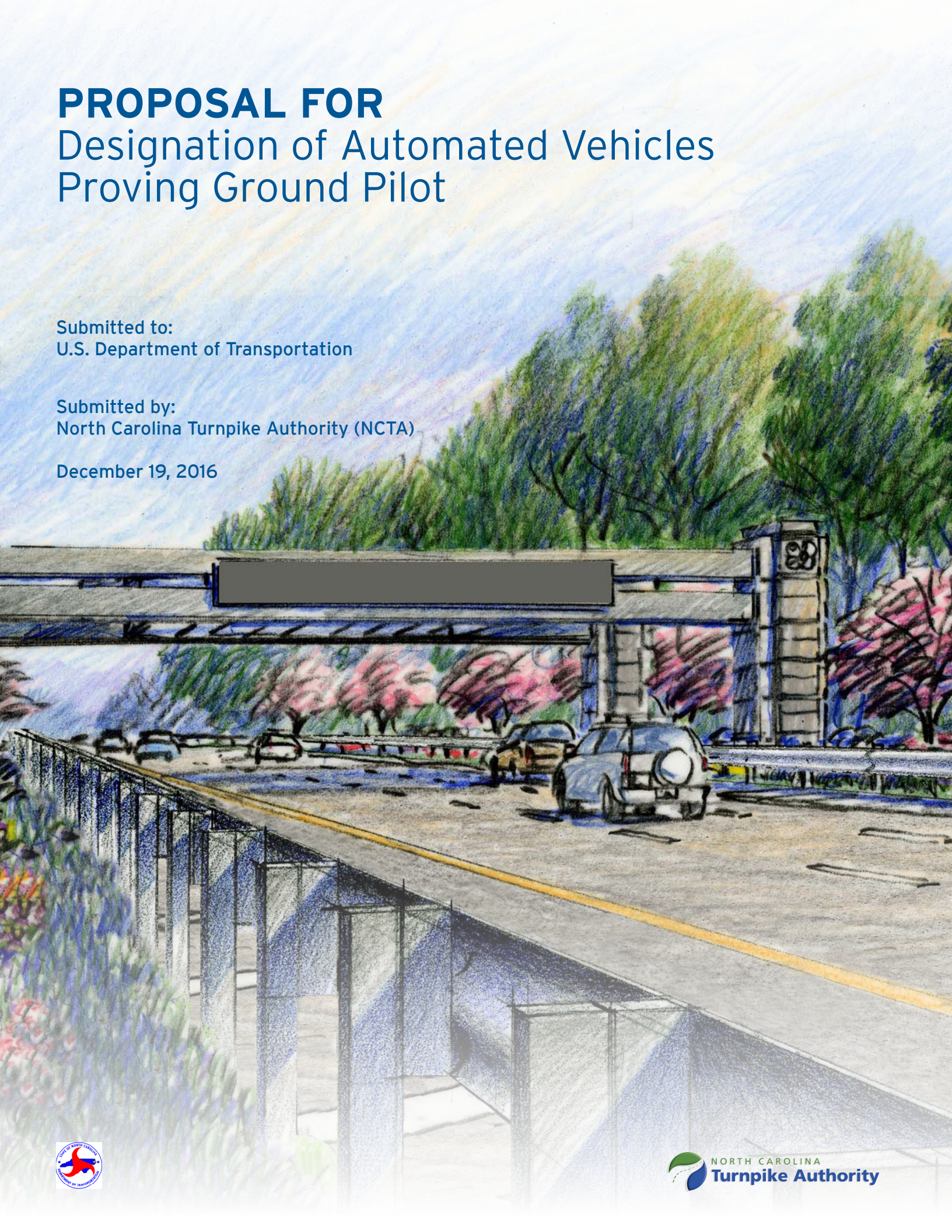
PROPOSAL FOR
Designation of Automated Vehicles Proving Ground Pilot

Submitted to:
U.S. Department of Transportation

Submitted by:
North Carolina Turnpike Authority (NCTA)

December 19, 2016



NORTH CAROLINA
Turnpike Authority

December 19, 2016

Office of the Secretary, U.S. Department of Transportation (DOT)
Docket No: DOT-OST-2016-0233 (ref)
submitted via automation@dot.gov

Re: Designation of Automated Vehicle Proving Ground Pilot

Dear Office of the Secretary, DOT:

The North Carolina Turnpike Authority (NCTA), with full support from the North Carolina Department of Transportation (NCDOT) and our partners, requests designation as a Community of Practice to research, develop and share best practices related to the safe testing, demonstration, and deployment of automated vehicle technology. NCTA proposes the Triangle Expressway to serve as a designated automated vehicle proving ground. The Triangle Expressway is an award-winning facility that is geographically located within the heart of the Research Triangle, home of three Tier 1 research universities, and within and adjacent to Research Triangle Park (RTP), the largest research park in North America. NCTA is submitting a fully compliant proposal that combines a world-class facility with world-class partnerships and world-class research to advance automated vehicle technology.

NCTA's Designated Safety Officer, **Dennis Jernigan, PE**, is committed to this role of ensuring the safety of the traveling public, the safety of North Carolina's roadway facilities, the safe implementation and testing of automated vehicle technology and participation in the Community of Practice. Dennis is ideal for this role based on his 25 years of experience with NCDOT serving in construction administration and current role as Project Controls Engineer with NCTA. Dennis is extremely knowledgeable of NCDOT's and NCTA's established safety plans and has been responsible for safety audits, maintaining safety during construction and operation of NCDOT's roadway network and serving on safety committees throughout his career.

In addition to Dennis's qualifications, NCTA's proposal offers the following unique advantages:

World-Class Facility | NCTA's Triangle Expressway is one of the most advanced freeways in the United States and the most interoperable all-electronic tolling (AET) facility in the U.S., accepting transponders from the Northeast, mid-Atlantic, Midwest and Southeast. Its existing robust Intelligent Transportation Systems (ITS) infrastructure provides the capability to monitor automated vehicle (AV) operations, collect data for research and study, and potentially communicate with AVs. NCTA maintains and operates its own state-of-the-art Traffic Management Center (TMC) for monitoring and responding, in real-time, to the traffic conditions experienced along its facilities.

