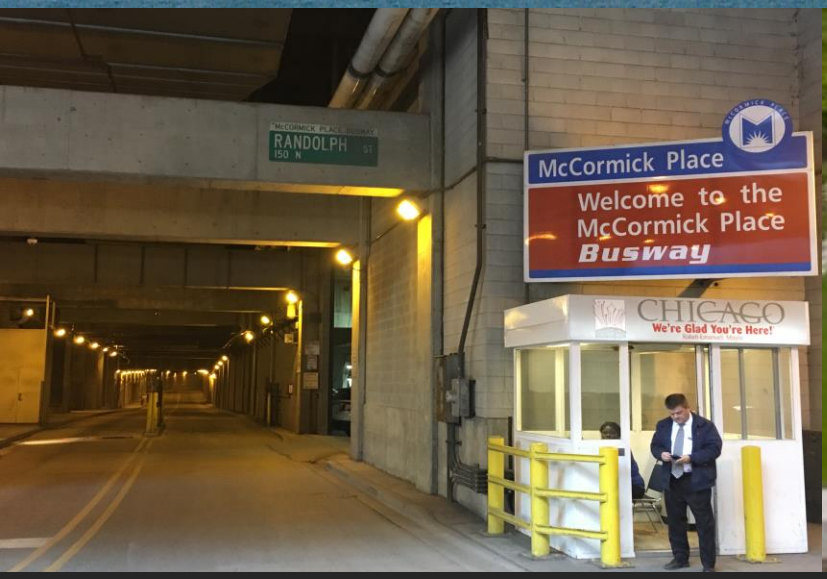

Autonomous Chicago Ecosystem (ACE)

Automated Driving System Demonstration Grant Application

NOFO: 693JJ319NF00001

CDOT
CHICAGO DEPARTMENT OF TRANSPORTATION

OFFICE OF THE MAYOR

CITY OF CHICAGO

RAHM EMANUEL
MAYOR

March 21, 2019

Dear U.S. DOT ADS Demonstration Grants Program Office:

Just over three years ago, Chicago broke ground at McCormick Place, now the premier convention facility in North America. As a gateway to our great City, the McCormick Place Event Center stands today as a mark of its rapid growth and prosperity.

Since 2011, Chicago has witnessed an unprecedented boom in tourism, growing from 39 million annual visitors to a record-breaking 57.6 million in 2018. McCormick Place has played an integral role in making Chicago a top global destination, with 20 of its 50 largest events breaking either attendance or participation records this past year. In total, its events generated nearly 3 million visitors in 2018, a 31% increase over 2017 figures.

Chicago is further reinventing itself in the transportation space. Though we already possess a world-renowned transportation system, I convened our New Transportation & Mobility Task Force to design the future of our City. Our Task Force report released last week details a roadmap for a vibrant public transit system that fosters innovation and technological progress through infrastructural modernization and new mobility offerings. Chaired by former U.S. Department of Transportation Secretary Raymond LaHood, the Task Force identified immediate actions and long-term strategies to build a multi-modal transportation ecosystem that is reliable, equitable and environmentally-sustainable for generations to come.

Testing automated driving systems through a McCormick Place Busway presents an opportunity to synergize Chicago's innovative transportation strategy with one of its most prominent tourism engines. Leveraging ADS technology in this high-traffic location would bring greater safety, accessibility and efficiency to millions of Chicago visitors each year. Pioneering such novel solutions would not only take our City one step closer to realizing its vision for transportation, it would provide residents and visitors alike one more reason to be in Chicago.

I look forward to the many new and innovative approaches developed through the proposed McCormick Place Busway initiative, and the long-term impact they will bring for Chicago's many residents, visitors and businesses.

Sincerely,

Rahm Emanuel

Mayor

CDOT
CHICAGO DEPARTMENT OF TRANSPORTATION

Ms. Sarah E Tarpgaard
Contracting Officer
E-mail: sarah.tarpgaard@dot.gov
Phone: 202-366-5750

March 21, 2019

RE: Automated Driving Systems Demonstration Grants NOFO Number: 693JJ319NF00001

Dear Ms. Tarpgaard:

Thank you for the opportunity to submit our Autonomous Chicago Ecosystem (ACE) Grant Application for the U.S. Department of Transportation Automated Driving Systems Demonstration.

We are excited to offer a very unique ADS ecosystem that will provide the ideal testing ground, and data collection environment to help ADS providers move from closed facility testing to real world solutions. Our proposal leverages the unique characteristic of the Chicago's McCormick Place Busway (Busway).

The Busway is a fully access controlled roadway in the heart of the Chicago entertainment district. As a result, we can easily move from a fully isolated test, to integrated testing with other vehicles and/or the public, all in a structured and controlled fashion. In addition, we are hoping that the ADS tested on the Busway will eventually replace the busses and transit vehicles that use the Busway now to support special events and shuttling convention attendees to and from the McCormick Place convention center from hotels to the north of the Busway.

Through this grant we will add a comprehensive data collection and data sharing environment. Our Data Management Program will be led by some of the nations most respected experts in the collection, annotation, analysis, and interpretation of large and complex data sets, as well as the use of large-scale analytics and machine learning. Our hosting environment will allow for users to tie in Argonne's High-Performance Computing facilities to provide access to high-end machine learning and other computing resources offered within Argonne's ALCF.

As a result of the unique environment, and the opportunity that the Busway provides, we already have multiple ADS vendors that are interested in the program.

Thank you for your time and consideration.

Kevin O'Malley
Managing Deputy Commissioner
City of Chicago Department of Transportation
30 N. LaSalle Street, Suite 1100
Chicago, Illinois 60602

Summary Table	
Project Name/Title	**Autonomous Chicago Ecosystem (ACE)**
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	Chicago Department of Transportation 30 North La Salle, Suite 500 Chicago, IL 60602
Point of Contact (Name/Title; Email; Phone Number)	Abraham Emmanuel Deputy Commissioner Abraham.Emmanuel@cityofchicago.org (312) 742 - 0804
Proposed Location (State(s) and Municipalities) for the Demonstration	State of Illinois / City of Chicago
Proposed Technologies for the Demonstration (briefly list)	• Multiple levels of Automation from 3 to 5 • Multiple ADS vendors with multiple vehicles. 4 initial venders, more likely. • Supports completely controlled progressive levels of testing from isolated single vehicle testing to full integration vehicles and pedestrians

	• Very robust data collection and management program • Leverages Globus software tools • Applies Machine learning models • Allows analyst to tie in Argonne's High-Performance Computing Facility
Proposed duration of the Demonstration (period of performance)	Initial Project. Three year base + data availability for 5 additional years. However, the City hopes to keep the Busway autonomous vehicle program in place from many years.
Federal Funding Amount Requested	$9,999,970
Non-Federal Cost Share Amount Proposed, if applicable	$2,133,858
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$12,133,827

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Project Narrative and Technical Approach

1.1 Executive Summary

The Chicago Metropolitan area includes a population of close to 10 million. It is a thriving, diverse metropolitan area with all the typical transportation demands and challenges that come along with a large metro area. Understanding the funding limitations, and the need to drive fundamental changes in transportation to make any significant improvements in the current conditions, the City has launched the Chicago Smart Mobility (CSM) program. A key goal of the CSM program is to promote technical solutions that will help drive fundamental changes and better utilize the capacity of the transportation infrastructure.

As part of the CSM program, the City has been actively looking for ways to leverage and promote Automated Driving Systems (ADS) to help mitigate the City's transportation challenges. Through this effort, the Chicago Department of Transportation (CDOT) has identified a unique opportunity within the City that will help move toward more efficient use of the City's transportation infrastructure and support the goals of the USDOT ADS demonstration Program.

As with most metropolitan areas, Chicago's congestion stems from a combination of regular commuters, special events and incidents. The City of Chicago draws millions of visitors annually to the City with several world class theatres, museums, parks, and stadiums. Chicago's downtown lakefront venues host special events including concerts, conventions, festivals, and sporting events causing an influx in the number of motorists. The City hosts over 50 major events and hundreds of smaller events annually.

