Application for Designation of Automated Vehicle Proving Grounds

Application Submitted by:
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Submission contains Confidential Business Information (CBI)

PennState
College of Engineering

LARSON TRANSPORTATION
INSTITUTE

Deployment of the Larson Transportation Institute's Autonomous Vehicle Proving Ground

Safety Officers:

Steve Williams, LTI administrative operations manager and safety officer, to act as liaison to national safety meetings

Dennis Kovalick, LTI test track direct manager, to act as on-site safety officer

Senior Investigators:

Dr. Eric Donnell, Professor of Civil Engineering and Director of the Larson Transportation Institute

Dr. Sean Brennan, Professor of Mechanical Engineering, Department of Mechanical and Nuclear Engineering with joint appointment to the Larson Transportation Institute

Dr. Martin Pietrucha, Professor of Civil Engineering and faculty associate of the Larson Transportation Institute

Mr. David Klinikowski, Director of the Altoona Bus Testing Program, Larson Transportation Institute

Dr. Suresh Iyer, Research Associate and lead researcher for PSU's heavy-vehicle emissions program, Larson Transportation Institute

Summary:

This proposal is written in response to the U.S. Department of Transportation's (USDOT) request to designate Penn State facilities and noted surrounding roadways as USDOT Automated Vehicle Proving Grounds in support of DOT-OST-2016-0233. Among the testing locations in this application are Penn State's closed-loop test track and supporting equipment therein, with testing able to extend to nearby roadways and interstate highways via partnerships with the local municipality and PennDOT.

This document is intended to provide the following: the history and details of the proposed facilities; details of ongoing projects utilizing this equipment within connected, automated, and autonomous systems; the existing and proposed safety management of the testing locations; an outline of proposed upgrades and data collection to occur over the 2017-18 calendar year relevant to this work; and example plans to further grow and utilize the facilities.

Figure 1. The proposed facilities include Penn State's test track which enables closed access and the ability to change pavement conditions.

History of the Penn State Test Track

The Penn State test track, shown in Figure 1, is a one-mile oval roadway which includes unique testing capabilities that reflect a long and rich transportation research history. The testing site concepts originated in 1969 with planning for a licensing and testing facility for PA motor vehicle operators. In 1971, construction at the test track included a location for pavement durability testing to assess pavement design. The Pavement Durability Research Facility is a full-scale experimental highway. Research included the evaluation of seal coat performance, the evaluation of in-situ instrumentation, the effects of tire types and pressures on pavement performance, and the use of in-situ instrumentation for resilient moduli measurements.

The facilities grew in use during the 1970's and 80's, eventually requiring in 1989 the development of a full-scale test track in support of the federal bus testing program (Figure 2). The Penn State Bus Research and Testing Facility located at the test track, is part of the Altoona Bus Research and Testing Center. The Bus Research and Testing Facility was designed and built in 1989 with funding provided by the Federal Transit Administration (FTA). Features at this testing location include a vehicle test lane on the inside edge of the pavement durability lane, a handling area, and a durability course. These areas are used during the safety, acceleration, dynamic towing, structural durability, and exterior noise portions of new model bus testing. All new model buses to be purchased with federal funds must be tested using the test track.

Figure 2. The federal bus testing program is ongoing at the proposed facility, readily enabling transit automation testing.

In support of heavy vehicle and transit testing, upgrades to the track have occurred regularly over the past 10 years to enable alternative fuels and powering systems testing. This includes a hydrogen fueling station, electric vehicle pack testing equipment, and multi-fuel stations. Certification of vehicle fuel economy and emissions is possible via equipment within a high-roof garage that includes a 400 horsepower motoring chassis dynamometer alongside a certified emissions test stand. In 2015, installation was completed of a DSRC radio network and dedicated DGPS base station on site in support of connected vehicle testing and autonomous vehicle testing of heavy-duty vehicles, in partnership with the Volvo Group.

Test Track Management and Personnel:

The proposed proving ground at the test track is an operational site for the Altoona Bus Research and Testing Center, which oversees the testing of new model buses in accordance with test procedures approved by FTA. The facility operates 24-hours per day, 5 days per week, and is fully staffed with test drivers, mechanics, and technicians. Presently, the management of the test track is included in the operation of the Bus Research and Testing Program. The organizational chart is provided in Figure 3.

Test track operations are coordinated by a full-time on-site manager who is identified in this proposal as the operational safety manager for on-site testing. The manager works with the administrative staff at Penn State's Thomas D. Larson Pennsylvania Transportation Institute (LTI) to coordinate the insurance and billing required for contracted testing. The manager is also

responsible for coordinating safety in accordance with the College of Engineering safety plan and participates in the International Committee for Proving Grounds Safety (ICPGS). The ICPGS is an informal voluntary group of test track professionals that meets twice a year to focus on sharing safety information and lessons learned regarding proving ground safety. The committee members collectively represent proving ground facilities throughout the United States and Europe.

