PROPOSAL FOR DESIGNATION OF AUTOMATED VEHICLE PROVING GROUNDS PILOT

SUBMITTED TO

U.S. DEPARTMENT OF TRANSPORTATION

SUBMITTED

BY

TRANSPORTATION RESEARCH CENTER INC.

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EXECUTIVE SUMMARY

Transportation Research Center Inc. (TRC) is pleased to submit this proposal for Designation as an Automated Vehicle Proving Ground. **TRC along with The Ohio State University were among the first to begin testing automated vehicles in the 1970's.** TRC is the ideal candidate for this designation because:

- We are the largest independent automotive proving grounds in North America
- We are 24/7 – we provide turnkey vehicle testing 24 hours a day, 7 days a week with 3 shifts of professional staff
- We are Experts – TRC brings to bear more than 40 years of automotive testing expertise to service our 1,000+ clients, including the US Department of Transportation's NHTSA, the rule makers for automotive safety. In other words, we test the tests. With TRC's strong collaboration with the Ohio State University's cutting edge automotive research, we are well positioned to meet current and future challenges in automotive product development.
- We are Confidential and Secure – With the industry's longest customer list, TRC takes client confidentiality and security extremely seriously. Many of our clients think of TRC as their home proving grounds.
- We are Looking Forward – TRC is excited to play a central role in the auto industry's biggest transformation in more than a century – the development and prove-out of automated vehicles. TRC is the key test facility supporting NHTSA's development of guidelines and regulations for Highly Automated Vehicles, as well as the safe and secure place to prove out Smart City concepts. TRC is supporting automated vehicle testing with an aggressive $100 million facility expansion over the next few years.

TRC is an independent automotive proving ground providing research and development, and compliance and certification testing for vehicles and components for crash testing, emissions testing, dynamic testing and durability testing. Encompassing more than 4,500 acres of land in East Liberty, Ohio, TRC conducts programs designed to test for safety, energy, fuel economy, emissions, durability, noise, crash, crash simulation and performance. We test trucks, buses, recreational vehicles, motorcycles, electric vehicles, passenger cars and components. Our services include research and testing programs. TRC operates 24 hours a day, 7 days a week for customer convenience. We maintain control over the scheduling of all test programs for the safety of all customers and provide secure handling of customers' proprietary information and test components.

TRC is an independent, **non-profit, multi-customer** Ohio corporation that manages and operates **test tracks** at an **automotive testing facility** in East Liberty, Ohio. Additionally, TRC is an ideal candidate for selection as a Designated Automotive Vehicle Proving Ground Pilot because:

- TRC **operates 18 distinct test tracks/courses** and automotive testing laboratories and includes capabilities suitable for testing light-duty, heavy-duty and off-road vehicles (Figure 1).
- TRC **already provides testing services to US DOT** and **is home to the National Highway Traffic Safety Administration's Vehicle Research and Testing Center (VRTC)**.
- TRC routinely provides testing services to a wide spectrum of vehicle manufacturers and has a **successful record of accomplishment assisting US DOT in developing and sharing best practices around the safe testing, demonstration, and deployment of automated vehicle technology**.
- As a successful, independent vehicle testing facility, **TRC is committed to safety and the collection and sharing of lessons learned and safety data** generated through testing and operation. TRC is a founding member of The International Committee for Proving Ground Safety (ICPGS).
- TRC has a robust safety program that engages many levels within the organization to ensure that Safety is a given. **The program boasts leadership through an experienced dedicated and Designated Safety Officer** who is responsible for the review and approval of all vehicle test programs conducted at TRC