World-Class Partnerships | For this initiative, NCTA has assembled a large and diverse group of partnerships with local universities, agencies, and organizations including NCDOT's Research and Development Unit, NC State University (including its Institute for Transportation Research and Education), University of North Carolina-Chapel Hill (including its Highway Safety Research Center), Duke University, North Carolina Agriculture & Technical State University, University of North Carolina-Charlotte, and The Regional Transportation Alliance. These partnerships provide NCTA with unmatched resources to research, study, and test automated vehicles and to share results with other stakeholders across the nation.

World-Class Research | NCTA provides the opportunity to study multiple issues associated with automated vehicles including work zone navigation, incident management strategies and digital mapping inadequacies. NCTA's existing, under construction, and planned roadways and projects provide a unique compilation of facilities and resources to study and test solutions to these problems that must be overcome for the safe deployment of automated vehicles.

We look forward to the opportunity to serve as a Community of Practice to advance automated vehicle technology. If you have any questions or require additional information, please do not hesitate to contact Dennis Jernigan or myself.

Sincerely,
North Carolina Turnpike Authority

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1 | NCTA OVERVIEW

NCDOT AND NCTA

The North Carolina Department of Transportation (NCDOT) has roots that date back over 100 years to when the North Carolina State Highway Commission was formed in 1915. In 1979, the State Highway Commission evolved into NCDOT and its present day multi-modal structure that provides a wide range of projects and services to meet North Carolina's transportation needs. NCDOT is responsible for maintaining approximately 80,000 miles of roadways, which is the second most miles of public roads maintained by a State DOT in the United States. NCDOT also maintains 18,000 bridges and culverts across the State of North Carolina, and regulates and implements programs to support rail, aviation, ferry, public transit, and bicycle and pedestrian transportation. The North Carolina Turnpike Authority (NCTA) is a unit of NCDOT that was created in 2002. NCTA has been authorized to study, plan, develop, construct, operate, and maintain toll highway projects in North Carolina, including the Triangle Expressway.

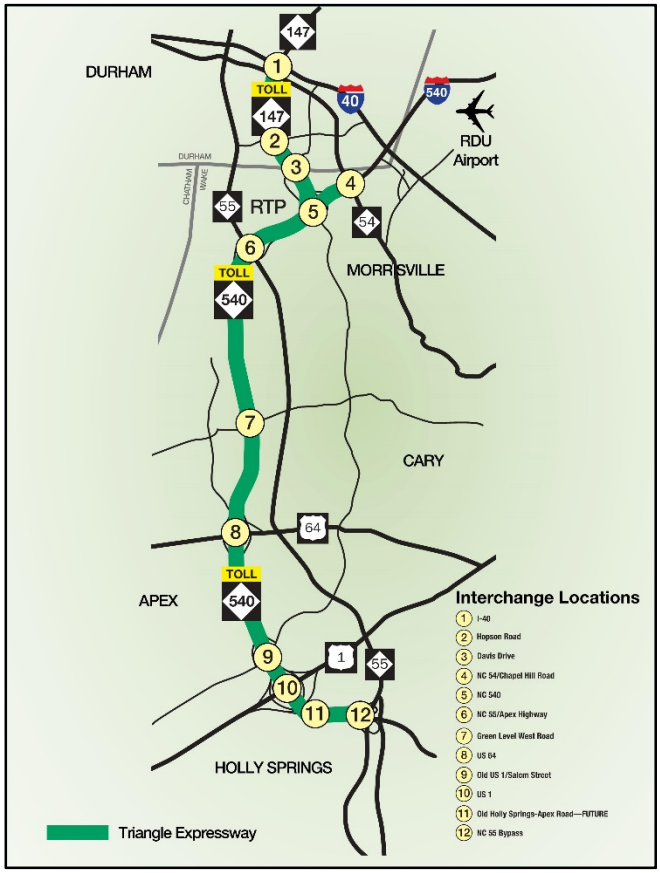

Figure 1 Triangle Expressway Corridor

Triangle Expressway

The Triangle Expressway is approximately 19 miles in length and extends south as NC 147 from the I-40 interchange in the Research Triangle Park (RTP) to the Northern Wake Expressway, and then northeast to the Northern Wake Expressway (NC 540)/NC 54 interchange, and south to the NC 55 Bypass in Holly Springs (see Figure 1). The expressway is a six-lane, 70 miles per hour (mph), fully access controlled facility that consists of ten interchanges and eighteen all-electronic toll (AET) collection zones. The Triangle Expressway is the single largest transportation infrastructure project in North Carolina history. It was opened in three phases: Phase I opened in December 2011, Phase II opened in August 2012, and Phase III opened in December 2012. There are currently proposals in the State Transportation Improvement Program (STIP) to extend the facility by approximately 30 miles.

The Triangle Expressway is a premier toll highway corridor nationally, having won five awards in the five years since it first opened including:

- The International Bridge, Tunnel and Turnpike Association (IBTTA) 2016 President's Award
- The IBTTA 2016 Toll Excellence Award
- The Southern Association of State Highway and Transportation Officials (SASHTO) 2013 award for Best Use of Innovation in the Southeastern Region
- The American Council of Engineering Companies (ACEC) 2012 People's Choice Award
- The ACEC 2012 Grand Award for Engineering Excellence in Transportation

Figure 2 Triangle Expressway Facility

The Triangle Expressway was the second AET facility in the United States and the first new toll road to be designed as an AET facility from inception when opened in 2011. The Triangle Expressway is the most interoperable toll road in the United States, accepting transponders from E-ZPASS, NC QuickPass, Georgia PeachPass, and Florida SunPass. To operate, monitor, and study the Triangle Expressway, NCTA maintains a robust Intelligent Transportation System (ITS) infrastructure that includes a two-parallel fiber optic backbone communication network (FON) along the

entire corridor to provide separate dedicated communications for the toll systems and the intelligent transportation system. This FON connects an ITS network of detectors, cameras, dynamic message signs, and a roadway weather information system, as well as a toll system network of overhead/gantry-mounted radio frequency readers, video cameras, and in-pavement detectors.

