TTI’s Connected and Automated Vision for the Future

The Texas A&M Transportation Institute (TTI) shares an industry vision where no vehicles collide and people can use connected and automated transportation to transform how they live, work and interact with their environment. To achieve this vision, research, development and testing are needed on how vehicles, users and transportation infrastructure all work together.

While automated vehicles are emerging and connected vehicle (CV) research is progressing, TTI believes the most significant gains in safety and mobility will occur at the nexus of these areas. TTI has created a world-class research environment on the Texas A&M University campus where researchers can collaborate, new transportation paradigms can be created, and future mobility and safety can be tested and evaluated.
In spring 2019, TTI is scheduled to move to the newly developed Texas A&M University System RELLIS Campus, a high-tech, multi-institutional research, testing and workforce development campus in close proximity to Texas A&M University. TTI already has several facilities located at the 2,000-acre campus, including a full-service safety proving grounds facility; an environmental and emissions facility; and a sediment and erosion control laboratory. In addition, the new Center for Infrastructure Renewal, a collaboration among TTI, the Texas A&M Engineering Experiment Station and the private sector, is next door to TTI's new State Headquarters Building. This research, testing and training facility reduces the cost and extends the life of infrastructure with new, better materials and construction methods.

Smart Intersection
The Smart Intersection further advances research in traffic signal control, detection technology, and CV infrastructure. It was developed with contributions from Econolite, the Texas Department of Transportation (TxDOT), and TTI. The first research use of this intersection is supporting a TxDOT project to alert pedestrians of turning buses at signalized intersections to improve safety using CV technology.

Facilities

- TTI Proving Grounds and Crash Testing Facility
- Visibility Research Laboratory
- Bridge Performance Test Bed
- Pavements and Materials Laboratory
- Driving Simulator
- Sediment and Erosion Control Laboratory
- Environmental and Emissions Research Facility
- Eye-Tracking Equipment
- High-Bay Structural Testing Facility
- Computer Modeling and Scanning Facility
- CAV Test Beds
CAV Test Beds

RELLIS Campus CAV Test Bed
TTI has developed a connected and automated vehicle (CAV) test bed at the Texas A&M University System REllis Campus in Bryan, Texas. The test bed is used to develop and test CAV applications and human-machine interfaces using vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle communication in a controlled environment. The test bed will leverage other automated vehicle expertise across the University in ground, aerial and subterranean applications.

Sponsors: Texas Department of Transportation and U.S. Department of Transportation

Connected Work Zone
TTI is deploying CV technology along the I-35 corridor to improve safety and mobility through work zones by providing in-vehicle devices to freight companies to receive work zone infrastructure data on lane closure location, capacity reduction, queue lengths and delay to assist in pre-trip and en-route planning for logistics.

Transit, Bicycle and Pedestrian Safety
TTI developed a concept of operations plan for designing, testing, piloting, demonstrating and deploying CAV technology hardware and applications to reduce and eliminate crashes involving transit, bicyclists and pedestrians. A pilot test was also conducted of the Mobileye Shield + collision avoidance system on a Texas A&M University bus in Phase I of the project. In Phase II, TTI is designing, developing and piloting a Smart Intersection/Smart Bus application with buses automatically communicating with smart traffic signals to provide visual and audio warnings to bicyclists and pedestrians. A smartphone app is also being designed, developed and piloted for bicyclists and pedestrians at the Smart Intersection.

Sponsors: Texas Department of Transportation

Physical Infrastructure

Evaluate Potential Impacts, Benefits, Impediments, and Solutions of Automated Trucks and Truck Platooning on Texas Highway Infrastructure
This project will help ensure the successful introduction of automated trucks and truck platooning on Texas highway infrastructure. The assessment includes identification of needed changes in road and bridge design and construction; impacts on statewide freight plans and networks; impacts on local and regional transportation planning; and related infrastructure costs and benefits.

Sponsor: Texas Department of Transportation

Establishing Highway Infrastructure Criteria for Machine Vision
As vehicle technology continues to expand into new areas, a need is developing to synchronize vehicle technology capabilities with traditional physical highway infrastructure. One of the most heavily used elements of the physical infrastructure space on a highway is pavement markings. Many new vehicles use cameras and machine vision algorithms to detect and read pavement markings to provide features such as lane departure warning and lane-keeping assistance. TTI is leading a research project designed to develop pavement marking criteria that will provide reliable detection with in-vehicle camera systems. The results will be used by agencies interested in specifying and maintaining their highways to a level that will provide reliable machine vision detection.