The City currently utilizes a 2.3-mile grade separated, restricted access two-way roadway in the heart of the city, called the McCormick Busway (Busway) to shuttle people between venues along the lakefront. The Busway is a limited access isolated roadway with no open intermediate intersections with public roads. The use of the Busway allows for quick access between venues and parking along the lakefront, while avoiding the downtown traffic. For example, the operator of the City owned Millennium garage, currently uses school buses to shuttle people from the Millennium garage to Soldier Field's stadium during Chicago Bears football games. Convention attendees take shuttles along the Busway to get to and from Hotels just north of the Busway.

The City of Chicago, with several world class theatres, museums, parks, and stadiums, draws millions of visitors annually to the City. Most of these venues are concentrated within the downtown/lakefront area including destinations of the Theatre District, Navy Pier, Millennium/Grant Park, Museum Campus, and Soldier Field.

The location of the Busway and frequent lakefront destinations within the City of are shown in Figure 1.

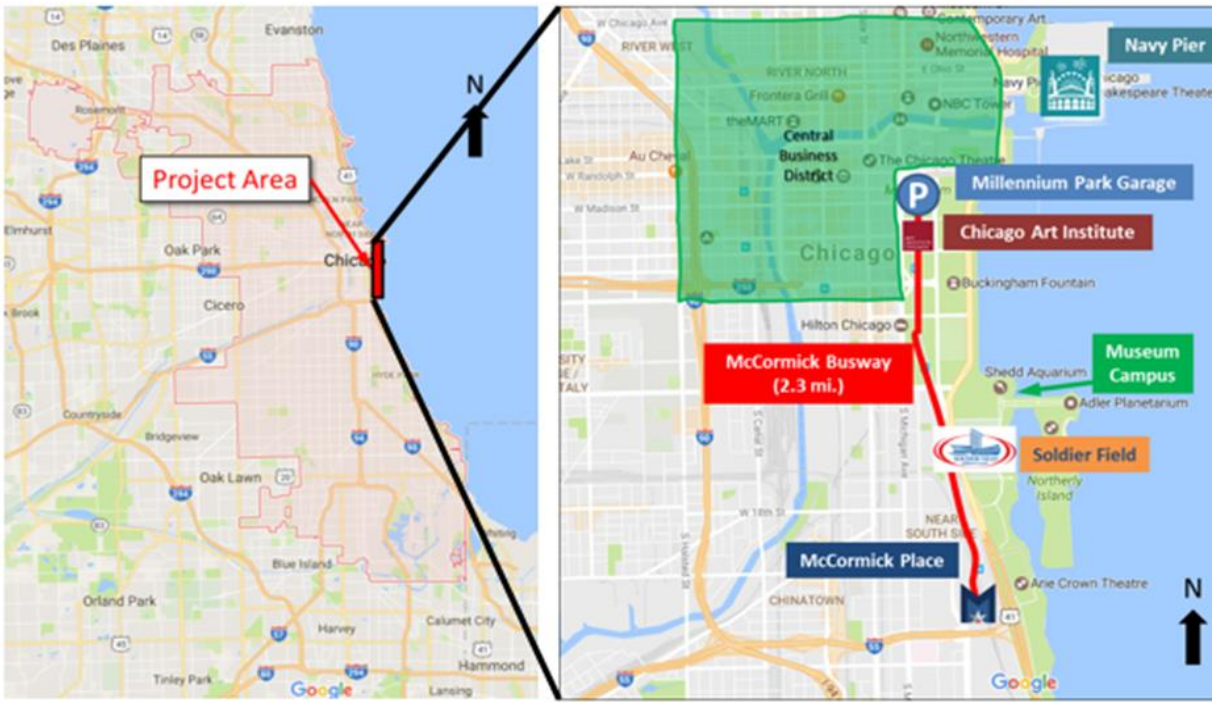

Figure 1 : Frequent Lakefront Destinations within the City of Chicago

The Busway is ideal for testing ADS, and for progressing that testing, a step at a time, from a fully closed and controlled environment, to real world operational programs.

Being a private, fully controlled access roadway that connects parking, points of interest and a large convention center in the heart of a large urban environment, the Busway provides the perfect environment to test and demonstrate ADS in a managed and safe manor, while introducing many aspects that could not be addressed in a traditional testbed.

With the Grant funding, the City would like to create a complete ecosystem for the testing of autonomous vehicles that leverages the unique characteristics of the Busway. The Busway will provide an environment that will allow these vehicles to safely move from isolated testing to real operational solutions. The intent is to make the busway available to any vehicle vendor that will work within the rules, time frames and procedures established for the Busway, while supporting the goals of the USDOT Grant.

We already have the following vendors that are expected to work with the team and use the facility for testing **(Innova, VIA, National Express, Transdev, Bosch)**. The City has branded the program the Autonomous Chicago Ecosystem (ACE).

ACE offers several advantages over traditional ADS testing facilities:

- It is a real roadway, with real world challenges such as walls, trees, buildings, tunnels, worn roadway markings, diverse weather conditions and varied lighting.
- On the Busway, we will be able to allow for isolated testing of all levels of autonomous operations and integrated testing with other ADS, as well as provide a controlled set of public users, when the vehicles are ready.
- The flexibility of the Busway will allow us to test many different scenarios at every level of automation.
- Once solutions are tested, we can allow for real operational solutions that meet actual needs for the public, such as shuttles to and from McCormick Place and other venues in the region.
- When they are ready, vendors will be able to observe, and learn from real public's interaction with their vehicles.
- The program will allow for testing in a dense urban environment.
- With all the points of interest in the area, the City expects this program to expand to allow for autonomous vehicles to access the venues in the area. With the potential for future real public service, the Vendors are incentivized to participate.
- The Ecosystem will be set up to support a full set of ADS safety data from the vehicles and the supporting roadway infrastructure.
- We are expecting multiple vendors to participate and provide data.
- Very robust data collection, aggregation and distribution program.
- Leverages the Globus environment and tools.
- We'll be applying machine learning models to support the data analysis, aggregation and distribution.
- Will allow analysist access to tie in Argonne Labs High Performance Computing Facility.

Under this project, the City will set up the program, and implement a data collection and reporting process that will meet the USDOT goals for data safety analysis within the three-year project time frame. In addition, it is expected that the program set up under this project will continue for many years, acting as the launching ground for an aggressive program to support the safe and rapid deployment of ADS in the Chicago area. Providing safe and efficient transportation to, from and between the venues near the busway is a priority in driving the economic vitality of the City.

The ACE program includes support from all the appropriate agencies including; The City of Chicago, CMAP, the Illinois Department of Transportation (IDOT), McCormick Place, Metra, ILAVA, and MPC, as well as the consulting industry, local developers and the ADS vendor community.

Since the roadway is already in place, we can quickly start working with the vendor community and running tests. Some initial testing could be done within the first six (6) months, if the vendors are ready.

The City already has a base project team to support this project under our CSM umbrella. As a result, we can start quickly and accomplish more over the life of the grant.

Program management, field systems design, field integration, monitoring and oversite will be provided by our CSM project team that is already contracted with the City. The CSM project team is led by Parsons Transportation Group, and includes AECOM, Jacobs, TranSmart and Alrek. The team has a deep pool of resources that can support the program as-needed, as it grows. The following provides a few highlights of the Core project teams.

Parsons is a three (3) Billion per year engineering and technology company. They are the nation's leading large-scale transportation systems integrator. They have helped plan, deploy and manage many of Nation's largest and most sophisticated technology related transportation systems and solutions in the country. They are a consistent industry leader and have won many awards for their ability to deliver, first of their kind, innovative solutions that drive industry norms and standard. The Parsons CSM is already under contract to support the CSM program, so they can get started on aspects of this project as soon as CDOT is notified.

We have added other members to the team to support the expected needs of the program.

