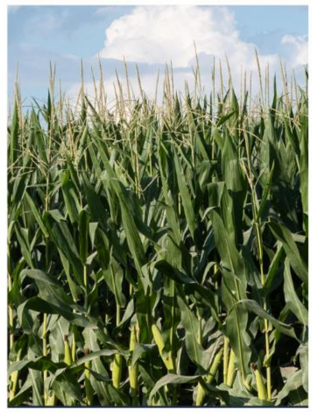
D.A.T.A in Ohio

Deploying Automated Technology Anywhere



Application By:
Ohio Department of Transportation through DriveOhio

Submitted to:
United States Department of Transportation

DriveOhio

Ohio Department of Transportation

DriveOhio

1980 W Broad St. I Columbus, OH 43223

March 21, 2019

Sarah Tarpgaard, HCFA-32
U.S. Department of Transportation (USDOT)
Federal Highway Administration (FHWA)
1200 New Jersey Avenue, SE; Mail Drop: E62-204
Washington DC 20590

Re: Automated Driving System Demonstration Grants
Funding Opportunity Number 693JJ319NF00001

Dear Ms. Tarpgaard,

We are pleased to submit an application in response to the Notice of Funding Opportunity (NOFO) issued on December 21, 2018, titled Automated Driving System Demonstration Grants. The focus of this grant is directly in line with the mission of DriveOhio, which is tasked by the Ohio Department of Transportation to advance smart mobility initiatives. In development of this application, we have collaborated with the Transportation Research Center (TRC), many universities, agencies, and organizations, forming and strengthening relationships that will continue to develop throughout the execution of this project. We likewise look forward to collaborating with USDOT to enhance the quality of life for residents of Ohio and the nation, while providing meaningful data through the ADS rural ride-hail and highway freight platooning demonstrations described herein.

For this purpose, DriveOhio requests funding through this NOFO. To extend the reach of these funds, we have coordinated matching funds, as well as passenger vehicles, heavy vehicles, donated labor hours additional equipment, described herein.

Thank you for this opportunity,

James A. Barna, P.E.
Executive Director

Summary Table	
Project Name/Title	D.A.T.A. in Ohio: Deploying Automated Technology Anywhere
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	Ohio Department of Transportation 1980 West Broad Street Columbus, OH 43223
Point of Contact (Name/Title; Email; Phone Number)	Cynthia Jones Cynthia.Jones@drive.ohio.gov 614-466-1975
Proposed Location (State(s) and Municipalities) for the Demonstration	Southern Ohio, including: Athens County, OH Vinton County, OH Dublin, OH Marysville, OH East Liberty, OH
Proposed Technologies for the Demonstration (briefly list)	ADS L3 Passenger Vehicles ADS L3 Trucks with Platooning Autonomous ParaLift™ (supporting technology)
Proposed duration of the Demonstration (period of performance)	4 years
Federal Funding Amount Requested	$9,999,967
Non-Federal Cost Share Amount Proposed, if applicable	$7,791,095
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$17,791,062

Table of Contents

List of Figures

1.1. Executive Summary

1.1.a. Vision, Goals, and Objectives

ADS data from rural environments and cooperative highway applications are crucial to evaluate safety and inform rulemaking.

Worldwide, ADS testing and deployment has focused on low-speed applications in densely populated areas, resulting in a striking lack of data from rural environments and cooperative highway applications. This project, called **D.A.T.A. in Ohio,** consists of a multi-pronged, iterative demonstration approach focusing on rural environments and cooperative automation. The data and insights gathered through D.A.T.A. in Ohio will enable local, state, and federal agencies to develop more effective and informed ADS policies that benefit all regions of Ohio and the nation. With the goal of efficiently collecting a robust data set, D.A.T.A. in Ohio also brings together government and industry partners to aggregate and evaluate data from other existing projects.

Figure 1-1: D.A.T.A. in Ohio's Multi-pronged ADS demonstration approach

This collaboration will provide USDOT with more comprehensive information than could otherwise be collected through grant-funded ADS demonstrations alone.

1.1.b. Key Partners

Dedicated team of experts

The Ohio Department of Transportation (ODOT) is committed to enhancing its transportation system with leading-edge technology. To support that goal, it has established DriveOhio, which is a statewide center for advancing smart mobility backed by the full resources of ODOT. Through DriveOhio, ODOT has partnered with the Transportation Research Center (TRC), Inc., three leading public universities, industry partners (including Bosch, Columbus Yellow Cab, AutonomouStuff and Robotic Research) and community partners (including the City of Athens, Foundation for Appalachian Ohio, Buckeye Hills Regional Council, and the Diabetes Institute at Ohio University). We understand existing gaps ADS data set and developed a plan to fill those gaps through D.A.T.A. in Ohio. A detailed organization chart can be found in attached Part 2 – Management Approach.

Figure 1-2: D.A.T.A. in Ohio government, education, industry, and community partners

WHY DriveOhio?

- Focus on integrating rural & transportation-challenged populations into ADS ecosystem
- Dedicated team of DriveOhio experts ready to operationalize ADS projects
- Close-knit collaborators with demonstrated success on ADS initiatives
- Project Advisory Board with safety, policy, data analysis, and outreach experts
- Jump start on safety and through previous small- and large-scale initiatives
- 78% Local Match

1.1.c. Issues and Challenges

ADS data from rural roadways and Society of Automotive Engineering (SAE) Level 3 (L3) automated driving system (ADS) freight platooning is extremely limited. As outlined below, D.A.T.A. in Ohio will take a multi-pronged demonstration approach to gather needed data. Not only will demonstrations provide useful ADS performance data, but they will also provide insight into public benefits that can be achieved through ADS deployment.

ISSUES & CHALLENGES	TECHNOLOGIES/APPROACH	ANTICIPATED PERFORMANCE IMPROVEMENTS
Difficulty operating ADS technology in rural areas due to infrastructure limitations, topography, etc. Limited transportation options in rural areas due to distance between destinations and driver shortages	Rural ride-hailing using AutonomouStuff passenger vehicles, AutoWare toolkit, the CARMA platform, and Columbus Yellow Cab (CYC) interface	Better understanding of ADS limitations in rural environments; feedback for research and development; policy insights Improved mobility and transportation efficiency; reduced driver hours; increased access to food, healthcare, and jobs
Limited data on ADS highway platooning Human driver performance limits efficiency and safety performance of freight transport	Bosch ADS L3 trucks with platooning capability in highway application (includes single ADS system, multiple vehicle type platooning, and interactions between passenger vehicles and truck platoons)	Data on safety performance and ADS operation Closer platooning with ADS L3 and platooning capability, improved safety performance and fuel economy, increased highway capacity
Manual wheelchair loading, unloading and securement is time consuming and subject to human error	Robotic Research ParaLift™ automated wheelchair lift and securement system with CYC interface (ADS-supporting technology)	Enables wheelchair users to access driverless vehicles; improves efficiency, and safety performance for passengers
Significant gaps in ADS data due to limited testing and proprietary Original Equipment Manufacturer (OEM) data	ADS data-sharing partnerships: data to be Additional ADS data to be provided by existing projects funded outside of this grant Data-Sharing Partners: TuSimple, Smart Circuit, Ohio State University, Denso	Strengthened ADS data set and insights by aggregating and analyzing data from project sources outside ADS grant-funded demonstrations

Figure 1-3: Issues and challenges address by D.A.T.A. in Ohio

1.1.d. Geographic Area and Jurisdiction

Ohio is a microcosm of the U.S. Through a year in Ohio, deployments will experience transportation challenges related to all four seasons, including wet and dry conditions, falling leaves, and snow-covered roadways. Ohio's roadways range from two-lane rural routes to divided highways that traverse level, rolling, and mountainous terrain through a mix of urban, suburban, and rural areas. These factors make Ohio an ideal testbed for generating safety performance and rulemaking data transferable to the entire nation.