Sponsor: National Cooperative Highway Research Program

Vehicle Automation

Texas Connected Freight Corridors
The vision of this project is to use I 35, I-10, I-30, and I-45 to showcase CV applications applicable to TxDOT and its freight partners. These vehicle-to-vehicle (V2V) and V2I applications will communicate valuable traffic, safety, parking and routing information to truck drivers, with the goal of saving fuel and reducing costs, while improving safety and reliability.

Sponsor: U.S. Department of Transportation

Commercial Truck Platooning
TTI created a first-of-its-kind comprehensive freight platooning demonstration in Texas to build upon past and current platooning development projects and demonstrate the safety and fuel savings benefits that can be achieved by applying vehicle automation to freight truck platoons.

Sponsor: Texas Department of Transportation
Evaluation of CV Applications
TTI researchers have developed a platform to help the Federal Highway Administration (FHWA) evaluate CV applications and technologies in a realistic manner using advanced hardware-in-the-loop simulation techniques. The simulation model, VISSIM, was integrated with CV hardware and with ns-3, a communication simulation model.

Signal Phase and Timing
TTI researchers led the development of an interface between traffic signal controllers and roadside equipment to enable communication of real-time traffic signal status and timing to CVs. Researchers then designed and developed an open-source platform (Integrated Vehicle to Infrastructure Platform) to facilitate development and deployment of infrastructure-based CV applications. This platform is being improved to generate and broadcast conflict-free I2V required messages to improve intersection safety and mobility.

Wrong-Way Driving Detection and Mitigation Research
TTI researchers led the development of CV applications that detect and warn wrong-way vehicles, notify traffic management agencies and law enforcement, and alert affected travelers. The first step was to identify user needs and develop a concept of operations, functional requirements, and high-level system design. TTI researchers then built and successfully demonstrated a proof-of-concept CV wrong-way driving system at the RELLIS Campus to test and fine-tune the system components and operations prior to installing them on an actual roadway. Researchers also conducted human factors studies to investigate: 1) the in-vehicle information needs of right-way drivers when a wrong-way driving event occurs; and 2) the design of wrong-way driver alerts displayed on dynamic message signs and through in-vehicle systems. TTI is currently exploring opportunities to deploy the CV wrong-way driving system on a real roadway to further refine and evaluate the system.

Sponsor: Texas Department of Transportation

Collaboration with Texas A&M College of Engineering
Texas A&M Engineering has developed a fleet of vehicles including light-duty vehicles (e.g., sedan, SUV, pick-up truck), buses, trolleys, and heavy duty trucks to test different levels of automation and the interaction with infrastructure.

Bryan, Texas, is now among the first cities in the country to have self-driving vehicles, or trolleys, operating on their city streets. Two are operating in a looped, one-block pattern in the downtown area. Two safety drivers are onboard the 6-person vehicle, which can reach a maximum 10 mile-per-hour speed. The project is a collaboration between TTI and Texas A&M’s Department of Mechanical Engineering. TTI is assisting in evaluating rider response to the automated shuttle.

CV Pilot Deployment and Program Evaluation
TTI was selected by FHWA to lead the national evaluation of the CV Pilot Deployments. Teaming with partners—such as Kittleson & Associates, Inc., Gannett Fleming, Cadmus and JMC Rota—TTI is leading the national evaluation of the three CV pilot sites (in Tampa, New York City and Wyoming). This evaluation could also be extended to include evaluations of the Smart City and AMTC grants.
**CAV Policy**

**Policy Research**
The emergence of CAV technology presents significant implications for policy makers. TTI is working to better understand those implications and inform the decision making that will influence how automated travel can come about in a way that best serves the public interest. The Revolutionizing Our Roadways series outlines the TTI’s policy work in the following specific areas.

**Completed Research Reports**

*Revolutionizing Our Roadways series:*
- Legal Status of Low Speed, Electric Automated Vehicles in Texas
- Connected Vehicle Infrastructure Development and Funding Review
- What is the Legal Framework for Automated Vehicles in Texas?
- Policy Implications of Transportation Network Companies
- Mobility Effects of Connected and Automated Vehicles
- Implications of Automated Vehicle Crash Scenarios
- Consumer Acceptance and Travel Behavior Impacts of Automated Vehicles
- Cybersecurity Considerations for Connected and Automated Vehicle Policy
- Liability Considerations for Automated and Connected Vehicles
- Data Privacy Considerations for Automated and Connected Vehicles
- Vehicle Telematics as a Platform for Road User Fees

**Who’s on First: Early Adopters of Self-Driving Vehicles**
This study examined consumer attitudes of automated travel through the predicted use of ride-hailing services and self-driving cars as they become more available. The findings suggest that ride-hailing customers will help to shape self-driving car use patterns.