Figure 3 NCTA's State-of-the-Art Traffic Management Center

NCTA maintains and operates its own state-of-the-art Traffic Management Center (TMC) for monitoring and responding, in real-time, to the traffic conditions experienced along its facilities. The NCTA TMC operates 24 hours a day, 7 days a week, and 365 days a year (24/7/365). One of its primary functions is to monitor the Triangle Expressway 24x7 and serve as the coordination center between users, emergency responders and transportation officials when incidents impact travel on the Expressway. The TMC serves as the coordination center for roadway and ITS equipment maintenance, as well as construction activities. NCTA has documented and established plans, manuals, and procedures to provide safe and efficient operations while maintaining continuous communication on the Triangle Expressway. Located in Raleigh, North Carolina, the TMC is in close proximity to the Triangle Expressway and is co-located in the North Carolina National Guard Joint Force Headquarters Building.

The Triangle Expressway is uniquely located in the Triangle (Raleigh-Durham-Chapel Hill), the Research Triangle, and RTP. The Triangle Expressway's location connects one of the most educated, technologically advanced and thriving urban areas in the world while also providing a connection to the Raleigh-Durham Airport (RDU). This facility provides a vital role in the continued growth, advancement, and mobility of the people, services, and goods in North Carolina. For all these reasons and those described below, NCTA believes the Triangle Expressway is an ideal highway corridor to serve as a designated automated vehicle (AV) proving ground.

2 | MANDATORY CRITERIA

DESIGNATED SAFETY OFFICER

Dennis Jernigan, PE

NCTA Project Controls Engineer

Dennis Jernigan is a North Carolina Professional Engineer and a 25-year veteran of the North Carolina Department of Transportation. He is a 1990 graduate of North Carolina State University where he majored in civil engineering with a construction focus. Throughout his NCDOT career, Dennis has concentrated on construction administration, serving in the roles of Assistant Resident Engineer, Resident Engineer, Roadway Construction Engineer, NCDOT Division 5 Construction Engineer, and currently the Project Controls Engineer with the NC Turnpike Authority.

As the Roadway Construction Engineer, Dennis was responsible for project acceptance, claims and supplemental agreement administration and serving as a subject matter expert for NCDOT Divisions 5 and 8, where the Triangle Expressway is located. As Division Construction Engineer, Dennis and his staff of five Resident Engineer offices oversaw all construction, rehabilitation, resurfacing, and bridge replacement projects in Division 5, which includes Wake, Durham, Franklin, Granville, Vance, Warren and Person Counties. Over 200 projects were let and accepted during his tenure as Division Construction Engineer.

Dennis is committed to safety as demonstrated by his roles and responsibilities throughout the course of his career. Dennis has ensured that construction and operations adhere to and abide by NCDOT's *Workplace Safety Manual* and standard operating procedures in his roles in Division 5 and 8. Dennis performed regular safety audits and served on and was a co-chair of the Division Safety Committee. The goal of the safety committee was to identify safety trends and enact safety countermeasures. Throughout his career, Dennis

has supervised more than 100 staff and has personally worked on the majority of interstate, U.S., N.C., and secondary routes in the Triangle area. Most recently, Dennis managed the I-40 reconstruction project in Raleigh, NC and oversaw the implementation of new polices to establish a travel demand manager and a network travel management plan. This innovative safety policy created a contingency incident management plan to maintain safety and mobility during construction of an interstate highway corridor.

Dennis is organized to lead NCTA's Automated Vehicle Program (AVP) and brings the safety and management experience required to ensure the program is an active, integral contributor to the advancement of AV technology.

COMMITMENT TO SHARING

NCTA, NCDOT and our university and business research partners are committed to sharing approaches to safety and safety data generated through testing and operation of the automated vehicle program. Letters of Support from some of our university and business research partners are included in the Appendix.

3 | PROPOSED CONTRIBUTIONS

ELIGIBILITY AND ADMINISTRATION OF AUTOMATED VEHICLE PROGRAM

NCTA's Triangle Expressway is a world-class highway corridor through one of the fastest growing urbanized areas in the United States. Its facilities provide NCTA and its partners the ability to administer an Automated Vehicle Program that can contribute to the development of automated vehicle technology and best practices in multiple ways as described below. NCTA and NCDOT currently administer a variety of transportation programs related to safety, operations, the environment, education, and research. The NCDOT Research and Development Group, led by Neil Mastin, PE, has a long-standing history of administering an annual research program that distributes research results locally and nationally, maintains a research library, engages NCDOT personnel in national research programs such as the Transportation Research Board (TRB), American Association of State Highway Transportation Officials (AASHTO), National Cooperative Highway Research Program (NCHRP), Transportation Pooled Fund (TPF) Program, Strategic Highway Research Program (SHRP), Long Term Pavement Performance (LTPP) Program, and provides research management services with Universities. NCTA is excited to formalize an AVP with the wealth of resources at our disposal. Our Designated Safety Officer and Designated Point of Contact, Dennis Jernigan, PE will lead NCTA's AVP in constant coordination with our partners and USDOT.

AV LEADERSHIP

NCTA has been at the leading edge of implementing new toll collection technologies and we are organized to provide leadership in testing, deploying, and monitoring automated vehicle technology. NCTA and its partners are part of a region in North Carolina that thrives on innovation. We are eager to take the lessons learned from previous endeavors and apply them to the advancement of automated vehicle technology and to share results with other stakeholders across the nation. For examples of where our partners have provided AV leadership, see Section 5.

COMMUNITY OF PRACTICE

NCTA's proposed contributions to the Community of Practice make use of our right partnerships, facilities, and research opportunities to provide USDOT and stakeholders nationwide with practical results that can support the safe deployment of automated vehicles. Five such contributions highlighted below include Digital Mapping for New Roads, Work Zone Traffic Control, Incident Management, All-Electronic Tolling, and Big Data Analysis.

Digital Mapping for New Roads

Self-driving vehicles rely heavily on detailed digital mapping of roadways. So unmapped roads or reconfigured roads and intersections pose problems that must be solved for safe wide-scale deployment of AVs. While approximately 18 miles of the Triangle Expressway are in use today, approximately 30 miles have yet to be built and are undergoing engineering, planning, and environmental studies. The Access 540 project is building a new interchange along the Triangle Expressway (Toll NC 540) at Old Holly Springs-Apex Road (SR 1153) which is scheduled to be opened to traffic in 2018. Also, the Morrisville Parkway corridor from NC 55 to Green Level Church Road will be extended to include a new interchange on the Triangle Expressway. Construction is anticipated to be complete in 2019. Finally, new sections of NC 540 (Complete 540) are

scheduled to be constructed in three phases. The first phase which extends Triangle Expressway from NC 55 Bypass to US 401 is currently scheduled for construction contract award in 2018. These projects and the phased extension of NC 540 will provide unique opportunities to study and test autonomous vehicles on newly opened roadways and interchanges and reconfigured existing intersections.

