U.S. DEPARTMENT OF TRANSPORTATION
AUTOMATED DRIVING SYSTEM DEMONSTRATION GRANTS
"Los Angeles Autonomous Electric Transit Bus"

Project Name	Los Angeles Autonomous Electric Transit Bus
Eligible Entity Appling to Receive Federal Funding (Prime Applicants' Legal Name and Address)	City of Los Angeles Department of Transportation 100 S. Main Street, 10th Floor Los Angeles, California 90012
Point of Contact	Martha Melendez D'Andrea Supervising Transportation Planner II Martha.dandrea@lacity.org (213) 928-9769
Proposed Location	City of Los Angeles, California Westwood
Proposed Technologies for the Demonstration	Autonomous built electric transit bus Enhanced ADS for transit bus V2I Transit Priority System (Signal DSRC) V2X Intersection Sensors 4/5G Communication Data Lake Data Platform
Proposed duration of the Demonstration	Four years
Federal Funding Amount Requested	$ 9,999,904
Non-Federal Cost Share Amount Proposed	$ 9,483,068
Total Project Cost (Federal Share + Non-Federal Cost Share	$ 19,482, 972

LADOT TRANSIT

City of Los Angeles Department of Transportation – Transit (LADOT Transit)

CITY OF LOS ANGELES
CALIFORNIA

Seleta J. Reynolds
GENERAL MANAGER

ERIC GARCETTI
MAYOR

DEPARTMENT OF TRANSPORTATION
100 South Main Street, 10th Floor
Los Angeles, California 90012
(213) 972-8470
FAX (213) 972-8410

March 19, 2019

Secretary Elaine L. Chao
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 201590

Subject: **AUTOMATED DRIVING SYSTEM DEMONSTRATION GRANTS (693JJ319NF00001)**

Dear Secretary Chao:

The City of Los Angeles Department of Transportation (LADOT) is pleased to submit an application to the U.S. Department of Transportation (USDOT) "Automated Driving system Demonstration Grants" solicitation. LADOT believes that an autonomous future will provide safety benefits for pedestrians, bicyclists, new mobility users, and motorists and is submitting the Los Angeles Autonomous Transit Bus project grant application.

The City of Los Angeles, like many large cities, faces many transportation challenges. In response, our policymakers established several transportation policy goals: increasing mobility (Mobility Plan); keeping pedestrians, bicyclists, and motorists safe (Vision Zero); and improving air quality by decreasing congestion (Sustainability pLAn). With the rapid rise of technology in transportation, LADOT will need to deploy and support an ecosystem or mobility marketplace of advanced technologies to meet these policy objectives and create truly great streets for all Angelenos.

LADOT is preparing for these advanced technologies with the implementation of its Transportation Technology Strategy, *Urban Mobility in the Digital Age,* which details a framework for evaluating and deploying advanced technologies to ensure they are meeting our goals that provide benefits to our residents. The fifth and final platform strategy is to *Prepare for an automated future*. The USDOT "Automated Driving System Demonstration Grants" solicitation will provide LADOT and its partners the ability to demonstrate an autonomous transit bus on both a closed and on-street application in the Westwood neighborhood of Los Angeles.

We have carefully selected partners who with their expertise will be able to deliver an autonomous bus and provide key data to USDOT to evaluate the project and inform rulemaking.

The goals of the demonstration include improving the safety of transit buses for riders and the bus's interaction with other modes and pedestrians; collection and analyzation of data to verify the ADS is operating and using the data to make the optimal decisions; and collaborating with various partners. Ultimately, our autonomous transit bus deployment will aid transit riders who are predominately from disadvantaged communities and include transit-dependent students, seniors, and wheelchair users.

I am pleased to submit this application and look forward to working with USDOT, if selected, to deliver the project.

Sincerely,

Seleta J. Reynolds
General Manager

c: Corinne Ralph
Martha D'Andrea

TABLE OF CONTENTS

PART 1: Project Narrative and Technical Approach

EXECUTIVE SUMMARY

The City of Los Angeles, like many large cities, faces many transportation challenges. In response, our policymakers have established several transportation policy goals: increasing mobility (Mobility Plan); keeping pedestrians, bicyclists, and motorists safe (Vision Zero); and, improving air quality by decreasing congestion (Sustainability pLAn). With the rapid rise of technology in transportation, the City of Los Angeles Department of Transportation (LADOT) will need to deploy and support an ecosystem or mobility marketplace of advanced technologies to meet these policy objectives and create truly great streets for all Angelenos.

LADOT is preparing for these advanced technologies with the creation of the Urban Mobility in the Digital Age that details a framework for evaluating and deploying advanced technologies to ensure they are meeting our goals that provide benefits to our residents. The fifth and final platform strategy is to Prepare for an automated future. LADOT believes that an autonomous future will provide safety benefits for pedestrians, bicyclists, new mobility users, and motorists. The U.S. Department of Transportation (USDOT) "Automated Driving System Demonstration Grants" solicitation will provide LADOT and its partners the ability to demonstrate an autonomous transit bus on both a closed and on-street applications through the Los Angeles Autonomous Transit Bus project grant application.

LADOT and its partners see the benefits of an autonomous transit buses which due to market failure has lagged behind the single automobile and truck autonomous deployments. One of the main reasons is the market size of transit buses less than .02% of automobiles. In addition, transit buses are operated by public transit agencies which do not have access to research and development resources. This demonstration will build on an existing autonomous driving system (ADS), install the ADS on a transit bus specifically built to incorporate the sensors and dashboard, feed additional data from traffic signals and intersections to develop an autonomous L3/4 transit bus that can be safely operated on-street. We have carefully selected partners who with their expertise will be able to deliver an autonomous bus and provide key data to USDOT to evaluate the project and inform rulemaking.

Vison

LADOT and its partners will build on current ADS technology by adding additional data sources to build safer transit buses. Currently, the autonomous driving systems are centered on automobiles and low speed shuttles. This grant will fund research and deployment of an ADS transit bus that will safely operate on-street. There are several case studies that this grant will solve such as cross traffic blind spots, left turns, transit priority and emergency responders. The data from all devices will be made available on a Data Lake (City Data Insights) for easy access. Finding solutions to our case studies will provide valuable information that can be shared for other autonomous driving systems thereby increasing the safety of ADS. Finally, there will be several research projects that are included.

Goals

The goals of the demonstration include improving safety of transit buses for riders and the bus's interaction with other modes and pedestrians; collecting and analyzation of data to verify the ADS is operating and using the data to make the optimal decisions; and collaborating with various partners. Ultimately our autonomous transit bus deployment will aid transit riders who are predominately from disadvantaged communities and include transit dependent students, seniors and wheelchair users.

Objectives

The USDOT Automated Driving System Demonstration Grants (ADSDG) solicitation allows LADOT and its partners to deploy Level 3/4 autonomous transit buses in two operating environments. Phase 1 will deploy an autonomous transit bus within the University of California Los Angeles (UCLA) campus. Phase 2 will deploy autonomous transit buses expanding the Phase 1 route to run on-street in Westwood Village. Autonomous driving systems require data to operate safely. This project would build on current operational ADS by adding additional sensors to provide additional data to allow the ADS to make complex maneuvers such as left turns.