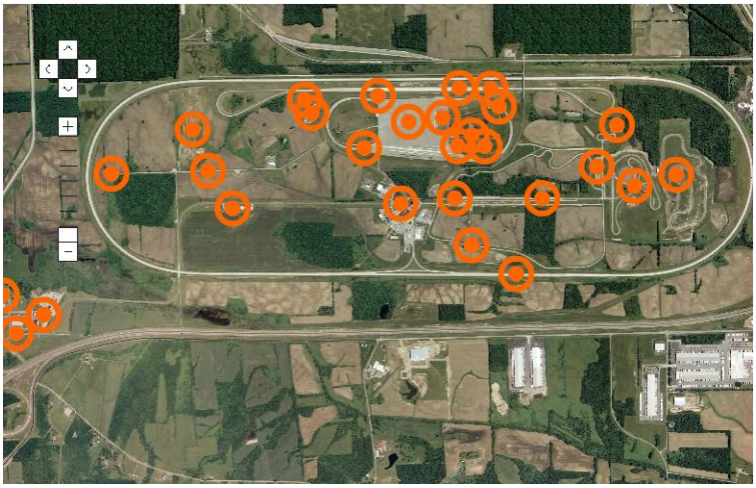

Figure 1 Located on 4,500 Acres in East Liberty, Ohio

MANDATORY CRITERIA

As an operational automotive testing facility, TRC has comprehensive procedures to ensure **Safety in Test Facility Operations**. The **Designated Safety Officer is Brett Roubinek, Vice President, Proving Grounds at TRC.** Mr. Roubinek is a 30-year veteran in driver training and driving safety, broadly focused on teen driving, advanced defensive driving strategies and techniques, performance driving, and motorcycle safety. He has written about these subjects in a variety of publications and served as an expert in broadcast media. Additionally, Brett has spoken about driver training and safety in panel discussions/forums with NHTSA and other organizations. Mr. Roubinek supported by several staff routinely engages Brian Gehle, Manager, Vehicle Operations, and Mark-Tami Hotta, President and CEO, when tests requiring nonstandard procedures are being conducted. Mr. Gehle is responsible for ongoing implementation of all processes and procedures related to vehicle testing. Mr. Gehle has more than a decade of experience managing vehicle operations and vehicle testing at TRC. Mr. Hotta is the former Chief Engineer, World Wide Proving Grounds at Ford Motor Company. Mr. Hotta was responsible for the design and launch of many driver-training programs, and mentored dozens of driver training instructors. Mr. Hotta received numerous top awards at Ford Motor Company for health and safety accomplishments. He led the design of enhanced proving ground safety protocol that reduced major accidents by 93% and track incidents by 96%. Mr. Hotta also served as Chair of the International Committee for Proving Ground Safety, and is currently the only representative from North America that is also actively participating in the European Proving Ground Safety Association.

TRC will commit resources to share lessons learned, approaches to safety and safety data generated through testing and operations. TRC staff routinely contributes and supports the sharing of information on test procedures, standards, and safety data. TRC is a founding member of the International Committee for Proving Ground Safety (ICPGS), a collaborative committee for the purpose of sharing safety-related lessons learned and best practices. ICPGS was started over 41 years ago in 1975, and has held 95 meetings since its founding. There are currently 27 active member organizations – all organizations actively involved in vehicle testing / proving ground operations. TRC is also a member of the ICPGS Steering Committee, which provides governance and ensures integrity of the committee. TRC has hosted the meeting 6 times, and 4 TRC personnel have served as the Chairperson of ICPGS, including TRC's current President and CEO. In 2010 TRC supplied safety data to researchers to support the development and publication of "Recommended Precision Statements for AASHTO Standard Methods of Test T22, T104, T105, T154, T186, and T242." TRC staff serve on the Board of the Ohio State Mobility Initiative (OSMI), which is essentially an automated vehicle information sharing and event collaboration activity.

PROPOSED CONTRIBUTIONS

ESTABLISHED AUTOMATED VEHICLE PROGRAM

The Center was developed by the State of Ohio as a transportation research and development proving ground with the purpose of encouraging motor vehicle research and development activities in Ohio. The Center began testing in 1974. In 1979, the State of Ohio's Transportation Research Board entered into a management agreement with The Ohio State University's (University) College of Engineering to oversee the operations of the Center. In 1987, the University established Transportation Research Center Inc., a non-profit corporation. TRC is governed by a Board of Directors chaired by the University's Dean of the College of Engineering.

Pioneering research work on automated vehicles was carried out by OSU professors during the 1960's and 1970's led by Prof. Fenton of the Electrical Engineering Department (Fenton, 1966; Fenton et al, 1968; Fenton and Montana, 1968; Fenton and Olson, 1969; Bender and Fenton, 1969; Ott et al, 1970; Bender et al, 1971; Rue et al, 1972; Hauhsdottir and Fenton, 1985; Fenton and Selim, 1988; Fenton and Mayhan 1991). The cars used in this pioneering work, shown in Figure 2, had a sensor in front that sensed the current inside a wire carefully taped to the road and served as the path to be followed.

Figure 2 Early Automated Vehicle Tested by OSU Professors at the TRC Inc. Proving Ground

Wired V2V communication was used between cars and platooning experiments were also carried out at that time. TRC proving ground was founded as a test bed for these early research efforts. The connected and automated vehicle research, testing and deployment by OSU staff incorporating the TRC proving ground continued with participation in the 1997 Automated Highway System Demo, the 2004 and 2005 DARPA Grand Challenges, the 2007 DARPA Urban Challenge and the 2011 Grand Cooperative Driving Challenge.

TESTING AND DEPLOYING AUTOMATED VEHICLE TECHNOLOGY

The National Highway Traffic Safety Administration (NHTSA), a division of USDOT, has its in-house test laboratory, Vehicle Research and Test Center (VRTC) on TRC premises.
TRC provides technical staff including project managers, engineers, scientists and technicians. TRC is the preferred contractor for managing and executing various advanced vehicle technology research projects. TRC is currently managing over 50 research projects for NHTSA's VRTC, including automated and connected vehicles, cybersecurity, electronics reliability, among others.

TRC supported government and industry research as part of a major initiative by the U.S. Department of Transportation (USDOT) for a Connected Vehicle Research Program. Crash Avoidance Metric Partners (CAMP), the National Highway Traffic Safety Administration (NHTSA), and NHTSA's Vehicle Research and Test Center (VRTC) collaborated for elements of the vehicle-to-vehicle (V2V) portion of this initiative, which had three phases of testing with TRC involvement in each phase. The first phase, which consisted of 50 vehicles, occurred at TRC in November 2011. The second phase involved 100 vehicles and took place in California in January 2012. The third and final phase, in March 2012, was conducted at TRC with 200 vehicles. Each phase consisted of evaluations that addressed the communications performance of V2V systems in various congested traffic scenarios. Testing is shown in Figure 3.