City Tech was added to lead vendor outreach and public outreach for the program. City Tech transforms cities into testbeds for new ideas. With partners and people, they remake essential city services and infrastructure using advanced technology, and then expand these solutions to other cities. With their partners, they are diverting rainwater from overloaded sewer systems, easing subway congestion during large events, and launching a digital directory of public health services in Chicago. City Tech's partner consortium helps cities adopt technology solutions to strengthen urban infrastructure and essential services, while providing product, market, and business development opportunities for corporate partners.

Argonne National Laboratory (ANL) will lead the data aggregation, analysis, and management. ANL is a multidisciplinary science and engineering research center, where talented scientists and engineers work together to answer the biggest questions facing humanity. Born out of the University of Chicago's work on the Manhattan Project in the 1940s, their goal has been to make an impact — from the atomic to the human to the global scale. Specific to the capabilities required across a range of ADS technology development tasks, highlighted research capabilities available at Argonne include; Large-Scale User Facilities/Advanced Instrumentation, Applied Mathematics with a focus on Deep Learning and Optimization, Advanced Visualization and Data Storage Facilities, Systems Engineering and Integration and Cybersecurity. ANL staff already have significant experience working with ADS, as well as ADS data management and analysis.

Illinois Institute of Technology (IIT) is a private, technology-focused research university offering undergraduate and graduate degrees in science, engineering, architecture, business, design, human sciences, applied technology, and law. IIT is particularly strong in high-performance computing, artificial intelligence, data science, cybersecurity, and networking.

The IIT CS department has a number of faculty with deep expertise in key capabilities required for the current project: data science, machine learning, data-intensive computing, and cybersecurity.

1.2 Goals

The primary intent of the ACE program is to provide a complete ecosystem to help ADS vendors to move their ADS vehicles from testing to a real-world solution in a controlled, safe and systematic fashion, and to collect appropriate supporting safety data to support that goal. The unique location and setup of the Busway supports a systematic, safe and stepped approach to testing the vehicles. Our proposed data management program will provide valuable data and analytical tools to identify risks, opportunities, and insight to support continued improvements in safety and reliability, as well as support the removal of government barrier and rulemaking priorities.

As indicated previously, the Busway is located adjacent to many of the key attractions in Chicago. While the City has multiple transit options to get downtown, there are limited options to move visitors from one venue to another, or to help balance parking availability with parking demand.

One of the City's goals of the ACE program is to support the development of improved options for the last mile for City visitors, whether they are attending a game, going to a conference, visiting Navy Pier, or any of the venues in the Museum Park.

The City sees one of the keys to the vitality of the downtown entertainment district to be the ease of transportation within the region. The City would like to make it as easy as possible for conference attendees staying downtown to get to McCormick Place, the Museum Park, or Navy Pier. Driving just a percentage of visitors from a one stop trip to a multistep visit can go a long way to improving the vitality of the entire area.

The Busway is a fully deployed roadway facility with a variety of typical roadway issues that may be challenging for ADS to manage. As a fully controlled environment, we can manage the coordination between ADS tests and live interactions with other vehicles and the public**. What this means is that we can allow for each tested vehicle to progress from fully closed to a fully integrated environment at each level of automation**.

To ensure safety, the entire roadway will be monitored from the City's TMC and all the participating vendors will be required to allow for the monitoring of their vehicles, and for an appropriate degree of data sharing with the program. All the ADS vehicles on the facility will be monitored and tracked in real time.

Within the Busway, we can allow for a controlled integration of multiple ADS vehicles types and for integration with other vehicle types. The current use of the Busway is sporadic and

revolves around special events. That said, vendors can perform initial testing in a closed environment and, when they have demonstrated that their vehicles are ready, we can set up a controlled and monitored integration process with the other ADS vendors and/or live event transportation activities, as the vendors demonstrate that their vehicles are ready.

When a vendor has demonstrated their safety and reliability at a level of automation on the Busway, they may then be allowed to extend their testing, to include access to Navy Pier and the Museum Park, and eventually throughout the City. Full level-five automation of the busway will require the resolution of rules and regulations, as well as approval from the ACE program. See Section 1.6 for details related to regulatory issues.

The program will set up a testing, validation and data collecting ecosystem, and set the ground work for moving to full ADS functionality on the roadway network, one safe and controlled step at a time. Each vendor will be required to share a set of safety data with the program. We have set aside **$742K** of the project funds to support the vendors efforts to share data within the ACE ecosystem. The project team will work with the vendors to ensure that we can collect the appropriate data to support the program. In talking with vendors, there are various level sensors that are currently being used. In some cases, we may pay the costs to add sensors to supplied vehicles to meet the data collection and analysis goals. For example, not all vehicles use Lydar. The intent is to add Lydar to any vehicle that is not using it to allow for improved data analysis. The project is designed to support this addition. Any added sensors will be used for data collection only.

The ACE program will include a data collection program that will aggregate, validate, and compile the appropriate safety data to allow public agencies to assess appropriate rules and remove government barriers in a structured and phased fashion, allowing for appropriate testing and demonstrations at each step along the way. The goal is to provide a comprehensive set of data that will help drive the safe progression and advancement of ADS in an open and collaborative fashion. Understanding the pure volume of raw data available, the data management team will utilize analytical tolls and machine learning to identify the appropriate subset that will support safety analysis and allow for more efficient evaluation.

See Section 1.5 for more details relating to the infrastructure and Section 3 for more details relating to data management.

1.3 Focus Areas

There is currently a wide range of testing and demonstration of ADS going on throughout the Country. However, those test facilities are limited to either specific vehicles, testbeds or tasks. The Busway will allow for a controlled and phased approach to eventually bring full level-five automation to the public to meet real public needs in filling last mile gap in an urban

tourist centric environment. Within the ACE program, we can support the testing of ADS busses, shuttles, shared vehicle and taxi services.

The characteristics of the Busway can support a wide array of ADS testing for a variety of transportation markets including freight, personal mobility, and public transportation. We will also support testing for service transportation-challenged populations, including older adults and individuals with disabilities.

The ACE program is ideal for looking at entry, egress, and options to make transfer easy, which could include design of ADS for accessibility, usability, and safety, including securement and restraint systems for wheelchairs and other equipment for people with disabilities. Within the Busway, we can provide for safe testing and add real public passengers whenever we are ready.

The Busway provides a unique environment which will support a collaborative ecosystem that will allow the vendors and USDOT to collect the experience and data required to safely move ADS from testing to real world solutions. The ACE provides a platform for a wide variety of testing and demonstrations. The following table identifies the focus areas for the initial vendors that have already indicated their interest to use and support the ACE program.

Focus Areas for the Initial Vendors

Innova EV focus is on providing first and last-mile services and generally expand transportation options across campuses, cities, and neighborhoods. They are interested in testing more advanced levels of automation and interactions with users in preparation for fully autonomous solutions. They are particularly interest in interactions with the elderly, as they are a big part of their current clients.

National Express current focus is on accessible fixed route, paratransit, and employee shuttle services. In Chicago, National Express provides paratransit services on behalf of its customer, the PACE division of the Regional Transit Authority, as well as shuttle services. National Express is interested in using the Busway to explore the potential for on-road ADS operations across multiple platforms and vehicle types. As well as services related to individuals with disabilities.

VIA operates the most powerful on-demand transit systems in the world. Their cloud-based technology dynamically routes vehicles in real time in response to demand, turning any fleet into an advanced on-demand transit network. They operate consumer shared ride services at scale in Chicago. VIA is interested in using the Busway's ideal proving ground for automated vehicle and use case testing, as well as initial limited service options leveraging automated driving solutions in a safe environment. VIA is interested in the collaboration across providers and being part of a diverse ecosystem with a wealth of data that can improve implementations. VIA intends to participate in the process of data sharing, collective resource development, and reimagination of state transit to create a seamlessly integrated system for Chicago.

