AUTOMATED AND CONNECTED VEHICLE INFRASTRUCTURE COOPERATION FOR SAFETY

Automated Driving System Demonstration Grant Submission
Funding Opportunity Number: 693JJ3198NF00001
CFDA Number: 20.200
Highway Research & Development
March 21, 2019

Submitted to:
United States Department of Transportation (USDOT)
Federal Highway Administration (FHWA)
1200 New Jersey Ave, SE;
Washington DC 20590
Attn: Sarah Tarpgaard, HCFA-32

Submitted by:
City of Fremont Public Works
DUNS Number: 0765491040000

Partners:

Fremont Police Department
Fremont Fire Department
Fremont Department of Human Services
Alameda County
Xtelligent
Tesla
Volvo

CITY OF Fremont

Public Works Department
39550 Liberty Street, P.O. Box 5006, Fremont, CA 94537-5006
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March 21, 2019

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

Re: Automated Driving System (ADS) Demonstration Grant # 693JJ319NF00001

Dear Ms. Tarpgaard,

The City of Fremont is pleased to submit this application for U.S. Department of Transportation NOFO 693JJ319NF00001 "Automated Driving System Demonstration Grants." The following pages detail our extensive plan to demonstrate Automated Driving System (ADS) interaction with intelligent, connected road infrastructure to improve safety and reliability of ADS. Our location in the greater San Francisco Bay Area is ideal due to the proximity of several key automated vehicle development companies, a major vehicle manufacturing facility (Tesla) within our borders, and the large number of commuters that pass through daily that can benefit from wide deployment of ADS technology.

Our consortium includes numerous city agencies, including the Public Works Department, Police Department, and Human Services. We have also included iconic companies such as Tesla for AV/CV integration, and Xtelligent for the V2I/I2V connected infrastructure component.

The ADS future is an exciting one, but the gap between real-world readiness and aspiration can be quite different. Our goal and proposal contained herein describes targeted demonstration of real-world interaction of ADS systems and the roadway environment. Fremont recognizes that there are very few L3 and above ADS systems available, and a strong technology demonstration requires high penetration. Therefore we will also augment ADS systems with Connected Vehicles (L2 and below) to simulate higher levels of ADS penetration on the roadway and the safety enhancing effect of routine V2I/I2V communication.

Fremont is fully committed to the successful deployment of ADS and supporting V2I/I2V technologies through this U.S. DOT ADS grant opportunity. We look forward to continued engagement.

Sincerely,

Hans Larsen
Public Works Director
City of Fremont

SUMMARY TABLE

Project Name/Title	Autonomous and Connected Vehicle Infrastructure Cooperation for Safety
Eligible Entity Applying to Receive Federal	City of Fremont, California
Funding (Prime Applicant's Legal Name and Address)	City of Fremont Department of Public Works
Point of Contact (Name/Title; Email; Phone Number)	Sheila Marquises, Senior Transportation Engineer; 510-494-4745; smarquises@fremont.gov
Proposed Location (State(s) and Municipalities) for the Demonstration	Fremont, California
Proposed Technologies for the Demonstration (briefly list)	1. ADS Vehicle to Infrastructure object location reporting for enhanced safety 2. Infrastructure to ADS Vehicle traffic signal status and timing reporting for enhanced reliability of phase detection 3. Traffic signal connected-freight priority over 4g/LTE, around major factory in southern Fremont, CA.
Proposed duration of the Demonstration (period of performance)	36 Months
Federal Funding Amount Requested	$4,740,695
Non-Federal Cost Share Amount Proposed, if applicable	$1,321,869
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$6,062,565

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This Project Narrative will follow the format suggested in the funding notification:

1. EXECUTIVE SUMMARY

a. Vision, goals, and objectives

The City of Fremont Public Works Department (FPWD) proposes to demonstrate the integration of Automated Driving Systems (ADS) with the traffic management system through Vehicle-to-Infrastructure (V2I) technologies for enhanced safety. We've assembled a consortium including automotive, infrastructure, and government partners that are unified in our vision towards a connected and data-enabled ADS future that can genuinely enhance safety and quality of life in Fremont and the Nation. We will provide our own city environment for testing. We specifically intend to demonstrate three features of ADS in order to improve safety in our city:

1) Demonstrate increased safety by incorporating Vehicle-to-Infrastructure (V2I) communication of ADS vehicle location and speed into traffic signal control infrastructure, as well as location of pedestrians, bicyclists and other roadway users;

2) Demonstrate an increase in the reliability of ADS ability to determine traffic signal phase and timing status by incorporating Infrastructure to Vehicle (I2V) communication over 4g/LTE cellular; and

3) Traffic signal infrastructure integration of freight truck real-time location information into signal controls to reduce stops, improve congestion caused by freight, and reduce pollution generated by freight.