Current V2I and ADS

USDOT awarded LADOT a 2016 Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant that included a V2I transit priority system. The communication between our traffic signals and our transit buses would provide green light assist. The project completed design and is now being deployed. The transit priority system that uses DSRC to communicate with the bus will be installed in the Proterra buses for this project thereby leveraging previously funded USDOT autonomous features.

Team Partners

A project of this scope requires partnerships that includes private companies, research institutions and the city. Each has products and proprietary systems that must be integrated to fulfill the demonstration.

ROLE/TECHNICAL CAPACITY	
LADOT	**OPERATIONS, TRAFFIC SIGNALS, GRANTS MANAGEMENT, TECHNOLOGY**

LADOT Transit Operations

Operations of Transit Bus – LADOT Transit plays a key role in mobility within the City of Los Angeles. LADOT Transit operates a family of public transit services including DASH (local fixed route), Commuter Express (AM/PM peck), and Cityride (senior and disabled paratransit services). LADOT operates 31 DASH routes and 14 Commuter Express using a fleet of 360 buses. LADOT contracts with private service contractors to operate service.

LADOT Traffic Signals

The Automated Traffic Surveillance and Control (ATSAC) System is the centralized traffic control center for the City of Los Angeles. The system provides real-time monitoring and adjustment of signal timing for nearly 4,600 signalized intersections citywide.

LADOT Grants

LADOT Grant Management – LADOT is an FTA grantee and LADOT FTA grant staff will take the lead on compliance and reporting. LADOT has been an FTA grantee since 2001 and is currently managing over $52M in FTA grants funds including a Low or No Emission grant for electric buses and electric infrastructure. LADOT has the technical experience in deploying demonstration grants with either FHWA or FTA.

LADOT Technology

Our LADOT Technology group plans and deploys projects that advance the Department's Transportation 2.0 Strategic Plan. The Plan envisions an electric, shared, active, and autonomous mobility system that tackles congestion, enables economic development, provides equitable services, and saves lives.

ROLE/TECHNICAL CAPACITY	
UCLA Transportation SMERC UCLA Smart Grid Energy Research Center	**OPERATION OF BUS AND RESEARCH**

Operation of Transit Bus

UCLA Transportation Operations operates 18 buses on a fixed route within the UCLA campus.

UCLA Research

UCLA Smart Grid Energy Research Center, will lead the research team to look at strategies that are most beneficial in encouraging customer acceptance of autonomous bus operations and do these strategies vary based on socio-demographic identification. A substantial portion of the customers using the pilot autonomous on-street bus service and interacting with it would be members of the UCLA community (faculty, staff, students) or patients of UCLA Health. This would allow for greater ease in communicating with stakeholders about their changing perceptions about autonomous bus service over the course of the project. Stakeholders from various socio-demographic groups could be engaged about their sense of safety as bus riders, drivers of automobiles, scooter operators, pedestrians, or bicyclists. Outreach strategies to stakeholders, including signage, electronic communication, or even special signalization on buses, could be employed to determine potential impacts on acceptance of the new technology being tested.

ROLE/TECHNICAL CAPACITY	
PROTERRA	**TRANSIT BUSES MANUFACTURER**

Proterra is 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. Proterra has sold more than 400 vehicles to 38 different municipal, university, and commercial transit agencies in 20 states across the USA. Proterra's configurable EV platform, battery, and charging options make its buses well suited for a wide range of transit routes. With unmatched durability and energy efficiency based on Altoona and testing, Proterra products are proudly designed, engineered and manufactured in America, with offices in Silicon Valley, South Carolina, and Los Angeles. For more information, visit: http://www.proterra.com.

Well in advance of the new Buy America requirements in the FAST Act, Proterra's buses already contain greater than 70% domestic content. And since our vehicles are proudly built in South Carolina and Los Angeles, partnering with Proterra provides transit agencies with the confidence of knowing that the FY 2020 Buy America requirements have already been demonstrated.

ROLE/TECHNICAL CAPACITY

AUTOMATED DRIVING SYSTEM DEVELOPED FOR TRANSIT BUS

Founded in 2014, EasyMile is one of the leading companies that specializes in autonomous vehicle technology and has a global reach with headquarters in Toulouse (France) and regional offices in Denver (USA), Berlin (Germany), Melbourne (Australia) and Singapore. With more than 100 highly-skilled and passionate employees with expertise in robotics, computer vision and vehicle dynamics, EasyMile supplies smart mobility solutions and autonomous technologies powering driverless vehicles – developing software that enables automation for various transportation platforms, a powerful in-house fleet management solution for autonomous vehicles, and providing smart mobility solutions for transporting passengers or logistics on private sites, urban, suburban or rural areas in diverse environments.

To meet this challenge EasyMile developed the EZ10, a 100% electrical shared driverless shuttle. The EZ10 is the most deployed autonomous shuttle in the world. Since 2015, EasyMile has successfully deployed our vehicles over 250 times in over 23 countries on 4 different continents. Thanks to our "Safety First" approach, we are proud to mention there have been no accidents involving our vehicle in operations. Our R&D, testing and deployment processes with a focus on risk assessment and management make our vehicle the safest on the market.

ROLE/TECHNICAL CAPACITY

DATA MANAGEMENT FOR SAFETY FINAL REPORT

The RAND Corporation is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous. RAND is nonprofit, nonpartisan, and committed to the public interest.

RAND's research and analysis address issues that impact people around the world, including security, health, education, sustainability, growth, and development. As a nonpartisan organization, RAND is widely respected for operating independent of political and commercial pressures.

RAND researchers have advanced degrees in more than 350 disciplines and apply state-of-the-art methods to address a broader range of issues than any other research organization. The RAND Corporation is a global organization. U.S. locations include Santa Monica, California, the home of its headquarters campus and nearby the project site.

ROLE/TECHNICAL CAPACITY	
verizon	**4/5G COMMUNICATIONS, INTERSECTION SENSORS, CITY DATA PLATFORM**

5G Communication Network

Verizon is the first telecommunications provider to deploy 5G in Los Angeles and is expanding rapidly nationwide. Combined with the ability to provide computational resources at the edge of the network through our Multi-Access Edge Compute (MEC), this next generation wireless network promises to deliver on the the bandwidth and latency requirements of V2X and Connected and Autonomous Vehicles (CAV).

C-V2X

Verizon's Cellular Vehicle to Everything Solution, powered by our MEC, will support broadcast messages to vehicles, pedestrians and bicycles utilizing sophisticated computer vision on smart cameras and information from the traffic cabinet. This data complements the information available to CAVs, especially in non-line of sight environments.

City Data Insights

Verizon's City Data Insights will offer a cloud-based central data repository as a managed service, which will serve as the Enterprise Data Management platform for the Demonstration project. Data will be collected from test vehicles deployed at demonstration project locations, the C-V2X Solution and other sensor data made available by LADOT and municipalities in Los Angeles. Verizon will store and analyze the data and provide access to the USDOT, LADOT project teams and other user groups based on pre-defined policies.