Figure 3 Vehicle-to-Vehicle Communication on the TRC's Skid Pad

NHTSA, in 2013, awarded a contract to TRC to conduct Connected Vehicle Research. As part of the contract, TRC has been involved in developing objective test procedures for various applications of connected vehicle technology. These tasks include:

- Light Vehicle Intersection Movement Assist and Intersection Collision Avoidance research
- Commercial Connected Vehicle Safety Applications Evaluation
    - Intersection Movement Assist
    - Forward Collision Warning
    - Blind Spot/Zone Warning/Lane Change Warning
    - Emergency Electronic Brake Light Warning (warnings for Hard Braking events)
- DSRC (V2V) Radio Objective Testing

In 2015, NHTSA awarded a contract to TRC for functional testing of automated vehicles. As part of this contract, TRC has been involved in:

- Defining the performance of Level 2 Automated systems
- Documenting operational characteristics for each automated driving function
- Developing preliminary performance tests for park assist, low speed automated driving (traffic jam assist) and high speed automated driving.
- Procuring and verifying next generation testing capabilities for automated vehicles.

Providing continuous vehicle testing since 1974, TRC has developed many procedures for testing vehicles. The impact laboratory offers a comprehensive vehicle safety development facility for crash, HYGE Sled, static testing, and instrument calibration in vehicle impact. It includes a crash barrier capable of testing vehicles up to 10,000 lbs. at velocities up to 60 mph, and an outdoor impact area that can manage impact of two moving vehicles at any angle at velocities up to 100 mph. An impact simulator features a 24-inch HYGE pneumatic drive that can simulate crash speeds up to 100 mph. A 9,000-ft skid pad and 50-acre vehicle dynamics area are complemented by a winding road course and dynamic handling course. A 7.5-mile oval test track contains four asphalt lanes on the front straightaway and curves and five asphalt lanes on the back straightaway. Parabolic banking allows neutral speeds up to 140 mph (see photo). A wide variety of pavement types, including gravel, cobblestone, and paved rough roads are available for testing.

- **7.5 Mile Test Track.** The 7.5-mile (12.1-km) oval test track contains four asphalt lanes on the front straightaway and curves and five asphalt lanes on the back straightaway. The 7.5-mile test track's parabolic banking allows neutral speeds up to 140 mph (225 km/h) as depicted in Figure 4. The test track features level 2-mile (3.2 km) straightaways.

Figure 2 7.5 Mile Oval Test Track

- **Dynamic Handling Course.** The 1.75 mile asphalt Dynamic Handling course consisting of a variety of slow, medium, and high-speed corners, slight elevation changes, and turns of varying camber. This facility is used for vehicle dynamics studies, performance evaluation, and automated vehicle training.
- **Profile Roads.** The Profile Roads courses provide a realistic testing environment for ride evaluation of passenger cars and sport utility vehicles. The facility includes Tire Slap, Unsprung Mass Vibration, Long Curb, Water Drain, Speed Bumps, Road Joint, Undulation Road, Positive & Negative Shocks, Stability Road, Belgian Block Roads, Chip & Seal Roads, Concrete Choppy Road, Concrete Downhill Wavy, Concrete European Union Road and a High Speed Railroad Crossing.
- **Winding Road Course.** The 1.5-mile winding road course with wet and dry pavement capabilities provides input for vehicle handling and lane-keeping. This course also contains two depth-controlled hydroplane test areas as well as a 203-foot radius wet vehicle dynamics handling area. Vehicle Training and "Ride and Drives," as well as driver/vehicle distraction and collision avoidance studies can be performed on this course.
- **Paved Rough Roads & Salt Bath.** The Paved Rough Roads and Salt Bath are ideal for durability testing of passenger cars to sport utility vehicles compromises 855 ft. of light duty and 1,215 ft. of medium duty concrete bumps imbedded in a 4,200-ft. asphalt roadway. The 60 by 14-ft. Salt Bath is adjustable from 3 to 15-in. deep.
- **Gravel Durability Course.** The level 2.6-mile (4.2-km) Gravel Durability Course provides a series of twists, turns, and straightaways, which is ideal for durability testing as well as lane keeping capabilities of automated or partially automated vehicles.
- **The Paved and Gravel Hilly Road Courses** contain over eight miles of roadway including a 1,000-foot, 10% asphalt slope, various stone slopes, a 23% asphalt slope, a 1.5-mile gravel road, two level cross-country courses and an off-road course. The Paved & Gravel Hilly Road Course is excellent for durability testing and vehicle performance testing of vehicles ability to safety navigate, maintain speed on a combination of paved and unpaved roads with line-of-sight challenges such as hills and curves.
- **Salt Spray Road, Stone Chipping Road, Curb Impact, & Chuckholes.** The Salt Spray Road, Stone Chipping Road, Curb Impact, and Chuckholes consists of parallel 20-foot x 990-foot lanes. One lane consists of both high and low spray saline solution, 3% by volume. The other lane provides a vehicle testing course that allows customers to distribute any specification of grit in a controlled manner to allow stone chipping of test vehicles and to test the ability of on-board sensors to capture data under conditions with debris in the road and under heavy rain conditions.