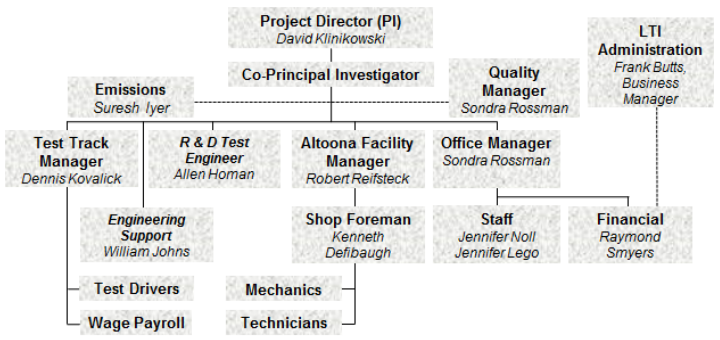


Figure 3. The staffing and organizational chart for the LTI test track.

The test track is staffed with three shifts of five test drivers. Mechanics and test technicians are available during the day shift. These personnel are available for vehicle and equipment testing, research support, facility maintenance and vehicle repair work. The test track operates year round and supports testing in all weather conditions.

Current Capabilities of the Test Track

The test track presently includes many of the core capabilities needed to perform connected, automated, and autonomous vehicle tests. Most critical to all of these tests are:

1) The ability to ensure access control, i.e. the ability to prevent any unauthorized access to the track from non-test vehicles and the public at large. This enables safety-critical tests to be performed safely away from public exposure.
2) The ability to control pavement surfaces, including pavement markings, signage, signaling systems, and even wetting or icing the surface (in winter weather) under controlled conditions. This allows vehicle testing in novel situations such as, for example: iced roads, incorrectly marked roads, unmarked roads, and special traffic signaling.

Additionally, the track supports many core capabilities that are essential to advanced vehicle testing, several of which are noted below.

The Differential GPS System

An on-site Differential GPS base station is maintained at the test track to ensure access to differential corrections in the test track and surrounding area. The station is calibrated regularly and includes the ability to reprogram for both defense and civilian correction standards. Corrections are broadcast using standard wireless radio protocols.

The Dedicated Short-Range Communication (DSRC) Radio Network

To facilitate connected vehicle testing, the test track maintains a DSRC radio network. This consists of three on-site DSRC road-side base station sites that are networked to the central garage facility. An additional 3 rover units are also regularly used on-site, and the radio coverage of each unit is shown via color-coded test results around the test track in Figure 4.

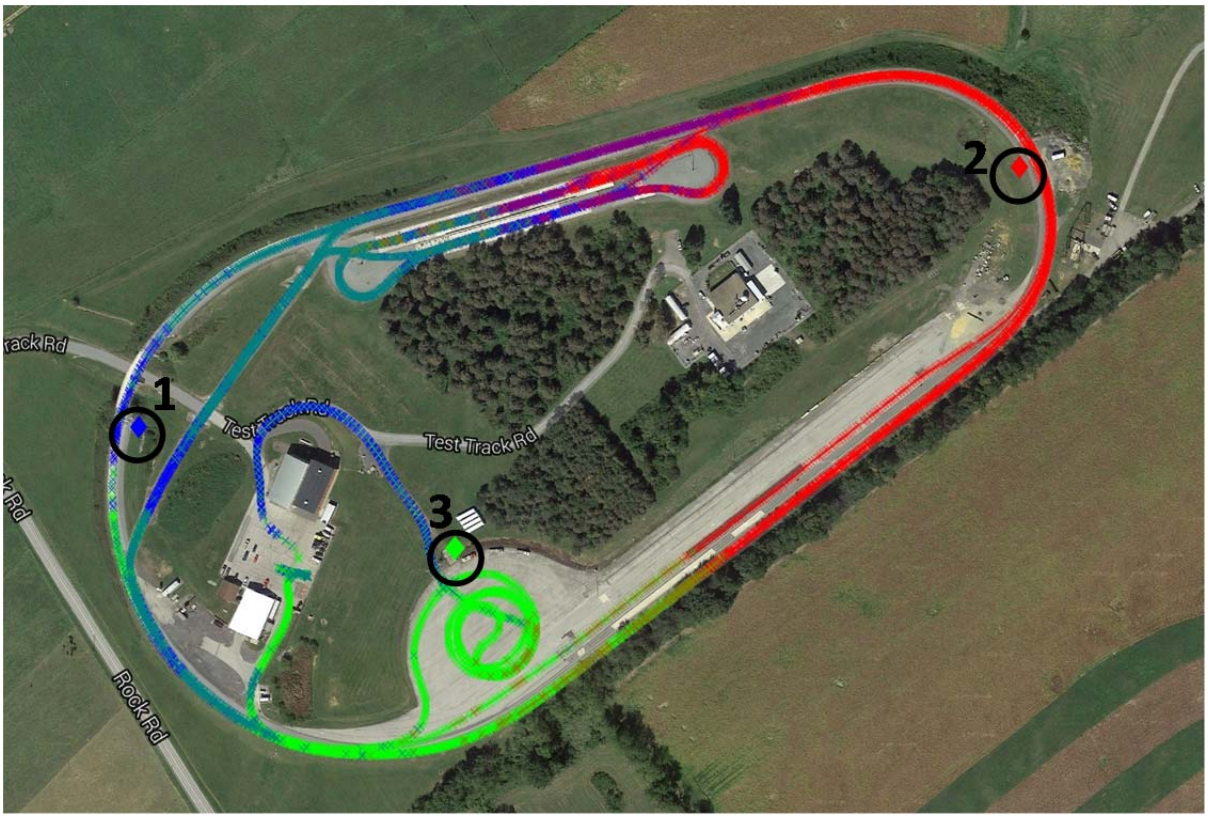


Figure 4. There are three DSRC radio system coverage at the LTI test track.