ROLE/TECHNICAL CAPACITY	
CALSTART	**CALSTART**

Project Manager and Final Report

As a technology-neutral consortium and nonprofit CALSTART has experience working with multiple stakeholders to deliver demonstration grants. For example, CALSTART and LADOT Transit partnered in a California Transportation Commission grant that demonstrated a new-to-market 33' electric transit bus. The project took three years to complete and was a success. CALSTART will provide project management and technical services as outlined in the Letter of Commitment. CALSTART has 25 years of experience in managing diverse transportation technology teams and projects. CALSTART has successfully managed more than $400 million in federal, state and regional grants and incentives including the CLEAN Truck demonstration program for the California Energy Commission (CEC), the California Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) for the California Air Resources Board, the EV Smart project for the Department of Energy, and U.S. Departments of Defense, Commerce, Transportation and others.

Issues and Challenges

- A transit bus is longer and heavier than an automobile. The length of the bus will require additional sensors. The weight of the bus will make the need to avoid accidents paramount.
- Intersection blind spots. The need for additional sensors to transmit data to allow for on-street operation.
- Left turns again require additional sensors to transmit intersection data for safe maneuvers.
- Emergency responders will need to communicate with the ADS to initiate safe response.
- Traffic signal (Transit priority system) data will need to be incorporated.

Geographic Area of Demonstration

The project will be deployed at the UCLA campus and Westwood Village located in Los Angeles California. This is an urban setting that includes many obstacles for operating an autonomous bus in an on-street setting. If this project is successful in this complex urban area than it can be transferred to operate in areas that are just as complex or less complex.

For the Los Angeles 2028 Olympics, UCLA campus facilities will be used during the games. Athletes will be using UCLA facilities such as Pauley Pavilion and the Los Angeles Tennis Center. Olympic athletes and support personnel will live in the UCLA's student housing during the 2018 Games and train at Drake Stadium. Athletes will use the Ronald Regain UCLA medical center for medical services.In the Los Angeles 1984 Olympics, LADOT showcased its cutting-edge technology traffic control system - ATSAC. In this same spirit, Los Angeles would like to again introduce to the world to a new cutting-edge technology, autonomous buses, that will improve safety.

FIG 1 UCLA CAMPUS ROUTE (PHASE1)

FIG 2 UCLA AND WESTWOOD VILLAGE ROUTE (PHASE 2)

FIG 3 UCLA AND WESTWOOD VILLAGE ROUTE

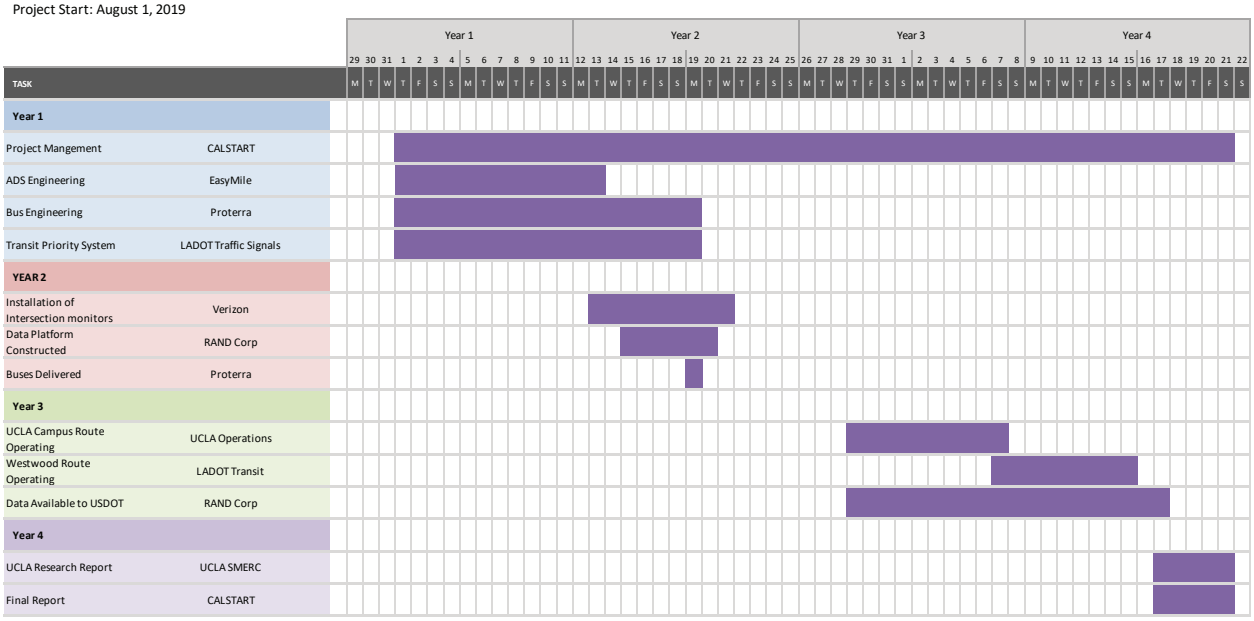
Period of Performance

The project would take four years to implement with the on-street demonstration scheduled for the later part of the third year.

Los Angeles Autonomous Electric Transit Bus

LADOT

Project Start: August 1, 2019



GOALS

The proposed Los Angeles Autonomous Electric Transit Bus Project will provide research and development of an ADS for electric transit buses. The Los Angeles Area, especially the westside experiences significant congestion. With congestion comes poor air quality. Los Angeles is looking to entice more single occupant drivers into using transit to improve congestion and air quality. But transit buses like other vehicles using the street are prone to traffic incidents. The results of a bus incident are exacerbated due to the weight of the bus. In the recently published Federal Transit Administration (FTA) Bus Safety Data Report 2008-2016 shows that in 2016 National Transit Database (NTD) bus transit operators reported 15,185 events that resulted in 117 fatalities and 17,492 injuries. As shown below the majority of the fatalities were from the pedestrians, bicyclists, and occupants of other vehicles These statistics demonstrate that if you are hit by a bus the results are deadly and riding on a bus may result in injuries.

Fatalities and Injuries by Person Type

- Fatalities: 24% of transit fatalities in the analysis period were transit customers and workers.
- Fatalities: 76% of transit fatalities were pedestrians, bicyclists, and occupants of other vehicles.
- Injuries: 84% of transit injuries in the analysis period were transit customers and workers.
- Injuries: 16% of reportable injuries were pedestrians, bicyclists, and occupants of other vehicles.

Looking at the collision trends from 2008 to 2016, 96% of collision fatalities resulted from collisions between transit buses and persons or non-transit vehicles and 88% of the collision injuries were between transit vehicles and non-transit vehicles.

Collision Types Resulting in Fatalities and Injuries
Collision Injuries, 2008-2016

- 96% of collision fatalities resulted from collisions between transit vehicles and either persons or non-transit vehicles.
- A large majority (88%) of collision injuries resulted from collisions between transit vehicles and non-transit vehicles.

Safety is one of LADOT's Goals as a department. LADOT's Vision Zero initiative looks at reducing pedestrian fatalities by reducing speed and installing infrastructure to make walking and bicycling safer. As a transit agency LADOT was one of the first agencies to install Mobileye Shield Plus to help bus drivers detect pedestrians and bicyclist in their blind spots. This was the first level autonomous feature installed on our buses. This grant solicitation will allow LADOT and USDOT's shared goal of improving Safety to reduce the number of bus related fatalities and injuries. Added sensors, communication with traffic signals and operating algorithms create a data rich environment that can better inform safer bus operations.