WHY RURAL OHIO?

- Microcosm of the U.S.
- Current trends focus on urban and standalone highway deployments
- 97% of land is rural nationwide[1]
- 19% of U.S. population in rural areas[1]
- 54% of roadway fatalities occur on rural roadways (2.4x that of urban areas)[2]

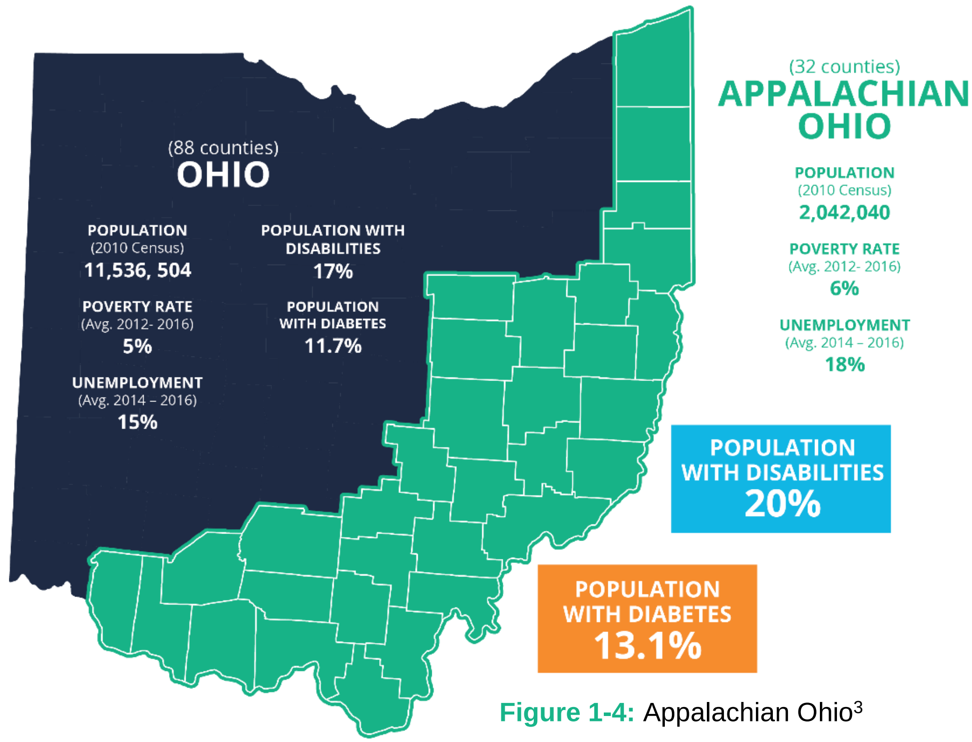


Figure 1-4: Appalachian Ohio[3]

All D.A.T.A. in Ohio demonstrations will be conducted in Ohio and can start without delay. In 2018, Governor Kasich issued an executive order which authorized testing and pilot programs for Society of Automotive Engineering (SAE) Level 3-5 ADS-equipped vehicles on all public roads (Executive Order 2018-04K). D.A.T.A. in Ohio partner TRC in East Liberty, Ohio, maintains the nation's largest independent vehicle proving ground and test facility and houses NHTSA's Vehicle Research and Test Center (VRTC).

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[1] American Community Survey 2013-2017
[2] http://www.ncsl.org/research/transportation/traffic-safety-on-rural-roads.aspx
[3] https://www.ohio.edu/medicine/di/needs-assessment.cfm: Appalachian Regional Commission *Health Disparities in Appalachia,* 2017; Rural Healthcare Access: Research Report, Appalachian Rural Health Institute, 2019.

1.1.e. Proposed Period of Performance

Of the 4-year performance period, the first year is dedicated to planning, vehicle procurement, and software integration. Years 2, 3 and 4 will focus on testing and demonstration iterations, first in series, then in parallel. D.A.T.A. in Ohio will provide this data to USDOT in near real time and for five years after completion of the performance period. We will also continuously apply insights from testing and demonstrations to identify gaps and select new scenarios for subsequent test and demonstration iterations during the performance period.

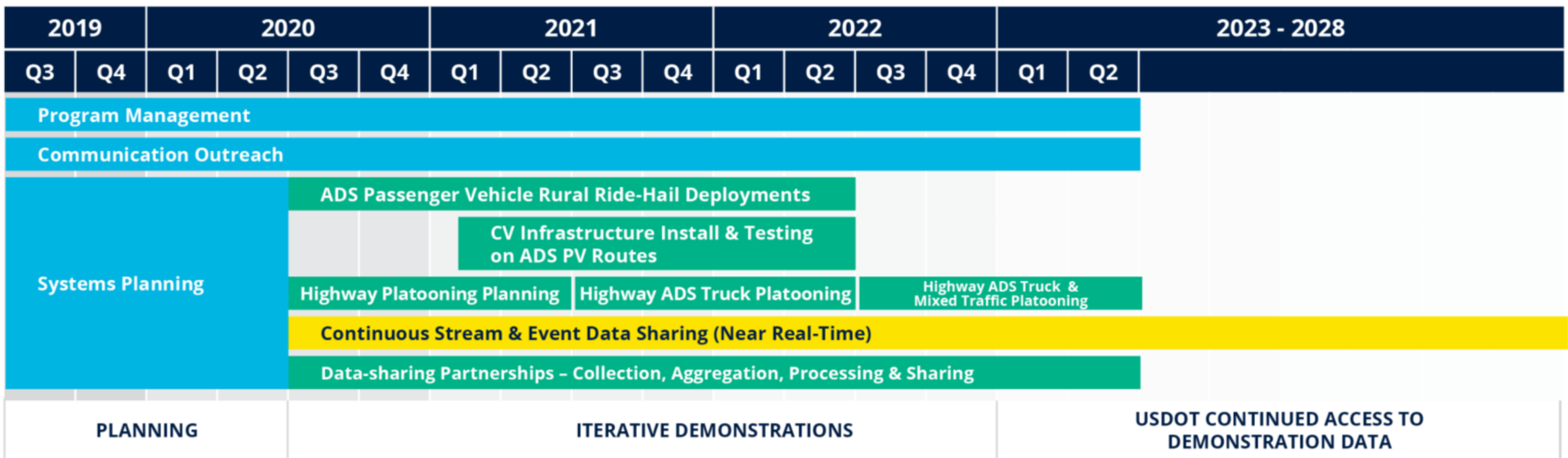

Figure 1-5: Project Schedule

1.2. Goals

1.2.a. Safety

For ADS to be safely integrated into the Nation's on-road transportation system, we must have a robust strategy for assessing and safe deployments. This process will first occur in controlled environments off public roadways and then in a safe and transparent manor on the public roadways.