Figure 4 New Sections of NC 540 scheduled to be constructed

Work Zone Traffic Control

Establishing policies and protocols for work zones to safely accommodate autonomous vehicles will be critical to protecting construction workers and AV users. NCTA has an established Maintenance of Traffic (MOT) Evaluation plan to provide guidance for construction work zones and lane closures along Triangle Expressway as shown in Figure 5. As described above, new sections of the Triangle Expressway for Access 540, the Morrisville Parkway, and Complete 540 will provide unique opportunities to study and test autonomous vehicles in varying real-world work zone conditions. Additionally, NCTA and NCDOT maintain a *Work Zone Safety and Mobility Policy* and comprehensive *Maintenance/Utility Traffic Control Guidelines* which can be used in research studies to determine whether existing work zone strategies are compatible with AV technology and what new guidelines should be considered to more safely accommodate automated vehicles.

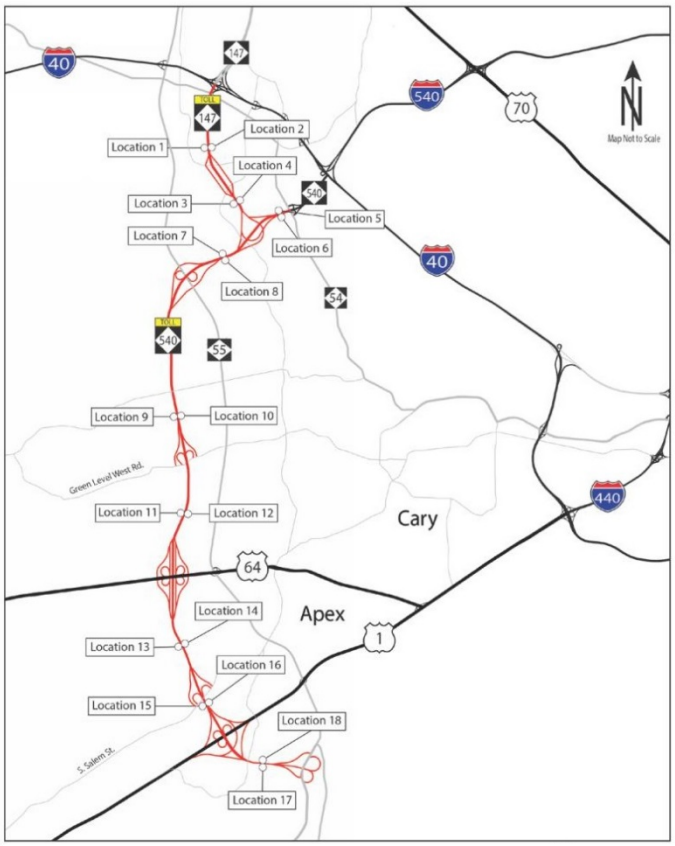

Figure 5 Maintenance of Traffic Locations

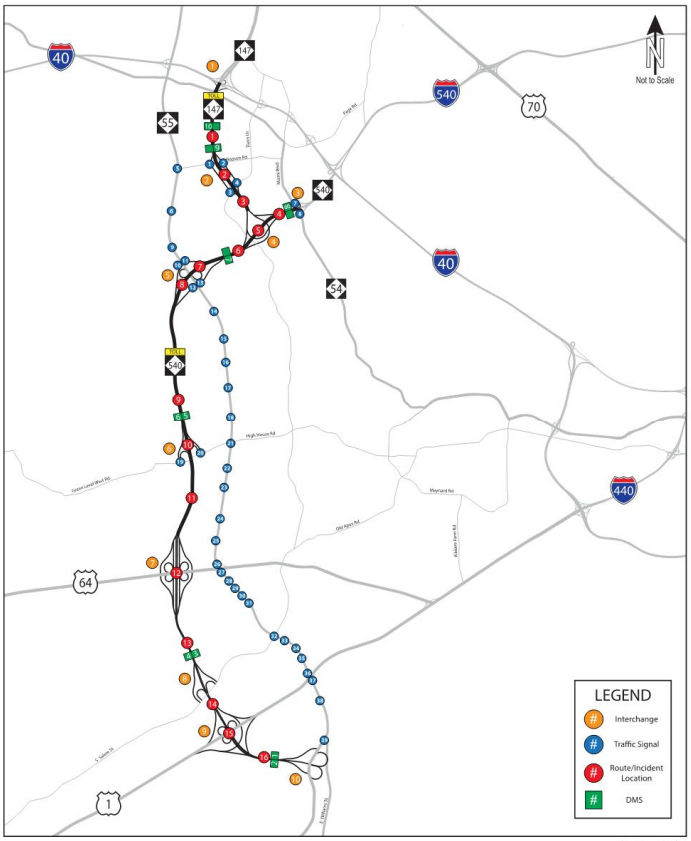

Figure 6 Triangle Expressway Detour Plan

Incident Management

Temporary detours due to incidents can also pose problems for automated vehicles. NCTA's TMC is vital in implementing NCTA's detailed Traveler Information Management System (TIMS) by assisting with expediting the detection, verification, response, and clearance of incidents from NCTA roadways. TMC operators are

responsible for communicating and coordinating with first responders, as well as disseminating incident information to applicable Dynamic Message Signs (DMS) and the TIMS database. TIMS feeds the 511 and the Traveler Information web site, to notify the motoring public of incident locations so they may seek alternate routes. TIMS also currently includes detailed detour plans for 16 incident locations, as shown in Figure 6, along the Triangle Expressway and Standard Operating Procedures for managing incidents. NCTA's TMC and TIMS provide a comprehensive resource of traffic management professionals, technology, and policies to study and monitor automated vehicle operations during incidents. The effectiveness of existing and new incident management strategies and policies for automated vehicles can be studied and monitored using these resources.

All-Electronic Tolling (AET)

More research is needed to study the interaction between automated vehicles and tolling systems. The Triangle Expressway was the second AET facility in the United States and the first new toll road to be designed as an AET facility from inception when opened in 2012. The Triangle Expressway is the most interoperable toll road in the United States, accepting transponders from E-ZPASS, NC QuickPass, Georgia PeachPass, and Florida SunPass. NCTA can provide the right resources to study the interaction between AVs and AET facilities to ensure safe and reliable toll collection methods and safe navigation of AVs on toll facilities.