For LADOT, an autonomous bus will improve and may eliminate fatalities and injuries. This safety concern is experienced by every transit agency in the United States.

DATA FOR SAFETY ANALYSIS AND RULEMAKING

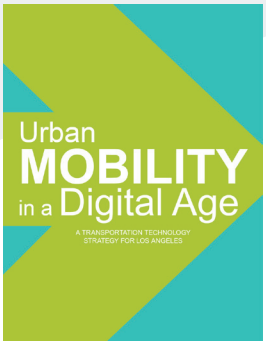
Autonomous driving systems rely on data for informed decisions. EasyMile's ADS will pull from a variety of data sources. It is important to note that the jump from a L1/2 autonomous vehicle to a transit bus on a complex on-street road requires more data sources that can be relayed quickly. This project will incorporate the following data sets:

PARTNER	DATA
LADOT Traffic Signals	Provide DSRC data to EasyMile for Transit Priority System (V2I)
Verizon	Intersection Monitors (V2X), 4/5G
Los Angeles Fire Department	Transponders

The enhanced intersection sensors are essential to deploying an autonomous bus on-street. These data sets are important for our project as well as for other autonomous vehicles and curb management.

LADOT and its partners understand the data requirement expressed by USDOT in this solicitation and is ready to provide data in near real-time either by streaming or periodic batch updates. RAND Corporation will be receiving the data and packaging the data for USDOT. RAND will provide data management and will evaluate the data to determine if there are any issues with the ADS and its operation.

COLLABORATION



LADOT is an early adopter of advanced technologies to improve the lives of our residents. With the Urban Mobility in the Digital Age, LADOT has a platform for integrating new technologies. LADOT is also unique in that it is a traditional city department of transportation with jurisdiction over traffic signals, streets and curb space as well as a transit agency that operates over 350 buses. To implement this project, LADOT will collaborate with EasyMile, Proterra, UCLA, RAND Corp, CALSTART and the Los Angeles Autonomous Group.

- EasyMile will provide an ADS that will integrate new data sources to provide an autonomous transit bus that can operate on-street.
- Proterra will provide specially built electric transit buses that can host the ADS.
- LADOT will provide grant management, traffic signal and transit operations. LADOT is committed to creating a safe city that includes autonomous modes.
- UCLA is working across academic departments including engineering and public policy on autonomous vehicles and safety. UCLA will operate the autonomous transit bus for the first phase. UCLA will provide best practices and new trends.
- Los Angeles Autonomous Group
- RAND will define the evaluation framework and metrics through consultation with Team members. For the vehicle- and roadside infrastructure-generated data, how might these be combined into usable metrics, and how can we establish thresholds for what would be considered “safe”.
- CALSTART will provide Project Management. As a leader in emerging technologies, CALSTART has experience in managing demonstration grants at the state and federal level.
- The Los Angeles Autonomous Group, that is comprised of transportation professionals from the State of California (Caltrans), the Southern California Association of Governments (SCAG), Los Angeles Metro, and City of Los Angeles will provide guidance during the implementation of the project

FOCUS AREAS

Significant Public Benefits: The Los Angeles Electric Transit Bus project will provide ADS to public transit riders and the general public who interact with buses on a daily basis. The ADS will make transit riders, automobiles, pedestrians, bicyclists, scooters and motorcycle riders safer. As noted above, the bus driver currently has difficulty in assessing conditions occurring around the bus. ADS will allow the bus to process more data to make safer driving decisions. According to the American Public Transportation Association (APTA) 2017 Public Transportation Fact Book there are over 65,000 buses in operation in the United States with 99% wheelchair accessible. Many transit agencies, including LADOT Transit, are adding L1 safety technologies (Mobileye Shield +) to transit buses but there are other autonomous features that are not available to transit buses. This grant solicitation will fund autonomous technologies to make a safer transit

bus. With over 5 billion bus riders a year, this technology would provide benefits to not only bus riders but others who interact with buses on a daily basis.

Addressing Market Failure: With the USDOT ADSDG funding, the Los Angeles Autonomous Electric Transit Bus project invests in safer public transit buses. All public transit is operated by states, cities or townships and is limited to federal and local funding for capital and operations. Currently, there are no private ADS that is being developed for transit buses. The market for autonomous buses is low with only 65,000 buses nationwide. In contrast, there are over 263 million automobiles, a much bigger market. The current ADS deployment is shaped by automobile companies who want to sell their autos to rideshare services or subscription services to eliminate the driver thus saving money. It is not LADOT's intent to eliminate the driver in a public transit bus but rather to improve safety to our riders and our residents.

Economic Vitality: The ADSDG grant funding would directly benefit US ADS companies and bus manufacturers. EasyMile, the ADS supplier, has a regional office in Denver, Colorado where the enhanced ADS will be developed for this project. The bus manufacturer, Proterra, is 100% compliant with Buy America with over 70% domestic production of American subcomponents in 34 states. Public transit contributes to economic development by connecting workers with employment especially low-income workers.

Complexity of Technology: The ADS Transit bus project will build on current V2I ACTMTD project that connects LADOT traffic signals with LADOT Transit buses. Additional sensors at intersections will allow for additional data for the EasyMile ADS to operate with greater confidence. This is a new product for EasyMile which is successfully demonstrating low speed autonomous shuttles. Transit buses are higher capacity buses and this project will be demonstrated in a campus and on-street. Attachment A details EasyMile's and Verizon's technologies included in this project and describes each firms products.

Transportation-challenged Populations: Transit buses unlike other transportation modes are designed to improve mobility for transportation-challenged populations. For many wheelchair users, public transit allows them to live a healthy and productive life. The Autonomous Transit bus will make travel safer for seniors and wheelchair users either on the bus or getting ready to board the bus.

REQUIREMENTS

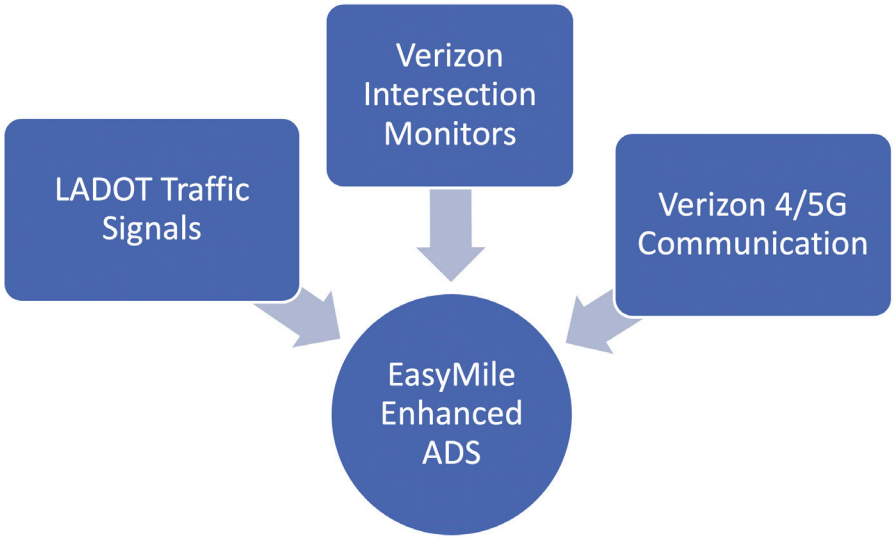
The proposed Los Angeles Autonomous Electric Transit Bus project complies with the USDOT's requirements for this grant solicitation as demonstrated below.