> **TIERED APPROACH TO SAFETY AND DATA**
>
> - **Controlled environment testing,** focusing on testing the necessary capabilities, while producing targeted data
> - **Safety driver training** provides experienced drivers trained in ADS and capabilities
> - **Field operational testing** will provide a final safety check before passengers are allowed on the deployment

1.2.a.i. Controlled Environment Testing

The D.A.T.A. in Ohio team has experience vetting early stage prototypes and working with partner entities to provide a comprehensive safety metric to evaluate ADS. With a controlled testing environment and strikable surrogate vehicles and pedestrians, demonstration ADS will be subjected to targeted scenarios designed to pressure test the system before deploying. For each scenario tested, data will be provided and can be used for future deployments. If the ADS raise safety concerns, these will be addressed and retested, generating data on both the process taken and the new results gathered.

1.2.a.ii. Safety Driver Training

The D.A.T.A. in Ohio team has extensive experience in driver training, offering world-class courses for high performance driving. In the coming year, TRC Inc. will be rolling out a dedicated safety driver training course targeted at setting industry best practices for drivers of prototype ADS deployments. They address faults common in ADS and how to safely resume control of the vehicle. Each deployment will only have drivers who have undergone this training and have firsthand experience with responding correctly to these system faults. This course will also train drivers in the expected performance of the system and what to look for to trigger an event flag for data recording.

1.2.a.iii. Field Operational Testing

After controlled environment testing, the ADS will be deployed on the proposed course for final validation before passengers are included in the demonstration. The results of this final testing will provide important data that will feedback any unexpected problems to the controlled environment testing, providing a more robust vetting process. This testing will be done under a diversity of conditions (e.g. peak traffic, sunrise, rain) to provide a comprehensive safety check.

1.2.b. Data for Safety Analysis and Rulemaking

FOCUS ON SAFELY INTEGRATING ADS

- Complete the dataset with understudied environments and applications
- Contextualize data by integrating vehicle, weather, roadway, and infrastructure information
- Apply data insights to ongoing demonstration iterations, and share with policy makers
- Evaluate connected vehicle (CV) infrastructure impact on ADS safety

For ADS to be safely integrated into the Nation's on-road transportation system, we must plug holes in the existing ADS dataset. To that end, D.A.T.A. in Ohio will take a three-tiered approach to gathering data for ADS and safety performance evaluation purposes. We will use our ADS deployments to identify risk events, then recreate those and similar events through hardware-in-the-loop (HIL) simulations and controlled environment testing. By manipulating variables in controlled settings, we can better understand causes, extrapolate insights, and provide a baseline for developing mitigation strategies.

1.2.b.i. Completing the Dataset

D.A.T.A. in Ohio demonstrations target understudied, challenging applications and environments, specifically rural roadways and ADS truck and passenger vehicles with platooning capabilities. Data will be collected in two forms: continuous data streams and event logs. The attached Part 3 – Data Management Plan Draft provides an overview of how data will be captured, transmitted, stored, and archived for the duration of the project, and accessed by different stakeholders, including USDOT researchers and project evaluators and the public.

Through data-sharing partnerships, we will efficiently gather data from a wider variety of vehicles, ADS technologies, applications, and environments than would be possible through grant-funded ADS demonstrations alone. The resulting robust data set will enable broadly applicable ADS safety performance analysis and rulemaking. Both D.A.T.A. in Ohio demonstration data and shared partner data will be available to USDOT researches, program evaluators, program partners, and the public through the USDOT Secure Data Commons (SDC).

1.2.b.ii. Contextualizing Data

Streaming data will be contextualized by flagging undesirable or unexpected ADS behavior for further analysis. Preset criteria for ADS or vehicle behavior, as well as safety operator real-time reporting, will trigger additional data to be saved immediately before, during, and after flagged events. ADS and vehicle data will then be merged with weather, road, camera, and infrastructure data to get a fuller picture of what happened and why.

TRIGGERING EVENT LOGS

Pre-set criteria include:

- Sudden breaking
- Sudden lane change
- High accelerations

Safety Operation Feedback:

- Pushbutton on dash for safety or operational concerns
- Recorded audio file with comments

1.2.b.iii. Evaluating Connected Vehicle Infrastructure's Impact on ADS Performance

Initially, on-road demonstrations will be conducted on rural roadways without Connected Vehicle (CV) infrastructure to gather baseline safety performance data. We will then strategically install Roadside Units (RSUs) along the same roadways to evaluate the impact of CV infrastructure on ADS safety performance. These efforts will focus on enhancing safety performance under special conditions, such as freeway merges, work zones, incidents, and sharp roadway curves. We will also leverage Ohio's existing connected vehicle infrastructure, the U.S. 33 Smart Mobility Corridor, to strengthen our dataset without the need for extensive infrastructure investment.

1.2.c. Collaboration

Support from state and local agencies, research facilities, industry, and local communities will drive the successful implementation of D.A.T.A. in Ohio demonstrations. Part 2- Management Approach details the role each partner listed below will fulfill in the D.A.T.A. in Ohio demonstration activities.

CORE PARTNERS
- ODOT
- DriveOhio
- TRC
- OU
- UC
- OSU

TECH PARTNERS
- AutonomouStuff
- Robotic Research
- Bosch
- Mobikit
- Columbus Yellow Cab

INDUSTRY PARTNERS
- Campbell's Market (Vinton County)
- Honda
- Denso
- TuSimple

AGENCY PARTNERS
- Ohio Department of Health
- Ohio BMV
- Vinton County Board of Commissioners
- NW 33 Innovation Corridor Council of Governments (COG)

CITY PARTNERS
- Athens
- McArthur
- Cincinnati
- Columbus
- Youngstown
- Marysville
- Dublin

DATA PARTNERS
- TuSimple
- Smart Circuit
- OSU
- Denso

Figure 1-6: D.A.T.A. in Ohio partners from government, education, industry, and the community

1.3. Focus Areas

1.3.a. Significant Public Benefits

Fifty-four percent of all fatal traffic crashes occur on rural roads, so the D.A.T.A. in Ohio data-driven insights have great potential to save lives. Combining ADS data with connected vehicle and infrastructure data, will also produce rich datasets that can be used to derive insights into mobility, efficiency and environmental impacts, which are key aspects of Transportation System Management and Operations (TSMO).

1.3.b. Addressing Market Failure and Other Compelling Public Needs

Industry and government alike have failed to adequately address mobility and transportation safety needs in rural areas. ADS offers one potential solution, but due to the initial investment needed for pilot deployments, they tend to center on densely populated areas where high definitions (HD) mapping and infrastructure is more cost-effective.

D.A.T.A. in Ohio has carefully crafted its set of complementary ADS demonstrations to collect rural data in a cost-effective way by leveraging Ohio's unique research facilities at TRC, existing infrastructure, and data from other ADS initiatives statewide.

Armed with the data and insights from D.A.T.A. in Ohio's ADS demonstrations and data-sharing partners, we have the potential to improve mobility and access to food, healthcare, and jobs and encourage industry investment in underserved rural areas by making transportation more efficient.

1.3.c. Economic Vitality

As a state agency that works with federal funds, ODOT and DriveOhio are familiar with focusing purchases on domestic goods through the Buy American regulation. ODOT through DriveOhio commits to prioritizing American goods and products in accordance with this and other applicable regulations. Major purchases through this project include a Dodge Caravan, three Ford Transit vans, and Navistar equipment. The vehicles will be purchased through matching funds, as shown in Part 6 – Budget.