Figure 7 All-Electronic Toll Gantry on Triangle Expressway

Big Data Analysis

Research studies often require large collections of data and analysis of that data to produce statistically reliable results. The Triangle Expressway's existing robust ITS infrastructure provides the capability to monitor AV operations and collect large amounts of data for use in research and study. NCTA's ITS infrastructure includes the FON that provides separate dedicated communications for the toll systems and connects a network of travel and traffic information systems, data readers and recorders. Additionally, NCTA's university and business partners have the resources to analyze the vast amount of data collected to provide useful results that can be shared with USDOT and stakeholders across the nation.

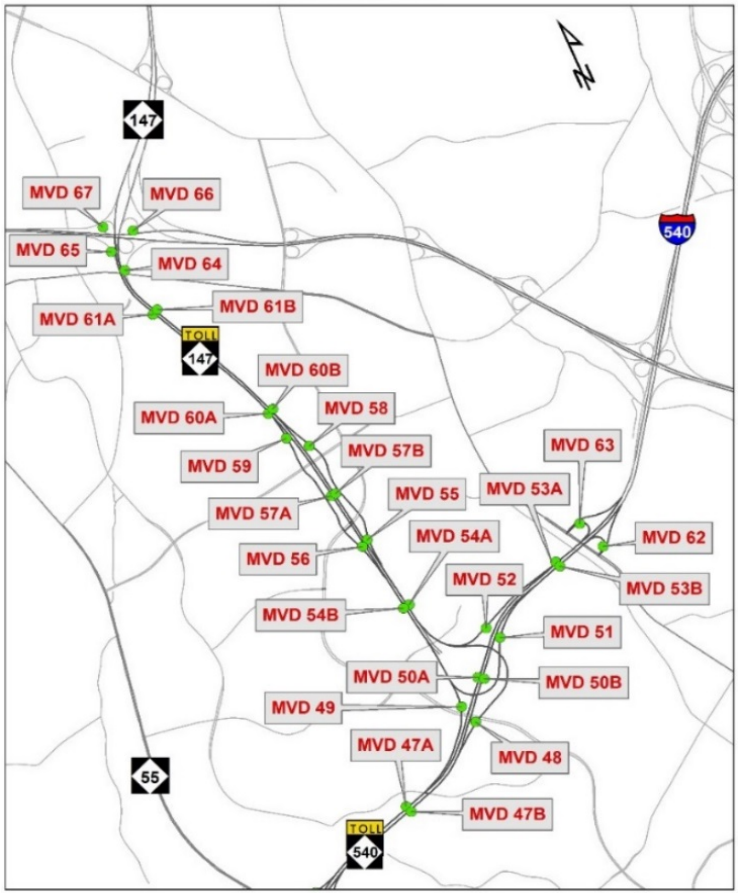

Figure 8 Locations of MVDs on a section of Triangle Expressway

CONTINUED RELATIONSHIP WITH USDOT

NCTA and NCDOT have strong existing working relationships with USDOT's Federal Highway Administration (FHWA) and other Department agencies such as the National Highway Traffic Safety Administration (NHTSA) and Federal Railroad Administration (FRA). Our staff works closely with FHWA's John Sullivan, PE (NC Division Administrator) to ensure that North Carolina's roads and highways continue to be among the safest and most technologically sound in the world. We are willing and eager to maintain and strengthen our many working relationships with the Department to partner with and support its relevant research program offices to support the advancement of automated vehicle technologies. We look forward to the possibility of sharing any outcomes of our AVP with other stakeholders at meetings and conferences, such as the Automated Vehicles Symposium, Florida's Automated Vehicle Summit, and other events facilitated by the Transportation Research Board, ITS America, Institute of Transportation Engineers and others. Our partners have participated in many successful joint research

efforts with USDOT and are excited to partner with the Department on future AV research projects using NCTA's resources. Constant communication is key to any good relationship and our Team would submit quarterly reports to the Department to document our progress on our AVP activities.

4 | COMMITMENT TO SAFETY

NCTA's existing safety management plans, policies and procedures demonstrate our capability to control risks in all proving ground testing and operations. The following sections provide details on those existing plans, policies and procedures.

SAFETY MANAGEMENT PLAN

NCDOT prioritizes planning, designing, constructing, and maintaining transportation facilities that are safe for all users. NCDOT envisions a transportation network with zero fatalities and has collaborated with key stakeholders to develop the 2014 North Carolina Strategic Highway Safety Plan (SHSP) to implement strategies and goals to work towards achieving this vision. The SHSP's goal is to cut fatalities and serious injuries in North Carolina in half based on 2013 figures by the year 2030. This goal will be achieved through emphasizing strategies and actions that address demographic considerations, driving while impaired, emerging issues and data, intersection safety, keeping drivers alert, lane departure, occupant protection/motorcycles, pedestrians and bicyclists, and speed.

NCDOT has established the *Workplace Safety Manual*, *Safety Policy and Procedure Manual*, and *Maintenance/Utility Traffic Control Guidelines* for all workers and road users while considering mobility and access. The Triangle Expressway has the potential to serve as the ideal testing ground for automated vehicles in work zones. Phase 1 of the Complete 540 project will extend the Triangle Expressway by 7.8 miles and is scheduled to be under construction from 2018 through 2020. As described in Section 3, additional Triangle Expressway extension projects and new interchanges on existing highways are proposed. With these planned construction projects and a robust ITS infrastructure already in place, NCDOT's existing manuals and policies can be used in research studies to determine whether existing work zone strategies are compatible with AV technology, what new guidelines should be considered, and how Smart Work Zones can be implemented to safely accommodate automated vehicles for travel information, queue management, speed management, incident management and work zone performance.