Electrification and Charging Systems

The Vehicle Research and Testing Laboratory is equipped with power-processing equipment for testing batteries and electric vehicles. This equipment consists of an AV-900 and ABC-150 power processors from Aerovironment, Inc. The equipment provides hardware-in-the-loop simulation and test capability for vehicle battery packs and electric drivetrains. The systems are capable of testing motors, inverters, and energy storage components and are also capable of simulating energy storage systems in the vehicle, such as the battery, flywheel, drivemotor/inverter, auxiliary power unit, or fuel cell. The flexibility of the systems allows for simulation of a constant DC bus (infinite battery source) or real battery behavior. The behavior (battery impedance) of the simulated battery can be a function of battery type, load, State of Charge (SOC), ambient temperature, age, recent history or any number of parameters. Dual channels provide the ability to simultaneously perform two different tests. This bi-directional capability allows clean AC power to be sent back to the utility grid, eliminating the need for resistive load banks and the associated cooling equipment.

The facility is equipped with sufficient electric vehicle charging facilities to be able to perform a fast charge on multiple heavy duty vehicles simultaneously. An on-campus charging system exists for Tesla and other passenger electric vehicles.

Vehicle Testing Laboratory

The use of autonomous or automated vehicle technologies, for example platooning strategies such as Cooperative Adaptive Cruise Control, are motivated by the potential increase in fuel economy and emissions reductions due to changes in vehicle operating conditions afforded by automation strategies. The LTI test track maintains an emissions test stand facility capable of testing heavy vehicle system emissions including transit buses, heavy trucks, and tractor-trailers. As part of the Bus Research and Testing Facility, LTI completed the construction of a 10,000 square foot vehicle research and testing laboratory located adjacent to the test track in 2004. The laboratory is equipped with four test and maintenance bays and provides ample space for vehicle maintenance and testing.

Figure 5. The proposed facilities include Penn State's test track (left), campus and surrounding community

The Vehicle Testing Laboratory is equipped with a 350 HP, large-roll (72 inch diameter) chassis dynamometer (Figure 5) suitable for heavy-vehicle emissions testing. The dynamometer is located in the end test bay and is part of the heavy vehicle emissions analysis laboratory. The emissions laboratory consists of a full-scale dilution tunnel and exhaust emissions analysis system for testing heavy-duty diesel and alternative-fueled buses for a variety of tailpipe emissions including; particulate matter, nitrates of oxygen, carbon monoxide, and hydrogen. The computer-controlled dynamometer is capable of simulating over-the-road operation for a variety of vehicles and driving cycles. The test track facility is equipped to fuel gasoline, diesel, liquefied natural gas and methanol. Compressed natural gas and high-pressure hydrogen are available individually or as a blend from a fast-fill fueling facility located on campus.

Figure 6. A mobile mapping vehicle (left) is used at the track to generate lane-marker position maps that can be compared to camera images from the vehicle to test camera registration of lane markers (right).

Mapping Vehicle

The researchers at Penn State utilize a mobile mapping vehicle (Figure 6) that can host LIDAR and camera systems with DGPS systems to obtain roadway geometric layouts, lane marker positions, and visual representations of the roadway. The LIDAR systems include Velodyne and SICK models. Such roadway geometric data is useful for map-based localization of autonomous vehicles, performing sensor calibration tests, determining variability in lane marker conditions, and identifying errors in positioning measurements of vehicles.

Friction Measurement Systems

The LTI test track hosts an annual international friction workshop and maintains a range of pavement surface characteristic measurement systems to fully identify road friction. These systems include an ASTM-E274 locked-wheel tester, ASTM-E303 British Pendulum tester, ASTM-E1911 circular dynamic friction tester and ASTM-E2157 circular texture meter (Figure 7). The track is equipped with a test lane that includes wide range of friction surfaces, and this lane is calibrated during each friction workshop event thereby allowing comparison of international friction measurement standards.

Figure 7. The road friction measurement equipment available at the test facility allows mobile, spot-specific friction measurements.

Crash Safety Research

It is likely that autonomous vehicle testing may require special certification of vehicle performance in crash-prone situations. The Penn State Crash Safety Research Facility (Figure 8) is one of the few university-owned crash testing facilities in the United States. A focal point for research pertaining to vehicle accidents, the facility provides researchers with the means to examine crash-related injuries and occupant safety issues; vehicle and highway apparatus design, testing, and analysis; and crash-related data and literature. The facility also offers educational and training opportunities for students, transportation officials, and the public.

Research facilities include a rail guidance system for full-scale crash testing; large- and small-scale pendulums for impact testing of vehicles, vehicle components, and highway structures; and advanced computer and sensor systems for high-speed data acquisition, vehicle impact simulation, and data analysis. The facilities, systems, and equipment enable researchers to test passenger vehicles, buses, and heavy vehicles for factors such as structural integrity and crashworthiness. The full-scale crash testing

Figure 8. The LTI test track hosts a crash safety research facility that is regularly used to study vehicle/barrier responses during crash events.

facilities give researchers the opportunity to investigate vehicle interaction with roadside barriers, lampposts, and signs.