When considered collectively, TRC provides courses, tracks, facilities, laboratories, and the technical and engineering services personnel needed to conduct detailed and exhaustive testing of all vehicles, including automated vehicles. The following summarizes the many conditions that can be replicated and tested at TRC:

1. Various roadway types (highway, two-lane, rural)
2. Wide variety of speeds (1-200 mph)
3. Day and night testing
4. All season testing
5. Variable friction surfaces
6. Ability to generate rain/low visibility
7. Accommodate **testing of most normal driving conditions** by automated vehicles
    - Detect and Respond to Speed Limit Changes and Speed Advisories
    - Perform High-Speed Merge (e.g., Freeway)
    - Perform Low-Speed Merge
    - Move Out of the Travel Lane and Park (e.g., to the Shoulder for Minimal Risk)
    - Detect and Respond to Encroaching Oncoming Vehicles
    - Detect Passing and No Passing Zones and Perform Passing Maneuvers
    - Perform Car Following (Including Stop and Go)
    - Detect and Respond to Stopped Vehicles
    - Detect and Respond to Lane Changes

- Detect and Respond to Static Obstacles in the Path of the Vehicle
- Detect Traffic Signals and Stop/Yield Signs
- Respond to Traffic Signals and Stop/Yield Signs
- Navigate Intersections and Perform Turns
- Navigate a Parking Lot and Locate Spaces
- Detect and Respond to Access Restrictions (One-Way, No Turn, Ramps, etc.)
- Detect and Respond to Work Zones and People Directing Traffic in Unplanned or Planned Events
- Make Appropriate Right-of-Way Decisions
- Follow Local and State Driving Laws
- Follow Police/First Responder Controlling Traffic (Overriding or Acting as Traffic Control Device)
- Follow Construction Zone Workers Controlling Traffic Patterns (Slow/Stop Sign Holders)
- Respond to Citizens Directing Traffic After a Crash
- Detect and Respond to Temporary Traffic Control Devices
- Detect and Respond to Emergency Vehicles
- Yield for Law Enforcement, EMT, Fire, and Other Emergency Vehicles at Intersections, Junctions, and Other Traffic Controlled Situations

8. Accommodate **testing of automated vehicles under abnormal conditions** (i.e., put the automated vehicle into situations where hazard avoidance/crash avoidance is required)
    - Control loss
    - Crossing path crashes
    - Lane change/merge
    - Head-on and opposite direction
    - Rear-end
    - Road departure
    - Low speed situations such as backing and parking maneuvers.

CONTRIBUTIONS TO THE COMMUNITY OF PRACTICE

TRC is an active member of the Ohio Smart Mobility Initiative (OSMI) Advisory Board. The Ohio Smart Mobility Initiative launched in July 2015 with the following goals:

- Improve safety on the roadways and for vulnerable road users
- Provide transportation options for the elderly and persons with disabilities
- Generate solutions for transportation in the era of urbanization
- Provide a means of transportation without generation of GHG
- Workforce development and retention for key technologies in CV/AV arena including skilled trades
- Create a development hub in Central Ohio for CV/AV technology utilizing TRC, OSU, SPARC, and the NW US-33 Innovation Corridor. This would allow research to be conducted at OSU with government and industry partners in collaboration with contained test beds and validated on the public roads.
- Create a Midwest development hub for freight and goods movement in collaboration with the States of Michigan and Pennsylvania.

The purpose of the OSMI Advisory Board is to review business plans, advise regarding growth strategy, and develop funding models. TRC is an active member of the transportation community. The Advisory Board membership includes The Ohio Department of Transportation, The Ohio State University, Jobs Ohio, Columbus 2020, The Ohio Turnpike, KPMG, Union County Economic Development Partnership, and SPARC Ohio.

TRC staff holds memberships in professional societies and serves on technical committees, including:

- SAE - Active Safety Committee, Truck and Bus committees, Dummy Test Equipment Committee, Highway Tire Committee, Human Biomechanics & Simulation Steering Committee, Session Organization and Chairmanship: SAE 2008 World Congress.
- Transportation Research Board - Transportation Research Part F; Traffic Psychology and Behavior, Vehicle User Characteristics Committee, TRB Simulation and Measurement of Operator and Driver Performance
- Human Factors & Ergonomics Society
- Central Ohio Injury Biomechanics Engineering Consortium
- Flex-TEG (Technical Evaluation Group for the Flex Pedestrian Legform)
- Association for the Advancement of Automotive Medicine
- Sponsor of NSF IUCRC's
    - Center for Child Injury Prevention Studies (CChIPS),
    - Smart Vehicle Concepts
- Sponsor of the Injury Biomechanics Symposium at The Ohio State University

Numerous technical papers have been authored or co-authored by TRC personnel. For example, TRC has more than 300 articles and published papers available through SAE, IEEE, the Transportation Research Board, and other periodicals that provide information and contribute to the community of practice – dating back to the late 1960's with articles even providing information on the design and planning of the facility! The preponderance of articles and data generated at the TRC and released to the transportation community through technical articles, journals, presentations, and meetings demonstrates TRC's ability and willingness to contribute to the Community of Practice. We anticipate that our participation will continue to be in the form of participation on committees, through preparation and submission of technical articles, and where permitted by clients, release of testing data.