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

Our consortium includes the following key partners:

- City of Fremont Department of Public Works will be the lead agency for the project. FPWD is responsible for transportation and transportation infrastructure within the City of Fremont and is well-equipped and experienced to manage and execute the project as the lead.
- City of Fremont Police Department will be providing guidance on critical safety risks and assisting in advising and supervising demonstrations.
- City of Fremont Human Services Department will provide input on how best to deploy ADS technologies to benefit communities that can benefit most from ADS deployment.

- Tesla is a major automotive manufacturer with a manufacturing site in the City of Fremont. It was recognized as one of the leaders in developing automated vehicle technologies and has been working closely with Fremont over many years.
- Xtelligent is a vehicle-to-infrastructure (V2I) and cooperative intelligent transportation system (C-ITS) venture and will be providing technology, engineering, and R&D capability to enable cooperation between ADS and the traffic management system in Fremont.
- Volvo Group is a major automotive OEM with strong ADS focus. It maintains presence across the U.S. and manufactures its vehicles for the American market in the U.S.

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

Fremont is a city of 235,000 people located to the northeast of San Jose, to the south of Oakland, and across the bay from San Francisco. This generates a high amount of commuter through-traffic. Notably, Fremont is also home to the Tesla manufacturing facility with an immense amount of freight trucking. Our city is continuously exploring ways to enhance cooperation with our manufacturing partner, Tesla.

At the same time, Fremont has numerous safety issues around traffic signal intersections that are not readily mitigated with traditional methods of improving safety (e.g. crosswalk paint, pedestrian signals, etc.). We recognize the potential of ADS-equipped vehicles to improve safety in aggregate, but also seek near-term solutions to the problem. Of particular interest to the city is the potential for Vehicle-to-Infrastructure (V2I) and Infrastructure-to-vehicle (I2V) communication to enhance safety.

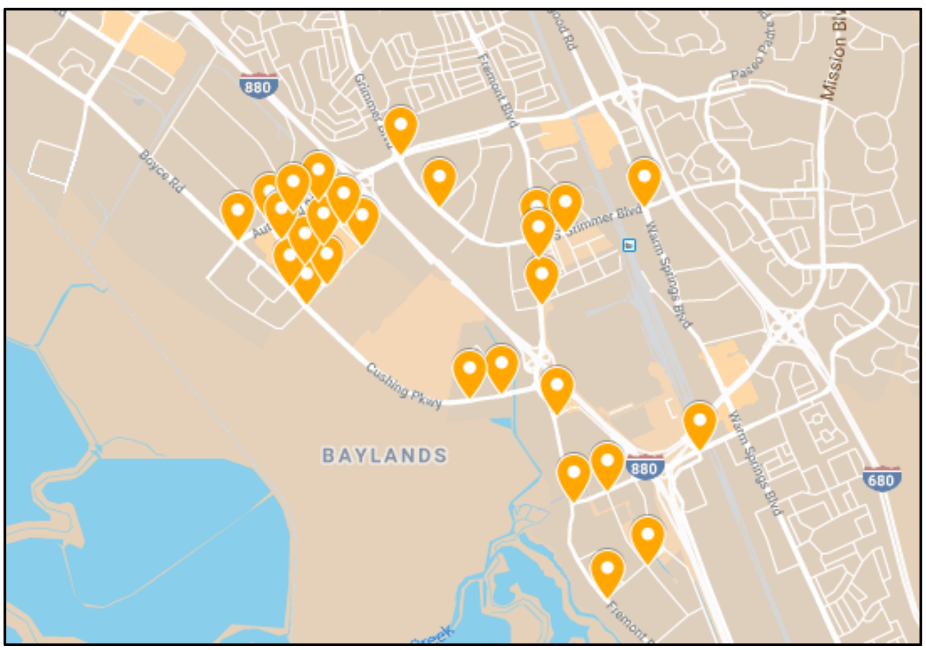
Seamless I2V communication between ADS platforms and their Connected Vehicle (CV) counterparts can offer ADS systems enhanced reliability of traffic signal Signal Phase and Timing (SPaT) state data. Current ADS sensors are occasionally limited in ability to recognize signal status due to poor visibility, a setting or rising sun, objects blocking the view, etc. Having a backup channel of communication broadcasting current SPaT data can materially reduce the risk of ADS systems running through red lights and causing collisions during poor-visibility conditions. We intend to the degree to which this kind of I2V communication enhances the reliability of ADS systems recognizing traffic signal condition.