Transdev is the largest private provider of multiple transportation modes in North America. Offering bus, paratransit, BRT, streetcar, ferry, coach, taxi, private driver, and shuttle services, Transdev operates 200 million annual passenger trips in 200 North American cities. ACE provides Transdev an ideal proving ground and partner ecosystem to test and validate vehicle safety, transit service use cases, and civic partnerships. Transdev stands ready to participate in Chicago's automated vehicle proposal as an industry partner, including using the McCormick Place Busway for internal research and commercial service development.

Chicago's plan to develop a secure automated mobility data sharing platform will allow Transdev, the US Department of Transportation, and other demonstration program participants to upload, combine, analyze, and ingest operational data and observations from vehicles and fixed sensors in a secure, controlled manner. This data will support further expansion and improvement of Transdev's automated vehicle services while helping to inform local and national regulation.

Additionally, Chicago's plan pushes forward the integration of managing multiple modes of transportation within the same network. This increases the ability to test various connected modes of transportation together in a more controlled environment and moves the bar further and faster down the road to a better V2I, V2V and general V2X network.

Robert Bosch, LLC (Bosch) Utilize our expertise in sensor technology, systems integration, software, and services, as well as our own IoT cloud, to offer connected, cross-domain solutions. Bosch believes that the ACE program will help answer many questions on ADS implementation by providing the perfect proving ground for a variety of use cases and ADS providers. The proposal brings together the right subject matter experts as well as stakeholders to form an ecosystem that will ensure the outcomes of this demonstration offer innovative, equitable, and replicable mobility solutions.

Renovo Auto is an autonomous vehicle software company focused on building products that enable the global commercialization of autonomous vehicle fleets via our Aware platform, the first truly open software platform for autonomous vehicles. Renovo combines Silicon Valley agility with proven automotive capabilities in a singular commitment to transform the way we move people and things. Renova has also expressed interest in supporting the program. Details have not been worked out.

1.4 Requirements

The Busway provides the perfect environment to research and evaluate many ADS technologies. The fact that the Busway is primarily used for special events allows us to close the Busway to the pubic when it is not being used for a special event. As a result, we can

immediately test multiple levels of autonomous operations and systematically progress the level of integration with other vehicles and even provide controlled and limited access to the public when the vendors are ready for that level of testing.

We have support letters from multiple ADS vehicle providers that have the intent to use the facility to test their ADS technologies and make use of the multi-level testing and data collection that can be performed on the Busway.

Participants in the program will be required to share all relevant and required data with the City and the USDOT throughout the project, in near real time. We will work closely with the USDOT to 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 (See Section 3).

The ACE program will support testing and demonstrations at various levels of autonomy and integration. In addition, the Busway includes several relevant characteristics that can help in testing the ADS readiness for public roadways; including tunnels, limited rail crossing, varied lighting, walls, building, diverse weather and traditional roadway signing and stripping.

We have vendors on board that are interested in demonstrating and testing each of the required scenarios and much more. For example, Innova is particularly interested in 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 program will promote and support the testing needed for the vendors vehicles to progress from one level of automation and integration to the next *(The program will include testing up to level 5 automation)*, through a comprehensive and collaborative testing process at each stage and will 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.

Currently, sensor data from vehicles in-use is not widely available to the at-large research community. Moreover, vehicle decisions and planning information synchronized with the environmental data is even more difficult to obtain. In order to understand the safety implications of HAV systems, this type of synchronized environment data, vehicle data, and strategic decision-level information is key. One of the main goals of this project is to collect real-world sensor data as well as the accompanying vehicle operational, path, and strategic information within a range of scenarios and environments.

Within this project, it is expected that data and analysis will be provided via implementation platforms and data collection at every layer depending on the assets and capabilities provided by the specific vehicle/platform provider. At each level of testing, sufficient evidence and data must be provided to ensure that a vehicle or technology has met the desired goals of safe, reliable, and robust operation.

1.5 Approach

The City intends to set up a comprehensive ADS Ecosystem, designed to promote and support the progressive testing and promotion of autonomous vehicles in a safe, collaborative efficient fashion. The program will include four main components; program management, vendor outreach, data collection and evaluation, Physical Ecosystem.

Program management and vendor outreach are addressed in "Part 2 – MANAGEMENT APPROACH, STAFFING APPROACH, AND CAPABILITIES". Part 3 focuses on the Data Management Plan. The section below addresses the physical and technical components of the Busway infrastructure.

1.5.1 Technical approach to implement and evaluate the demonstration

As indicated in previous sections. The program is designed to support multiple levels of automation and integration with other vehicles and the public. Through this grant, the City will add some minor civil and system enhancements to the Busway to support improved access, upgrades to the communications backbone, full monitoring of the Busway, two signalized intersections, five roadside DSRC stations, Kiosks, and gates to control access at each end of the facility. Figure 2 below shows a high-level schematic of the system.

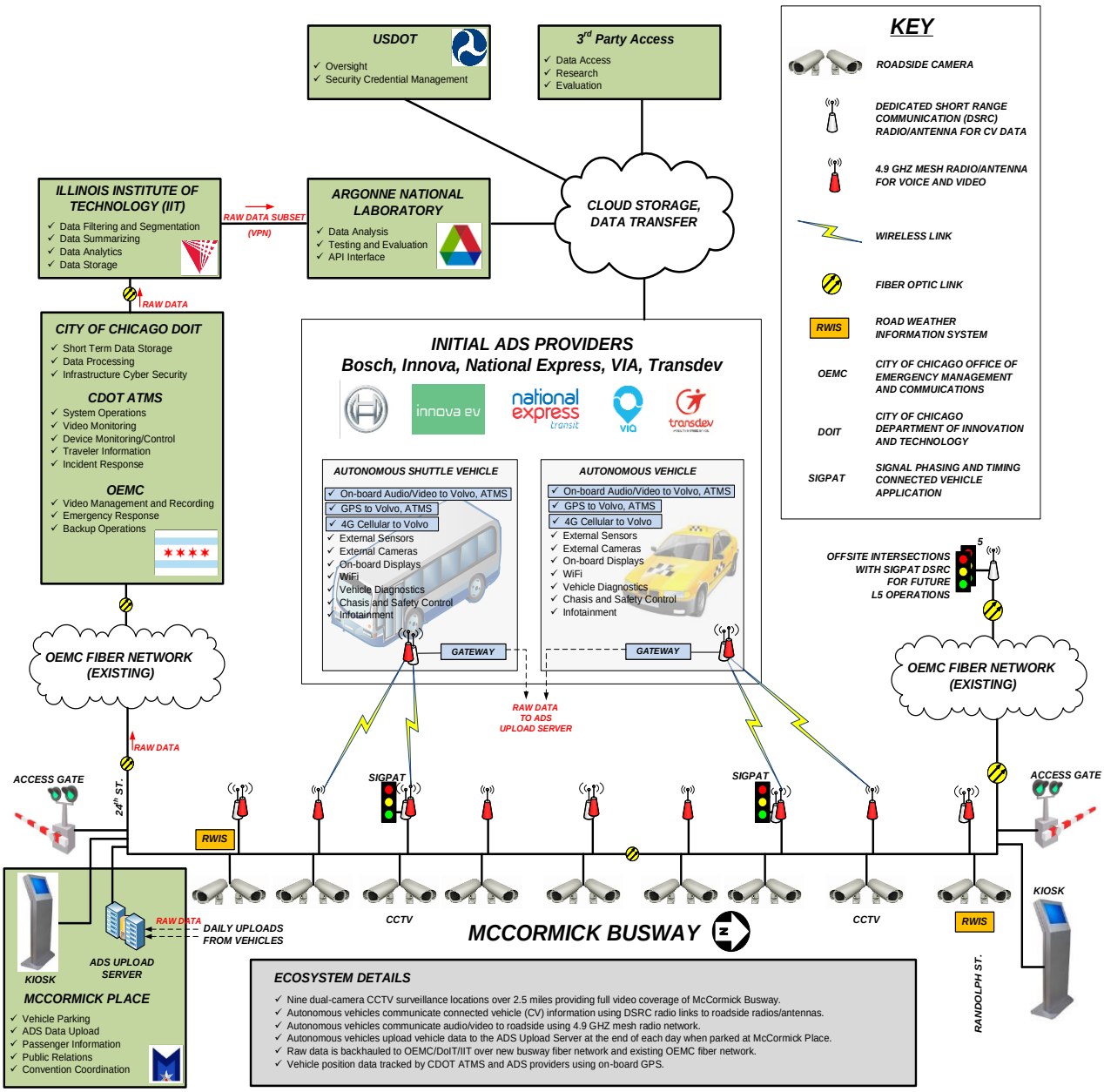

Figure 2 : High Level Schematic of the Chicago Autonomous Vehicle Ecosystem

The City already has a significant amount of communications infrastructure adjacent to the busway. Through this project we will implement a high speed, high capacity, hybrid fiber/wireless communication along the busway that ties into the City's existing communications infrastructure at both the north and south end of the project.