Ongoing Connected, Automated, and Autonomous Projects at the LTI Test Track

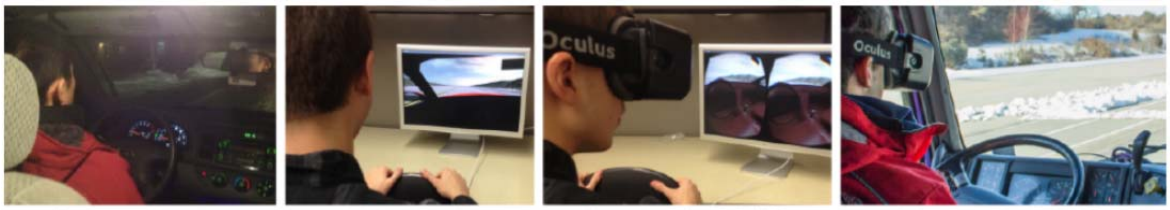
In addition to many OEM projects whose activities are protected by Non-Disclosure Agreements, researchers at Penn State are heavily involved in projects that utilize advanced testing capabilities to study connected, automated, and autonomous vehicles. A sampling of these projects is highlighted below.

ARPA-E Research Testing Automated and Connected Vehicle Testing

Penn State was recently awarded a 3-year ARPA-E project entitled "Maximizing Vehicle Fuel Economy through the Real-time, Collaborative, and Predictive Co-Optimization of Routing, Speed, and Powertrain Control." The goal of this project is develop and commercialize a hierarchical, model-predictive control system that uses traffic-level, vehicle-level, and powertrain-level automation systems to reduce the fuel consumption of commercial vehicles by 20%. This project specifically utilizes connected vehicle technologies and on-vehicle automation systems to achieve this performance improvement, and the project scope includes extensive field testing at the LTI test track.

National Science Foundation Testing Tele-operated Autonomous Vehicles

The goal of this project, entitled "Assessing Risk Compensation in Real and Virtual Man-Machine Systems" (National Science Foundation #1635663), is to determine how technology-mediated interactions between a driver and vehicle affect the driver's perception of risk. The 3-year project scope (starting in 2016) includes operation of autonomous vehicles through teleoperation that is mediated by Virtual Reality and Augmented Reality interfaces (Figure 9), with drivers both in the vehicle and within external driving simulators. This project includes driving simulator and live vehicle testing using virtual environments that are mapped to match the LTI test track.



(a) on-road baseline (b) simulated (c) simulated with HMD (d) on-road with HMD

Figure 9. The NSF project examines a range of technology-mediated methods to control a vehicle, comparing driver performance and risk-taking in a range of interactions, including with autonomous vehicles that are being teleoperated.

Penn State Study on the Impact of Autonomous Vehicle Systems on Traffic Behavior

Penn State researchers are developing software using the Robot Operating System that allows interaction between either a simulated or live vehicle interacting with a simulation of virtual traffic elements (Figure 10). The goal of this integration of a traffic simulator (AIMSUN) with live vehicle data is to develop tools that allow an understanding of how to model, then predict, and then control traffic behaviors that result from autonomous and/or connected vehicle technologies. The scope of this work includes integration of traffic simulation software to enable synchronization of the simulation software with vehicle and infrastructure signaling elements by merging information collected live at the LTI test track.

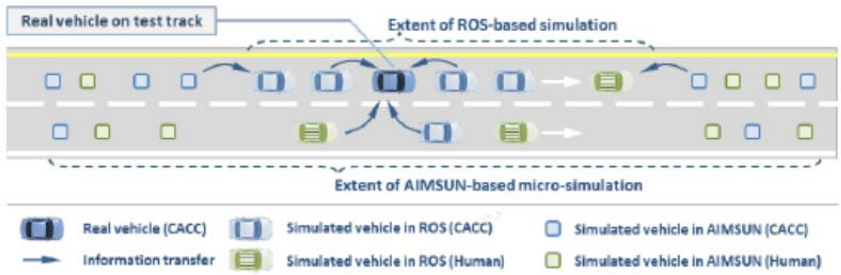


Figure 10. Connected and autonomous vehicles can influence surrounding traffic behaviors, and the PSU team is developing software that can capture vehicle behaviors at the test track for use in traffic simulation studies.

Safety Management Protocols for the LTI Test Track

Safety Management Personnel

LTI is pleased to offer a two-person safety management team for all automated vehicle testing at the closed-loop test track. Mr. Steven Williams, Manager of Safety and Facilities at LTI, will serve as the primary safety officer for this application. Mr. Williams is a member of the Penn State College of Engineering safety committee – LTI is a unit within the College. In this role, he serves as a partner to the College and is responsible for implementing its Integrated Safety Plan, which sets forth the overall mission and vision for safety and security of all work spaces in the College, which includes the test track. Mr. Williams' role as the LTI safety manager specifically includes the following functions:

- Establishes safety and security goals for LTI, and ensures that they are consistent with the College and University
- Engages in regular communication of safety concerns, initiatives, and trends between the College and LTI
- Evaluates LTI compliance with established College safety programs, policies, and regulations
- Develops mechanisms to implement new safety policies and procedures that are required by the University or College
- Ensures safety training needs within LTI are met

- Identifies safety and security funding needs
- Develops feasible solutions to all safety issues in consultation with the University's Environmental Health Services team
- Maintains records of all safety meetings and action items

Mr. Williams developed and maintains the LTI safety plan, and is also responsible for ensuring that each project undertaken at the test track contains a standard operating procedure, and that testing is executed in accordance with the procedure. Mr. Williams will participate in all national safety meetings organized by USDOT and share safety best practices with all proving grounds partners.

