Door and Automatic Access Ramp management (opening and closing) - one of the most critical functions in transportation systems because of potential injuries, failures and unavailability.

The PLC outputs take the highest priority over the other robotics, electronic or computer systems. In case the PLC encounters a failure, its certification level ensures that it will reach its fail-safe state. In this state, our fail-safe brake will be automatically activated to enable vehicle to stop.

Redundant Braking System

Braking safely is crucial. Vehicles equipped with the technology provided by EasyMile use four independent braking systems. For example, on the EZ10:
During normal operations,

- The autonomous system can change its speed to decelerate smoothly, using the regenerative braking system.
- For harder deceleration, the system, can also use the electrical calipers.

In case of an Emergency Stops,

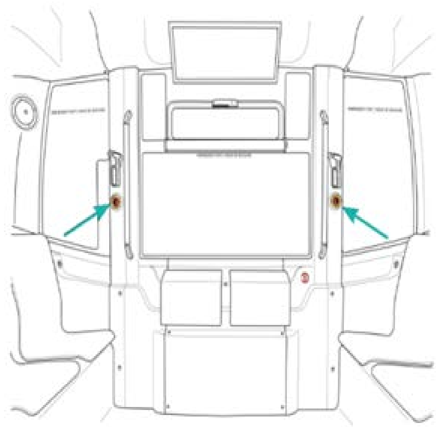
- The autonomous system uses both of the previous braking systems but also the hydraulic braking.

In case of complete power loss, or when the vehicle is turned off, the fail-safe brake is automatically activated.

This architecture mitigates risks of failure in 2 braking systems and even a potential failure in the battery system that would lead to complete loss of electric power. This design will incorporate the existing safety features of the Proterra bus.

Manual E-Stop

In case of an emergency situation, passengers of the vehicle can rely on redundant emergency buttons to request an e-Stop. The schematic shows the location of two interior buttons on an EasyMile vehicle. These will be designed and added to the larger Proterra bus to provide the same functionality.



In order to mitigate the risk of a short-circuit or a contact meld inside the button, the emergency buttons installed meet the following requirements:

- Health status can be monitored (normally closed)
- Resistance to single mechanical failure (double contacts)
- Multiple emergency buttons are located in the vehicle.
- They are continuously monitored by the PLC. If an error is detected, an E-Stop is required

Most standards and specifications require that a true Emergency Stop be a red button. In addition, it is often required that the button be located on a yellow background. These colors indicate that the device is an emergency control. We intend to use this recognizable color scheme in the Proterra automated vehicle.

Cyber-security

Because safety also comes with security, cybersecurity is one of the main focuses throughout the entire project development and is embedded in every aspect of the software development process and validation protocols. The product and software team will set up various security gates to ensure the integrity of the whole system.

- During the design phase EasyMile will work with Proterra to located access to computer ports which will be locked so only authorized operators can access them.
- The EasyMile software code is continuously tested with tools that check to ensure that it is well written and does not have vulnerability to hacking attempts.
- Both the vehicle computer and the supervision tool necessitate authentication (login/password) to be able to access the data. The fleet management to be used is built in such a way that even if it is hacked, the safety of the vehicle cannot be compromised.

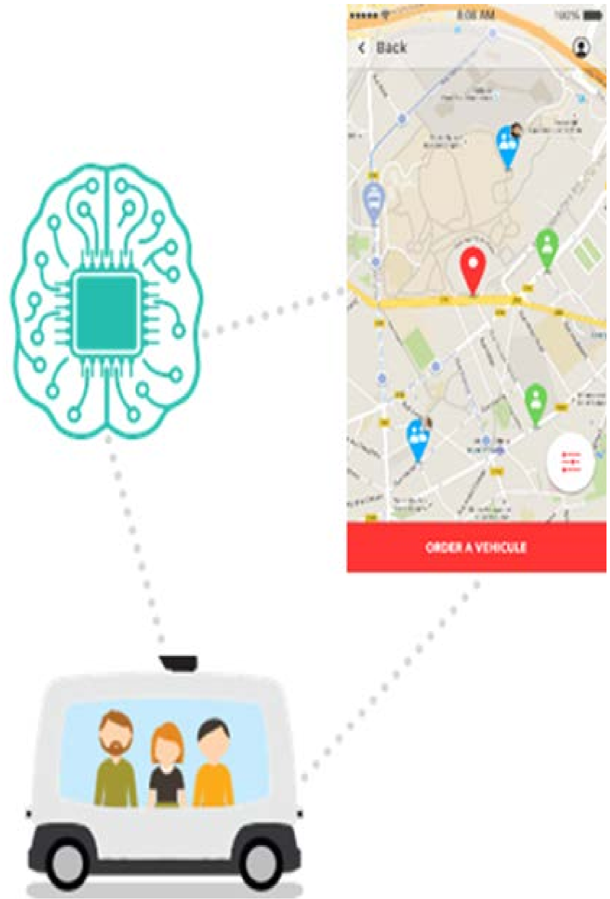
- Mechanisms exist in the EasyMile's software to make sure that the embedded software is actually the EasyMile's software, meaning that an outsider could never incorporate unauthorized code into the vehicle. This will be applied to the Proterra automated vehicle.
- The Proterra automated vehicle will have an on-board security chain that stops the shuttle if any disturbance happens on the main computer.
- "Penetration tests" will be conducted, in which security experts will act as hackers to spot any security flaws.
- The vehicle will be connected using 3G/4G or Wi-Fi via an encrypted communication.
- The vehicle will stop if it deviates from its predefined trajectory and if the software crashes or does not respond as it should. To prevent any remote access, the protection relies on encrypted communication with EasyMile's servers and authentication with certificates. Advanced password protection policies that have been implemented by EasyMile will be use in this deployment.
- The manual driving controls and the safety loop of the vehicle for autonomy will be separated from the automated vehicle software will note be able to be controlled remotely.
- If the vehicle deviates from the trajectory, it would only be detected in a very short distance and automatically stop.