In addition, sensor and V2I equipped vehicles can inform traffic signal infrastructure of their location and speed, as well as the presence of pedestrians, bicyclists, and other non-vehicle roadway users. This data can be consumed by the traffic signal infrastructure to optimize signal timing for both flow and safety, by placing automatic pedestrian calls, bicyclist calls, or to interject immediate signal timing changes (e.g. red lights) in the event of pending safety-critical incidents (e.g. a vehicle on course to run a red light, a pedestrian J-walking in front of oncoming traffic, or other issues). We expect to demonstrate various scenarios where traffic signals change condition based on inputs by surrounding sensor-equipped vehicles in proximity to the intersection.

d. Geographic area or jurisdiction of demonstration; and (NOTE: Demonstrations can span multiple geographic areas or jurisdictions.)

The focus area for the initial demonstration will be the areas immediately south and southeast of the Tesla manufacturing facility. This will involve up to 28 intersections that are currently engaged in a DOE-funded C-ITS deployment efforts. The ADS project will build on top of existing efforts to integrate vehicle location data from Tesla and Volvo.

Demonstration area traffic signals (Fremont, CA):



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

The proposed period of performance will include three years of demonstrations in Fremont, California. The initial area of focus will include approximately 28 intersections in proximity to the Tesla manufacturing facility in south Fremont, but may expand to include others as necessary to sufficiently demonstrate the technology. We believe that real-world testing is a critical feature to genuinely evaluate proposed technologies.

Schedule for implementation and evaluation of the demonstration:

Milestone	Deliverables	2020		2021		2022		Responsible Party
		1H	2H	1H	2H	1H	2H	
Equipment Installation	Procurement of Xtelligent interface devices	■						Xtelligent
	Provisioning of Xtelligent	■						Xtelligent
	Device management platform setup	■						Xtelligent
	Device installation	■						Fremont
Systems interconnection	Tesla freight API connected to project cloud server	■						Tesla
	Volvo ADS API connected to project cloud server	■						Volvo
	Infrastructure interface devices connected to project cloud server	■						Xtelligent
Logic Implementation								
1) ADS object detection to infrastructure	Message characteristics assigned	■						All
	Infrastructure reaction logic determined	■	■					All
	API opened		■					Volvo
2) SPaT to ADS	Message characteristics assigned	■						All
	API opened		■					Xtelligent
3) Freight to infrastructure rationalization	City freight policy determination	■						Fremont
	Infrastructure implementation		■					Xtelligent
Demonstrations								
1) ADS object detection to infrastructure	Baseline data collection	■	■	■	■			Fremont
	Test latency of data transmission			■	■			Xtelligent
	Test pedestrian crossing scenario			■	■			All
	Test pedestrian intent scenario			■	■			All
	Test red light running scenario			■	■			All
	Test speeding scenario			■	■			All
2) SPaT to ADS	Baseline data collection	■	■	■	■	■		ADS
	Test reliability of activated system			■	■	■		ADS/Xtelligent
3) Freight to infrastructure rationalization	Baseline data collection	■	■	■	■	■		Tesla
	Single truck test				■	■		Tesla/Xtelligent
	One shift test				■	■		Tesla/Xtelligent
	Full day test				■	■		Tesla/Xtelligent
Data Evaluation	Pre/post data evaluations						■	Xtelligent
	Reporting						■	All

2. GOALS

Our proposed demonstration aligns with the goals contained in the Notice of Funding Opportunity Section A: i) Safety, ii) Data for Safety Analysis, and iii) Rulemaking.