Vehicle data, camera images, and audio will be backhauled to the City's communications network over an existing fiber optic network that is operated and maintained by the City's Office of Emergency Management and Communications (OEMC). Existing OEMC fiber optic cable runs along Michigan Avenue, parallel to the busway for its entire length. We propose to make two tie-connections to the OEMC network, one at the north end at Randolph Street

and one at the south end at Cermak Road, to form a fully redundant fiber backhaul communications network. Once on the OEMC fiber network, all data will be aggregated at the City's Department of Innovation and Technology (DoIT) server farm. From DoIT, raw data will be passed to the Illinois Institute of Technology (IIT) and then to Argonne National Laboratories. OEMC and their network support/operations group at Motorola are already key participants on the Chicago Smart Mobility program, and as part of this project, we will expand their roles as necessary to facilitate the integration of the busway network.

Weather information will be collected in real time using road weather information system (RWIS) sensors at both ends of the busway. The data from these sensors will be processed by the City's ATMS with a either a direct connection to the sensors, or through an API with a third-party RWIS provider.

To monitor and enhance operations of the autonomous shuttle vehicles on the busway, surveillance cameras will be installed on each vehicle and along the entire length of the busway. Vehicles will also have a two-way audio connection so that operators can interact with passengers, or pre-recorded messages can be played describing the autonomous vehicle experience. Three on-board cameras will be installed. One forward facing windshield camera will look ahead of the vehicle to provide operators with information on roadway conditions, including weather, pavement conditions, and unauthorized pedestrian or vehicle activity. Two additional on-board cameras will monitor activity inside the vehicle and will give operators information on rider comfort and safety. Images from these cameras will also be recorded for security purposes at OEMC.

All facility cameras will be high definition, power over Ethernet (POE) units mounted in a weatherproof and vandal-resistant IP-67 housing. A total of nine (9) dual-head fixed CCTV cameras will be installed to provide full coverage of the McCormick Busway. Video from the cameras will be fed to a video analytics system that automatically identifies anomalies in normal operations, such as unauthorized pedestrians or a stalled vehicle on the busway.

The busway is characterized by several horizontal curves, and a short underground section where it crosses commuter railroad tracks. This character dictates that a larger number of relatively lower-height cameras will provide better coverage than a small number of cameras mounted high in the air. The area adjacent to the busway also varies significantly, requiring three different camera mounting configurations as described below:

- In depressed sections where retaining walls abut the busway, cameras will be mounted directly to the retaining wall using epoxy filled anchors, with rigid galvanized conduit running between cameras also mounted to the wall. A typical busway section of this kind is shown in Figure 3.

- In sections of the busway with adjacent clear space, cameras will be installed on 30-foot strain poles, using IDOT standard structures and foundations. These cameras will be installed behind existing barriers, or else new guardrail will be installed for protection. A typical busway section of this kind is shown in Figure 4.

Figure 3 : Retaining Wall Adjacent to Busway

Figure 4 : Clear Section Adjacent to Busway

- One section of the busway near the southern end has limited options for camera installation because of the proximity of the railroad on one side and buildings on the other. However, this section contains lighting poles that are suitable for camera and communications/power cable installation. A steel messenger cable will be attached to each pole with clamping hardware, and cables will be lashed to the messenger between poles. Figure 5 shows this area of the busway with limited space where cabling will be installed aerially on light poles.

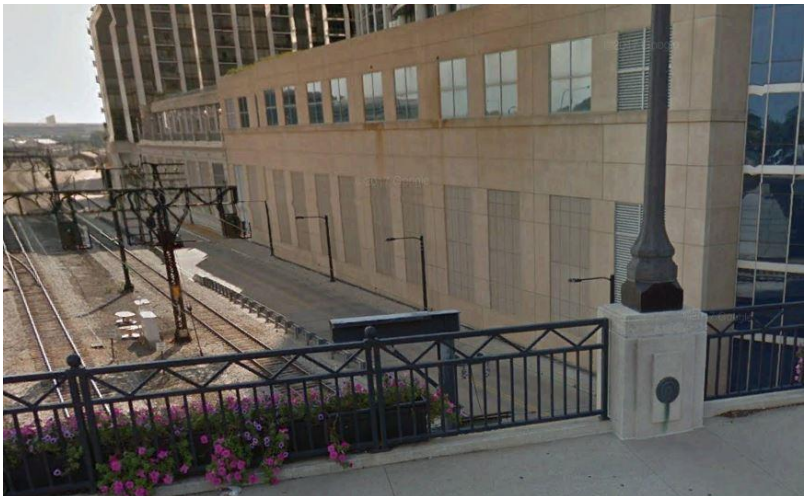

Figure 5 : Aerial Installation on Light Poles

To minimize the amount of splicing hardware required at each busway camera location, a small 12-fiber cable will be installed between cameras, of which only two fibers will be used. A field-hardened Layer 3 switch will be installed in a small cabinet at each location. The switch will be capable of routing packets to either one of the OEMC network tie-ins, providing fault tolerant communications in the event of a cable cut.

To support communications between the fiber on the busway and the autonomous vehicles, two wireless communications systems will be implemented. For vehicle data, on-board DSRC units will communicate between vehicles and one of four roadside receiver units. DSRC communications offers the low latency and high bandwidth necessary to support autonomous and connected vehicle data transmission.

For video and audio communications, a separate mesh radio network using the 4.9 GHz public safety band will be installed between the vehicles and roadside cabinets. A wireless subscriber unit and omni directional antenna will be installed on each vehicle and connected to an on-board access point that aggregates communications with the vehicle's cameras and a local video recording device. At each of the roadside cabinets, a wireless access point and omnidirectional antenna will be installed to receive communications from the vehicle. As the vehicle passes each roadside cabinet, a handoff connection to the mesh network will be made through each successive access point. The access point will be connected to the Layer 3 switch in the cabinet, and then backhauled to the rest of the network as described previously.

1.5.2 Physical Roadway

The Busway is a diverse fully access controlled roadway. Use of the Busway is limited to special event busing and few agency maintenance vehicles. The facility offers a wide variety of conditions that are ideal for testing the safety of ADS. It has all the features of a normal public use facility. The pictures below provide a sample few of the various cross sections of the facility. The facility is already fully usable and will require only a few enhancements to be ready for ADS testing.