<u>Black Box and Vehicle Monitoring</u>
The vehicle condition will be reported every half a second and stored with no duration limit in the vehicle supervision software servers. This data contains the results from the information processed and analyzed by the vehicle such as:

- Quality metrics (sensors, location and route monitoring)
- Position
- Assignments sent to the vehicle by the supervision system
- Usage statistics

The EasyMile solution is made with a Black Box module. The module records the raw data from the various sensors exchanged between the vehicle's hardware and software. If there is a critical event, all data 30 seconds prior to and 15 seconds after the event are recorded in a file to help understand and diagnose the event.

<u>Fleet Management Software</u>
The EasyMile Fleet Management software suite is the electronic "brain" of the whole system and will be applied to the Proterra ATS. It is designed to be flexible and modular, so as to enable different operating scenarios and to adapt to various customer needs.



Multiple vehicles: Thanks to the use of an EasyMile communication protocol dedicated to supervising the fleet of autonomous vehicles, the software suite can be adapted with other manufacturers.

Modular: The modular architecture of the EasyMile Fleet Management software suite allows easily integration to third-party software to replace or add to certain proposed functions.

Interoperable: Application Programming Interfaces (APIs) allow third-party to connect to the EasyMile system that will be installed on the Proterra ATS. This system at provides connection at different levels based on other systems' needs (Position, Monitoring, Booking, Mission).

Scalable: The Fleet Management System has been designed from its beginning by EasyMile to be fully scalable and adapted to large fleet of vehicles.

The Proterra's Zero Emission Bus

Two 40-foot, electric Proterra buses will be used for this project. Having designed the vehicle purely as an electric vehicle, Proterra began with a light-weight, durable composite monocoque body structure manufactured from high strength fiberglass, carbon fiber, and resin with a balsa wood core. The benefits of using the composite body include: a lighter total vehicle weight (reducing the impact to local roads and infrastructure), improved vehicle efficiency and fuel economy, improved thermal and noise reducing properties, exceptional torsional stiffness (resulting in an excellent ride and handling), increased durability (LA Metro has reported that their composite bus bodies are expected to last up to 20 years), corrosion resistance, and best-in-class safety (better impact resistance). Most 40' electric buses that have traditional metal framed bodies weigh an average of 5,000 lbs. more than Proterra's Catalyst electric buses.

Additionally, the Catalyst battery-electric buses have a recessed cavity under the bus body between the axles for the high-voltage battery packs. Much like purpose-built light-duty electric vehicles, placing the high voltage battery packs under the body increase vehicle safety (located outside of the passenger cabin and below the side impact zone), improves the ride and handling (centering mass between the axles and low to the ground), and optimize the use of space around the vehicle (allowing for a rear window and a clean, simple powertrain design).

Description	Energy Storage (kWh)	Charging Strategy	Design Operating Profile (hours)
40' Bus Catalyst E2 Max	440	60 kW charger In-Depot (Plug-In)	Up to 24

Orlando Utilities Commission (OUC) strongly supports the conversation of the public transportation sector from internal combustion engines to electric. They will be supporting the LYNX infrastructure needs with a charging system.

Three Phases of Demonstration for Safety

1. SunTrax, a testing ground for Phase 1, is a long-term partnership between the Florida Department of Transportation, Florida's Turnpike and Florida Polytechnic University and a high-tech hub for the research, development, and testing of emerging transportation technologies related to tolling, intelligent transportation systems and other advanced transportation concepts. Construction on the oval track is scheduled to be completed in spring 2019 and construction will begin in fall 2018 on the track's 200-acre infield which will include a simulated urban environment complete with buildings, pedestrians and more for automated and connected vehicle testing.
2. LYNX will move the vehicle a demonstration of typical revenue service on its existing LYMMO Bus Rapid Transit service, locally known as LYMMO. Initial testing will occur without passengers to ensure that the technology works in the real-world transit lanes. It will then move into a demonstration of the technology in a typical revenue service upon successful completion of testing.
3. A LYNX bus operator or staff member will be present onboard during operations to ensure all systems operate as designed, and to assist or take control should issues occur. LYNX and UCF will analyze the data during this operational period to identify how the electric vehicle performs in relation to the existing vehicles powered by Compressed Natural Gas, how the automation performs as designed and identification of parameters and potential causes when human intervention is required, and gather information from users on their interactions with the technology and recommendations for additional development