As an additional strength of the ADS demonstrations selected for this project, safety performance and efficiency gains from ADS deployment may strengthen the business case for investing in rural areas, potentially bringing jobs, goods, and services to underserved populations.

1.3.d. Complexity of Technology

The ADS L3 passenger vehicles and ADS L3 freight vehicles with platooning capabilities are included in our demonstrations, allowing high-speed platooning; high-accuracy lane level localization under challenging conditions; time-synchronized collection, sharing and analysis of ADS big data; ADS and CV infrastructure integration; and unanticipated behavior from vulnerable road users (VRUs), such as pedestrians, cyclists, and scooters.

EVALUATING L3 ADS PERFORMANCE

- Highway, two-lane, rural roadways
- Wide range of speeds (0-70 mph)
- Day and night operation
- All seasons, low visibility, etc.
- Variable surface friction (paved, unpaved, gravel)
- Unexpected behaviors from other vehicles, pedestrians, cyclists, etc.
- Car following (stop and go, lane changes, etc.)
- Emergency vehicles (EMT, fire, police, etc.)
- Speed limit changes and advisories
- Variable local and state driving laws
- High-speed (freeway) and low-speed merge
- Work zones: people directing traffic
- Police/first responder: directing traffic

1.3.e. Diversity of Projects

The D.A.T.A. in Ohio demonstrations integrate multiple data sources and technologies: ADS L3 passenger vehicles and ADS L3 trucks, platooning capabilities and cooperative, connected vehicle environments, and ParaLift™ supporting technology. As directed by data needs, these technologies will be used in a variety of environments and applications, including highway (rural/suburban/urban), rural roads, work zones, and four-season weather conditions, among others.

1.3.f. Transportation-Challenged Populations

Transportation-challenged populations are present everywhere, but their transportation burden is magnified in rural environments. Lack of transit systems, limited direct routes, long travel distances, and uneven roads are just some of the added challenges rural environments pose. Our rural ride-hail features ParaLift™ technology, which enables autonomous access and securement for wheelchair users. ParaLift™ is essential supporting technology as driverless vehicles become increasingly prevalent, providing wheelchair users equal access to ADS transportation.

1.3.g. Prototypes

Commercially available and cutting-edge L3 ADS prototype technologies will be tested in closed-course and controlled environments prior to on-road use to promote safe operation of the ADS in deployment environments. ADS software will be regularly evaluated and updated. Furthermore, safety performance tests will be repeated after each upgrade before putting vehicles back on public roads. ADS-equipped demonstration vehicles will also have a safety operator who can override the ADS, should it fail to operate safely or appropriately for the situation.

1.4. Demonstration Requirements

1.4.a. ADS Technology Research and Development

This proposal focuses on physical demonstration of SAE Level 3 and above automation and ADS technologies. All ADS equipped demonstration vehicles will be drive-by-wire and street-legal, with:

- Lane level localization
- 3D sensing
- Perception of other vehicles and vulnerable road users for safe operation
- Situational awareness
- Decision making appropriate for their intended application.

Research and development is built into our team, as core partners include research-focused public universities and the TRC Inc. Details on their qualifications can be found in Part 2 – Management Approach.

An ADS-enabling technology, Robotic Research's ParaLift™ will be tested in parallel with the ADS deployment to assess future capabilities that are required to bring ADS technologies to persons with disabilities.

1.4.b. Physical Demonstration

The purposed of D.A.T.A. in Ohio is to deploy iterative physical demonstrations of ADS passenger and freight vehicles and cooperative automation technology in rural environments and highway applications. Additional testing methods, including hardware-in-the-loop simulations and closed track testing, will be used to inform physical demonstrations and where safety performance or operational concerns preclude on-road use (e.g. crash scenarios). Additional testing will also be used to obtain data in scenarios that are missing from on-road testing by creating various challenging scenarios. For these targeted collection scenarios, a combination of simulated and physical vehicles will be used, providing robust data for safety performance analysis and rulemaking purposes.

1.4.c. Near Real-Time Data Gathering and Sharing

All data from deployment activities, targeted collection, and data-sharing partners will be aggregated into a common structure and stored using the ITS JPO data sharing platform. Common trends in event behaviors will be identified using analytics tools provided by Mobikit and in-depth event reviews to identify specific event groups and types for further investigation. Mobikit.io is a data analysis and sharing platform that provides spatiotemporal data science, analytics, and visualization capabilities. Mobikit.io ingests real-time raw vehicle data collected via wireless, cellular, fiber, and dedicated short range communications (DSRC) and provides a variety of high-performance services including data processing/cleaning, feature extraction, data sharing and rights management, visual and notebook-based analytics, and machine learning-based event feeds. These capabilities can enable all the participants in the D.A.T.A. in Ohio ecosystem to collaborate efficiently and perform rapid analytics on vehicle data, aiming to democratize and accelerate collaborative innovation of autonomous transportation solutions.

The D.A.T.A. in Ohio team will leverage their full set of skills and capabilities, including expertise in ADS safety performance, testing, simulation, algorithms, and infrastructure to explore potential causes of the unexpected behaviors, delivering insights and working to identify root causes. In addition to data collected through our demonstrations, D.A.T.A. in Ohio will aggregate and provide relevant ADS, CV, and infrastructure data from the government agencies, universities and industry partners and projects listed in **Figure 1-6**. This data-sharing will allow USDOT to identify and address more ADS challenges than would be possible through grant-funded activities alone. This creates data-sharing relationships that could last beyond the length of this single demonstration. Details on data types, collection, storage, and access can be found in the attached Part 3 – Data Management Plan draft.

1.4.d. Input and Output User Interfaces

We will leverage Columbus Yellow Cab's (CYC) existing remote reservation and payment system for the ADS and ParaLift™ ride-hail. Not only will we have access to its operator and rider smartphone apps for scheduling and tracking rides, eliminating the need for costly development, but we will have unfettered access to CYC's comprehensive, real-time demonstration data for integration and comparison with overall project data. CYC's robust, proven, and flexible system can accommodate ridesharing and single use pickups, vehicle real-time location tracking, and on demand and future scheduling. CYC will also provide a dedicated phone line for non-smartphone users, with a phone or desktop interface for community partners to schedule rides for others. Using this line, hospitals or other destinations can arrange for a ride after someone's appointment or schedule rides for future visits. Users can also request a ParaLift™ equipped vehicle, as needed.