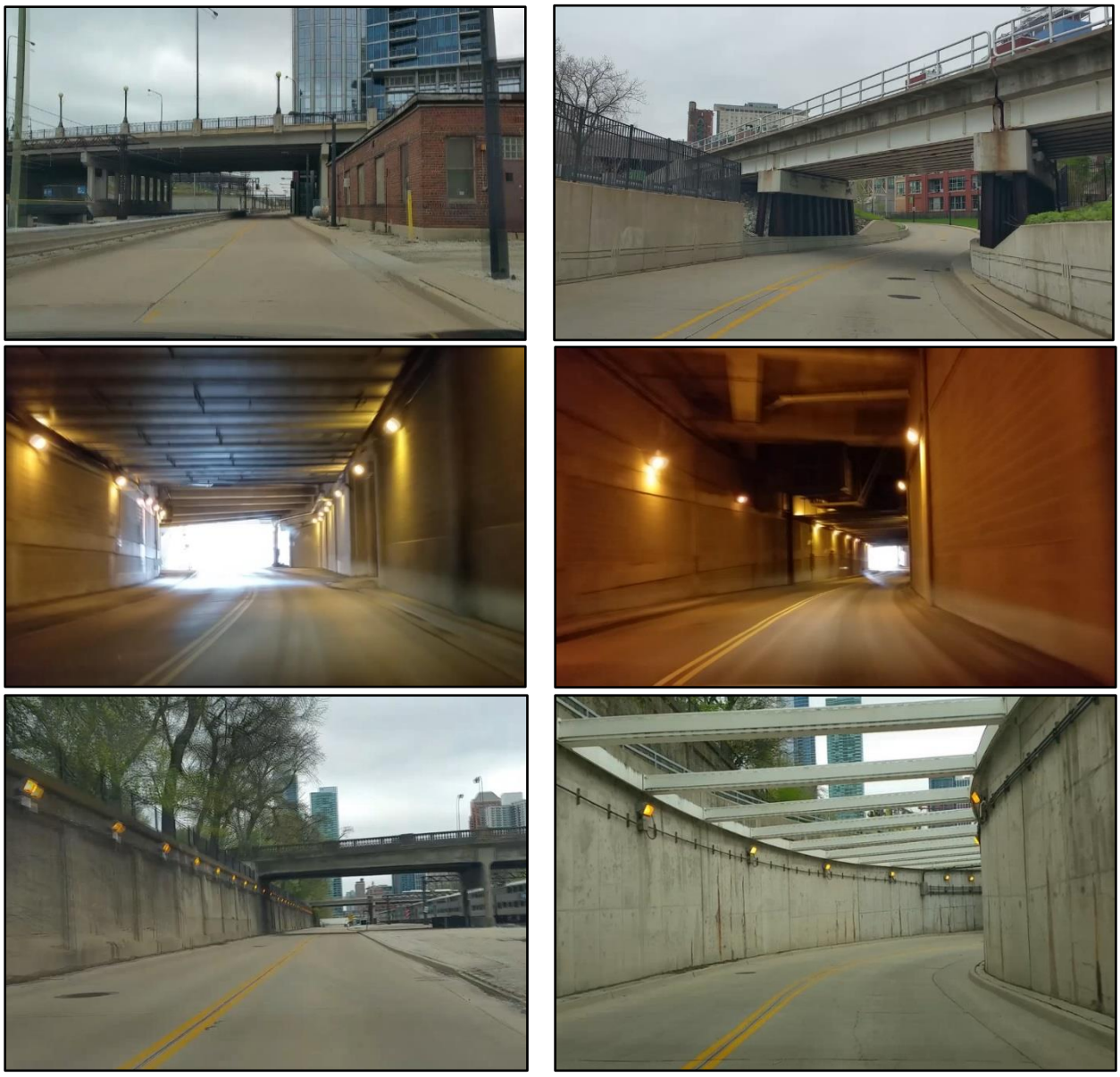

Figure 6 : Facility Images – Cross Sections

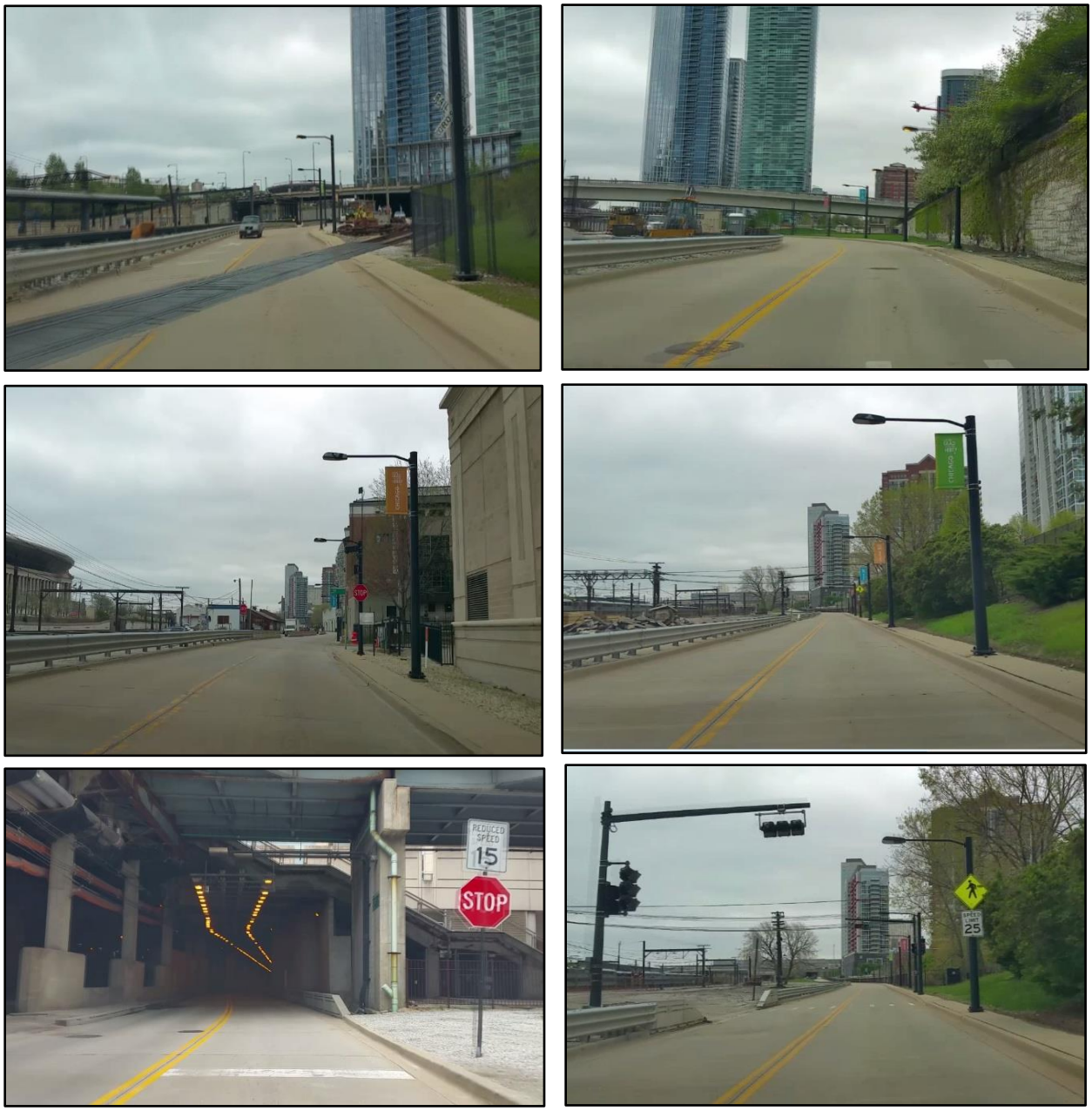

Figure 7 : Facility Images - Continued

Civil Infrastructure enhancements will be focused on passenger comfort and safety at locations where they board and deboard vehicles. These enhancements consist of the following:

- Pedestrian connections to existing McCormick Place convention center walkways.
- Pedestrian connections to existing McCormick Place convention center walkways.
- Raised platform boarding facilities for ADA handicap access. These platforms will be similar to bus rapid transit boarding facilities shown in Figure 8 on the following page.
- Upgraded lighting on pedestrian walkways and boarding areas.

- Transit shelters equipped with radiant heating elements and seating areas, similar to Figure 9 on the bottom of this page.

Figure 8 : Typical Raised Platform Boarding with Handicap Access

Figure 9 : Typical ADA Compliant Shelter with Seating

Final boarding locations will be chosen, and civil site design will be performed as part of the project.