The City of Fremont has developed this proposal specifically to address the mutual NOFO/Fremont goal of enhanced safety, rooted in data and collaboration. Situated in the San Francisco Bay area, we have watched the frequency of ADS street testing increase in frequency on our streets. However, aside from regulatory approval for testing, there is very little collaboration between ADS companies and the city. We are responsible for the safety and well-being of our citizens. Our police force maintains public safety and investigates crime. Our fire department responds to fire and medical emergencies. And our Public Works Department is responsible for the construction, maintenance, and operation of our city streets. The opportunity for widespread collaboration between ADS and city agencies with a goal of enhanced safety is quite strong.

We have noted over $80 Billion of combined investment into automated driving systems yet are aware of several areas for improvement that we propose to demonstrate.

First, ADS and their connected vehicle counterparts are equipped with cameras, radar, lidar, and other sensors to detect location and roadway objects with varying levels of precision. However, they currently do not collaborate with other systems to verify accuracy of each vehicle's independent determination of location and object recognition. On the city side, our traffic intersections are limited by the current state of the art object detection systems: video, induction loops, and manual pedestrian call (push) buttons. Also each year we have approximately 110 incidents of vehicles striking pedestrians or bicyclists at our intersections. There were 4 fatalities last year. We want ADS systems to tell our traffic signals where vulnerable roadway users are, so that those signals can react to help protect their safety.

By understanding location, speed, and where other roadway users are located (pedestrians, bicyclists, scooters, etc.), our traffic signals can adjust in real-time. For example, our city is home to the California School for the Blind. If one of our blind citizens approaches an intersection and begins crossing without depressing the manual pedestrian button, nearby ADS systems can detect the motion of an object stepping into the roadway. This can be reported in real-time to the traffic signal, which can immediately implement yellow and then red lights to protect the life. Our children, elderly, and impaired citizens will greatly benefit from this enhanced cooperation between ADS systems and traffic signal control infrastructure.

The City of Fremont acknowledges that the penetration of ADS systems is not enough to see improvement in incident metrics on any wide or statistically significant scale. However, we will measure the effectiveness of this through several demonstrated scenarios. We will watch latency, system reaction time, and reliability of reporting from ADS systems.

Second, we are aware that ADS systems broadly require a redundant understanding of traffic signal status obtained directly from the city infrastructure. While increasingly reliable in their independent ability to detect signal status, certain conditions can reduce this reliability and decrease safety of ADS: sun glare, fog, weather precipitation, or objects blocking line-of-sight (e.g. a tall truck in front of an ADS vehicle waiting in a queue). Our goal is to demonstrate a simple, cellular (4g/LTE) based transmission of traffic Signal Phase and Timing (SpaT) data to ADS systems. Our City specifically intends to test this over cellular, rather than through expensive RSU/OBU systems most cities cannot easily budget for. Our consortium will measure any increase and report any increase in reliability of ADS' understanding of traffic signal status.

Third, by communicating real-time location to traffic signal control infrastructure, ADS systems have the potential to greatly improve traffic signal timing according to our city's policy goals. On September 28, 2017, the Metropolitan Transportation Commission released the results of the annual Bay Area freeway congestion analysis. The City of Fremont is bounded by two of the top five most congested Bay Area freeways: #4 ranked northbound Interstate 680 and #5 ranked northbound Interstate 880. Fremont also experiences significant regional cut-through traffic due a severe job and housing imbalance in the Silicon Valley, Peninsula, and Central Valley.

Our city is home to the Tesla manufacturing facility, located on Fremont Boulevard; one of Fremont's heavily travelled corridors experiencing 18,754 average daily traffic volumes. The facility is also located between Interstate 880 and 680. With the Tesla manufacturing site expansion and increase of vehicle production, an estimated 2,000 commercial trucks per day is expected to travel the Fremont roadways. For comparison, the Port of Oakland, one of the top ten busiest container ports in the United States, serves about 3,000 trucks daily.