Mr. Denny Kovalick, Test Track Manager, will serve as the safety officer at the test track facility. Mr. Kovalick has managed the test track for 10 years, and has implemented the LTI safety management plan for all projects administered at the test track. He routinely oversees many testing projects, including the Federal Transit Administration's Bus Testing Program. Mr. Kovalick participates in regular safety meetings with Mr. Williams, and will also participate in the national safety meetings organized by the USDOT.

Safety Management Process

Penn State's College of Engineering develops the mission and vision for safety and security for all laboratories and other research space. The College's safety management process is shown in Figure 11. The process ensures that all projects administered at the LTI test track are consistent with university policy, and that all safety expectations are clearly communicated to all responsible parties before testing is undertaken.

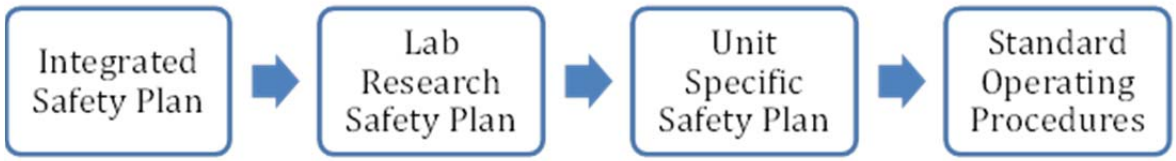


Figure 11. Penn State College of Engineering Safety Management Process.

Each step in the College safety management process is described in detail below.

The Integrated Safety Plan (ISP) creates a structure for managing safety and health within each unit of the College. LTI, which includes the test track, is a unit in the College of Engineering. The three core elements of the ISP are: Leadership Commitment, Employee Involvement, and Self-Review. Mr. Williams is LTI's safety leader and is committed to workplace safety and health. He clearly assigns and communicates safety responsibilities to all employees. He engages test track personnel, including Mr. Kovalick, in LTI-specific safety meetings when all new testing contracts are initiated. Mr. Williams routinely undertakes a test track self-review process to assess program safety limitations, which is complemented by periodic worksite inspections. The ISP is designed to provide a safe work environment for all projects administrated at LTI, including the test track.

The Laboratory Research Safety Plan (LRSP) is a central safety resource for LTI. It includes general information about emergency contacts and safety processes for laboratory spaces at LTI. For example, it describes policies related to testing chemical hazards, biological agents, and other materials and equipment. It outlines when various safety equipment (e.g., vests, eyewear, etc.) should be used during testing. Safety testing procedures for automated vehicles have not yet been integrated into the LRSP; however, Mr. Williams and Kovalick will work collectively with USDOT, PennDOT, vehicle manufacturers, and other partners to develop appropriate policies and procedures to execute the prescribed tests, and the procedures will be included in the LRSP.

The Unit Specific Safety Plan (USP) is consistent with the LRSP, but must be completed by research project investigators when they are under contract to test chemical hazards, biological agents, or physical hazards. The plan must clearly articulate the safety precautions that will be used during specific tests. The USP identifies test track-specific risk areas and which safety precautions apply to test track research. This plan is reviewed and certified by test track manager annually.

Standard Operating Procedures (SOP) are a set of written procedures explaining how to safely work within the scope of a project. The SOP identifies any required personal protective equipment required for the project. It also identifies unique project needs, such as safety training requirements, special equipment requirements, specific equipment operations (i.e. emergency shutoffs), and references to safety manual locations. When testing automated vehicles, Mr. Williams and Kovalick will work with USDOT, PennDOT, vehicle manufacturers, and other partners to develop SOPs for any testing performed at the test track.

Test Track's A2LA Certification

LTI initiated a quality management program in 2012 in accordance with ISO/IEC 17025 general requirements for the competence of testing and calibration laboratories. This standard is used by testing and calibration laboratories in most major countries. ISO/IEC 17025 is the standard for which most labs must hold accreditation in order to be deemed technically competent. In many cases, suppliers and regulatory authorities will not accept test or calibration results from a lab that is not accredited. This effort involves a systematic, program-wide enhancement of procedures and management practices to ensure the quality of all data, reporting and administrative practices. The practice for maintaining accreditation involves an ongoing effort of calibration, audits, documentation and periodic recertification by an approved, outside organization. LTI is accredited and continues to work to maintain accreditation by the American Association of Laboratory Accreditation (A2LA).