- The project focuses on research and development of automation by further developing EasyMile's ADS to meet the rigorous safety requirements of an on-street project using an electric transit bus. While EasyMile is successfully operating a slow speed shuttle in Las Vegas, Nevada, this project would follow the natural progression to more complex operating environments. First, the project will operate with additional signal traffic data in a campus setting. Second, the project will include signal traffic data and intersection sensor data to provide sufficient data for the transit bus to not only operate in a straight line but also make right and left turns safely. The transit bus will reach Level 3/4 automation.
- The demonstration will operate a Level 3/4 automation on the UCLA campus and Westwood Village.

- Data from EasyMile, LADOT traffic signals, Proterra buses, intersection sensors, and emergency transponders will be collected by EasyMile to operate the ADS with the data collected using a Verizon Data Lake. The data will be made available to USDOT and the public for the minimum five years after the award performance period expires. RAND Corp will also be reviewing the data and in consultation with USDOT, will produce findings on the added safety to ADS by adding these extra data sources.
- The Proterra buses will be outfitted with voice annunciation system that will inform riders of the approaching stop and passengers waiting for the bus that the bus has arrived.
- The additional traffic signal data, intersection sensor data, and a fast communication platform are critical pieces in the development of an ADS to operate on-street. Difficult left turns need this additional data to make the movement safely. This project will be able to be replicated throughout the United States.

TECHNICAL APPROACH

The Autonomous Transit Bus project builds on EasyMile's ADS (see attachment A for details of ADS system) to provide the necessary data to enhance the EasyMile ADS to make the complex decisions of on-street traffic maneuvers. The Autonomous Transit Bus project brings together strategic partners to demonstrate the next stage of ADS.



There are three case studies this project will address to deliver an on-street ADS (see Attachment A).

- Modify electric transit bus to incorporate ADS including additional sensors.
- Traffic Signal Transit Priority System through DSRC communication with ADS
- Intersection sensors to avert blind spots in data communicated to the ADS through 4/5G communication
- Emergency Responders transponders that alert autonomous bus to follow emergency vehicle protocol.

Obstacles

Bus (None)

The project will use an Altoona tested Proterra battery-electric bus that meets the FMVSS standards. The Proterra 35' bus also meets FTA Buy America requirements.

Sensors

The project will use Verizon intersection sensors that will transmit data to the ADS to provide cross traffic information currently unavailable to autonomous vehicles. This information is critical for this project including the speed of the data transmission.

If the project is selected, Verizon will determine if there is a need for a Buy America waiver on any of its equipment.

Transit Priority System

LADOT's traffic signal V2I technology was part of a USDOT ATCMTD grant and at that time the equipment was only available from one firm. Since that time there are several firms that have entered the marketplace. LADOT is proposing to use the existing equipment supplier since the engineering was already performed.

Commitment to provide data

This is the single most important requirement of this grant. USDOT is looking for safety data to help inform rule making. The Los Angeles Autonomous Electric Transit Bus project choose partners who are experts in the field of collecting, sharing and analyzing data.

Verizon City Data Insights provides a robust data collection platform that is powered by 4/5G communication network. The collection and use of the data from traffic signals, intersection monitors and the bus's sensors are key to a safe autonomous demonstration. Verizon is responsible for the Data Management Plan and execution.

RAND Corp will provide a data analytics for the various data sources. RAND is a leader in research and will provide data analysis to aid USDOT in their safety rule making.

CALSTART provides specific project management that will orchestrate the different project partners to provide the data USDOT requires.

Risk Identification, Mitigation, and Management

The Project will be managed by CALSTART who has experience with managing demonstration projects at the state and federal level. The partners will initially convene monthly to discuss milestones, project schedule and project expenditures.

CALSTART and LADOT will keep the USDOT appraised of progress. Any risk, mitigation and management will be addressed y CALSTART and project partners. Any issues will be brought to the group in a timely manner to discuss solutions that will move the project forward.

Project Cost and Cost Share Management

LADOT is responsible for the grant budget including requests to USDOT for reimbursement and tracking local match. Partners will submit expenses and corresponding local match to LADOT.

ATTACHMENT A

Easy Mile (CONFIDENTIAL)

The EasyMile system that will be installed on a 35 foot Proterra bus will be adapted from the proven EasyMile Technology. The ADS demonstration will allow this technology to be developed and safely deployed. We include EasyMile's product information to show its product is a mature autonomous driving system and lends itself to enhancements such as applying its ADS to transit buses.

The current EasyMile shuttles are not that different from a human being. It requires the same information to reach its destination:

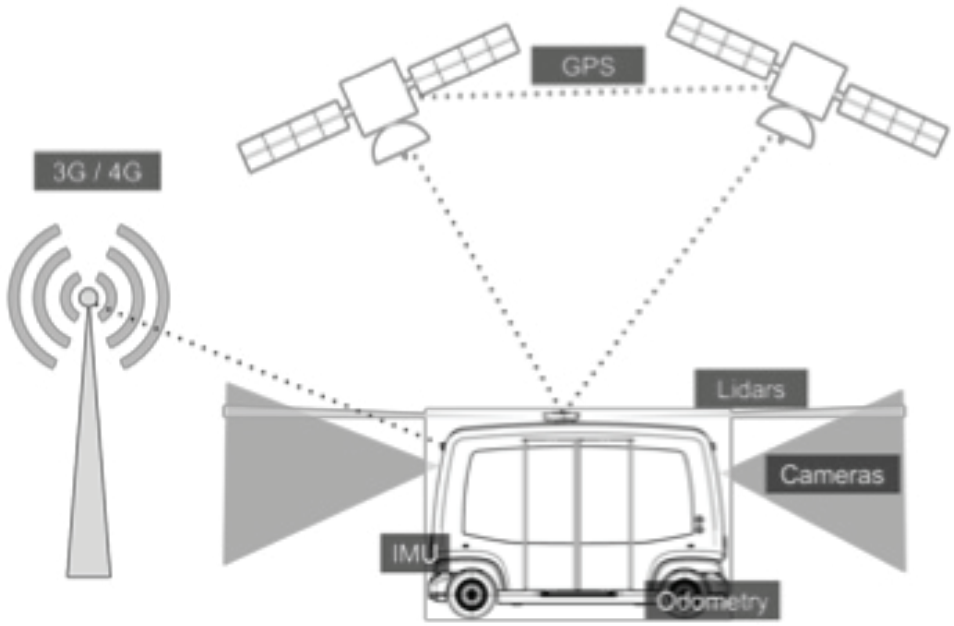
- Where is it located?
- Where is it going and how can it get there?
- What are the environmental conditions and how should it adapt its behavior?

To do so, all current EasyMile's vehicles, including the EZ10 are 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 human need not pay attention in those circumstances.

The EZ10 is preprogrammed by EasyMile engineers or certified partners to run on predefined routes or network of routes, under certain circumstances.