WORKING WITH THE USDOT PROGRAM OFFICES

TRC is no stranger to US DOT and is a long time collaborator and supporter of US DOT program offices. In particular, TRC regularly collaborates with NHTSA VRTC staff and supports vehicle testing by NHTSA. Additionally, TRC, as part of the Columbus Smart City Challenge is working with the City of Columbus and its stakeholders/partners in collaboration, and consultation with, FHWA JPO staff. We participate in coordination meetings and participate with US DOT staff on the development of vehicle testing standards. These activities, as well as involvement in the US DOT Community of Practice's meetings, and conducting AV technology tests and deployments for industry and government are the most effective ways for our program to remain engaged in the fast pace of AV technology/product advancement.

COMMITMENT TO SAFETY

TRC is committed to safety and has detailed measures and processes in place to ensure the safety of all test participants and observers. TRC operates and maintains a dedicated Environmental Health and Safety Office. As part of Transportation Research Center Inc.'s (TRC) commitment to customer satisfaction and continual improvement, the organization renewed its registration to the ISO 9001:2008 Standard on January 6, 2015 (Certificate No. US007260-1). The ISO 9001 Standard is an international model for quality management systems. Organizations are required to identify and document best business practices, and to implement these practices to achieve consistent quality services to meet and exceed customer expectations.

TRC operates under the following EH&S guiding principles:

1. TRC is committed to continual improvement in TRC's environmental, health, and safety program by setting objectives and targets and by evaluating our performance to those goals.

2. TRC is committed to prevention of pollution by using processes and materials that prevent, reduce, or minimize pollution. This includes recycling, control mechanisms, material substitution, and efficient use of resources.
3. TRC is committed to compliance with all applicable environmental, health, and safety regulations, laws, and other internal and external requirements.
4. TRC provides education and training to ensure understanding of the environmental, health, and safety policies throughout the organization.

SAFETY MANAGEMENT PLAN

TRC retains complete control of the facility and is solely responsible for the scheduling and review of test procedures for all tests conducted at the facility. TRC's Facility Operating Guidelines are a comprehensive set of allowable operational conditions for each facility and include the following procedures and guidelines:

- Vehicle refueling
- Incident reporting and investigation
- Test plan submission, test plan review and facility scheduling
- Dynamic Driving Definitions
- Test Personnel Requirements
    - Driver Licensing
    - Physical condition
    - Training
- Test Vehicle Requirements
    - Required safety devices
    - Communications requirements
    - Use of lights for specific test conditions
- General Driving Instructions
- Personal Protective Equipment
- Motorcycle, ATV and MUV Testing
- Ballast Securement
- Driver instructions for each facility or test course

OPERATIONS SAFETY

The Vehicle Operations Group reviews all facility schedule requests for compliance with the Facility Operating Guidelines. Any requested exceptions must be reviewed and approved with conditions and constraints, or disapproved by the designated Safety Officer. These requests may require special safety equipment, surveillance, medial and rescue personnel standby and graduated speeds requirements.

All facility schedule requests are reviewed to determine compatibility with companion traffic. Any test program presenting a potential risk to companion traffic must be scheduled as partial-exclusive or full exclusive use of the test facility. Partially automated vehicles are evaluated on a case-by-case basis and may require partial-exclusive or full exclusive use depending on the potential risk presented by the testing.

Highly automated vehicles (HAVs) typically require partial-exclusive or full exclusive use of test facilities unless the speeds and compatibility with companion traffic are deemed to be low risk. Unmanned HAV's require exclusive use of the test facility and potential exclusive-use of test facilities in close proximity. HAV testing typically will require special safety equipment, surveillance, medial and rescue personnel standby and graduated speed requirements. Vehicles must be equipped with an emergency stop button that is tested and verified immediately before the beginning of testing.

TRC's Facility Operating Guidelines are maintained in accordance with the requirements of ISO management system at TRC. TRC is registered to ISO 9001 and 14001 with regular audits by a certified registrar. The document is reviewed and updated periodically as required by the management system.

RESEARCH, APPLICATION, AND DATA SHARING

STATE AND LOCAL SOLUTIONS

The City of Columbus was the winner of the USDOT Smart City Challenge in 2016. The city's Smart Columbus project contains two AV projects with applications in passenger last-mile and urban freight movements. Additionally, the Smart Columbus project contains a specific healthcare and mobility challenge project. As OSU is a member of the Smart Columbus project, these current projects, and future AV projects to be determined later, offer an opportunity for local and regional AV applications to be developed. Furthermore, the City of Columbus has committed to sustaining the Smart City Challenge beyond the period of performance of the USDOT grant. This commitment is key to future AV applications.