Institutional Review Board Certification

Federal law requires that any testing involving human test subjects undergo institutional review board (IRB) approval. This is to ensure that the safety, ethics, and subsequent data maintain the integrity and safety of all subjects involved with careful consideration given to the need for subject consent in situations that may impose risk or harm to the test subjects or public. Even though IRB approval and/or review is mandated for any research conducted with human subjects at universities, there is growing uncertainty and concern on the level of IRB protections that need to apply to ongoing vehicle testing. Driving is an inherently dangerous task but one that is within accepted risk to the public; however, the purpose of autonomous vehicle testing is to ensure that

additional risk is not involved, and ideally that exposure to additional risk is more than offset by reduction in accidents and/or accident severity. Because of the uncertainty with the assertion of safety inherent in new technologies, it is likely that safety discussions are needed that ensure compliance with national and international standards for IRB, as violation of such agreements might be deemed as unethical testing.

Because the IRB approval process is unclear for autonomous vehicle testing, it is sufficient to simply note that at present the Penn State team maintains IRB protocols for advanced vehicle testing. This includes specific, regular, and certified training on dealing with human subjects and resulting data.

Partnerships with the Surrounding Community for Infrastructure Access

The LTI test track has the potential to anchor testing capability into the surrounding community, including the Penn State Campus, the surrounding local community, and nearby interstate highway systems. This is particularly useful because the garage and gated area can serve as a vehicle parking/storage, work, and data-collection facility, while at the same time allowing users access to a variety of road environments for testing.

State College Township Partnerships and Access

The university is an integral part of the local community and thus has a long history of working cooperatively with the Borough of State College on projects of mutual interest. Researchers from LTI have used borough roads and streets for field data collection and open field-testing on a variety driver and traffic control device related issues. One of the most extensive of these was the study, "Real World On-Premise Sign Visibility, The Impact of the Driving Task on Sign Detection and Legibility" (2002), which compared test track and open-field testing of real-world driving tasks and conditions impacting on-premise sign detection and legibility. This study involved mounting signs for mock businesses at actual business locations in and around the borough over a period of several months so that daytime and nighttime testing could be completed. Activities similar to this have been conducted over the years, and the Larson Institute has maintained a strong working relationship with State College.

There has been on-going conversations between LTI and the borough regarding this solicitation discussing the suitability and use of borough locations to conduct live field testing of connected or automated vehicle technologies similar to what is being done by Uber in the City of Pittsburgh. The borough is open to the idea of acting as a test bed for these technologies, and they have provided a letter for this solicitation response to demonstrate that support (see Appendix).

PennDOT Partnerships and Interstate Access

LTI has a long history of work cooperatively with both the Commonwealth of Pennsylvania and the Borough of State College. Over the nearly 50-year history of LTI, PennDOT has been an integral partner in advancing the state of the art and the state of the practice in transportation. This history is bolstered by on-going master agreements for the promotion of research, education, and training between the university and the Commonwealth and LTI and PennDOT. We have had discussions with department officials, and we anticipate being able to have access to state roads and streets for testing technologies that are ready to go beyond the limitations of

trials on a closed facility. These arrangements will be guided by PennDOT's nearly completed Autonomous Vehicle Testing Policy, the draft of which was issued November 2, 2016, with an on-line public hearing on December 12, 2016. The policy was developed by a task force composed of internal and external stakeholders and it made the following recommendations which address many of the "regulatory challenges associated with higher levels of automation" (as discussed in the solicitation):

- Testers of highly automated vehicles (HAVs) must submit testing proposals to PennDOT and enter contracts attesting that the vehicles meet all federal and state safety standards and meet the policies adopted by PennDOT.
- PennDOT has to be notified prior to any HAV being used without an operator in fully self-driving mode.
- PennDOT and the Pennsylvania Turnpike Commission may temporarily restrict HAVs from certain routes. Otherwise, HAVs may be tested on any road in the state. Municipalities can also ask PennDOT to temporarily restrict HAVs on local routes.
- Platooning of HAVs will be restricted to two commercial or three passenger vehicles. However, testers can ask to use more HAVs in platooning, but PennDOT can ask for a safety demonstration first.
- The HAVs must be able to record data that can be used to investigate crashes involving the HAVs. PennDOT will have access to the data.
- Testers must certify that cybersecurity protections are in place for the HAVs.
- PennDOT will collect data on total miles operated by HAVs, total number of hours of operation, and size of HAV fleets. PennDOT may also ask for other information such as counties where HAVs are being tested and percentage of testing done on limited access highways. PennDOT can also ask for information about the economic impact of HAV testing.
- PennDOT and State Police will make annual reports on HAV testing to the Legislature.

In coordination with the Pennsylvania District 2 Traffic Management Center in Clearfield, Penn State can obtain access permission to selected interstate locations for autonomous vehicle testing. Depending on the safety requirements of these tests, as well as the shared safety agreements negotiated over the 2017 year for such facilities, public access to these locations can be limited in agreement with PennDOT to ensure public safety. We are aware that PennDOT is submitting a separate initiative in support of this autonomous vehicle testing RFP to coordinate activity across the state, and our involvement in this activity