EASYMILE SENSOR STACK

The software has been designed to know the vehicle's exact position with centimeter-level precision, at all times. By merging the types of data below, the software can obtain this level of precision: Software for the ADS demonstration will be developed to the same standard as the EZ10.



- Laser scanning the environment
- Cameras
- Differential GPS
- Visual location
- Estimation using an Inertial Measurement Unit (IMU)
- Odometry estimation

Each of these safety technologies are described in more detail below.

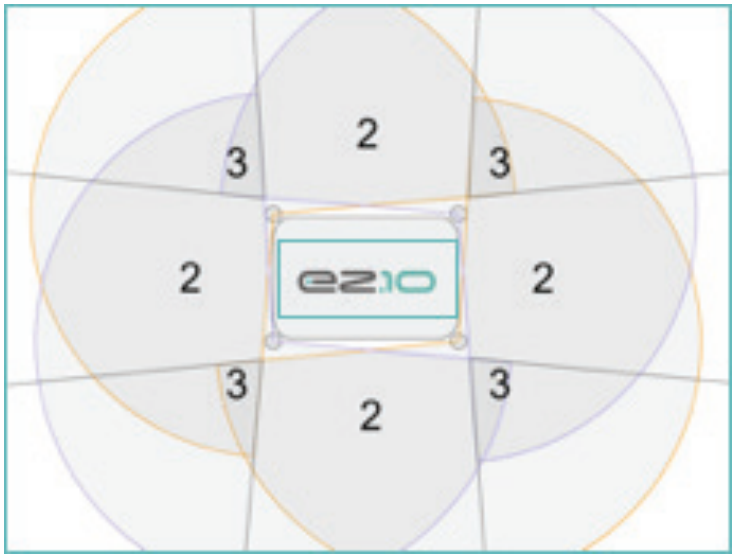
ENVIRONMENTAL LASER SCANNING - LIDARS

The current EZ10 shuttle is equipped with several different LiDars to ensure redundancy in information collection. The Proterra bus built for this demonstration will be built to the same standards whenever possible.

- 4 LMS, also called Safety LiDARs on the EZ10
  - One at each corner of the vehicle
  - Strategically positioned 12in above the ground
  - Single layer LiDAR
  - Range of 130 ft
  - 270° horizontal scanning
  - Used for obstacle detection by high-level software
  - Used for obstacle detection by the Safety Chain
  - Used for navigation by the high-level software

There is currently no certified LiDAR on the market, which is why EasyMile has chosen to include redundant sensor coverage sourced from different suppliers. This architecture mitigates any risk of failure of a single sensor.

The four Lidars, each scanning 270°, located at each corner of the vehicle, offer a 360° redundant perception of the environment. Any obstacle within 130 ft of the EZ10 will be detected by at least 2 to 3 lidars.



- 2 LDRMS, also called Localization LiDARs on the EZ10
  - trategically positioned on the roof of the EZ10 to detect fixed elements in the environment (buildings, statues, tree trunks, signs, streetlights, etc.) without being disturbed by moving elements in the environment that are usually smaller and that will not be in the sensor's field of view (pedestrians, cars, bicycles, etc.)
  - 4 layers
  - Range of 720ft
  - 110° horizontal scanning
  - 3.2° vertical opening
  - Used for navigation by the high-level software

- 2 VLP16, also called 3D LiDARs on the EZ10
  - One at the front and one at the rear of the vehicle (bi-directional vehicle)
  - LiDARs 16 layers
  - Range of 260ft
  - 180° horizontal scanning
  - 32° vertical opening
  - Used for navigation by the high-level software
  - Used for obstacle detection by high-level software

GNSS corrections are received via the 3/4G network, and are determined using a set of SmartNet reference bases. They do not require the installation of an additional reference base dedicated to this project, which are often problematic and vulnerable to cyber attacks.

INERTIAL MEASUREMENT UNIT (IMU)

The EZ10 is equipped with an inertial unit capable of integrating the vehicle's movements (acceleration and angular velocity) to estimate its orientation (roll, pitch and heading angles), linear velocity and position.

ODOMETRIC ESTIMATION

The EZ10 has sensors on the wheels to measure the vehicle's movement. Odometry is based on the measurement of wheel movements to reconstruct the overall movement of the vehicle. Starting from a known initial position and integrating the measured displacements, the current position of the vehicle can be calculated at any time.

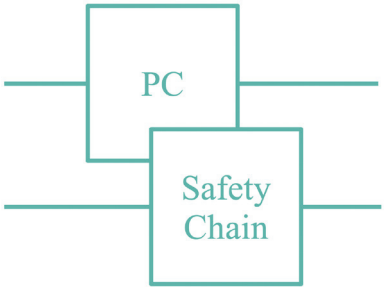
SOFTWARE ARCHITECTURE

INDEPENDENT OBSTACLE DETECTION FUNCTION

The processing power needed to run an autonomous vehicle is huge. There is no certified processing unit with enough computing power to enable obstacle detection functions. Our approach is based on adding an independent safety layer: the Safety Chain. This architecture mitigates the risk of processing unit failure (due to hardware or operating system fault).

By design, the EZ10 is composed of two main levels:

- An industrial-grade computer with a tailor-made version of Linux enabling better control of processing and cyber-security than commercial OS (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 PLC (Programmable Logic Controller) 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 our Safety Chain 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 of Safety Chain, emergency button activation or detected failure of monitored components. This will enable to ensure that vehicle and its passengers are safe.
- Safe Door and Automatic Ramp management (opening and closing) - one of the most critical function in transportation systems because of potential injuries, failures and unavailability.

The PLC outputs are always considered with the highest level of 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.

SUPERVISION - SYSTEM BRAIN

EasyMile has developed EZ Fleet, its own Fleet Management system able to handle a fleet of any type of autonomous vehicles based on real field data from the ongoing projects around the world. The EZ Fleet is the electronic brain of the whole system. It is designed to be flexible and modular, so as to enable different operating scenarios and to adapt to the various needs of our customers.

EASYMILE'S DRIVERLESS SOFTWARE STACK

LOCALIZATION AND NAVIGATION CAPABILITIES & KNOWN ENVIRONMENT AND PRE-PROGRAMMED PATHS

To move autonomously, the vehicle runs along a pre-programmed route designed by a deployment engineer. Thanks to localization techniques, the vehicle knows its position on the route and moves from one station to another following its trajectory.

During deployment, the engineer makes an acquisition by driving in manual mode with the vehicle (trajectory, environment, GPS position, etc.). This acquisition is then cleaned, the trajectories reworked to be comfortable for passengers, and serves as a reference map for the vehicle during operations. This map contains the programmed speed for each road section, the activation of the indicators or bell if necessary, the presence of red lights, traffic signs (Stop, Yield, etc), stations, etc.

DATA FUSION AND INTERPRETATION

The high-level software collects, fuses and interprets data from the above-mentioned sensors.

In particular, a technique called S.L.A.M (Simultaneous Localisation And Mapping) laser, consists in measuring, using laser beams (our LiDARs), the distance from surrounding objects (buildings, trees,...) and thus makes it possible to create a mapping of its environment. This system requires sufficient "hang points" for the laser detectors that are used to locate the vehicle in its environment. The environment around the road planned for the EZ10 in Reno is very rich in "hang points" for LiDAR localization.