The cities of Dublin and Marysville along with Union County Ohio have formed a Council of Governments as a result of winning The Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) program grant, "Northwest 33 Smart Mobility Corridor." This project is intended to advance the state of transportation technology while being affordable, practical, scalable, and replicable. Fiber along US-33 will support dedicated short range communications (DSRC) units with the low latency suitable for both safety and mobility applications as well as on-road testing of automated vehicles. A wide range of connected fleets will utilize this roadside infrastructure upon deployment, including city, county, transit, and private fleet vehicles consisting of passenger, first responder, public service, and other heavy vehicles. Honda R&D North America, located adjacent to the TRC supported the NW 33 Smart Mobility Corridor application and has stated intentions to utilize this corridor as well as the TRC facility for testing of automated vehicles.

RESEARCH AND EXTENSION RESOURCES

TRC through a long-standing relationship with The Ohio State University's College of Engineering continues an **established automated vehicle program**. TRC is actively engaged with the following centers and laboratories:

- The Center for Automotive Research (CAR)
    - University Transportation Center (UTC) - Crash Imminent Safety (CrIS)
    - Control and Intelligent Transportation Research (CITR)
    - Automated Driving Laboratory
- Driving Simulation Laboratory
- Simulation Center (SIMCenter)

The Center for Automotive Research (CAR) is an interdisciplinary research center in The Ohio State University's College of Engineering. CAR research focuses on: energy, safety and the environment, aimed at improving sustainable mobility. CAR offers state-of-the-art facilities for students, faculty, research staff and industry partners. With a concentration on preparing the next generation of automotive leaders, CAR is recognized for: interdisciplinary emphasis on systems engineering, advanced and unique experimental facilities, collaboration on advanced product development projects with industry and a balance of government and privately sponsored research.

> The goal of the university's **Crash Imminent Safety University Transportation Center (UTC)** is to increase understanding of technology design and improve the ways humans interact with intelligent, automated and semi-automated vehicles. The UTC research team comprises over 20 faculty and researchers from Ohio State and partner universities, including Indiana University-Purdue University Indianapolis, North Carolina Agricultural and Technical State University, University of Massachusetts-Amherst and University of Wisconsin-Madison.

In their development of driver-assisted advanced technology, engineers at the Center for Automotive Research aim to develop technology that optimizes a safe driving experience. Harnessing both theoretical and applied research, these engineers target the control and coordination of automated or semi-automated cooperative mobile systems, while exploring methods that boost automated driving and safety mechanisms, including cruising, steering and lane change as part of highway travel and intersection access, turning, merging and stop-and-go operations for urban driving. These developments are not just trialed in a laboratory setting. CAR takes its research outside the realm of controllable conditions by putting its vehicles to the test. No stranger to competition, the **Control and Intelligent Transportation Research laboratory** has participated in the U.S. Department of Defense's DARPA (Defense Advanced Research Projects Agency) off-road challenges and urban challenges since 2004.

Professors at the Center for Automotive Research collaborate closely with TRC and conduct their vehicle testing at TRC. Professor Dr. Levent Guvenc, Director of the **Automated Driving Lab** at OSU and Professor Dr. Bilin Aksun Guvenc are heavily involved in developing automated vehicles and solving the first mile/last mile mobility problem. They bring with them decades of experience in automated driving development and are involved with TRC in various research projects.

OSU Driving Simulation Laboratory (DSL). OSU's DSL occupies 5,800 square feet within OSU's SciTech Research Park. The laboratory houses three different simulator setups. 1) A full-immersion simulator with a 260- degree front-projection cylindrical edge- blended screen and six high- resolution projectors. 2) A turntable drive-on for testing full vehicles with a single front-projection screen. All internal controls (steering wheel, etc.) are those of the actual customers' vehicles. 3) A desktop simulator for creating and troubleshooting driving scenarios is also in use here.

The Simulation Innovation and Modeling Center (SIMCenter) is an interdisciplinary research center for virtual simulation and modeling in the College of Engineering. SIMCenter is one of three industry-facing Centers in the Ohio State University College of Engineering tackling the most challenging problems in land transportation. SIMCenter's focus is on the application of computer aided-engineering tools, and where needed, the development of new computer-aided engineering tools. Simply put, **SIMCenter's** mission is to advance the state of computer-aided engineering in the transportation industry.

PreTalen, Ltd is a U.S. SBA-defined Woman Owned Small Business (WOSB) with personnel located in Ohio (headquarters), Maryland, New Mexico, Indiana, and California. PreTalen has a contingent of Top Secret/SCI cleared and SAP-eligible personnel that support a plethora of DoD organizations to include Air Force Research Laboratory (AFRL), U.S. Army CERDEC, GPS Directorate (USAF), Joint Navigation Warfare Center, as well as various organizations within the Intelligence Community (IC). PreTalen employs approximately 65 people that provide engineering services in the domains of Cyber and Position, Navigation, and Timing (PNT) research and development. PreTalen is partnering with TRC to apply these PNT capabilities to enhance automotive navigation resiliency. With this partnership, automated vehicles will be rigorously tested against signals which may threaten vehicle navigation. This enables TRC and PreTalen to jointly characterize threats and propose mitigation strategies to industry to preserve proper vehicle navigation and control and safeguard vehicle passengers and property from harm.