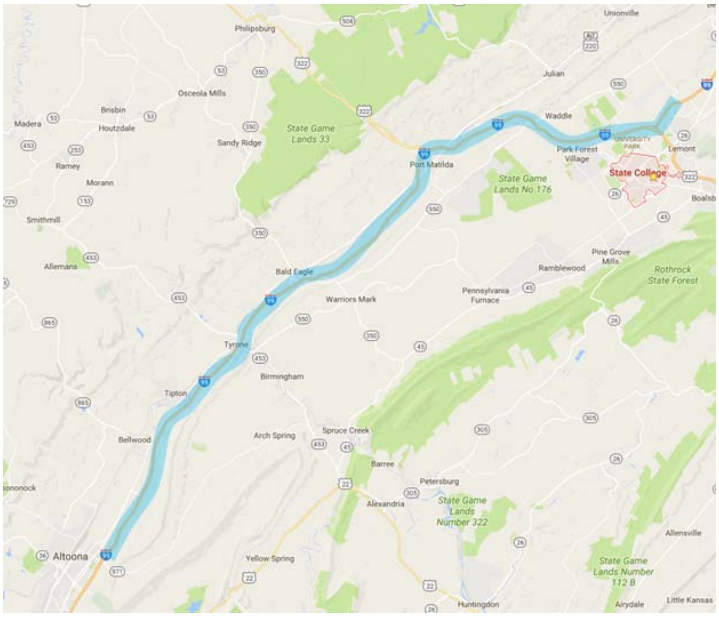


Figure 11. The I-99 corridor connects the LTI test track and the Altoona garage facility, providing a unique testing area with staging areas at each end.

is already beginning with the understanding that additional coordination through PennDOT would be required as activities grow.

The location most likely used for testing would be the recently-opened Interstate 99 corridor between Penn State and Altoona. This location, shown in Figure 11, is particularly advantageous as it is book-ended on each end by Penn State garage facilities in Altoona, and the LTI test track in State College, thereby providing staging areas for vehicle test preparation, data archiving, etc. Further, this roadway is very lightly utilized (particularly at night), and is situated within forested areas that are unpopulated nearby the roadway. It is mountainous, and thus presents real-world challenges for platooning automation strategies. It is well-marked with few on/off ramps and one interstate exchange area. It is prone to icy and foggy conditions in the winter. Finally, it is well-connected (fiber-optic connections) to the local Traffic Management Center, and thus the present condition more readily enables upgrades if autonomous vehicle testing should require facility upgrades in future years.

It is anticipated that, as activity grows, the RTMC activities will be coordinated state-wide across all 4 RTMCs as well as the State-wide Traffic Management Central in Harrisburg. The Appendix to this application provides a letter of cooperation from PennDOT Secretary Leslie Richards, which outlines their role in serving in a coordinating capacity among LTI and two other proving ground testing partners in Pennsylvania.

Data Management Plan

Data is typically shared with OEM partners via secured site access (Sharepoint and Box, in particular), or via direct distribution of hard drives – the common practice in Penn State's SHRP-2 involvement and data collections. Internally, most project data repositories are maintained via Box, as this system supports encryption and access-monitoring on all data. For road mapping projects, the Penn State team has in the past established SQL servers to enable location-based queries of road information and road data. For any vehicle or road data collection and in keeping with IRB protocols, care is taken to de-identify road users prior to public release, or have protected this information accordingly.

It is anticipated that, as part of the DOT coordination of nationwide autonomous vehicle testing facilities, that data sharing standards will be further defined and established, and the Penn State team looks forward to such discussions to obtain improved public access to federally-funded project data, establishing common data-sharing formats, and defining core vehicle data that should be captured for vehicle system comparisons between test facilities and over time.

LTI Autonomous Track Improvement Activities over the Next Year

Over the 2017 calendar year, planned upgrades to the test track include several aspects with specific focus on improving autonomous vehicle testing. These are:

1) **Installation of track-perimeter power and communication systems** (Ethernet) that enable rapid installation of V2I hardware, signage, or other signalization elements. During the installation of the DSRC network in 2015, it was found that different configurations of the radio positions on the road-side could impact the V2I performance, where some installation positions could cause black-out zones of coverage. It is highly desirable to be able to study such situations by selectively changing the physical

mounting locations. However, such flexibility demands that power and communication hardware be available throughout the perimeter of the track, and not simply at the fixed locations chosen earlier.

2) **Testing of DGPS corrections transmitted via 3G, 4G, or DSRC systems**. It has been seen repeatedly that DGPS systems on roadways near the track can have their differential correction broadcasts blocked by trees, terrain, houses, and other elements. If differential corrections are broadcast via other methods independent of wireless modems (as currently used), then this enables much greater positioning accuracy of the automated and autonomous vehicles.
3) **Development of a command-and-control center for telemetry collection (contains Confidential Business Information [CBI])**. The goal of this task is to establish a climate-controlled data collection facility that enables processing of vehicle data that synchronizes road-side measurements (traffic cameras, DSRC radio feeds, signage, and traffic simulations) with telemetry obtained from vehicles at the track. This same facility is meant to facilitate motion coordination, tracking, and testing of autonomous vehicles. The design of this facility is to support loading-dock and low-speed autonomous docking operations for OEM partners operating heavy autonomous trucks, to collect synchronized data for CACC platoons for evaluation of performance and fuel-economy, and as a staging area for tele-operated control of automated vehicles.

