TTI’s Capabilities in Connected and Automated Transportation

TTI’s Connected and Automated Vision for the Future
The Texas A&M Transportation Institute (TTI) shares an industry vision in which 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 underway on how vehicles, users and transportation infrastructure all work together.

While automated vehicles (AVs) 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 System RELLIS Campus where researchers can collaborate, new transportation...
TTI is located at 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 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.

Facilities

**RELLIS Campus**

**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 supported a TxDOT project to alert pedestrians of turning buses at signalized intersections to improve safety using CV technology. Other applications are under development.

**Facilities**

- TTI Proving Grounds and Crash Testing Facility
- Visibility Research Laboratory
- Bridge Performance Test Bed
- Pavements and Materials Laboratory
- Driving Simulation Laboratory
- 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 (I2V) communication in a controlled environment. The test bed will leverage other automated vehicle expertise across the University in ground, aerial and subterranean applications.

**Transit, Bicycle and Pedestrian Safety**
TTI developed a concept of operations plan for designing, testing, demonstrating and deploying CAV technology 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. TTI designed, developed and tested 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 beta smartphone app was developed and tested for bicyclists and pedestrians at the Smart Intersection. The system is being installed at an intersection near the Texas A&M Campus.

**Sponsors:** Texas Department of Transportation and U.S. 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 at a level that will provide reliable machine vision detection.

**Sponsor:** National Cooperative Highway Research Program

**Traffic Safety Improvements at Low-Water Crossings**
TTI researchers are investigating low-cost approaches to improving traffic safety at low-water crossings, with a focus on easy-to-install and maintain devices, such as reflective pavement markings; flood-detection sensors; flood warning devices; and infrastructure-to-infrastructure (I2I) and I2V technologies. Full-scale testing of these methodologies is under way and being demonstrated.

**Sponsor:** Texas Department of Transportation

### Freight

**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

**Advanced Freight Transportation Systems Management and Operations**
TTI researchers are working on advanced freight systems and technology, including improved intelligent transportation system (ITS) and CAV solutions, as part of a new transportation systems management operations initiative and approach to highway management. This project will establish a concept of operations that the department will use to implement specific freight solutions for safety and mobility to prepare for increased freight demand.

**Sponsor:** Maryland Department of Transportation State Highway Administration
**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.

**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).

**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

**Vehicle Automation**

**First Autonomous Shuttle Deployed at Texas A&M**
TTI led a technology demonstration of the Navya Autonom Shuttle on the Texas A&M University Campus in fall 2019. This autonomous, self-driving, 11-passenger electric vehicle was developed for use in public transportation service. The 90-day demonstration ran in a one-mile loop around campus and was programmed to recognize obstacles in its path. Researchers explored the technology’s potential and gauged public acceptance to improve campus mobility while maintaining (and possibly improving) safety. TTI’s partner in the project was Texas A&M Transportation Services.

**CAV Planning**

**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

**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

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

*Sponsor:* Texas Department of Transportation

**Quantifying Impacts of Automated Vehicle Technologies to Public Safety, Health and Equity**
This project seeks to estimate the anticipated impacts of AVs on safety, health, travel behavior and equity outcomes. Study results will be used to inform and assist policy makers and transportation agencies in developing countermeasures to prevent potential negative impacts.

*Sponsor:* Robert Wood Johnson Foundation
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 TTI’s policy work in several 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

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

Consumer Acceptance and Future Use of Self-Driving Vehicles
Frisco, Texas, became the first city to test a self-driving shuttle on the state’s public roads. Launched by Drive.ai, the service provided free rides to employees and residents of a large office campus. Travelers could request a ride using a Drive.ai app, and the shuttles drove them short distances. At the conclusion of the pilot test, TTI conducted a survey and focus group, including both Drive.ai riders and non-riders, to monitor consumer acceptance, trust and likely future use of self-driving vehicles.
Sponsor: Frisco Transportation Management Association

Impacts of Transformational Technologies on Underserved Populations
This study is examining the nexus of three intersecting concepts—mobility needs, transformational technology, and equity—to understand how technology-enabled mobility services impact a community’s ability to meet mobility needs for residents, particularly the underserved. Researchers are identifying barriers to mobility inclusion within underserved populations in specific rural and urban communities and recommending how these barriers can be ameliorated.
Sponsor: Transit Cooperative 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: Transit Cooperative Research Program
Driving Simulation Laboratory
The TTI Driving Simulation Laboratory provides a safe and controlled environment to quickly explore driver responses to new vehicle-based technologies. The simulator can provide Levels 2, 3, 4 and 5 automation to drivers, 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.

Human Factors Projects
The deployment of CAV technologies offers the potential to address the single largest factor contributing to motor vehicle crashes: human error. Although this technology can help drivers drive more safely, significant concerns regarding the degree to which drivers can successfully use this technology remain. 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 a driver’s individual needs, and
• human-machine interface design.

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
Texas AV Proving Ground Partnership

Cities and regions across Texas are partnering with TTI, The University of Texas (UT) at Austin’s 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 in which 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**—UT at Arlington 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, and San Antonio, as well as a team comprised of researchers from UT’s CTR, TTI and SwRI—have joined forces to advance emerging technologies to tackle technical, policy, and socioeconomic 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 on 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-world 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 operations 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.

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.