The fusion of data from the various sensors ensures redundancy and robustness in the vehicle's localization, with the weak points of one system being compensated by the strong points of the others.

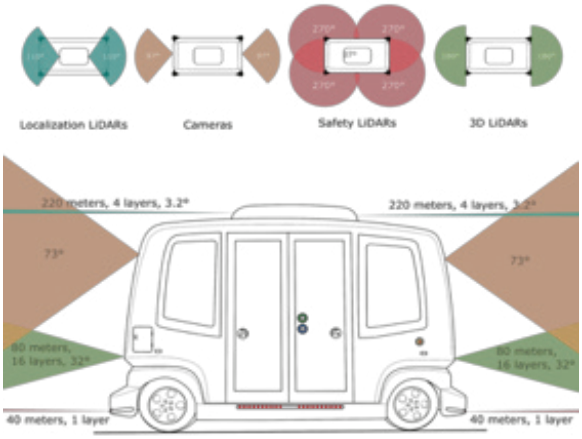
The presence of trees on the route, or indoor traffic are excellent examples of situations where GNSS coverage will be very low or non-existent. The system is then able to detect that the uncertainty related to GNSS information is too high (0 or very few satellites detected when the vehicles normally detect between 10 and 15) and to reject the information from this sensor. The fusion of data from the other sensors is good enough, so the vehicle will continue to run without any problems.

INTERSECTION MANAGEMENT - CONNECTED TRAFFIC LIGHTS

The proposed demonstration will be run on the UNR Living Lab's Virginia Street in Reno. Several types of intersections can be programmed along the EZ10 route, where the vehicle slows down or stops depending on the situation, in order to scan the environment and decide to continue. In all circumstances, the obstacle detection functions described above remain valid.

Intersections with Signage

At a Stop or Yield intersection, EZ10s are able to scan the environment and take the decision to cross the intersection when the area is free.



Pedestrian Crossing

Like Yield intersections, EZ10s are to scan a pedestrian crossing and make sure there is no pedestrian crossing or about to crossing before going through.

Intersections with Traffic Lights - DSRC

Vehicle to infrastructure (V2I) communication is a key component of EasyMile's technology. As shown in the graphic below, the EZ10 can communicate with traffic signals via a communication network (DSRC, ITS-G5, 3G, 4G, or 5G networks) and with other infrastructure (e.g., railroad crossings), as needed. The ultimate goal is to leverage these technologies in order to introduce more complex traffic situations without human intervention.

CAMERAS

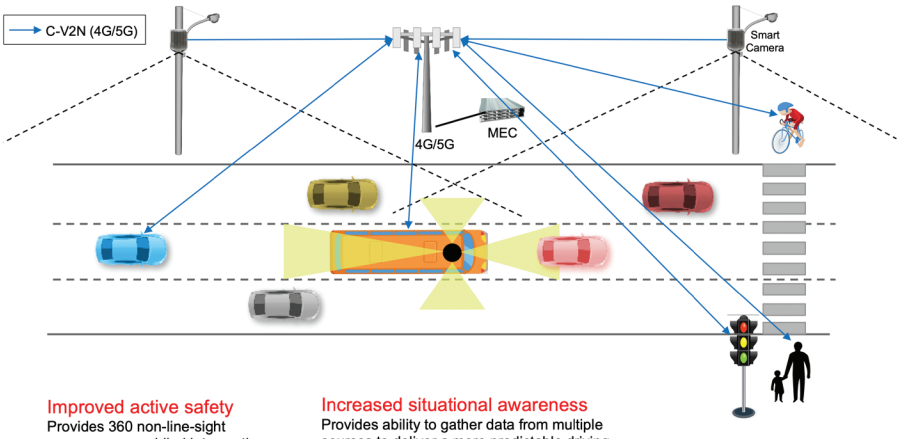
The EZ10 is equipped with indoor and outdoor cameras. EasyMile completes the development and validation of the use of these cameras for navigation and environmental detection.

DIFFERENTIAL GPS

The EZ10 is equipped with a GNSS antenna from the Canadian manufacturer Novatel. This antenna allows the EZ10 to find its way through space thanks to the constellations of GPS, Glonass and Galileo satellites.

EasyMile also uses the services of a GNSS - Real Time Kinematic correction provider referred to as "SmartNet" to refine the vehicle's position, with centimeter accuracy.

V2X is a key technology to complement ADAS



Improved active safety
Provides 360 non-line-sight awareness, e.g. blind intersection, blocked view, emergency stop

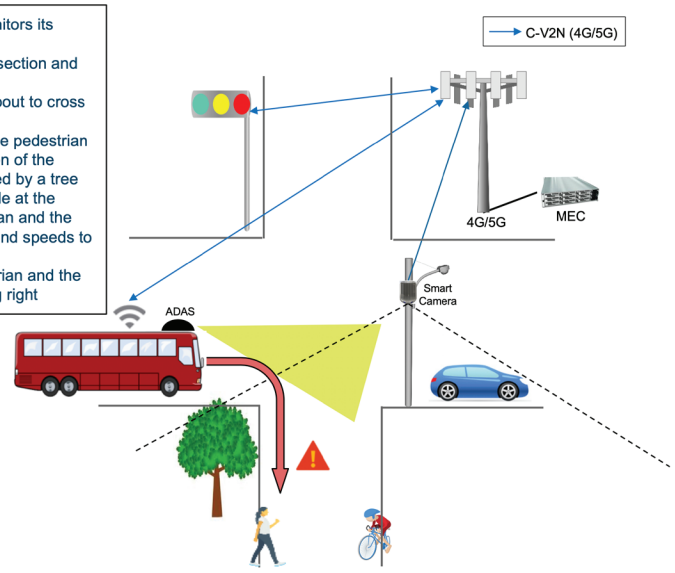
Increased situational awareness
Provides ability to gather data from multiple sources to deliver a more predictable driving experience, e.g. pothole, road hazard, traffic signal

verizon

2

Use Case 1: VRU Alert At A Blind Intersection

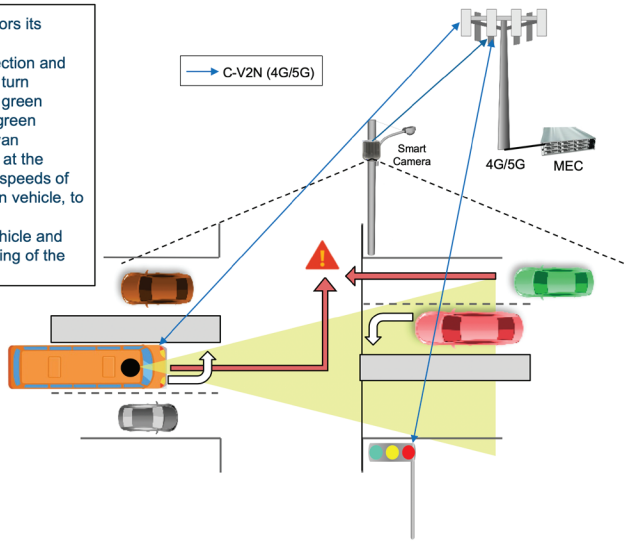
1. The Autonomous Bus (Bus) monitors its surroundings with its own ADAS
2. The Bus is approaching an intersection and about to turn right
3. A pedestrian and a cyclist are about to cross the road
4. The Bus' ADAS cannot detect the pedestrian and the cyclist since the detection of the pedestrian and cyclist are blocked by a tree
5. The Smart Camera on a light pole at the intersection detects the pedestrian and the cyclist and send their locations and speeds to the Bus using C-V2N
6. The Bus is alerted of the pedestrian and the cyclist and slows down in turning right