Although the main autonomous busway implementation will be focused on the controlled access busway, operations will extend north of the busway to the Navy Pier area and surrounding hotels. Initially, operations of the busway will be limited to Level 3 and Level 4 functionality, but the long-term goal is to achieve Level 5 operations along the entire path

from McCormick Place to Navy Pier, and eventually throughout the city. To support operations north of the busway terminus, we will extend the communications infrastructure and implement connected vehicle roadside technologies along Columbus Avenue and Illinois Street. DSRC radios will be installed at the five intersections shown in Figure 10.

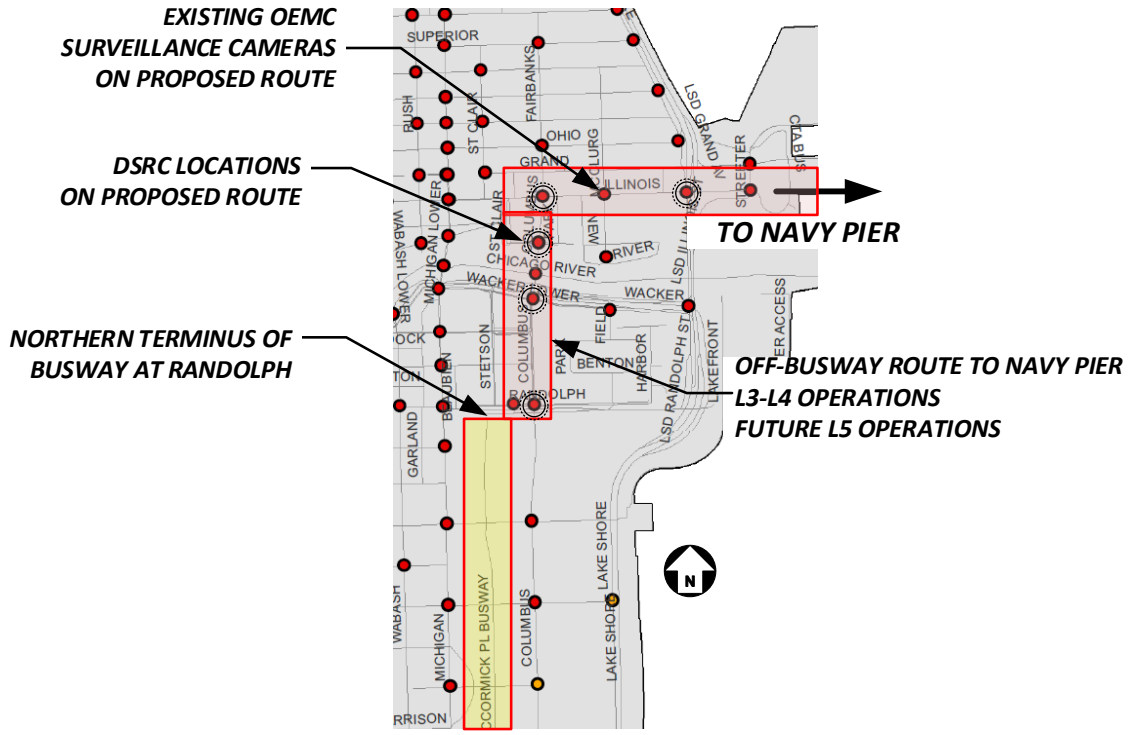

Figure 10 : Infrastructure North of the McCormick Busway

Cabinets at these intersections will be outfitted with DSRC radios and antennas, and connected to the signal controllers to support the following connected vehicle applications:

1. Eco-Traffic Signal Priority
2. Emergency Vehicle Preemption
3. Pedestrian in Signalized Crosswalk Warning
4. Red Light Violation Warning
5. Collision Avoidance (Intersection Movement Assist)
6. Reduced Speed/Work Zone Warning
7. Eco Approach and Departure
8. Spot Weather Impact Warning
9. Traveler Information

These applications will also be available on the busway itself, using the two existing busway traffic signal displays that control pedestrian access. The controllers that support busway and off-busway traffic signals will be upgraded to Advanced Traffic Controller (ATC) technology to take advantage of the NTCIP protocol and support for signal phasing and timing (SigPAT) connection vehicle operations. Analysis of connected vehicle safety applications will be performed as part of the project and used as a platform for the future expansion of the system to Level 5 operations on city streets.

The area north of the busway is already covered by the existing City-wide video surveillance system owned and operated by OEMC, as shown in Figure 10. These cameras are already available to the City's Traffic Management Center through a link between the ATMS and OEMC's Genetec video management system.

1.6 Legal, regulatory, environmental, and/or other obstacles to demonstrating the technology(ies)

1.6.1 Exceptions to Federal Motor Vehicle Safety Standards (FMVSS) and Federal Motor Carrier Safety Regulations (FMCSR)

As pilot/technology demonstration vehicles are not produced commercially, some of the proposed vehicles are not fully compliant with FMVSS and FMCSR. We may be requesting temporary exceptions to National Highway Traffic Safety Administration (NHTSA) for the Phase 1 technology demonstration for tests that extend off the busway. When the operation expands into city streets, the vehicles will be required to comply with the FMVSS and FMCSR requirements, or as appropriate, we will request phase specific exceptions to NHTSA based on operational conditions. The proposed roadway in which the vehicles operate in Phase 1 will remain limited access with low speed until all the federal standards are met, or an exception is approved.

1.6.2 Conformity to the Buy American policy.

We intend to comply with the Buy America requirements of this NOFO. None of the grant funds will be utilized for purchasing of vehicles. The grant funds will be utilized for developing a roadway for autonomous driving system testing and operations. The vehicle operator may be allowed to operate US built and non-US built vehicles on the proposed roadway. One exception to the Buy American policy will be with sensor packages we may be using on a test vehicle for data collection. Some of these components may be provided by our project partner Bosch and some may include non-US made components. Some of the grant funds,

not more than $1.2 Million, may be utilized to subsidize the cost of the vehicle operations and/or data capture so as to encourage the data sharing by the partners.

1.6.3 Data Sharing and Commitment to Evaluation

At the highest level, we will be collecting data from the infrastructure, the vehicles and environmental data. The project team is committed to participate in USDOT sponsored evaluation and share all the relevant data to third parties and the public. We will be continuously collecting data from the infrastructure and from the vehicles. The focus of the data collection will be to develop a data sharing platform that promotes the progression of ADS, supports regulatory decisions and identifies safety issues.

The field and vehicle data will be moved to a storage area for raw sensor data, onto which a variety of analytical and machine learning methods will be used to identify safety relevant and interesting cases. These cases and the relevant raw data describing these scenarios will then be transferred to a more broadly accessible storage/access location which can be used by a wider range of project partners and researchers. Ultimately, the goal is to use analytics to transform the raw sensor and vehicle behavior data collected within these efforts into actionable and rich data for a range of stakeholders (i.e. DOT, researchers, test agencies, the general public) at the access and fidelity required for intelligent decisions to be made. Argonne Labs will lead the data management program. The data management and analysis team has chosen Globus (https://www.globus.org/) to be the primary data storage provider for the raw unprocessed data. Globus is a sustainable, non-profit business within the University of Chicago. The relevant processed data and applicable subset of the raw data will be hosted on the Microsoft Azure cloud. See Section 3 for more data management data.

1.6.3.1 Infrastructure Data

Roadway sensors, cameras, and traffic signals will be collecting real time data from the Chicago Busway and all data will be logged in the backend systems provided by City of Chicago. The sensors will be recording vehicular speed, road surface conditions, every passthrough of the ADS vehicles, presence of non-ADS vehicles and pedestrians on the road. High definition video camera recording from the Busway will include around the clock footage from the entire length of the proposed roadway. All the video from the corridor will be saved for 30 days by default and incident data will be saved for as long as needed. City of Chicago's Office of Emergency Management and Communication currently have the capability to record and save 30 days or more of live video recordings from over 5,000 cameras. We will be utilizing the OEMC's Genetec system to monitor and record the live streams. The operations and evaluation teams will have full access to the video recordings for 30 days. From the Genetec system, they will have to ability to easily tag video streams of interest and store them as needed. This may be used for creating an incident specific data package or for general sharing of operations with the public and USDOT. At the two proposed traffic signals along the busway and the DSRC enabled signals north of the busway, we will be collecting

data on ADS vehicle's response to signal phase changes and communication with the traffic signals including receipt of Signal Phase and Timing (SPAT) messages and detection of the vehicle by the signal(infrastructure). We will deploy advanced video analytics technology to automatically detect incidents and near miss scenarios. At the rail road crossing, we will be collecting data on AV interaction with the rail road gate.