In addition to the labs and entities mentioned above TRC has created memorandum of understanding (MOUs) with the Society of Automotive Engineers (SAE) to advance automated vehicle technology standards with the hope of harmonizing with various government agency priorities. TRC has MOU's in place with other companies such as SEA Inc., and PMG Canada for collaboration as well.

EDUCATION PROGRAM

TRC is actively engaged in educational and training opportunities. In addition to the publication of methods, standards, and analysis of test data, TRC directly supports many community educational programs.

TRC is a founder and sponsor of the Injury Biomechanics Symposium at The Ohio State University. The purpose of the symposium is to stimulate and reward strong injury biomechanics research among students and recent graduates. The Symposium offers a welcoming and non-threatening environment where novice researchers can receive feedback and support for their original work. Participation from industry partners and sponsors provides networking opportunities for future careers. The symposium just passed its 10th year and boasts participation from universities around the world.

TRC has greatly expanded its internship program. In addition to its annual sponsorship of two $1,000 renewable scholarships to graduating seniors in Logan and Union Counties planning to enter a two- or four-year program specializing in automotive engineering or other automotive-related field, TRC has implemented an excellent intern-recruiting program that brings students from many universities to TRC to work during the summer. During the 2016 summer, TRC hired 16 interns, both graduate and undergraduate, from Schools such as Purdue University, The Ohio State University, Ohio Northern University, the University of Dayton, Rose-Hulman University, and Urbana University. TRC will work with The Ohio State University to create a similar model for an advanced vehicle technology theme such as electronics reliability, cybersecurity and functional evaluation of technology and perhaps more.

COMMITMENT TO OPEN DATA AND SHARING

Although TRC is a non-profit entity, staff routinely conduct tests on vehicles that are the proprietary property of an automotive manufacturer or supplier. At the same time, however, TRC does routinely share best practices, lessons learned, and information on testing procedures. As permitted under confidentiality agreements, TRC will make data available to the public by publishing the data in US DOT's Research Data Exchange or other similar data repository.

DEMONSTRATED INVESTMENTS

TRC has a mature, robust proving ground that is already suitable for testing of automated vehicles under many different conditions as described previously. However, we are committed to continuing to enhance our ability to conduct progressively more complex testing.

TRC has the capability as demonstrated to test automated vehicle technology today. However, the introduction of vehicle automation systems has caused a fundamental shift in the automotive industry requiring both the repurposing of yesterday's skills and the development of new skills. TRC is taking a similar approach to developing facilities to support this effort. To respond to this need quickly and efficiently TRC has developed plans, and will soon begin modifying existing proving ground facilities to support the development of this new wave of technologies. This will include refurbishing and modifying existing paved surfaces to present the vehicle with various environments that would be seen in the real world. Additionally various roadside elements including signs, signals and other road side furniture will be made available to customize these environments to represent an even broader set of scenarios (Figure 5).

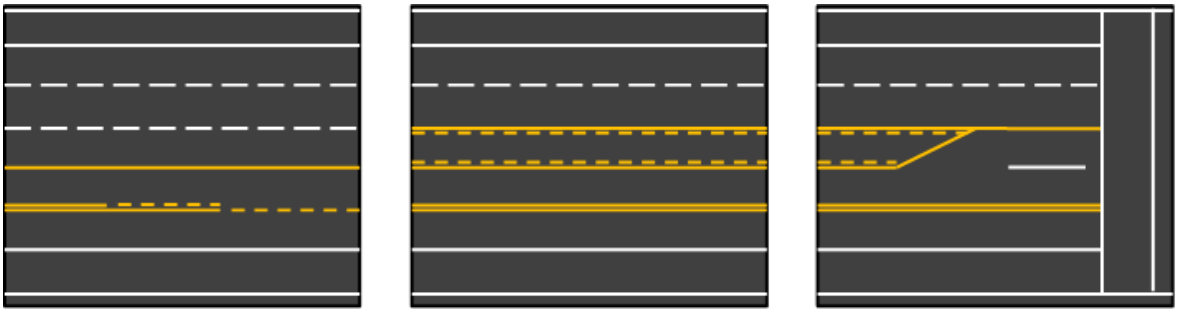

Figure 5 Test Facility Refurbishment

Though repurposing existing facilities provides a fast and efficient path for facility development, and will be a great leap forward, this will not provide all environments necessary for robust automated vehicle

development. In order to create a truly comprehensive environment for vehicle development and validation TRC is developing the SMART Center. This massive expansion will create courses specifically tailored for the development of Automated Vehicles. The design of the new facility is shown in Figure 6.