verizon

Use Case #2: Unprotected Left Turn Warning

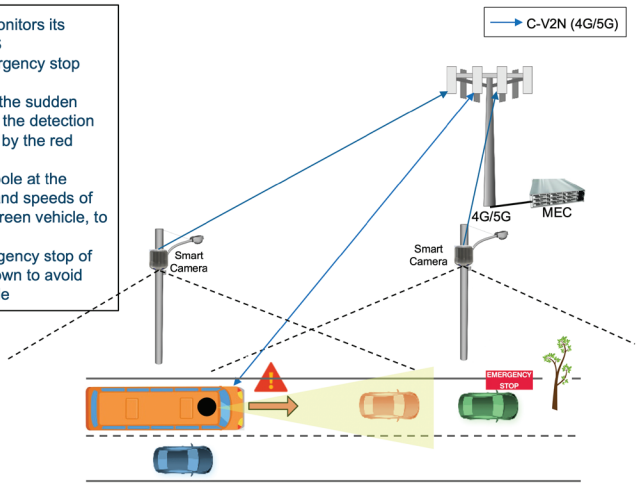
1. The Autonomous Bus (Bus) monitors its surroundings with its own ADAS
2. The Bus is approaching an intersection and about to make an unprotected left turn
3. The Bus' ADAS cannot detect the green vehicle since the detection of the green vehicle is blocked by the red minivan
4. The Smart Camera on a light pole at the intersection detects locations and speeds of all the vehicles, including the green vehicle, to the Bus using C-V2N
5. The Bus is alerted of the green vehicle and delays in turning left until the passing of the green vehicle



verizon

Use Case #3: Emergency Brake Warning

1. The Autonomous Bus (Bus) monitors its surrounding with its own ADAS
2. The green vehicle has an emergency stop due to a fallen tree on the road
3. The Bus' ADAS cannot detect the sudden stop of the green vehicle since the detection of the green vehicle is blocked by the red vehicle
4. The Smart Camera on a light pole at the intersection detects locations and speeds of all the vehicles, including the green vehicle, to the Bus using C-V2N
5. The Bus is alerted of the emergency stop of the green vehicle and slows down to avoid potentially hitting the red vehicle

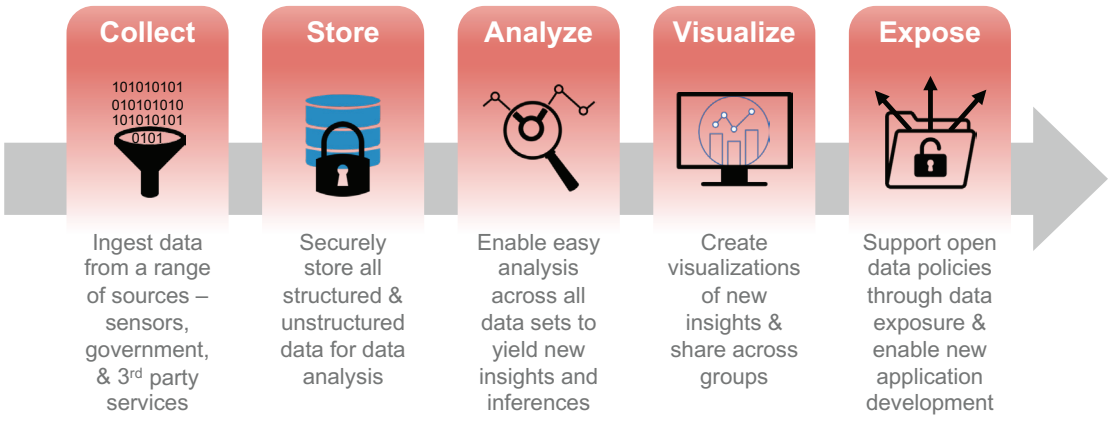


verizon

Verizon City Data Insights (CONFIDENTIAL)

Verizon's data management product and communications.

City Data Insights Platform Requirements…

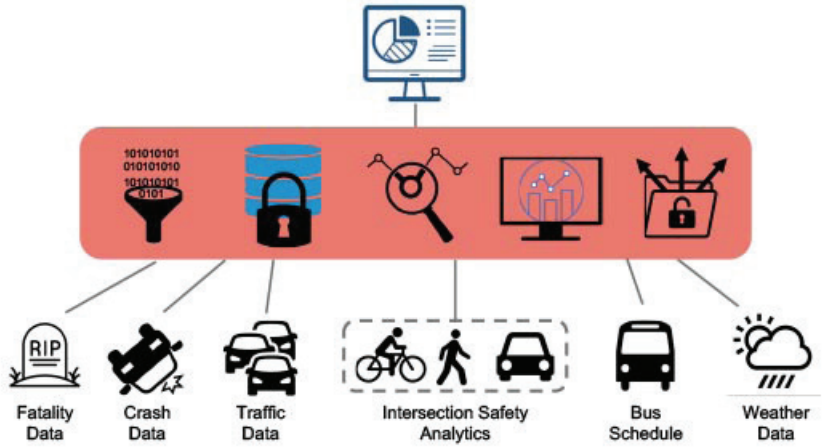


Collect	Store	Analyze	Visualize	Expose
Ingest data from a range of sources – sensors, government, & 3rd party services	Securely store all structured & unstructured data for data analysis	Enable easy analysis across all data sets to yield new insights and inferences	Create visualizations of new insights & share across groups	Support open data policies through data exposure & enable new application development

verizon

2

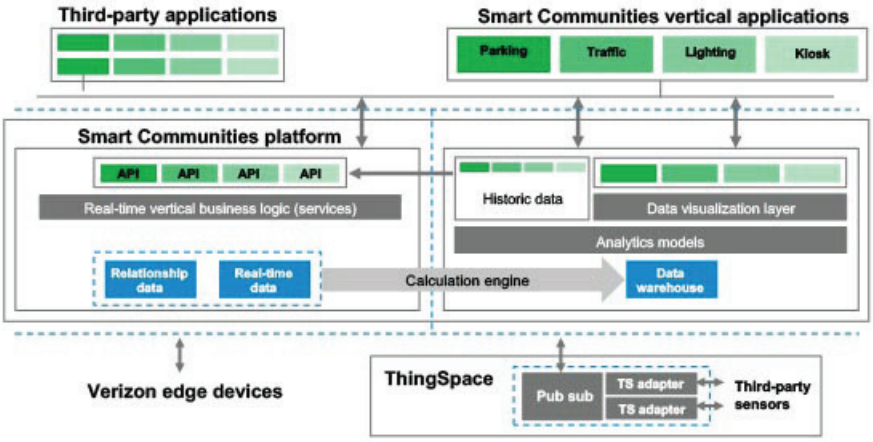
Data Example – Traffic Insights



verizon

5

NetSense: City data platform



verizon

7