Data for Safety Analysis and Rulemaking

EasyMile collects thousands of data points by fusing and interpreting data from the sensors. This data is collected and can be presented in numerous forms to allow for analysis. This data can be generated daily for reports on Key Performance Indicators (KPIs) and also provided real time feeds through our APIs. For this demonstration the following data points will be provided digitally to allow for a thorough analysis of the performance of the vehicle:

- Real Time Position: latitude (radian WGS84) / longitude (radian WGS84) / theta (radian)
    - Speed (m/s)
    - Average
- Top Speed
- Battery level (%)
- External/Internal temperatures (°C)
- Doors: open/closed
- Vehicle Activity
- # of Ramp Deployments
- Percentage of time in Autonomous Mode Versus Manual
- Percentage of time availability
- Schedule Adherence
    - Vehicle Pullout
    - On time Performance by Stop
- Passenger Counts (insert Partner APC)
- Number of uses of vehicle accessories
    - Wipers
    - Bells/Horns
    - Cameras

In addition, the software will be collecting some key metrics to provide a better risk analysis of the vehicle performance. The technology is premised on two major practices of Localization and Navigation while ensuring obstacle detection and avoidance.

A disengagement is considered “deactivation of the autonomous mode when a failure of the autonomous technology is detected or when the safe operation of the vehicle requires that the autonomous vehicle test driver disengage the autonomous mode and take immediate manual control of the vehicle” (California Department of Motor Vehicles definition).

EasyMile and Proterra are able to collect this data both digitally and through reports provided by LYNX, and will be able to provide information on the following:

- The total number of disengagements
- Circumstances or testing conditions
- Location
- Expected cause of the disengagement
- Total number of miles between disengagements

Some examples of potential causes for disengagements could be:

- Unexpected environmental changes
- Loss of Localization, causing a proper safety stop
- Poor driving road user
- Pedestrian not paying attention

- Unwanted movement of the vehicle causing safety system to stop vehicle
- System detects potential software malfunction
- System detects potential hardware Malfunction
- Obstacle that cannot be circumvented
- Passenger discomfort requesting a stop

Analyzing frequency and the cause of disengagements provides the best metric on how the autonomous technology is performing. The data from this metric will be key to identify risks, opportunities, and insights to advance rulemaking in parallel with the evolution of AV system capabilities including:

- Optimum speeds for AV's that provide the highest level of accuracy in obstacle detection
- Optimum speeds for speed limits on other road users
- Optimum management of AV and other non-AV buses operating on the same route (bus bunching, headway management, On-time performance, etc.)
- Education of for pedestrians along AV Routes
- Initial environmental conditions, such as warm sunny climates, and evolving into rain and snowier areas
- Passenger behaviors that affect performance of the AV
- Parking rules along AV routes
- Infrastructure improvements to support better localization for AVs
- Introduction of connected corridors to provide better information for AV's

Data Storage and Analytics

SunStore serves as the backbone of the region's Transportation Systems Management & Operations (TSM&O) efforts. Through SunStore, this area and this region are *Connection Ready* and ready to support the ADS demonstration. SunStore access is provided by the FDOT without cost to the project.

The data described above will be employed by UCF data analytics team members to draw further insights on the ADS performance in terms of meeting ridership needs and safety. Specifically, the data generated will be analyzed using state of the art statistical and machine learning methods to offer performance evaluation metrics for proposed system as well as future research efforts. A brief description of the performance metrics is provided below:

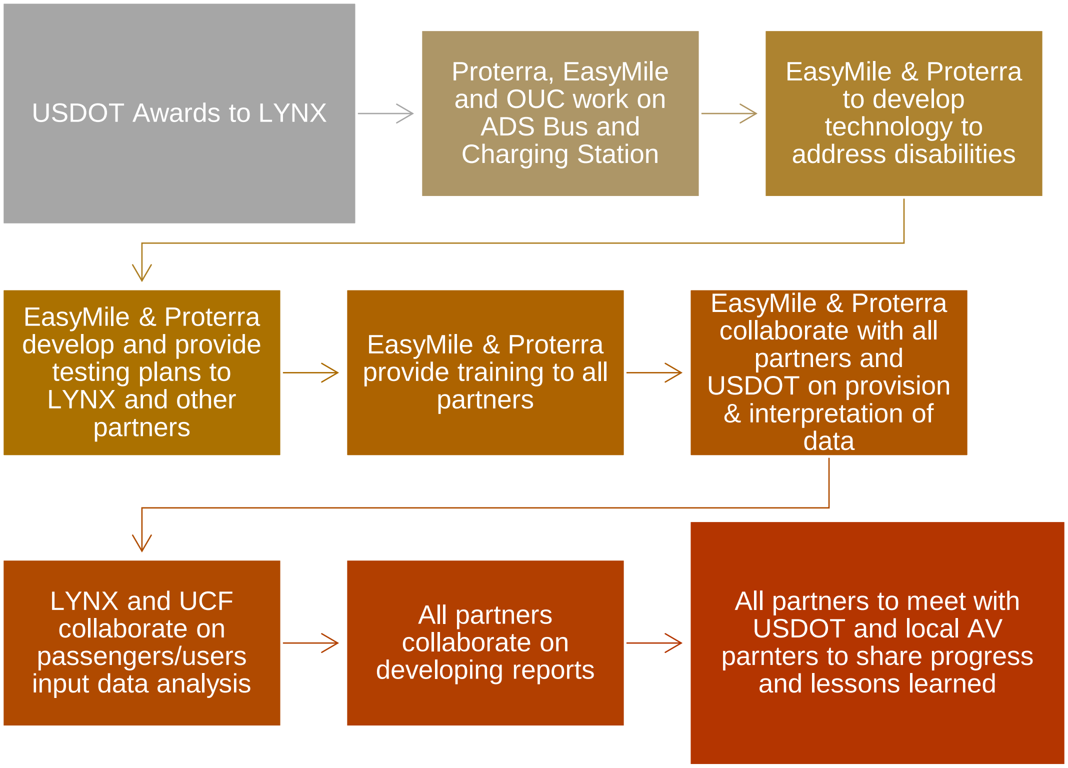
- *Modeling the number and probability of disengagements:* An important part of analyzing the safety performance is evaluating the occurrence and count of disengagements. The research team will develop an econometric model to identify the various factors affecting these events. For example, specific roadway conditions (such as grade), temporal conditions (such as rain and nighttime) and user factors (such as older individual or distracted driver) that might affect disengagements. Understanding these events would enable the research team to provide advance warnings to the operator of a potential event and provide additional time to ensure safe operation. The modeling framework would follow a negative binomial based regression model for number of disengagements and a binary logit model structure for probability of disengagement at an event level.

- *Comparing the performance of ADS infrastructure to existing infrastructure:* A major impetus for employing ADS infrastructure is to enhance the overall performance and safety of the service currently offered by LYNX. To conduct a comprehensive evaluation, the research team will compile data on current ridership, boarding and alighting times, challenges with boarding and alighting for disabled individuals (including measuring time to board and alight), run times of the bus with particular emphasis on times in the presence and absence of disabled individuals. Overall, by measuring these data prior to ADS installation a benchmark for manual infrastructure will be established. After adding ADS infrastructure, the same metrics will be recompiled to compare performance across two systems. The comprehensive analysis will offer clear guidance on the value offered by the ADS infrastructure under consideration providing valuable lessons for future installations. The comparison will include multivariate model developments drawing on approaches from various fields such as statistics, econometrics and machine learning.

Data Sharing Agreement

LYNX and its partners hereby confirm our agreement to negotiate and sign a mutually agreeable data sharing agreement with USDOT as a requirement for the award. LYNX has in place a Data Sharing Agreement signed with the Orlando Utilities Commission in 2018.

Collaboration



The success of this project will be based on the collaboration of each partner. That is the reason why every partner on this project has an important role as described below:

- Easymile and Proterra collaborate on development of automated 40' bus; collaborate with OUC on charging infrastructure.
- Easymile and Proterra provide overview of technology development of disability access for visual impairment, hearing impairment, mobility impairment, disadvantaged population (low income) and non-English proficiency; LYNX will provide input.
- Easymile and Proterra develop and provide testing plans to LYNX, UCF, City of Orlando and OUC.
- Easymile and Proterra provide training to LYNX, UCF, City of Orlando and OUC for operation, maintenance and integration.
- Easymile and Proterra collaborate with LYNX, UCF, FDOT and USDOT on provision and interpretation of data.
- LYNX and UCF collaborate on analysis of data and input from passengers/users
- All partners collaborate on developing reports on considerations in the design of automation systems for fixed route buses, incorporation of disability access into automation, lessons learned, and recommendations for further research and development.
- All partners are willing to meet with USDOT and with local AV partners (FDOT, Central Florida AV Partnership, UCF and Florida Polytechnic University, City of

Orlando, MetroPlan Orlando) to share progress and lessons learned and to gain input.

Focus Areas

Significant Public Benefits
Automated vehicle technology by EasyMile has been developed and demonstrated in smaller scale vehicle with capacities up to about 12 passengers. Most of these demonstrations do not involve revenue service but are on limited segments of roadways with limited interaction with vehicles and pedestrians. This project intends to move automated vehicle technology to a full size 40 foot transit bus with a demonstration of the technology in a typical revenue service on the LYNX bus rapid transit service, known as LYMMO. This service operates in downtown Orlando and will involve dedicated lanes that have adjacent and crossing pedestrian traffic, interaction with transit specific traffic signals, and interaction with other vehicles including buses without automation controlled by bus drivers, private vehicles in adjacent lanes at intersections and that enter the bus lanes without authorization, and bicycles that can cross or enter the lanes at any time from sidewalks and adjacent streets.