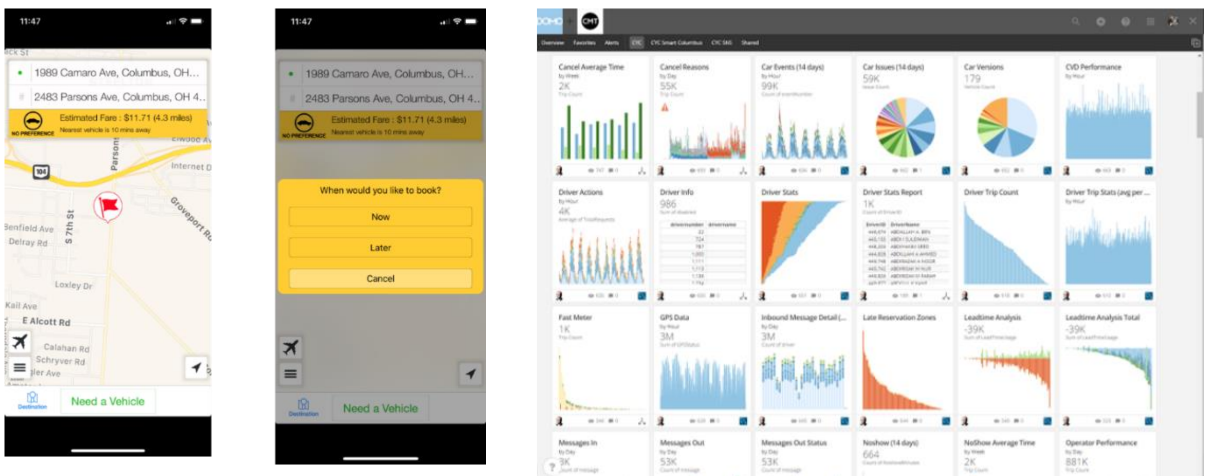

Figure 1-7: Example of Columbus Yellow Cab input/output interface

1.4.e. Scalability and Outreach

Ohio's topographical features, transportation system, urban/suburban/rural centers, and weather conditions are representative of the entire country, making the data and results from D.A.T.A. in Ohio replicable and scalable throughout both Ohio and the nation. ODOT through DriveOhio embraces its role as an instigator and coordinator to encourage technology in transportation. At the same time, Ohio's leading researchers at UC, OSU, OU, and TRC, unique research and testing facilities at the Transportation Research Center (TRC), experience with smart technology projects, and strong partnerships make Ohio the ideal location for developing, testing, and deploying new technologies.

Understanding the importance of outreach, D.A.T.A. in Ohio is already working with government agencies, universities, technology partners, and community and regional stakeholders, such as the Appalachian Regional Commission (ARC), the National Local Transportation Assistance Program Association (NLTAPA), and the Tribal Transportation Assistance Program (TTAP).

Before demonstrations even begin, we will work to identify key stakeholders and engage the public through town hall meetings to educate, inform, and raise awareness of the technologies to be demonstrated. Demonstration planning and design will include outreach components, building in communications, innovation, partnerships, training resources, safety, and professional development.

PROPOSED ENGAGEMENT PARTNERS

- Libraries
- Education
- Health
- NLTAPA
- ODOT County Garages
- ODOT District Public Information Officers
- Community Action Agencies
- Appalachian organizations
- Farm & dairy associations
- Extension offices
  - Athens County
  - Vinton County

OUTREACH METHODS

- Webinar
- Variable sign boards
- Town hall meetings
- Blogs
- Articles
- Letters to the editor
- Playbook
- Flyer distribution materials for locals
- County fairs/community events

Figure 1-8: Outreach and Scalability

1.5. Approach

1.5.a. Implementation and Evaluation

D.A.T.A. in Ohio's fundamental demonstration approach is designed to provide the USDOT with comprehensive, robust data to evaluate safety performance and inform rulemaking. This approach enables us to efficiently identify gaps in the ADS data set; target demonstration activities to fill those gaps; collect and share continuous stream and event data; and use data findings to inform testing and deployment iterations. The process will be the same for both ADS passenger vehicle and truck demonstrations.

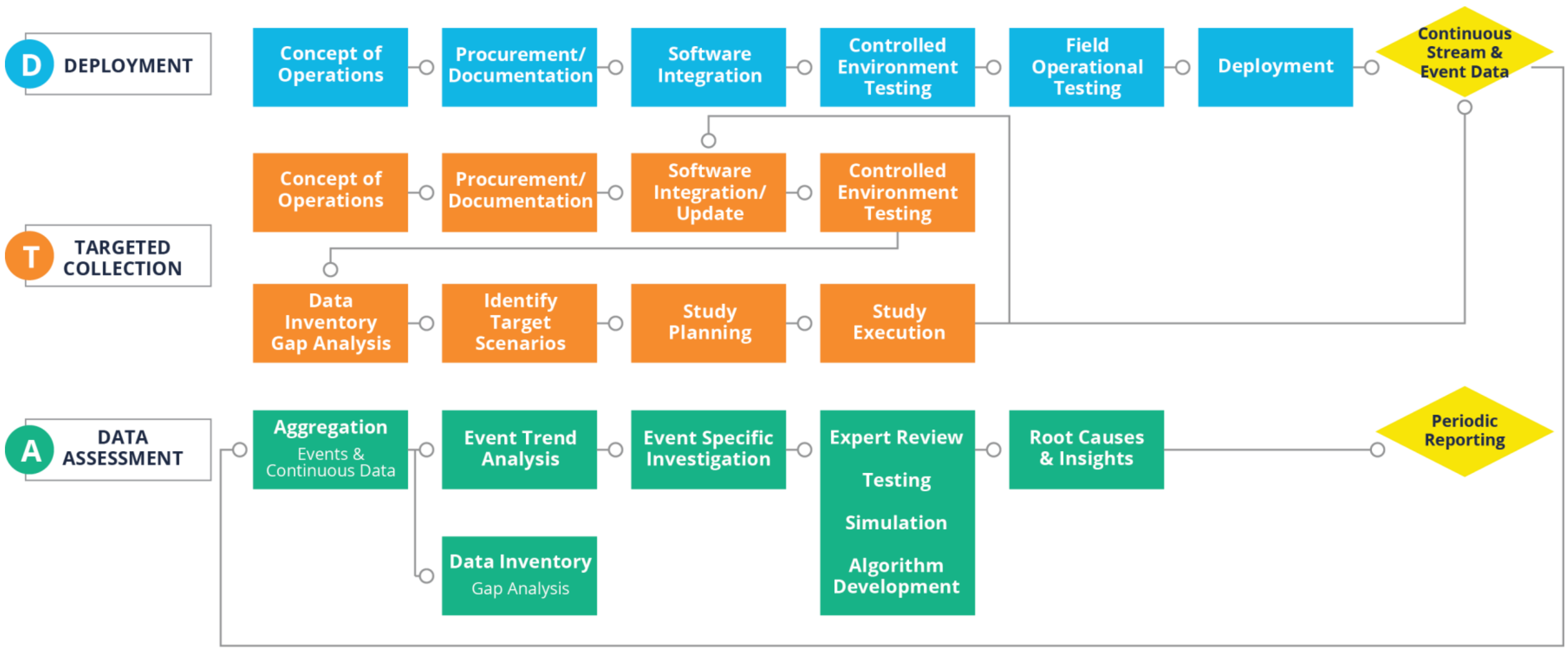

Figure 1-9: Connection between project activities.

1.5.a.i. Deployment

Deployment activities will begin with standard Concept of Operations (ConOps), Procurement, and Software Integration, followed by Controlled Environment Testing conducted at the TRC. This Controlled environment testing will validate safety performance prior to on-road use, based on published behavioral competencies for ADS evaluation[4] as well as our own expertise is this area.

As an additional safety precaution, ADS vehicles will be deployed without passengers for Field Operational Testing prior to and on the same routes as full deployment.

Figure 1-10: TRC test facility and proving grounds, East Liberty, Ohio

WHY TRC?