*Sponsor: Lyft*

**CAV Planning**

**Transportation Planning Implications of Automated Vehicles on Texas Highways**
TTI is assessing how to effectively incorporate transformative CAV technologies in transportation planning to assist in the decision-making process.

*Sponsor: Texas Department of Transportation*

**Policy and Planning Actions to Internalize Societal Impacts of CAV Systems into Market Decisions**
Researchers generated information for state and local governments about policy/planning actions that can be taken to stimulate the development of markets for CAV systems for all modes, providing the ability to internalize societal costs and benefits in industry market decisions (NCHRP Report 845).

*Sponsor: National Cooperative Highway Research Program*

**Preparing for the Connected Airport and the Internet of Things**
Researchers at TTI developed an evidence-based primer for airport operators and stakeholders on the Internet of Things within the airport environment (ACRP Report 191).

*Sponsor: Airport Cooperative Research Program*

**Providing Support to the Introduction of CAV Impacts into Regional Transportation Planning and Modeling Tools**
TTI developed guidelines for the implementation of travel forecasting methods and planning tools under uncertainty that address travel behavior and system performance changes resulting from CAV technology (NCHRP Report 896).

*Sponsor: National Cooperative Highway Research Program*

**American Automobile Association Foundation for Traffic Safety (AAAFTS)**
An objective of this research was to expand AAAFTS efforts to measure and benchmark Traffic Safety Culture to include awareness of and perceptions of the safety impacts of progressive levels of automated technology (SAE Levels 2-5). The research indicated that knowledge of different levels of automated technology was generally lacking and that experience with vehicle technology was significantly related to perceptions of its safety.

*Sponsor: Lyft*

This research for the ride-hailing company, Lyft, tested and confirmed two hypotheses. First, current ride-hailing users are more likely to use self-driving vehicles than non-users. Intent to use was highest among long-term users of ride-hailing services. They were more likely to use self-driving vehicle technology than non-users by a margin of almost 2 to 1. Secondly, among ride-hailing users, acceptance and likely usage increases with ride-hailing experience. The longer people have used ride-hailing services, the more likely they will use self-driving vehicles.
Driving Simulator
The TTI driving simulator provides a safe and controlled environment to quickly explore driver responses to new vehicle-based technologies. The simulator can provide to drivers Levels 2, 3, and 4 automation, in addition to CV information and warnings.

Instrumented Vehicles
TTI owns and operates two instrumented vehicles that can be used within human factors studies on the RELLIS Campus proving grounds or in naturalistic driving studies.

Monitoring, Assessing and Acting on Driver and Vehicle States to Enhance Safety
TTI developed and evaluated a vehicle-based countermeasure that detects unsafe vehicle operational parameters and driver stress states and directly assists the driver and vehicle to improve overall safety.

Sponsor: Toyota Economic Loss Settlement

Driver Training for Automated Vehicles
TTI is determining which types of commonly available training methods, such as traditional driver training or training provided by a vehicle, can be used to increase driver performance and safety and to decrease confusion and frustration.

Sponsor: Safety through Disruption (Safe-D) University Transportation Center

The deployment of CAV technologies offers the potential to address the single largest factor contributing to motor vehicle crashes. Although this technology can help drivers drive more safely, there remain significant concerns regarding the degree to which drivers can successfully use this technology. Driver confusion and errors can negate some of the positive benefits of this technology. TTI’s Human Factors Program researchers specialize in studying how the relationship between drivers and technology can be optimized to maximize safety. Safety-critical topics in their investigations include:

- methods to train drivers on the use of CAVs,
- adapting automation to driver’s individual needs, and
- human-machine interface design.
Texas AV Proving Ground Partnership
Cities and regions across Texas are partnering with TTI, The University of Texas at Austin’s (UT) Center for Transportation Research (CTR), and the Southwest Research Institute (SwRI) in San Antonio in the Texas Automated Vehicle Proving Ground Partnership. The statewide partnership is putting Texas on the path to becoming the nation’s first “Smart State,” which aims to create a platform for innovation to address community challenges.