1.6.3.2 Vehicle Data

Through this project, we will collect a core set of ADS relevant sensors data comprised of Lidar, RADAR, and imaging to provide perception of the vehicle's surrounding environment at a scale relevant for the desired operational domain and usage profile (i.e. full-speed vehicle versus speed limited shuttle). While some providers may leverage a subset of these sensors in their production implementation, when possible, the team will seek to supplement the production sensor suite with additional sensors to enable value/information regarding the value of each sensing element to be made. A budget was set aside to add Lidar to vehicles that do not have it with the vendor setup.

In addition, we will be collecting several trip details including but not limited to GPS bread crumbs, speed, weather data from onboard sensors, Passenger counts, Passenger trip lengths, Trip duration, Safety records, Miles travelled, Equipment failures, Turn signal activation, Vehicle recognition, Pedestrian recognition, Traffic signal recognition and interaction, Road conditions, Driving pattern recognition, Lane recognition, Lane Departure Warning, and Forward Collision Warnings. Location data and some data elements will be provided to the TMC real time, other data elements from the vehicles may be stored in the vehicle, uploaded at the end of the test period.

IIT will store a large set of raw data from all the vehicles and infrastructure. The data management gold team will develop the process to aggregate the data from all the sources and vendors. The relevant safety data will be accessed and formatted from the aggregated raw data, and summary reports will be available as part of the full data set (See Section 3).

Access points will be installed throughout the Busway for the transfer of real time data from the vehicles to the TMC when available. Otherwise vehicle sensor data and CAN bus data will be transferred from vehicles to the data center from and upload station located at the end of the test facility.

1.6.3.3 Environmental Data

In addition to the data described above the following data will also be available:

- Weather environmental data including wind, visibility, noise, and humidity, and road conditions at the RWIS station.
- Detailed roadway civil design drawings will be developed for evaluation.

- Qualitative data will be generated through user and vehicle operator interviews and feedback. The Civil User Testing (CUT) Group with the project partner City Tech will lead the qualitative data collection with user surveys and interviews.
- Any audio interactions with users

Summarized data will be made available via daily, weekly and monthly packages for download. Detailed incident data and video from the vehicles and the infrastructure will be packaged separately by incident and will be made available for researchers.

1.6.4 Risk identification, mitigation, and management

An important part in managing a project of this nature is Risk Management. A Risk Management Plan will be submitted as part of the Project Management Plan. We have included some highlights here. Risks will be tracked in a risk register, and any changes in the risk register will be discussed in the regular teleconferences and included in the monthly reports. Specifically, any risk with a grade of A, B, or C (see below) will be listed as an item for discussion in the teleconferences and included in the monthly reports. Risk mitigation actions will be identified for each such risk, will be identified in the risk register, and will be tracked to completion in the project action items. The risks listed on these tables are only the initial ones identified for the project. The table below lists ratings and codes used in the risk register.

Rating for Likelihood and seriousness of each risk			
L	Rated as low	E	Rated as extreme (used for seriousness only)
M	Rated as medium	NA	Not assessed
H	Rated as high		

Grade: Combined effect of likelihood/impact					
		Impact			
		Low	Medium	High	Extreme
	Low	E	D	C	A

	Medium	D	C	B	A
	High	C	B	A	A

Recommended actions for grades of risk

Grade	Risk Actions
A	Actions to reduce the likelihood and seriousness to be identified and implemented as soon as the project commences
B	Actions to reduce the likelihood and seriousness to be identified and appropriate actions implemented during project execution
C	Actions to reduce the likelihood and seriousness to be identified and costed for possible action if funds permit
D	To be noted - no action is needed unless grading increases over time
E	To be noted - no action is needed unless grading increases over time

Change to grade since last assessment

NEW	New risk	□	Grading decreased
-	No change to grade	□	Grading increased

We have identified a few of the key project risks in the two subsections below.

1.6.4.1 Physical Safety

Safety of the passengers and other Busway users will be our primary concern. All vendors that use the system will be required to follow a strict progressive certification process, that will define when each vehicle will be allowed to operate under what level of automation and integration. As part of the certification process, the vehicle operators will be required to provide documentation of prior testing and all known safety issues. Only vehicles complying with the Certification Board's minimum safety criteria will be allowed to operate on the Busway. To reduce the physical hazard, the vehicles will be thoroughly tested in closed off conditions, prior to any integrated testing. We will implement a vehicle certification process for each vehicle automation level. Vehicles will need to be certified to migrate to the next level of autonomy or integration.

Initially, all vehicle tests or demonstrations will include a concierge or driver in the vehicle and ready to take physical control of the vehicle or assist any passengers. The vehicle operations will be monitored around the clock from the Chicago Traffic Management Center. In addition, live video from the Busway will be accessible from the Chicago Emergency Management Center, Chicago Fire District 1, and Chicago Police District 1. In case of emergency, the concierge or passengers will be able to directly contact the Traffic Management Center via a radio, or cellular, communication system installed in the vehicle as part of the Busway project.

The sensors and the high definition cameras will be constantly recording and monitoring near miss scenarios. If a safety issue is identified, the vehicles operation will be suspended until the hazardous condition(s) is removed or mitigated. Vehicles with repeat safety incidents will be removed from operations until they are recertified as fit for operation on the Busway.

Data from the vehicles themselves will be evaluated utilizing machine learning algorithms for actual and averted incidents. The team from, Argonne Labs, and Illinois Institute of Technology, will be responsible for setting up the system to evaluate safety incidents, collecting all the relevant data, and recommending corrective action. See Section 3.

1.6.4.2 Business Risk

A key component of the project for the City is the continuation of the program at the completion of the three-year grant. Business risk with the project comes from the financial viability for the vehicle operators and the City of Chicago. If the cost of operations turned out to be unexpectedly high, either party may be forced to shut down their operation. While the vehicle operators and the City do not expect to make a profit from the Phase 1 operations, prospects for long-term autonomous vehicle operation beyond the Busway is certainly a motivating factor for the vehicle operators to come to the Busway and test their vehicles. If the ADS vehicle operators do not see the possibility for such expansion, they may be pulling out their vehicles from the Busway eventually. The project team will market the project and develop a detailed plan for expanding the operations into other parts of the city.

Financial loss from safety incidents is another risk to the City and the Operators. To reduce legal and insurance liability, all users of the ADS vehicles will be required to sign a waiver before boarding the vehicles. The project team will develop and administer the waiver agreements on behalf of all users. Also, we will try to mitigate financial risk to operators by providing safe storage space for the vehicles, access to electric charging stations, and provide physical security round the clock on the Busway.

1.6.5 Cost Share

The chart below shows estimated the in-kind contribution from the project partners:

Agency	Type of contribution	Quantity	Approx. Contribution to Phase 1
City of Chicago	CDOT Staff (PYE)	8.5	$1,707,887
Parsons	Reduced Labor Rates	N/A	$425,970

The team is providing a significant amount of soft match to support the program:

- The City has invested a lot into the development and maintenance of the Busway. ~ $34 M
- The City will continue to support and maintain the Busway outside the cost of the is project. ~$50K per year
- The Vendors will be providing all the vehicles for the testing. Potential value of the this is easily over $1M. They are not included as in kind because they will remain the property of the vendors.
- Argonne National Labs is hosting the filtered data and providing high band width access to the data with not costs to the project. With significant usage the value of the is easily over $500k per year. This is not listed as in kind because part infrastructure cost are already funded with federal dollars.