- Largest Independent test facility and proving grounds in the U.S.
- Houses NHTSA's only research and test lab
- 4,500 acres of road courses
- Wooded trails
- 7.5-mile high-speed oval test track
- 50-acre vehicle dynamics area ("black lake")
- Paved and gravel hilly road course

ADS Passenger Vehicle Ride-Hail

Because data from OEMs and ADS company testing is largely propriety and inaccessible to USDOT, researchers, and the public, it is critical that we gather independent, transparent data for safety performance analysis and rulemaking. Most ADS testing has also been limited to urban areas, although 97 percent of land in the U.S. is rural. This is in part due to the

[4] https://oas.voyage.auto/scenarios/
https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016

significant differences between urban streets and rural roads that make ADS testing easier and more cost effective in urban areas.

POPULATION DENSITY ALLOWS COST EFFECTIVE:	RURAL ROADS ARE MORE LIKELY TO BE:
Mapping of roadways and spaces	Unpaved/gravel
Installation of roadside units (RSUs)	Missing road lighting
Ridesharing opportunities	Unmarked
	Narrow

Figure 1-11: ADS challenges in rural vs. urban environments

Due to the cost of mapping rural areas, for the purposes of this project, ADS AutonomouStuff passenger vehicle deployment will be focused on a primary southern Ohio route between the cities of McArthur (Vinton County) and Athens (Athens County). We selected this route as an example of the need for improved transit between sparsely populated rural areas to neighboring cities for healthcare, goods, and services. Because we are demonstrating rural ride-hail, we will also deploy a non-ADS ParaLift equipped transit van that is not restricted to mapped routes as the ADS vehicles will be. This ParaLift vehicle will take passengers to and from their homes or other locations surrounding McArthur to meet the ADS AutonomouStuff vehicle. The ADS vehicle will then bring passengers along the mapped route to Athens, specifically to healthcare destinations, such as the Ohio University Heritage College of Medicine Diabetes Institute. This route is shown on **Figure 1-1**.

Once we have collected sufficient data from this rural route with limited connectivity, D.A.T.A. in Ohio will strategically install minimal CV infrastructure (RSUs) to enable baseline comparison of the impact of CV infrastructure on ADS performance. By contextualizing ADS data with CV system data, we will be able to better understand interactions between ADS vehicles and surrounding transportation system elements, such as traditional and emergency vehicles, signal operations, and transit systems. The City of Athens, Ohio, has committed to assist with both the ADS and CV portions of our demonstrations by providing access to its bus transit system (for outfitting vehicles with sensors and equipment), public right-of-way and signal infrastructure (for installing sensors and communications equipment).

To enhance the data set by providing more data volume and breadth of scenario coverage, we will also leverage Ohio's existing connected vehicle infrastructure on the U.S. 33 Smart Mobility Corridor for testing, funded outside of this grant. This additional suburban and rural connected vehicle data will enable comparison with the performance of more robust connected vehicle environments. Combined, these activities will facilitate our analysis of ADS potential impact on the passenger transportation network.

ADS Highway Truck Automation and Coordinated Platooning

Very limited data is available on high-speed ADS truck automation and platooning, although potential benefits in safety performance, the environment, and efficiency are significant. For these demonstrations, Bosch will install L3 automation enabling autonomous highway driving. The trucks will also be equipped with DSRC-based V2X communication capability to enable cooperative driving demonstrations where they interact with traditional vehicles, connected vehicles, and other L3 trucks and L3 passenger vehicles.

Continuous Stream, Event, and HD Map Data

Continuous stream, event, and high-definition (HD) map data will be collected during each phase of testing and deployment to provide complete recordings of vehicle and sensor data. Details on collection, processing, transmission, and storage can be found in the attached Part 3 –Data Management Plan (DMP) Draft.

ADS Vehicle Sensors

- Lidar: 360-degree range data (point clouds)
- Radar: range, range rate
- Camera: object detection
- Vehicle Controller Area Network (CAN) bus data: vehicle brake status, real-time fuel consumption, etc.
- Onboard Units (OBUs)

Connected Vehicle Data

- Basic Safety Message (BSM): location, speed, heading, brake application, wipers status, etc.
- Roadside Equipment (RSE) messages: BSMs, signal phase and timing (SPaT), traveler information messages (TIMs), etc.

Infrastructure data

- Weather data: Open Weather Map (OWM); FHWA Weather Data Environment (WxDE); National Oceanic and Atmospheric Administration's National Climatic Data Center
- Open Street Maps (OSM) and HD maps generated on project
- Network traffic mobility data: counts, travel time, etc.
- Network safety data: crash occurences, etc.
- Network event data: incidents, work zones, special events, etc.
- Private sector data: HERE, INRIX, etc.

Figure 1-12: Data sources and types

1.5.a.ii. Targeted Collection

Targeted collection activities will be used to address data gaps identified through deployment activities and replicate incidents allowing statistical assessment that is not possible with limited deployments. The targeted collection process will follow the same initial steps as deployment – Concept of Operations (ConOps), Procurement, and Software Integration – as shown in 1.5.a.i Deployments. During targeted collection, we will also add steps for software upgrade, gap analysis, target scenario identification, and study planning and execution.

Using deployment continuous stream and event data, we will track coverage of various elements in the parameter space to understand where holes exist in the data set at each phase of the project, including road type, atmospheric conditions, connectivity, and traffic type and density by graphical representation of distribution of samples. From this assessment, we can target areas with minimal point density gaps for identification and resolution in subsequent targeted testing cycles.

Based on this gap analysis, we will develop a targeted set of test scenarios for each gap identified. We will develop individual execution plans for each scenario, including all necessary external hardware and elements, such as surrogate vehicles, pedestrians, and atmospheric conditions. Planning and testing of these scenarios will be meticulously tracked and implemented following a master schedule to promote operational efficiency and continuous optimization. Targeted collection studies will be executed on public roads, at TRC controlled testing facilities, or simulated environments to promote safe execution.

The team will select a broad range of scenarios for simulated environment testing. Simulated environments that will be used include hardware-in-the-loop (HIL), vehicle-in-the-loop (VIL), and software-in-the-loop (SIL) components. With these scenarios, we will evaluate operational concepts, such as highway car-following, lane change, merging, and work zones (with or without the communication infrastructure).

Ohio State University MIL/HIL/VIL Testing SIMCenter	University of Cincinnati HIL System	Transportation Research Center
• CAV HIL simulator developed in-house for realistic recreation	• Developed for use in FHWA's CARMA platform • Developed using both traffic and finer vehicle dynamics simulator • Tests connected automated vehicle applications • Integrates vehicle and infrastructure	• Dedicated Connected and Automated Driving Test Facility (SMARTCenter) • Strikable cars, pedestrians, cyclists, and deer surrogates for safety performance testing

Figure 1-13: D.A.T.A. in Ohio core partner simulation expertise

1.5.a.iii. Data Assessment

For all Deployment and Targeted Collection activities, we will continuously collect, process, and analyze data to better understand ADS performance and operating conditions, incorporating our data analysis findings into ongoing and subsequent testing and deployment iterations. We will also use this data to generate safety performance and operational scenarios for Targeted Collection testing.