Members of the Texas Partnership are contributing their facilities, expertise and talents as part of a larger Texas network of proving grounds and test-bed sites. Proving grounds offer controlled environments on research campuses, where the complete life-cycle development of AVs can be assessed. These sites include The Texas A&M University System’s RELLIS Campus, which includes Texas A&M’s Proving Grounds, the UT campus, and the SwRI campus. Urban and freight test beds in the following cities offer real-world environments where a variety of scenarios may be explored:

- **Austin Area** — Austin-Bergstrom International Airport and Riverside Drive corridor.
- **Houston Area** — Texas Medical Center, Houston METRO HOV lanes and Port of Houston.
- **Dallas/Fort Worth/Arlington Area** — UTA campus, Arlington streets, I-30 corridor and managed lanes.
- **San Antonio Area** — Fredericksburg Road/Medical Drive corridor and bus rapid transit system.
- **El Paso Area** — Tornillo/Guadalupe Port of Entry.

Texas Innovation Alliance
The Texas Innovation Alliance is a shared commitment among local, regional and state agencies and research institutions to work together to improve mobility for Texas communities and businesses. Teams from across the state—Arlington, Austin, Bryan-College Station, Corpus Christi, Dallas-Fort Worth, El Paso, Houston, San Antonio, as well as a team comprised of researchers from UTA’s CTR, TTI, and SwRI—have joined forces to advance emerging technologies to tackle technical, policy, and socio-economic challenges. In creating a platform for innovation, partners of the Alliance form an action network capable of leveraging resources, co-creating solutions, and sharing real-time results for improving transportation service delivery.

Safe-D University Transportation Center
New technology and business operations are disrupting transportation in fundamental ways. The Safe-D University Transportation Center (UTC) seeks to maximize the potential safety benefits of disruptive technologies through targeted research that addresses the most pressing transportation safety questions. The center, a partnership between Virginia Tech Transportation Institute, San Diego State University and TTI, is focusing its efforts in three key areas: (1) cutting-edge research by leading transportation safety experts and their students; (2) education and workforce development with programs for all levels from grade school through college to continuing education for professionals; and (3) fully supported technology transfer, including practitioner training partnerships, social networking, commercialization and intellectual property management.

The center has identified an initial set of four disruptive technologies on which to focus its activities: connected vehicles, automated vehicles, transportation as a service, and big data analytics. These disruptors are emerging from industries and scientific domains not traditionally associated with transportation; the center’s interdisciplinary team can bridge the gap between traditional research and these disruptive forces. The center is supported through a federal grant with matching funds from the state of Texas. One of the first projects is to establish a CAV test bed on a public road in the College Station, Texas, area.
Through a request for information (RFI) process, Texas A&M University is seeking transportation technology demonstrations and research opportunities across the entire campus. The value proposition includes high levels of publicity and visibility; access to real-word test beds in a controlled environment; access to world-class faculty, research staff and students; and the opportunity to develop future sales channels and new marketplace entries.

Texas A&M’s Campus Transportation Technology Initiative explores new technologies to advance campus transportation operation and future planning priorities. By partnering with companies to bring technologies and innovation to the forefront of the campus transportation ecosystem, the University desires to provide transportation solutions to enhance the quality of life for everyone on campus. The goals of this initiative are: greater mobility, improved safety, enhanced connectivity and more efficient services.

The RFI will remain open through July 31, 2019. For more information, visit this website: smartcampus.tti.tamu.edu.

**TTI Expertise**

TTI employs more than 700 professionals, students and support staff from over 50 different countries. TTI staff are known for their credibility, technical expertise and reputation for objectivity. Many are recognized national and international leaders in their fields. TTI researchers contribute to the growth of the transportation profession by participating in and leading hundreds of local, state and national organizations. For example, since the inception of the TRB Cooperative Research Program, TTI has been a leading participant in the National Cooperative Highway Research Program. The Institute also has led and participated in cooperative research programs in transit, aviation, freight and hazardous materials.

With expertise in areas such as engineering, planning, economics, policy, public engagement, landscape architecture, environmental sciences, computer science and the social sciences, TTI researchers serve as objective transportation experts. They provide a resource to local, state and national agencies and groups, helping them solve transportation challenges and make informed decisions.

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