NCDOT AND NCTA SAFETY CONSIDERATIONS

NCTA proactively monitors safety conditions on the Triangle Expressway through quarterly crash analyses. NCTA uses Traffic Engineering Accident Analysis System (TEAAS) software to collect monthly crash data along the Triangle Expressway, which is separated into four segments. The data collected includes total crashes and the number of fatal and injury crashes reported along each segment. This data is analyzed over a rolling three-year period to determine the Total Crash Rate of the four segments selected, as well as for the entire facility. These Crash Rates can then be compared to the Critical Crash Rates, which have been statistically adjusted based on other roads with similar characteristics to remove the element of randomness. This is a check to determine if any of the segments on the Triangle Expressway have rates exceeding predetermined average rates for similar locations. The results of this analysis is reported on a quarterly basis in the Triangle Expressway Operations Statistics Report.

NCTA develops quarterly Maintenance Rating Program (MRP) Reports and annual Maintenance of Traffic (MOT) Plans for the Triangle Expressway. The MRP Report evaluates the roadway features and toll facilities on the Triangle Expressway and provides an overall performance rating score based on road surface, unpaved shoulder, drainage, roadside, and traffic control device conditions. The MOT Plan is used as a guidance for allowable one- and two-lane closure time periods for work zone lane closures along the mainline to help reduce the risk of incidents and congestion along the Triangle Expressway.

NCTA's state-of-the-art TMC is staffed by highly trained operators that monitor and manage traffic operations on the Triangle Expressway 24 hours a day, 7 days a week, and 365 days a year. The operators coordinate incident response and maintenance/construction work along the Triangle Expressway and monitor roadside technology and toll facilities. Operators can communicate travel conditions and emergencies to customers via 10 full-color DMS, NCDOT's 511 system and TIMS website. They can also quickly dispatch toll technology technicians to address equipment failures through the Maintenance Online Management Software (MOMS). Additionally, in the event of incidents on the facility they can use interoperable 800MHz radio frequency dispatch from local 911 and statewide Highway Patrol communications to dispatch State Highway Patrol (SHP) and Incident Management Assistance Patrol (IMAP).

Figure 9 NCDOT's Incident Management Assistance Patrol

The NCTA Safety Patrol program consists of dedicated SHP and IMAP services provided on Triangle Expressway. This program provides one SHP officer and one IMAP responder to the facility during working hours, Monday through Friday. During this time, the assigned SHP officer and IMAP driver are responsible for patrolling the facility and responding to incidents reported by operators.

5 | RESEARCH, APPLICATION, AND DATA SHARING

NCTA has the full support and access to resources of the NCDOT's Research and Development Unit, one of the leading DOT research and development centers in the U.S. The Research and Development Unit oversees transportation-related research that investigates materials, operations, planning, traffic and safety, structures, human environments, natural environments and more. The functions of Research & Development are:

- To develop an annual research program that initiates 20-25 new projects per year and manages approximately 80 active research projects. The annual research program goals are:
    - Improve NCDOT Planning, Engineering and Business Practices
    - Support NCDOT Operations and Maintenance Activities
    - Conduct research that can be implemented
    - Develop relationships with researchers so they understand the needs and operations of NCDOT to maximize research benefits;
- Provide implementation and technology transfer support of local and national research for business units;
- Rapid turnaround, 80-hour Technical Assistance Projects;
- Distribute research results locally and nationally;
- Research Library Services with revamped library and historical information dating to the 1920s;
- Engage NCDOT personnel in national research programs: TRB, NCHRP, TPF Program, SHRP, LTPP, etc.
- Provide Research Management Services – Administer contracts for Branches/Divisions/Units working with Universities

ABILITY TO PROMOTE AUTOMATED VEHICLE TECHNOLOGY PARTNERSHIPS

In addition to having the support of the Research and Development Unit, NCTA has partnered with leading universities, research institutes and regional organizations with research experience and resources in automated vehicle technology in the State of North Carolina to collect, analyze and share data across the stakeholders of this pilot program. The following section lists the partnership members supporting NCTA in this effort and their capabilities.

Partnerships

REGIONAL TRANSPORTATION ALLIANCE (RTA)

The RTA is the business coalition that is a recognized regional business voice for transportation initiatives and policy across the Triangle. RTA members include more than 125 of the leading businesses in the State market, 23 chambers of commerce, two metropolitan planning organizations, regional transit agency GoTriangle and the City of Raleigh's transit agency GoRaleigh, as well as the Raleigh-Durham Airport Authority (RDU). RTA has a demonstrated track record of success in accelerating regional mobility priorities, policies, and practices in concert with key elected and transportation partners.

UNIVERSITY OF NORTH CAROLINA (UNC) CHAPEL HILL – HIGHWAY SAFETY RESEARCH CENTER (HSRC)

HSRC's mission is to improve the safety, sustainability and efficiency of all surface transportation modes through a balanced, interdisciplinary program of research, evaluation, and information dissemination. HSRC has worked with a diverse group of government, non-government, corporate and foundation sponsors such as AASHTO, National Institutes of Health, New York DOT, North Carolina DOT, North Carolina Governor's Highway Safety Program, TRB (NCHRP), U.S. DOT (FHWA, NHTSA, RITA), U.S. EPA, AAA Foundation for Traffic Safety, National Safety Council, etc.

INSTITUTE OF TRANSPORTATION RESEARCH AND EDUCATION (ITRE)

ITRE is an institutional center located at NC State University and chartered by the North Carolina General Assembly. Transportation research is the core of ITRE's mission. It conducts surface and air transportation research, training, technical support activities for municipal, state, federal, and international clients in order to address critical transportation issues. To support NCTA's AVP, ITRE can leverage its existing partnerships with Federal Highway Administration (FHWA), I-95 Corridor Coalition, Capital Area Metropolitan Planning Organization (CAMPO), RTI International, IBM, and SAS as well.

DUKE UNIVERSITY'S HUMANS AND AUTONOMY LAB (HAL)

Research in Duke University's HAL focuses on the multifaceted interactions of human and computer decision-making in complex sociotechnical systems with embedded autonomy. Current research projects include workload reduction for operators of autonomous systems, identification and assessment of the impact of transition from low to high task loading, development of a safety simulation for mixed manned and unmanned robotic environments, developing predictive models for operator trust of autonomous systems, and the use of Functional Near-Infrared Spectroscopy (fNIRS) for cognitive state detection and prediction.