This project will also develop prototype automation systems that take into consideration the needs of individuals with impairment and disabilities. The project team intends to ensure that any automation that reduces or removes the need for a vehicle driver does not unintentionally create a barrier to persons with impairments or disabilities by the remove of removing assistance provided by the vehicle driver.

Addressing Market Failure and Other Compelling Public Needs
EasyMile has not been able to begin a project in the U.S due to the high cost and complexity of integration with an FMVSS compliant vehicle. Building on a vehicle specifically designed for autonomy requires significant less investment but would not comply with FMVSS thus rendering it not commercially viable or scalable. Also, the demand for 40' bus AV's has not been established to approve the cost of research, components, and validation as a high priority for manufacturers.

Economic Vitality

The Proterra Catalyst 40' bus is 100% Buy America compliant, has over 70% domestic production of American sub-components in 34 states and is assembled in the US.

Phase 2 Demonstration is the downtown urban core, the historic and cultural heart of Orlando, with 74,000 workers, 16,910 residents within a one-mile radius of downtown, and over 11 million square feet of office spaces. With the region's first Sunrail commuter system and expansions of the downtown LYMMO, Orlando joined the Energy Secure Cities Coalition (ESCC) as its 10th American City.

Central Florida is advancing several intelligent transportation system technologies aimed at enhancing pedestrian safety and easing congestion, funded by an $11.9 million grant from the Federal Highway Administration. Plans call for applying the technology to the development of Creative Village, where UCF / Valencia downtown campus will open in 2019, adjacent to LYNX Central Station and is served by the LYMMO BRT.

LYNX partnered with the City of Orlando consortium in the USDOT's Smart City Challenge Project application. While not USDOT funded, the City continues to pursue its Smart Orlando project.

In related work, LYNX has developed the Autonomous Vehicle Mobility Initiative (AVMI) with the specific objective of providing the Orlando metropolitan region and in partnership with the City of Orlando and METROPLAN Orlando, with research, planning, design and implementation support of AVs in urban transit utilizing Electric Buses.

A LYNX EV/AV initiative is planned to coincide with service needs driven by the opening of the UCF / Valencia College campus and Creative Village developments in 2019. When complete, this sustainable neighborhood development will represent a diverse and dynamic mix of uses including up to 1,200,000 square feet of office/creative space, 750,000 square feet of higher education space, 1,500 residential units, 1,500 student housing beds, 150,000 square feet of retail/commercial space and 225 hotel rooms. At build-out, Creative Village encompasses well over $1 billion in new development.

Complexity of Technology

The technology proposed to be used for this demonstration was effectively proven on the EZ10 shuttle platform of EasyMile which is a *Level 4* according to the SAE definition of Driving Automation Systems for On-Road Motor Vehicles - J3016_201806. A Level 4 system is an Automated Driving System (ADS) that can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances. The EZ10 is preprogrammed by EasyMile engineers or certified partners to run on predefined routes or network of routes, under certain circumstances. Adapting the technology to a 40-foot electric bus with the same effectiveness and safeness is one of the major goals of this project.

Diversity of Projects

Being able to have a mass transportation vehicle that accurately detect, recognize, anticipate and respond to the movements of all transportation system passengers could be the breaking point to develop safer transportation across the Nation. It is essential that the deployment of technology does not cause public transit services to become less accessible to any individual already using the service or who might be prevented from using the service. Conversely, the deployment of technology should consider the needs of all passengers and not just accommodate but improve the access and ease of use of the services.

Transportation-challenged Populations

Drivers of public transit vehicles currently provide assistance to individuals, including individuals with disabilities that enable them to use the services. Some are obvious while others are just as important but are more subtle.

Autonomy presents numerous advantages to mobility, but also needs to consider accessibility for all. During the scope of this project, a safety operator will be on board at all times thus providing comparable support to a bus driver today. However, it is still important to design features that support a completely autonomous ridership. There are a number of areas that we will attempt to address within this project:

- External Communication Tools. *Objective: Provide individuals with visual impairments multiple options to track and board the vehicle.* Today AV technology available is similar to an automated train at the airport. We are able to provide audio announcements for every movement of the train, including arrivals, departures, door location and next stop. In addition, we can explore adding in text & mobile applications that provide the same information for the rider.

- Rider Interaction Systems. *Objective: To allow the rider to send a communication to the bus or call center about a request for assistance.* An autonomous vehicle needs to be able to vary the time at station to ensure all passengers have ample time to board a vehicle. Our technology can adapt based on the request from the passenger if notified. We will explore developing both physical notification tools at the stop as well as phone and mobile applications that provide the rider this option. By notifying the vehicle of the extra assistance required, it can remain at the stop until directed by the passenger to leave, again through a physical button or phone.

There is more development around automated wheelchair restraint systems that can be explored during the scope of this project.