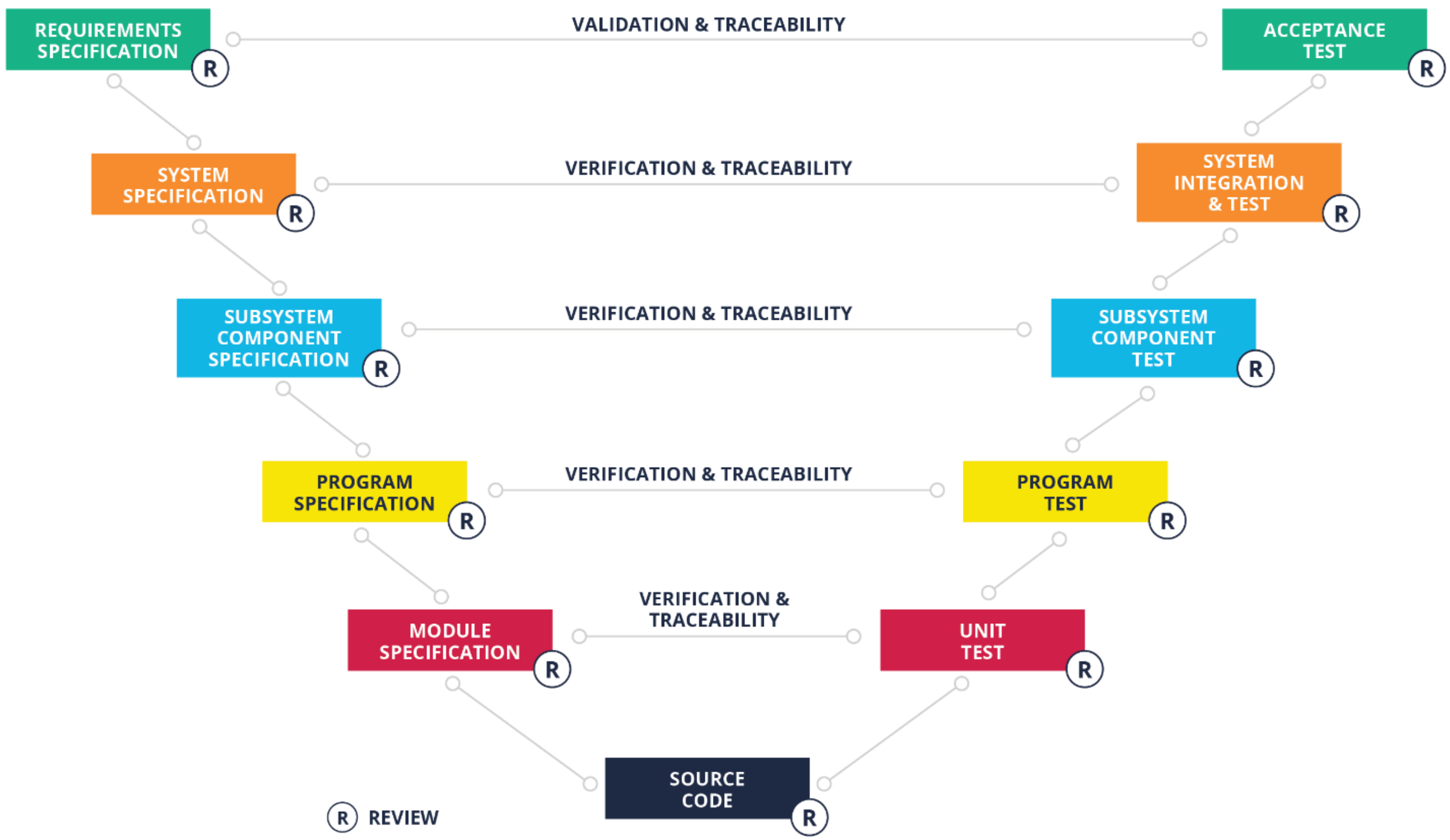

Figure 1-14: V-diagram functional safety performance testing

The V-Model will be followed to identify operational concepts and system requirements for analysis, as it is a best practice in ITS[5] and vehicular system[6] development. The V model shown in **Figure 1-14** represents a methodological process of creation, followed by verification and validation. The left side of the V works its way from requirements through design to implementation. At each step, the system is broken into subsystems that are treated in parallel (e.g., there is one set of system requirements, but separate designs for each subsystem). The right side of the V iteratively verifies and validates larger and larger chunks of the system as it climbs back up from small components to a system-level assessment.

1.5.a.iv. Software and Technology Kit

AutonomouStuff and AutoWare

D.A.T.A. in Ohio will use four AutonomouStuff vehicles equipped with AutoWare and sensors that enable automated driving for demonstration activities. D.A.T.A. in Ohio partners will procure three of these ADS development platforms and will borrow one from the University of Cincinnati. AutoWare is an open-source software for autonomous driving maintained by Tier IV. As such, all data used as input to ADS algorithms with be available and transparent, down to the sensor output level.

Figure 1-15: AutonomouStuff AutoWare technology kit

By leveraging open-source, freely available software, D.A.T.A. in Ohio will avoid software development costs and the opacity of propriety software options. AutoWare.ai[7] is a prototype project, but in an implementable state of development providing the

[5] https://ops.fhwa.dot.gov/publications/seitsguide/index.htm
[6] Motor Industry Software Reliability Association, Development Guidelines for Vehicle Based Software, November 1994.
[7] www.autoware.ai & www.autoware.auto

fundamental building blocks needed to move through a mapped environment: Localization, Object Detection, and Path Planning.

Cooperative Automation Research Mobility Applications (CARMA[8])

For this project, D.A.T.A. in Ohio has identified Cooperative automation, with and without connectivity to the infrastructure, as a key testing component to understand the corresponding safety benefits. The CARMA platform has been selected for testing platooning, cooperative lane-change/merge, and response to work zones. CARMA was developed by FHWA and is a platform designed to be vehicle and technology agnostic and enable research and development of Cooperative Automation Strategies. The current implementation of CARMA, CARMA2, is capable of up to Level 2 automation. CARMA3 will be capable of Level 3 driving and is expected to be released in 2020, which coincides with the deployment schedule for D.A.T.A. in Ohio.