UNIVERSITY OF NORTH CAROLINA (UNC) CHARLOTTE – CENTER FOR TRANSPORTATION POLICY STUDIES

UNC Charlotte's Center for Transportation Policy Studies is dedicated to the study of transportation-related issues and policies. The center's objectives are to:

1. Address issues that are relevant and timely so that the center's research can influence transportation policy;
2. Conduct quality multidisciplinary research that is both scholarly and practical;
3. Conduct research that affects future transportation investments and development patterns and promotes positive social change in the region and state;
4. Disseminate completed research to professionals, practitioners, and policy-makers;
5. Facilitate collaboration among researchers in various disciplines;
6. Form partnerships among the university, local and state governments and private-sector transportation stakeholders.

NORTH CAROLINA AGRICULTURE & TECHNICAL STATE UNIVERSITY (NC A&T)

NCTA has requested the support of NC A&T State University. The University offers fundamental and advanced research opportunities in the area of Civil Infrastructure with focus in transportation engineering.

DEMONSTRATED RESEARCH AND RESOURCES

NCTA's partners have carried out many activities and programs related to automated vehicle advancements. For example, ITRE is involved in the following relevant programs:

EcoPRT Project – A research project demonstrating small two-seat autonomous vehicle technology on the North Carolina State University campus.

Highway Research – ITRE has a long history of freeway research and understands macroscopic and microscopic operations of human driven vehicles for comparison to operations of autonomous vehicles.

Data Collection – ITRE has experience deploying data collection devices for large projects as well as working with big data creation and analysis through the i2D instrumented vehicle program where over 20 million seconds (and growing) of data are used for understanding driver behavior.

Duke University's HAL is involved in the following relevant projects:

Detecting Long Distance Driver Cognitive Disengagement – In this project, HAL is testing the hypothesis that functional Near Infrared Spectroscopy (fNIRS), which essentially measures blood oxygenation in the brain, can detect different cognitive states in long distance driving settings. Objectives include attempting to detect distraction from focused attention on the road, discerning possible boredom from a state of drowsiness, and overall mental workload.

Risk-aware, Human-cooperative Planning for Autonomous Systems – HAL's vision is to revise the relationship between human and robot to a cooperative partnership, where both parties share the responsibility of managing risks. HAL is collaborating with the Jet Propulsion Laboratory on this project, under the direction of the Office of Naval Research.

UNC's HSRC's two most important areas of research are "Driver Behavior" and "Shaping the Future of Transportation Safety". HSRC researchers study how behavior and safety interact in the real world. It has been involved in both the development of analysis-ready databases that include naturalistic driving data, and research using these datasets to better understand behaviors of drivers and passengers. For example, HSRC's researchers were at the forefront of using in-vehicle camera technology to directly observe driver behavior, most recently distraction among young drivers. In addition, HSRC has used naturalistic driving data to study roadway curvature and alignment to understand how to best design roadways.

In addition to the above-mentioned research projects, all of our university partners are part of the University of Transportation Centers (UTC) program.

- UNC Chapel Hill and Duke University are part of the National UTC for Collaborative Sciences Center for Road Safety.
- North Carolina State University and UNC Chapel Hill are part of the Regional UTC for Southeastern Transportation Research, Innovation, Development and Education Center.
- North Carolina A&T State University is part of the Tier 1 UTC for Center for Advanced Transportation Mobility.
- UNC Charlotte is part of the Tier 1 UTC for Mineta National Transportation Research Consortium.
- UNC Charlotte is also part of the Tier 1 UTC for Center for Advanced Multimodal Mobility Solutions and Education.

DISSEMINATION OF INFORMATION AND SHARING

NCTA and its partners are committed to providing open data and sharing performance metrics and test results. Specifics for some of the partners include:

- NCDOT's R&D Group routinely shares information with TRB, AASHTO, NCHRP, TPF Program, SHRP, LTPP, and various universities.
- RTA has the ability to inform many stakeholders in North Carolina who can then further disseminate information.
- ITRE can disseminate information through its existing partnerships with FHWA, I-95 Corridor Coalition, Capital Area Metropolitan Planning Organization (CAMPO), RTI International, IBM, and SAS.
- UNC's HSRC can disseminate information through its existing partnerships with its diverse group of

government, non-government, corporate and foundation sponsors as noted above.
- UNC Charlotte's Center for Transportation Policy Studies is dedicated to disseminating research to professionals, practitioners, and policy-makers; facilitating collaboration among researchers in various disciplines, and forming partnerships among the university, local and state governments and private-sector transportation stakeholders.

6 | DEMONSTRATED INVESTMENTS

CAPITAL IMPROVEMENTS

NCTA has the capability to augment existing infrastructure along the Triangle Expressway to support AV activities due to its adherence to sound fiscal management and overall vision to continuously seek ways to improve the facility to its users. From the 2015 NCTA Annual Report, "Capital expenditures for the Triangle Expressway were approximately five percent under budget. During the latter part of Fiscal Year 2014, the Turnpike Authority developed a fiscally-responsible plan to utilize approximately $61.3 million in unallocated bond proceeds. In addition to funding outstanding construction expenditures, reimbursing NCDOT for pre-construction expenses, and reimbursing interest payments to the Turnpike Authority's reserve accounts, this plan includes providing capital contributions for two additional interchanges along the Triangle Expressway, at Old Holly Springs-Apex Road ("Access 540") and Morrisville Parkway."

In addition to the availability of funds for AV in existing capital improvement programs, NCTA performs a quarterly maintenance rating program, which insures that the facility exceeds its own internal criteria for adequate infrastructure elements, including traffic control devices, roadway lighting, pavement markings, signage, and delineators – all of which are vital to AV operability. A quarterly assessment of pavement condition is also undertaken, vital to providing a safe test track for AV. No other roadway facility in North Carolina currently has such a robust asset management program.

AUTHORIZATION OF PROVING GROUNDS

The NCTA has enabling legislation for planning, development, construction and operation of toll facilities within the state of North Carolina. The legislation enables NCTA to plan, program and carry out projects along the Triangle Expressway that could include capital or safety improvements to the facility to allow a structured program for AV testing.

The North Carolina General Assembly (NCGA) introduced two bills to study AV in 2015. These bills and legislative support led to the creation of the North Carolina Connected and Autonomous Vehicles (CAV) Roadmap program, which is completing a formal year-long study of policy needs, institutional changes, and broad program vision for both addressing AV and developing the technologies in North Carolina.