- Visual Impairment – Individuals with visual impairment need to be able to understand how to access and utilize the transit system without relying on the assistance of others, especially in an automated environment designed to not have a human driver. The individual must be able to determine when a vehicle arrives, that the vehicle is a transit vehicle and not another vehicle stopping at or near the stop. The service or route being provided by that vehicle must be easy to identify and understand. The individual must be able to determine the location of the doors to board the vehicle and whether the doors are opened or closed. If the individual is required to take an action to open the doors on an automated vehicle, such as pushing a button, the individual must be provided information on what action is required, where the interface is located, and how it works. Next the individual with a visual impairment must understand what is expected of them once they board the vehicle. If they are requested to interact with the vehicle to close the door, they must understand the action requested, where the interface is located, and how to use it. The individual must understand if they are to locate a seat and if so where it is located, or if they are expected to use an interface to identify their intended destination including the location of and function of the interface. It is also necessary for the individual with a visual impairment to understand if a fare is required to be paid, how much the fare is, and how they pay and confirm the payment has been made. The operation of the vehicle must be understood by the person with a visual impairment, so they understand the progress and the completion of their trip, without the requirement of assistance from others. If the vehicle is not moving after the individual has taken their seat, the individual must be able to understand if it is waiting for a red light, is on a timed departure or waiting for another individual with a trip reservation, or is waiting because they did not complete one of the boarding procedures and therefore have another step to complete in the automated boarding process. Arrival at the desired destination needs to be clear to the individual with a visual impairment in a manner that does not single them out in a manner not done to other individuals. For example, the vehicle cannot call them out by name and announce their destination, reducing their privacy when not done for the other passengers. The individual must be able to understand when the vehicle has arrived, fully stopped, and that the doors are opened and it is safe to exit. If the passenger is expected to interact with the vehicle to open the doors, it must be made clear that the vehicle is ready for the doors to be opened, where the interface is located and how it works, and if the individual is expected to interact after exiting to complete the exiting process and close the door. Additionally, as the technology allows a more customer-responsive service and possible dynamic routing, the individual with an impairment will need to know where they are located in relation to their intended destination. Is the door to the office directly ahead, the next building to the left, or located on the other side of the street behind them? Most of these functions are currently handled through interaction with a vehicle driver. Operation of vehicles without a human presence should include automation to make these interactions as seamless as possible, ideally minimizing the need for physical interaction with the vehicle as much as possible and requiring a little instruction as possible. When audible queues are used, they must be clearly understood and not lost in the background noise, must be presented in all languages used by the transit agency for communications with customers, and must be unexpected and potentially missed.

- Hearing Impairment – Some solutions for visual impairment can use audible messages, but it must be understood that these solutions cannot be used exclusively as they could marginalize individuals with hearing impairment. All user interfaces must be designed to operate in a manner that does not exclusively require eye sight, does not require hearing ability, and that does not require the ability to read. Ideally interfaces will have multiple means of interaction, each of which provides the same level of interaction for all individuals.
- Mobility Impairment – Some individuals with a mobility impairment may be able to access and utilize a driverless automated vehicle without assistance, but may require additional time in boarding, fare payment, seat selection, and exiting at the end of the trip. Automated vehicles need to be able to react and provide this added time as needed to ensure the individual has had enough time to complete each step in the boarding and alighting process. These individuals may be more vulnerable at greater risk for injury should the vehicle start to move before they are securely seated or the doors prematurely close. Individuals with mobility impairments who use mobility aids such as wheelchairs or walkers require additional assistance to board, ride in, and exit from transit vehicles. Transit agencies attempt to make as many transit stops accessible as possible, but cannot provide level boarding without gaps at all stops. This necessitates kneeling buses

that reduce the effort to step into and out of a vehicle and ramps or lifts for individuals that cannot otherwise step into the vehicle or are using a mobility aid. When the vehicle arrives at the stop, a driverless automated vehicle needs to have a means of determining whether it is required to kneel or to deploy a lift. The technology solution should rely on as little interaction as possible by the passenger to ensure that the majority of passengers are able to use the interface regardless of constraints caused by a disability. The technology must be able to identify a location in which the door is not blocked by an obstruction such as a bench, pole, mailbox or mud puddle. It also must ensure that if a lift or ramp is deployed, it can be deployed without obstructions and deploys to an unobstructed level firm and stable surface measuring a minimum of 48 inches parallel and 30 inches perpendicular to the lift or ramp as required by the Americans with Disabilities Act. Deploying a ramp or a lift to an inaccessible location such as a drainage swale, a non-stable surface, or an area obstructed by street furniture results in the vehicle and associated trip being inaccessible. If a ramp or lift was deployed, the technology must be able to determine when it is no longer needed and is safe to retract. Consideration must be given to whether the person using the mobility aid needs extra time to board and whether there are more than one person needing the lift or ramp, so it doesn’t retract prematurely. Once the individual is onboard, the individual needs a dedicated and secure location to place their mobility aid. It cannot be blocking an aisle or require the individual to exit and reenter the vehicle to allow others onboard to enter and exit. The mobility aid will require a form of automated securement to prevent it from moving while the vehicle is in motion to prevent damage to the device and possible injury to the others onboard. Consideration also needs to be given to a solution that works whether the mobility aid user continues to use the mobility aid during their travel or is able to self-transfer to a seat on the vehicle. If the individual continues to use the mobility aid, then they need to be offered the ability to be secured by a seatbelt while using the device as users of wheelchairs and similar aids tend to be more vulnerable during vehicle maneuvers and stops. Each of these functions need to be able to be performed successfully in a manner that does not require intervention of others as they are currently performed by the driver of a transit vehicle.