With an expected 4,000 truck trips around the manufacturing facility, idling trucks is a cause for growing local and regional concerns with air quality and greenhouse gas emissions. Roadways around the Tesla manufacturing facility are already at maximum capacity and expansion is unfeasible. For these reasons, city staff see an opportunity to improve flow and reduce the immense noise and air pollution our city endures from the freight trucks being forced to stop and reaccelerate their mass across our traffic signals more often than is necessary. We intend to measurably reduce this activity by allowing our traffic signals to prioritize the continued movement of large, diesel freight vehicles when safely possible.

The benefits of this project along the project corridor include:

- Decreased travel time, congestion, fuel consumption
- Increased manufacturing throughput and performance, and economic growth
- Technology and logistics solutions applicable to other commercial vehicles
- Transferable results to other agencies facing similar transportation issues

All efforts will be carefully documented and success will be measured with data. Each demonstration will include baseline/benchmark data sets, which will be compared to data obtained during performance of a demonstration.

Collaboration is a clear goal of this consortium. By finally including City agencies and infrastructure into the communication with ADS systems, we see a clear opportunity to improve safety and performance of both ADS systems and the city transportation environment.

3. FOCUS AREAS

Our proposed demonstration aligns with and/or satisfies the Focus Areas contained in NOFO Section A:

a. Significant Public Benefit(s): City infrastructure to vehicle (V2I/I2V) cooperation is a key enabler of the autonomous vehicle future, while notably being able to improve safety today. Our goals listed above include demonstration of enhanced ADS reliability, increased traffic signal awareness for safety, and rationalizing freight movement to reduce noise pollution, air pollution, and freight-related traffic congestion.

b. Addressing Market Failure and Other Compelling Public Needs; ADS systems have the potential to revolutionize transportation, but the timing of their technological readiness and wide market adoption is debated. Public trust is a primary concern which can lead directly to market failure. City infrastructure to vehicle cooperation can address several key issues ADS companies are working on, and enhance some of their more important features, as described throughout this proposal.

c. Economic Vitality: As described in b. above, the technology demonstrations proposed herein can enable the near-term economic viability of ADS systems by improving their safety and associated public trust.

d. Complexity of Technology: Consortium members include ADS Level 3 (Volvo), connected freight (Tesla), and connected infrastructure (Xtelligent).

e. Diversity of Projects: This proposal outlines valuable technology demonstrations that affect safe ADS operation in all environments: urban, suburban, and rural. It also includes freight along with all other roadway users.

f. Transportation-challenged Populations: This proposal includes technology demonstration to enhance transportation-challenged populations attempting safe crossing of a traffic intersection. Given the number of fatalities at our nation's intersections, this is a meaningful effort.

g. Prototypes: All systems include prototypes ready for demonstration with adequate preparation. Volvo currently operates an L3 ADS system. Tesla's manufacturing facility already utilizes a real-time freight location system to time deliveries. Xtelligent has already developed its connected infrastructure traffic signal control system and is piloting an early version of it in real urban environments.

4. REQUIREMENTS

Describe how your proposed demonstration satisfies the Requirements contained in NOFO Section A:

a. Focus on the research and development of automation and ADS technology (per the SAE definitions), with a preference for demonstrating L3 or greater automation technologies: Our proposal and associated demonstrations are focused on the R&D of ADS technology to infrastructure integration to improve safety and collaboration across transportation networks.

b. Must include a physical demonstration: The technology demonstrations described herein will include real traffic intersections in the City of Fremont, CA, cooperating with freight vehicles and ADS vehicles. Each demonstration will be real-world. There are no models or simulations involved.

c. Must include the gathering and sharing of all relevant and required data with the USDOT throughout the project, in near real time. The Recipient must ensure the appropriate data are accessible to USDOT and/or the public for a minimum of five years after the award period of performance expires: The consortium will comply with this requirement.

d. Must include input/output user interfaces on the ADS and related applications that are accessible and allow users with varied abilities to input a new destination or communicate route information and to access information generated by the ADS: The Volvo ADS system includes input/output user interfaces as described in this requirement, and which will be used in the execution of this project.

e. Must address how the demonstration can be scaled to be applicable across the Nation to similar types of road environments, and include an outreach task to share demonstration status, results, and lessons learned with other jurisdictions and the public, in furtherance of technical exchange and knowledge transfer: All efforts described herein are based on real-world needs that are applicable throughout the nation. The Fremont, CA physical environment is characteristic of the rest of the nation's road networks. Xtelligent has designed its system to be interoperable with any traffic signal controller manufacturer, allowing these demonstrations to be nationally scalable. Furthermore, our elected reliance on standard cellular connections includes infrastructure already installed throughout the nation over decades.