AUTOMATED VEHICLE TESTING OR DEPLOYMENT

NCTA is committed to dedicating the necessary resources for testing and deployment to determine automated vehicle technology feasibility by January 1, 2018. As demonstrated by NCDOT and NCTA's programs of capital investments, active legislation/policy, established standards and operational procedures, commitment to safety and maintenance, the Triangle Expressway will be able to test and deploy AV technology with the following notable items:

- Ability to quickly establish and procure dedicated short-range communications (DSRC) and other V2I technology, as needed, for connected vehicles (CV) operations along a controlled freeway facility with well-maintained infrastructure that is necessary for L3-L5 levels of AV (high quality lane markings, signage, consistent geometric design of the facility)
- Active, or soon to be active, construction projects at key interchanges along the facility that will enable AV testing in work zone environments
- Variable roadway volume environments – spatial and temporal occurrences of higher volume commuter traffic contrasted with lower volume off-peak conditions

In addition, ITRE at NCSU, one of the key partners to NCTA, is currently part of a research team, EcoPRT, demonstrating a small two-seat autonomous vehicle technology at NCSU and involved in freeway research understanding macroscopic and microscopic operations of human driven vehicles for comparison to operations of autonomous vehicles.

7 | READINESS

ABILITY TO TEST

The Triangle Expressway is currently fully operational and open for testing. NCTA's robust ITS infrastructure along Triangle Expressway, state-of-the-art TMC, the Smart Work Zone program and the commitment to dedicate the necessary resources to determine the feasibility of automated vehicle technology makes the Triangle Expressway an ideal proving ground.

MULTIPLE USER TESTING

Testing on the Triangle Expressway will support multiple users and data generated by the proving ground will be shared openly to the public. The Triangle Expressway allows for all types of vehicular traffic. NCTA, NCDOT, RTA, and the partnering universities and research institutions have a long-standing history of openly sharing data to the public.

DESIGNATED POINT OF CONTACT

As described in Section 2, Dennis Jernigan, PE will be the Designated Safety Officer and Designated Point of Contact.

ENGAGEMENT WITH AFFECTED COMMUNITIES

NCTA is currently not aware of any communities that may be affected with Triangle Expressway serving as a designated automated vehicle proving ground. If necessary, NCTA can involve NCDOT's Public Involvement group to engage the affected communities and develop a public engagement plan to promote public involvement.

8 | ADHERENCE TO LAWS, REGULATIONS, AND FEDERAL POLICY

LOCAL, STATE, AND FEDERAL

Though no enabling legislation currently exists in the state of North Carolina with regards to automated vehicles, no current legislation or administrative rules prohibit AV activities. In response to the need to address this issue, the North Carolina General Assembly has been working with NCDOT to initiate studies into AV policy. Two NCGA bills were introduced in 2015 (S.B. 600 and H.B. 782) that fostered the development of the North Carolina (CAV) Roadmap program. This program, under the sponsorship and direction of NCDOT and the North Carolina Division of Motor Vehicles (NCDMV), is currently undertaking a study to understand what actions, activities, and processes are required to prepare North Carolina for automated vehicles.

The study will address the following:

- The measures necessary to successfully implement AV technology, including any legislative changes.
- How AV technology can promote research and development in North Carolina.
- Any other matters NCDOT and partner agencies deem relevant.

Immediate CAV program goals include:

- Assessing the Department's and the State's current AV conditions (testing and operations) and provide recommendations for changes.
- Benchmark against industry and current federal, state, local, and international initiatives.
- Provide near-term actions for NCDOT and key State agencies.

Broad program initiatives moving forward include:

- Spurring Early CV Tech Deployment for wirelessly connected vehicles, mobile devices and infrastructure
- Measuring Deployment Benefits in terms of safety, mobility and environmental impacts
- Resolving Deployment Issues related to technical, institutional, and financial barriers.

The CAV Roadmap program held a workshop on February 23, 2016 with 24 state, regional and municipal agencies, chambers of commerce and private businesses and program activities are currently underway. A final report, *NC Readiness for Connected and Autonomous Vehicles*, was submitted in November 2016.

Figure 10 North Carolina CAV Roadmap Project Schedule

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA) L3-L5 AUTOMATED VEHICLES

NCTA and supporting partners will adhere to the primary subject areas outlines in the NHTSA's *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety* for any testing or deployment of L3-L5 systems on public roads for this pilot program.

9 | SUMMARY

NCTA has demonstrated the ability to be fully compliant with the combination of a world-class facility, partnerships, and research to advance automated vehicle technology.

Compliance Items	Compliant	Section	Page
Mandatory Criteria	✓	2	3
Designated Safety Officer (Dennis Jernigan, PE)	✓		3
Commitment to Sharing	✓		4
Proposed Contributions	✓	3	4
Eligibility and Administration of Automated Vehicle Program	✓		4
AV Leadership	✓		4
Community of Practice	✓		4
Continued Relationship with USDOT	✓		6
Commitment to Safety	✓	4	7
Safety Management Plan	✓		7
NCDOT and NCTA Safety Considerations	✓		7
Research, Application and Data Sharing	✓	5	8
Ability to Promote Automated Vehicle Technology Partnerships	✓		8
Demonstrated Research and Resources	✓		10
Dissemination of Information and Sharing	✓		10
Demonstrated Investments	✓	6	11
Capital Improvements	✓		11
Authorization of Proving Grounds	✓		11
Automated Vehicle Testing or Deployment	✓		11
Readiness	✓	7	12
Ability to Test	✓		12
Multiple User Testing	✓		12
Designated Point of Contact	✓		12
Engagement with Affected Communities	✓		12
Adherence to Laws, Regulations, and Federal Policy	✓	8	12
Local, State and Federal	✓		12
NHTSA L3-L5 Automated Vehicles	✓		13

Table 1 NCTA's Compliance Matrix for USDOT's Automated Vehicles Proving Ground Pilot

CONCLUSION

NCTA, together with NCDOT and our partners, thank you for consideration as a Community of Practice to research, develop and share best practices related to the safe testing, demonstration, and deployment of automated vehicle technology. NCTA's Designated Safety Officer, **Dennis Jernigan, PE**, is committed to this role of ensuring the safety of the traveling public, the safety of North Carolina's roadway facilities, the safe implementation and testing of automated vehicle technology and participation in the Community of Practice. NCTA, with its world-class facility, world-class partnerships, and world-class research, eagerly awaits our selection to proudly serve as a designated automated vehicle proving ground.