- Senior Citizens and Visitors – Transit agencies provide service to senior citizens and to visitors who are unfamiliar with the service. These individuals need to be taken into consideration while providing solutions for individuals with disabilities as the solutions provided would also provide benefit to them. Both would benefit from solutions that are intuitive, do not require reading of small print or an unfamiliar language, and provide assistance when visually seeing the surrounding do not help due to unfamiliarity with the area. Both senior citizens and visitors not familiar with a service may require additional time to board and interact with the systems on an automated vehicle and may need the vehicle to kneel or the deployment of a lift or ramp to assist with limited mobility or with luggage or carrying of packages.

Prototypes

The EZ Catalyst will be meet FMVSS standards for a 40’ passenger vehicle as required to operate on public roads.

Requirements

This project intends to move the vehicles with automation technology into revenue service on its existing LYMMO Bus Rapid Transit service, locally known as LYMMO. Initial testing will occur without passengers to ensure that the technology works in the real-world transit lanes. It will then move into revenue service upon successful completion of testing.

A LYNX bus operator or staff member will be present onboard during operations to ensure all systems operate as designed, and to assist or take control should issues occur. LYNX and UCF will analyze the data during this operational period to identify how the electric vehicle performs in relation to the existing vehicles powered by Compressed Natural Gas, how the automation performs as designed and identification of parameters and potential causes when human intervention is required, and gather information from users on their interactions with the technology and recommendations for additional development.

EasyMile will provide a real time API, updating every ½ second to the SunStore system with all data points described above.

The demonstration vehicle will be equipped with numerous large digital interfaces on the vehicle displaying route information and information with riders. EasyMile and Proterra will develop these interfaces to ensure that individuals with visual impairment and mobility impairment have alternate interfaces that still provide full functionality and information to the passenger. All interfaces will be developed as vehicle-based solutions that do not require passenger to bring technology to be able to access the vehicle, such as a passenger provided mobile device. This will ensure that individuals are not excluded from using vehicle due to an impairment, disability, or requirement of the passenger to have a mobile device or other technology.

Digital interfaces will also be supplied to ensure that passengers in specialized seating areas such as wheelchair securement locations have the same information and access to functionality as customers using other interfaces.

LYNX will install its Computer Aided Dispatch (CAD) and Automated Vehicle Location (AVL) equipment for operation of the vehicle. Easymile and Proterra will work with TripSpark, the existing CAD/AVL vendor, to develop any required integration to the equipment due to automation to ensure that the system logs on and advances from trip to trip throughout the day. This integration will ensure that project vehicle is fully integrated into the provision of LYNX services and is included in existing real-time information systems provided to all passengers.

Automating a Proterra bus does not require any exemption from FVMSS. Proterra and EasyMile anticipate no federal exemptions being required based on the regulations in place today.

Approach

We have developed a 5-phase approach to the development of the EZ Catalyst:

1. Specifications – The main objective of this phase is to clearly define what will be the behaviors of the vehicle within its environment and how the operators will be able to interact with it. This work consists in discussing and specifying what are the needs for the application and the main performances that should be reached and verified at the end of the project. Several documents will be the outputs of this phase, they will be proposed by the EasyMile team and then discussed and validated together with the Proterra Team.
   - Customer requirements: it corresponds to a scope of work for the project. It is a list of high-level requirements needed for the application (from the language definition to the definition of what are the obstacles that the vehicle should be able to avoid)
   - Missions description: it is a description of what are the uses cases that the vehicle will meet during its service and of what will be its expected behaviors in each situation (from the external signalization to the strategy for braking and traction)
   - Interfaces definitions: this document will give an overview of all the interfaces that will be accessible for the different operators (for examples: operation dashboard on a touchscreen panel, manual buttons and commands, distant site control center, mobile application)
   - Application specific requirements: if needed, we will include a project dedicated document to define some specific features that should be included

   Some other documents will also be adapted for the project and shared during this phase. They will give some information and requirements to the Proterra team in order for them to understand and prepare the integration of EasyMile system inside the platform:
   - Drive by wire requirements: expected performances to be reach by the actuators
   - Control command requirements: expected control loop performances for the traction, braking and steering systems
   - Mechanical & electrical requirements: this document will give the list of the components to embed, their main characteristics and their positioning constraints

2. Safety – The aim of this phase is to adapt the safety concepts that has been defined for our previous vehicles in order to:
   - fulfill the requirements of the applicable standards for the project,
   - take into account the specificities of the situations encountered by the vehicle