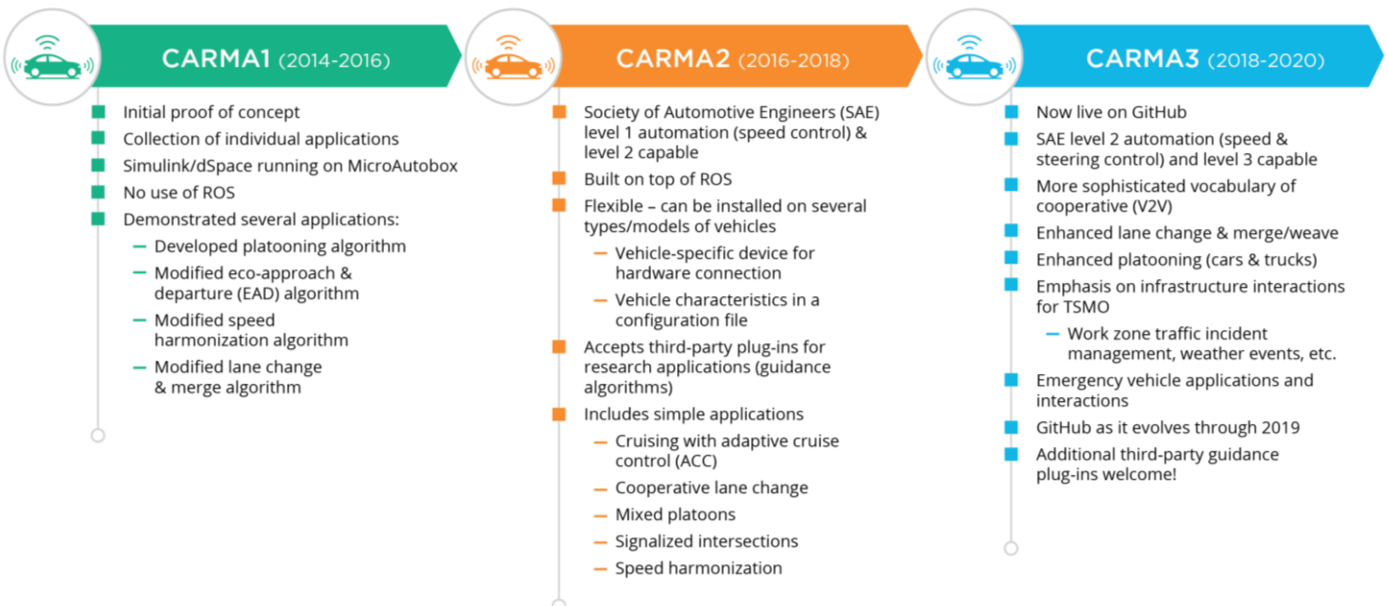

Figure 1-16: CARMA platform capabilities by version

[8] highways.dot.gov/research/research-programs/operations/CARMA

CARMA3 will leverage AutoWare's capabilities and be used by D.A.T.A. in Ohio to test cooperative automation applications. The University of Cincinnati team has participated in the development of CARMA 1 and 2 and is experienced in using the platform for field testing. D.A.T.A. in Ohio will conduct testing under different levels of cooperative automation, as defined by different information classes with L3 automation: Class 0 is no communications capabilities; Class 1 is one-way communications (status from vehicle); and Class 2 is two-way communications (status and commands from and to vehicles).

As these software platforms are in prototype phase and rapidly developing, the D.A.T.A. in Ohio team will periodically reassess software needs and options throughout the course of this demonstration project. Also, the team will not only deliver near real-time testing data, but also contribute to the AutoWare and CARMA open-source initiatives by uploading new or enhanced automation software using web portals such as Github[9].

1.5.b. Legal, Regulatory, and Environmental Obstacles

1.5.b.i. Exemption from Regulations

Our demonstrations require no exemption under federal, state or local regulations. Executive Order 2018-04K established guidelines for testing SAE level 3-5 ADS-equipped vehicles in the State of Ohio, authorizing use on any public road or highway in Ohio per terms and conditions set forth in Ohio Revised Code Section 4501.01(B). Our demonstration vehicles will be compliant with those terms and conditions.

1.5.b.ii. Buy American Act

As stated in section 1.3.c, ODOT through DriveOhio acknowledges the Buy American Act and its requirements. The project team does not anticipate any conflicts but will assess the planned purchases during planning and design to identify any situations that would require a waiver. If such a situation arises, we will evaluate other options, then submit a waiver if necessary in accordance with the procedures of the Buy American Act.

1.5.c. Commitment to Provide Data and Participate in Outcome Evaluation

ADS-equipped vehicles have the potential for significant, positive impact not only on safety performance, transportation system efficiency, and fuel economy, but also on quality of life and equality of opportunity for our nation's people. As such,

[9] https://highways.dot.gov/research/research-programs/operations/CARMA/collaboration

D.A.T.A. in Ohio is passionate about evaluating ADS performance and is committed to providing USDOT, state and local agencies, and the public with data to inform safety performance analysis and rulemaking.

OSU, UC, and OU fulfill their data-driven innovation and discovery mission through collaborative research with government agencies, industry, and other educational institutions while educating the next generation of educators, researchers, and innovators every day. TRC continually leverages data-driven insights in vehicle systems development, has a long history of supporting federal vehicle safety performance programs and rulemaking, and houses and supports the NHTSA Vehicle Research and Test Center (VRTC).

ODOT through DriveOhio and its core partners have structured demonstrations not only to provide ADS data, but also to contextualize that data for enhanced analysis and broad application. With its contextualized approach, technical and policy experts, and unparalleled dedication, D.A.T.A. in Ohio's demonstration will have application beyond the ADS technology itself, providing insight into larger issues, such as access to healthcare and food and equality of opportunity, and improving mobility and access for wheelchair users. More information on data collection, processing, storage, and access can be found in the attached Part 3 – Data Management Plan (DMP) Draft.

1.5.d. Risk Identification, Mitigation, and Management

D.A.T.A. in Ohio's strategy for risk management is rooted in strong Project Management Plan (PMP) expertise and best practices from the Project Management Body of Knowledge (PMBOK). Our project managers are highly experienced in projects of similar scope and scale (see Part 2 – Management Approach for details) and will leverage that expertise to anticipate and address potential risks before they impact the project.

Risk Identification										Qualitative Baseline Assessment					Monitoring & Control	
No.	Name	Risk Group	Category	Project	Phase	Type	Description (Cause, Effect)	Risk Trigger	Engage USDOT	Probability of Occurrence	Impact to Cost	Impact to Schedule	On or near CP?	Rank	Status	Status Notes

Figure 1-17: Snapshot of Risk Register

Potential risks specific to this project will be identified and discussed at the D.A.T.A. in Ohio kick-off meeting with USDOT shortly after grant award. The D.A.T.A. in Ohio team will then develop and maintain a risk register based on those discussions and developments throughout the performance period. The risk register will be used to: identify potential risks; determine likelihood of occurrence, identify risk triggers, assess potential impacts; and develop mitigation strategies. We will regularly communicate risk status to USDOT.

1.5.e. Contribution and Management of Non-Federal Resources

D.A.T.A. in Ohio's collaborative team considers monetary and/or in-kind contribution as a signal of each partner's commitment to this project. As such, our partners have pledged the monetary and in-kind contributions (vehicle purchases, labor, and software) shown below and outlined their contributions in signed Letters of Commitment (see Part 4 – Letters of Commitment).

If D.A.T.A. in Ohio is awarded USDOT grant funds, ODOT through DriveOhio will execute cooperative agreements detailing pledged contributions, including type, dollar value, and contribution timing. ODOT through DriveOhio will also track and regularly report contribution status to the core partners. Since contributions will be part of legally binding cooperative agreements, in the event of failure to follow through on contributions, ODOT through DriveOhio may seek legal resolution.

ITEM	FEDERAL SHARE	NON-FEDERAL SHARE	TOTAL
DriveOhio	$327,700	$2,786,170	$3,113,870
DriveOhio Consultant	$0	$2,346,754	$2,346,754
TRC	$4,431,441	$2,034,626	$6,466,067
UC	$1,166,463	$157,143	$1,323,605
OSU	$200,056	$0	$200,056
OU	$150,031	$12,282	$162,313
AS	$1,089,253	$429,771	$1,519,024
Bosch	$2,535,152	$0	$2,535,152
Mobikit	$99,871	$0	$99,871
CYC	$0	$24,350	$24,350
PROJECT TOTAL	**$9,999,967**	**$7,791,095**	**$17,791,062**

Figure 1-18: Matching contributions by partners