5. APPROACH

Topic 1) Demonstrate increased safety by incorporating Vehicle to Infrastructure (V2I) communication of ADS vehicle location and speed into traffic signal control infrastructure.

As described in “Goals” above, this topic demonstration will focus on ADS systems providing critical safety information our city traffic signal control infrastructure in order to react to protect public safety. First, Xtelligent will install its interface devices into Fremont, CA traffic signal cabinets. Xtelligent’s control system is cloud-connected and capable of controlling traffic signal timing through the existing signal controller. Their adaptive traffic signal control platform is highly flexible to novel data inputs and is able to adjust signal behavior based on them. Second, ADS vehicles from Volvo will transmit the following data to the Xtelligent cloud platform via standard cellular modems:

- Real-time vehicle location and speed
- Real-time location and velocity of any detected non-fixed/roadway objects (e.g. other vehicles, pedestrians, bicyclists, animals, balls, scooters, etc. but not signs, poles, trashcans, etc.)
- Predicted type of non-fixed/roadway objects (e.g. bicycle vs scooter vs pedestrian).

The demonstration will include the intentional deployment of various roadway users in the intersection environment to test the reliability and latency of the relevant ADS information. Xtelligent’s software system will place pedestrian calls, force-off green signal phases when prudent to slow/stop traffic in order to protect vulnerable roadway users, and may also generally adapt signal timing to improve flow conditions.

Topic 2) Demonstrate an increase in the reliability of ADS’ ability to determine traffic signal phase and timing status by incorporating Infrastructure to Vehicle (I2V) communication.

This topic demonstration will include a I2V connection, whereupon the Xtelligent traffic signal interface device will transmit detailed SPaT data and future traffic signal data to the cloud. It will be immediately provisioned through an API and transmitted to the ADS vehicles. The ADS system will continuously compare SPaT data obtained through the API to the traffic signal status it obtains from direct sensor recognition of the signal heads. The comparison between both will be logged continuously and stored for data analysis and verification of improvement.

Topic 3) Traffic signal infrastructure integration of freight truck real-time location information into signal controls to reduce stops, improve congestion caused by freight, and reduce pollution generated by freight.

Here we will demonstrate the integration of Tesla manufacturing freight into our city's traffic signal control infrastructure, along with the benefits of adjusting signal timing to reduce the number of stops these vehicles endure on their way to and from the factory. Freight vehicles will be coordinated to platoon and optimize speeds in order to transit traffic signals during off-peak hours. Xtelligent traffic signal controls will optimize signal timing and coordination according to the arrival of these freight vehicles to enable smooth transit. FPWD will approve the timing logic and coordinate with Tesla manufacturing. This will both minimize freight vehicle stops and will minimize disruption to normal traffic patterns. Baseline data on stops, delays and traffic congestion will be collected and stored for comparison to demonstration data.

Our consortium does not anticipate applying for any additional regulatory hurdles as a result of these deployments. Volvo and Tesla will not be operating beyond their current scope, and their cellular data exchange with Xtelligent's connected infrastructure units is not subject to additional regulation. As the prime lead on this proposal and subsequent grant, the City of Fremont, CA has authorized this project. Our demonstration will not require exemption from FMVSS, FMCSR, or any regulation.

APPROACH TO LEGAL, REGULATORY, ENVIRONMENTAL OBSTACLES

If any unforeseen legal, regulatory, environmental, and/or other obstacles to demonstrating these technologies arises, this consortium will evaluate whether exemption or approval is possible, or whether a change in project scope is required. Our collective priority will be to keep the scope as-is and maintain the integrity of these demonstrations, and therefore to seek exemptions or approvals as required. However, if scope changes are required, this consortium will make the minimum adjustment required in order to preserve the intent and valuable public data the US DOT is appropriately mandating for this grant.