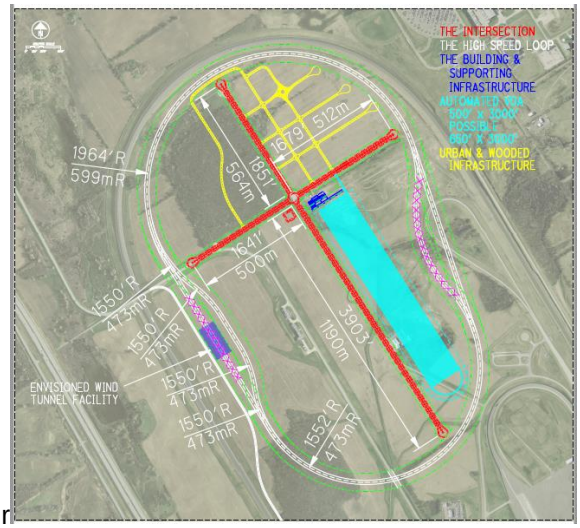

Figure 6 SMART Center

The SMART Center will be constructed in phases with Phase 1a targeted to be operational late 2017 and Phase 1b in 2018. Phase 1a consists of a high speed, six lane Intersection (red) with traffic signals, roadway lighting and variable signage; and the industry's largest, independent wet/dry VDA (light blue) configurable for creation of multiple designs of intersections/lanes with a wet portion available for low Mu testing. Phase 1b will provide an urban center (yellow) and features include intersections, roundabouts, cul-de-sacs, and wooded occlusion routes along with a support building (dark blue) that will contain the SMART Center control room and secure work bays. Phases 2 and 3 involve the construction of an indoor inclement weather test facility and a multiple lane high-speed highway loop (70 mph). These phases are targeted for completion in subsequent years. Other complimentary labs include high and low frequency radio antenna test chambers that will accommodate DSRC antennae and radar beam characterizations. These facilities are funded and expected to be online in early 2019.

TRC has created a new research group within the TRC. organization to enhance the engineering skills that will be used to evaluate Advanced Vehicle technology. TRC has acquired talent in cybersecurity, robotics, functional testing of automated vehicles and vehicle dynamics and simulation. TRC will continue to staff to provide high-caliber engineering services for automated vehicle technology.

READINESS

TRC is open for testing and has been testing automated vehicle technology since the early 1970's. TRC can support simultaneous testing by multiple users on a single test course such as the 7.5 oval or spread across several courses. TRC demonstrated the ability to collect and share data during the Connected Vehicle Research Program described above, and we anticipate hosting similar programs in the future. Infrastructure improvements associated with enhancing our ability to test automated vehicle technology in complex scenarios will be completed in phases. Phase 1a, as described above is anticipated to be complete in the 4th quarter of 2017. Refurbishment of an existing facility including standardized lane widths and pavement striping will be completed in the 2nd quarter of 2017. A dedicated point of contact for TRC is:

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ADHERENCE TO LAWS, REGULATIONS, AND FEDERAL POLICY

ADHERENCE TO LAWS AND REGULATIONS

TRC complies with all laws and regulations governing the testing of vehicles, including automated vehicles. All tests will be contained to the test facility, which is considered private land for the purposes of vehicle testing. TRC has been granted the ISO/IEC 17025:2005 Accreditation, from the Laboratory Accreditation Bureau. As part of the requirements for receiving this accreditation, TRC has agreed to follow industry testing standards as well as State Laws and Regulations. A letter of support from the Ohio Department of Transportation is included as Exhibit A.

ADHERENCE TO NHTSA'S POLICY FOR AUTOMATED VEHICLES

TRC has established contractual arrangements and agreements with various vehicle manufacturers and suppliers for the testing of vehicles at the facility. This includes agreements on reporting of test incidents should they occur with the proper authorities as well as the disclosure of test data and other information. As part of these agreements, TRC requires that each customer provide a detailed test plan describing the use of the facility, the type and nature of the tests, risks, etc. for review by TRC staff prior to test initiation. In some cases, customers wish to have TRC develop these procedures in which case an independent safety review by an non-project specific staff is conducted.

When testing automated vehicles, TRC will perform this testing in compliance with NHTSA's Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety, pgs 39-42. However, all vehicle tests will be performed on the TRC facility and will not utilize public roadways. TRC has already applied for and received the appropriate permits and jurisdictional approval to conduct vehicle testing at its facility.

The following elements of NHTSA's Policy are already TRC policy and will be adhered to for all tests:

- Solely persons designated by the manufacturer or other entity, who have received training and instruction concerning the capabilities and limitations of the vehicle, will operate the vehicle used in testing. The training provided to the persons designated by the manufacturer or other entity must be summarized and submitted to TRC's Vehicle Operations Group prior to testing.
- The operators testing the vehicles will hold a valid State driver's license.
- Before being allowed to operate a test vehicle, the persons designated by the manufacturer or other entity as operators of the test vehicles, may be subjected to a background check including, but not limited to, a driver history review and a criminal history check.
- The test operators are responsible for following all facility rules.
- All crashes involving test vehicles must be reported in accordance with the State laws in which the crash occurred.