The LTI Autonomous Vehicle Safety Review Panel

While the principal proving group facility included in this application is the LTI test track, there are candidate roadways near Penn State's campus that may be used to expand testing of automated vehicle technologies, if the opportunity exists. The Penn State team recognizes that vehicle operations may need to proceed from one facility to another, sometimes in a seamless manner. Thus, coordination of testing protocols and safety standards between venues is critical.

To coordinate any proposed expansion of testing beyond the test track, LTI proposes to establish an autonomous vehicle safety review team. This team would include the safety officers and investigators from LTI who are listed at the top of this agreement. Additional members of this review team will include Mr. Thomas Fontaine, State College Borough Manager; Dennis Prestash, PennDOT RTMC Operations Manager; Stanley Niemczak, Jacobs Engineering Group; and James Roman, PennDOT Regional Signal Operations Manager. This group will consider any testing requests offered by USDOT, and then coordinate transportation operations, safety management plans, and shared agreements between all of the proposed testing locations.

This team will also review safety recommendations and related operational outcomes that emerge from DOT connected vehicle pilot programs that are ongoing, as well as common standards that emerge as part of the coordinated effort of this project for autonomous vehicle testing. Such information will be used to guide and regularly update combined safety policies related to connected, automated, and autonomous vehicle testing.

APPENDIX

Letters of Cooperation from:

Pennsylvania Department of Transportation Secretary Leslie Richards
Borough of State College Manager Thomas Fountaine

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
HARRISBURG, PENNSYLVANIA 17101-1900

OFFICE OF
SECRETARY OF TRANSPORTATION

December 19, 2016

The Honorable Anthony Foxx, Secretary
U.S. Department of Transportation
1200 New Jersey Ave, SE
Washington, DC 20590

Dear Secretary Foxx,

I am pleased to submit this letter of support for the designation of automated vehicle proving grounds in Pennsylvania. PennDOT is acting in a coordinating capacity for three proving ground sites of our partners: the Pocono Raceway, Penn State University and the City of Pittsburgh.

This designation will bolster an already thriving industry that has made Pennsylvania one of the leading centers of HAV technology development. Each of our proving ground partners caters to a niche element of HAV technology. The Pocono Raceway will specialize in high-speed testing, platooning and at-grade intersection configurations; Penn State University on testing transit and commercial vehicles, and the City of Pittsburgh is studying the real-world challenge of operating on public streets. The combination of these applications provides a well-rounded array of operating facilities to enable the technology to continue to grow and HAV developers to flourish.

PennDOT has already committed substantial resources to the development of policies and partnerships to support HAV testing. Our Autonomous Vehicle Taskforce laid out the foundational policies for on-road HAV testing in Pennsylvania. We have organized staff to commit greater resources and attention to HAV programs. We consider the development of proving grounds to be the next logical step in the process of supporting HAV growth in Pennsylvania. We plan to commit additional resources including financial support, technical support through our network of traffic control device manufacturers and technological support through data sharing.

Pennsylvania has brokered an innovative approach to HAV testing, featuring collaboration between government, industry and academia. We are confident that the industry will find supportive and knowledgeable partners for future endeavors. Moreover, our team of partners for this proving grounds initiative are well positioned to scale up as innovation and opportunities emerge, so Pennsylvania can continue to build out its capacities and broaden its commitment to this transportation revolution in the making.

We look forward to your favorable response for our application.

Sincerely,

Leslie S. Richards, Secretary
Pennsylvania Department of Transportation

BOROUGH OF STATE COLLEGE

243 South Allen Street, State College, PA 16801-4806

December 15, 2016

Dr. Eric T. Donnell, Director
Thomas D. Larson Pennsylvania Transportation Institute
201 Transportation Research Building
University Park, PA 16802

RE: Letter of Support for Advanced Vehicle Technologies/Automated Vehicle Technology

Dear Dr. Donnell:

This letter is to express support for Advanced Vehicle Technologies, and particularly automated vehicle technology being developed at the Larson Transportation Institute (LTI) at The Pennsylvania State University. This significant opportunity for the Larson Transportation Institute is important to the Borough of State College. We are enthusiastic about this project and welcome the opportunity to be engaged in a partnership with Penn State University, the Larson Institute and the Department of Transportation to advance technologies related to automated transportation.

With the U.S. Department of Transportation's announcement of the creation of an Advisory Committee on Automation in Transportation, that it was assembling expects to help assess new transportation technologies, there is a clear alignment of Penn State's efforts in this area. The with Penn State Larson Transportation Institute's test tracking and testing facilities are ideally suited for this work. I would also like to think the prospect of using State College and the Centre Region's network of roadways as a test bed for advanced vehicle technologies.

While attending the National League of Cities Conference, held recently in Pittsburgh, Carnegie Mellon was demonstrating the Uber self-driving car and it was of great interest and I am committed to supporting work that brings similar technologies to State College.

If you have any questions or would like to discuss my support of LTI and its facility or the work they are doing, please do not hesitate to contact me.

Sincerely,

Thomas J. Fountaine, II
Borough Manager

TJF/ske

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COUNCIL PRESIDENT: THOMAS E. DAUBERT
BOROUGH COUNCIL: JESSE L. BARLOW, JANET P. ENGEMAN, DAVID J. BROWN, THERESA D. LAFER, CATHERINE G. DAULER, EVAN MYERS

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