- include the vehicle architecture and actuators capacities

This work will consist in assessing all the possible risks that are linked to the application, defining the corresponding safety levels and explaining how the autonomous vehicle will bring an answer to all these dangerous situations. One of the main outputs of this phase will be the definition of a safe architecture for the embedded components, the actuators and the link between the different ECU and systems. This architecture definition will a key element for the following integration work. Several documents will be the deliverables of this phase:

- Safety requirements: it will consist in a safety plan definition, a HARA (Hazard analysis And Risk Assessment) and the safety goals definition (PL / SIL)
- Functional safety concept: it corresponds to the definition of the functional safety requirements based on the architecture (allocation of safety level on the components of architecture) it is done jointly with the technical safety concept work. It defines what component is answering to each safety situations
- Technical safety concept: it defines the technical specification (HW & SW), the final architecture and gives the redundancy analysis.

During this phase, the EasyMile team will be supported by LYNX expert to ensure the objectivity of the analysis. Safety goals are a collaboration between Proterra vehicle components and the EasyMile system (example: a certain level of safety will be required for the braking actuator).

3. Integration – During this phase, the work consists in integrating all the EasyMile components inside the Proterra platform. Three main periods will be followed during this phase:
   - Design period:
     - Components integration design: starting from the mechanical & electrical requirements, the architecture and the redundancy analysis, some discussions will be done to define precisely where and how the components will be embedded
     - Core Control design: this work will consist in designing precisely all the schematics for the decided architecture. It will also include the state machine definition for the low-level software of the EasyMile system
   - Physical integration:
     - Integration (components mounting + wiring) is to be done by Proterra team, as they know better their own vehicle
     - EasyMile will be responsible for the procurement, the preparation of the components and their delivery to the partner
     - Verification of the control loop performances: this operation is important in order to be sure that the vehicle will be able to follow correctly the EasyMile system commands. It is a key point that will trigger or not the reception of the vehicle, it will also allow to verify that both systems are able to communicate. For the Proterra Catalyst, EasyMile will be responsible for the DBW HW and SW integration.
     - reception of the equipped vehicle: if the control loop performances are reached and the systems are able to communicate together, the EasyMile team will come to the partner premises to make a complete

verification of the vehicle integration. If the verification is validated, the vehicle will then be delivered to EasyMile Francazal tests site.

The control loop performances will be validated with EasyMile team based on a tests report that should be delivered by the partner team. Some complementary tests could be carried out together if some points are doubtful.

The reception of the vehicle will be validated by both teams through a test reports delivered by the EasyMile team.

The price for the transit of the vehicle is not included in the project, it should be discussed.

4. Robotics – This phase consists in adapting all the robotics software for the new vehicle. This work will be done first on a simulation and will then be carried out on the real equipped vehicle. The following tasks will be followed:
   - Test bench and simulation building: some preliminary measures will be done on the vehicle to understand the dynamics of its behaviors. It will allow the EasyMile team to produce a representative simulation of the vehicle.
   - Bring Up and first demonstration: when receiving the vehicle, the first task to be carried out will be to create the very first software image that will allow the vehicle to run in autonomous mode (without specific adaptation for the vehicle). This work will end with a first demonstration of the vehicle running in autonomous mode in South Carolina at Proterra's facility
   - Navigation, Detection and Safety ECU software adaptations: the classical EasyMile software modules will be modified to take into account the real dynamics of the vehicle. The safety software should also be adapted to follow the safety requirements that has been defined in the safety phase.
   - Mission and interfaces adaptations: the behaviors of the vehicle during the service will be modified to fulfill exactly to will be defined in the mission description document written during the specification phase. In the same way the operator interfaces (embedded display and site Control Center) will also be modified following the interfaces description document.
   - Software release: this task corresponds to the finalization of all the software of the system. At the end of a robustness tests period, an EasyMile internal document is edited and the system is ready to be deployed on a first pilot site.

   At this point a test report for the navigation, detection, mission and interface features will be available. A coverage matrix is annexed to the tests report in order to ensure that all the global requirements are correctly fulfilled.

5. Pilot Deployment – When the complete system is released in the Robotics phase, it is then possible to deploy the service onto the Orange Line for initial test runs. The deployment will be carried out by the EasyMile & Proterra team, the service will be operated by trained LYNX team members. The successive steps for deploying efficiently the service will be:
   - The site analysis and preparation: This operation consists in coming to the selected customer site, analyzing all the potential risks due to the environment and other site users. A document named SAR (site assessment report) is

edited to explain all the risks and the eventual mitigations needed to be installed in order to ensure the safety on site. These mitigations should be carried out by the customer with the project team support

- The setup on site: During this task, the vehicle is delivered on the customer site, the EasyMile engineers create the cartography and the paths of the site. A progressive ramp up of the service is done in order to reach the aimed level of speed. The service will be deployed with the grant of the site safety authority. Once the vehicle is deployed the operators are trained and able to follow the service efficiently.
- The support during the service: During the 5 months of the service, the EasyMile engineers still remain available to support the operators in case of a remaining bug or if something happens and a modification of the site cartography is needed.