Because Xtelligent, Tesla, and Volvo are U.S.-based companies or have manufacturing in the U.S., there will be no exemption required for BUY AMERICAN standards.

COMMITMENT TO DATA SHARING

As committed to above, this consortium will log and store relevant data for the participants, US DOT, and the public to access and benefit from this public funding. The storage medium is anticipated to be a secure cloud server through Amazon Web Services (AWS). While this grant is focused on safety, this consortium will also measure numerous other data points related to vehicular throughput, travel time, and other related mobility metrics.

Some of the expected data include:

- Status of vehicle systems (wiper status, light status, braking status)
- Signal Phasing and Timing (SPaT) messages
- High Resolution Controller Data
- Participant Attributes
- Traffic Counts
- Static Traffic Signal Data
- Weather Data
- Safety-Related Event Data
- Safety Device Event Data
- Derived Mobility Metrics
- Derived Safety Metrics
- Street Network for Simulation (if used)
- Simulation Model Outputs (if used)

APPROACH TO RISK IDENTIFICATION, MITIGATION, AND MANAGEMENT

The Fremont ADS grant proposal consortium was carefully chosen to enhance collaboration and reduce technical and management risk. Regardless, risks always remain and the intent of this ADS demonstration grant is to demonstrate novel concepts to further ADS safety. Prior to any demonstration, the consortium members will meet to review the existing demonstration plan and recommend any changes. Risks will be identified, classified according to probability and severity, and a proposal to mitigate each will be developed. This risk analysis report will be part of our final reporting to the US DOT. The project team has also gone through a risk identification, mitigation and management exercise to identify early risks to ensure that the project would be successful. The following are the key risks that we seek to actively manage:

- **Roadway user buy-in:** To ensure that other users of the roadway are bought into the demonstration, the project team has begun to socialize the project with all relevant government and community organizations. This includes Pacific Commons shopping center, LAM research, and other businesses.

- **ADS technology provider buy-in:** Integrating ADS data from multiple vehicles may be a challenge, but the project team has already demonstrated its ability to overcome this challenge by securing data-sharing commitment from key partners, including Tesla and Volvo.

- **Technical risks:** The technical aspect of integrating myriad ADS data sources could be challenging and rewarding. Each of the myriad data streams exhibit different precision, latency, reliability, and percent adoption across actual vehicles on the roadway. We anticipate considerable data science efforts and AI/machine learning required to correlate various data streams' behaviors with each other to remove duplicates, realign temporal displacements, anticipate pending conditions, and "plug holes" to provide a usable and continuous set of data to the optimization algorithm. To maximize our chance of success and mitigate risk, we have built a world-class data/technical team and advisors. For example, our team has the following expertise that can support the project:

    1) Artificial Intelligence (ML/Neural Networks)
    2) Autonomic Computing
    3) Cybernetics
    4) Dataflow/Reactive Programming
    5) Information-centric Networking
    6) Software-defined Networking
    7) Swarm Intelligence.

Beyond the main partnerships articulated in this application, we also have ready access to data fusion and integration experts from the National Renewable Laboratory that will be available on an as-needed basis during the project lifetime.

There are also significant risks associated with manufacturing, supply chain, and scalability of the proposed technology. To manage these risks, along with market risk, the project team has partnered with multiple industry incumbents and cities to leverage external know-how and expertise.

Siemens traffic signal controllers are well established and used extensively throughout Fremont, CA traffic signal control infrastructure. The project team will be leveraging AT&T and Amazon Web Services to ensure that the wireless connectivity and cloud platform are managed by organizations with deep expertise and experience. Multiple government entities will provide guidance and feedback.

6. Contributions

- Xtelligent plans to contribute $450,000 in in-kind support for the project, if the application is successful. This will be provided in the form of project management, engineering, and research support to ensure that the project is successful.
- Volvo plans to contribute $571,869 in in-kind support for the project if the application is successful
- FPWD will provide in-kind contribution totaling $300,000 to support the ADS through implementation of the traffic signal upgrades and conversion of streetlight network and technology outreach efforts to support extending the project activities across the County, region and across the United States. FPWD is already going through a controller upgrading process that can support the proposed project