VTTI DATA

Virginia Tech
Transportation Institute

VTTI*Data*

It has been more than a decade since the Virginia Tech Transportation Institute (VTTI) undertook a research project that would alter the face of transportation research: the 100-Car Naturalistic Driving Study.

The first large-scale naturalistic driving study ever undertaken and sponsored by the National Highway Traffic Safety Administration, the Virginia Department of Transportation, and Virginia Tech, the 100-Car project used a unique data collection system developed by VTTI. This system was designed to capture unobtrusively the real-world driving behaviors of 109 primary drivers and 132 secondary drivers traveling in Northern Virginia and Washington, D.C., as they made their normal, daily commutes.

VTTI collected 42,000 hours of data from close to two million vehicle miles of driving.

The results were immeasurable in providing the first accurate portrait of what causes risky driving behavior and paved the way for future naturalistic examinations of driver distraction, fatigue, error, and impairment. In fact, the impacts of the 100-Car Study are still tangible nearly 11 years after data collection began: currently, 14 analysis projects are actively using the data, and technical reports covering initial 100-Car analyses have been cited more than 1,200 times.

Since the groundbreaking 100-Car Study, VTTI has taken the lead on many naturalistic driving studies, gathering critical information that is continually mined to answer additional research questions. Now, more than 2.5 petabytes of data are stored on site, comprising a range of objectives, vehicle types (passenger cars, heavy trucks, motorcycles, and motorcoaches), drivers (teen, adult, commercial vehicle/transit, and older), and locales (currently, the U.S., Canada, Australia, and China).

Housing close to 90 percent of naturalistic data in the world collected from more than 4,000 instrumented vehicles to date, VTTI is the leader in providing unparalleled resources that can be tapped to answer the greatest safety and mobility issues facing the transportation community.

LOGAN WALLACE

6 EXPERIENCE:
A HISTORY OF NATURALISTIC DRIVING

<< VTTI broke ground in transportation research with the use of naturalistic driving studies.

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EXPERIENCE:
A HISTORY OF NATURALISTIC DRIVING

For more than 15 years, VTTI has undertaken a range of naturalistic driving studies that help tell the story of our transportation community. Using sophisticated cameras and discreet instrumentation, these studies provide a wealth of information about driver performance and behavior. Although empirical study methods that include test tracks, simulators, and surveys have their benefits, such controlled experiments and self-reported information do not account for driver choices and the associated risks and consequences that occur in the real world.

While an important factor of investigations and research endeavors, police accident reports have limited accuracy for determining pre-crash factors, especially if vehicles are moved from the scene of a crash and/or persons involved miss or forget the details of the event due to fatality, injury, stress, or the passage of time.

Through the use of naturalistic driving studies, researchers can gain a much more accurate understanding of driver error, distraction, fatigue, and impairment by studying voluntary participants experiencing everyday driving environments with real consequences, all with the ultimate goal of ensuring the safety of the traveling public.

LIGHT VEHICLES

100-Car Naturalistic Driving Study

The first large-scale naturalistic driving study ever undertaken, this National Highway Traffic Safety Administration-funded project was designed to collect pre-crash and near-crash naturalistic driving data. The resulting database comprises more than 42,000 driving hours totaling 6.4 terabytes for:

- 241 primary and secondary drivers, aged 18 to 73, in Northern Virginia/Washington, D.C.
- 108 light vehicles
- 12 to 13 months of driving per participant
- Two million vehicle miles traveled
- More than 8,300 events, including near-crashes and police- and non-police-reported crashes

Australian Naturalistic Driving Study

This pilot study was conducted in conjunction with the University of New South Wales as a proof of concept that VTTI's data collection system can be adapted for use in Australia.

Canada Naturalistic Driving Study

Funded by Canada's Deputy Ministers Responsible for Transportation and Highway Safety, this is the first large-scale naturalistic driving study conducted in Canada. Data collection is ongoing and will cover

up to 24 months. The data are expected to include:

- 125 participants in Saskatoon, Saskatchewan
- More than two million vehicle miles traveled
- 175 data-years of driving

The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk

Sponsored by the National Highway Traffic Safety Administration, this was the first naturalistic study to use participants' cell phone records, which were provided voluntarily. The effects of distraction from the use of three different cell phone types (hand-held, portable hands-free, and integrated hands-free) were investigated. Only drivers who reported talking on a cell phone while driving at least once per day were recruited for the study, and participants were continuously recorded for an average of 31 days. The resulting video and kinematic data cover:

- 204 drivers (129 females/75 males), aged 18 to 84, in the Blacksburg/Roanoke region of Virginia, the Northern Virginia suburbs, and the Raleigh/Durham region of North Carolina
- 191 drivers' cell phone records comprising 51,725 calls and 82,950 text messages
- More than 400 safety-critical events, including crashes, near-crashes, crash-relevant conflicts, and intersection violations
- 204 vehicles
- Approximately 180,000 vehicle miles traveled

Light-vehicle Builds and Model Deployment Support for the Safety Pilot Program

The U.S. Department of Transportation Connected Vehicle Safety Pilot Program was created to demonstrate the feasibility of connected-vehicle safety technology in a real-world environment. As part of the program, VTTI was selected to provide support to the Crash Avoidance Metrics Partnership Vehicle Safety Communications 3—a consortium of eight vehicle manufacturers—in pre-model deployment testing, model deployment data collection, processing, storage and analysis, and post-model deployment evaluation. More than 51,000 hours of data totaling more than 10 terabytes are expected to cover:

- 127 participants during a 12-month period
- 72 light vehicles equipped with fully integrated vehicle-to-vehicle systems
- More than 740,000 vehicle miles traveled

Second Strategic Highway Research Program Naturalistic Driving Study

By far the largest naturalistic driving study, this project covers more than 35 million miles (2 petabytes) of video, kinematic, and audio data during a three-year period for:

- More than 3,100 participants, aged 16 to 98, in New York, Florida, Washington, North Carolina, Indiana, and Pennsylvania
- An approximately equal mix of male and female drivers
- More than 3,300 vehicles
- Approximately 4,000 data years
- More than 500 crashes identified to date (analyses are ongoing)
- More than 5,000 near-crashes

Shanghai Naturalistic Driving Study

VTTI, General Motors, and Tongji University are jointly conducting this ongoing naturalistic driving field operational test in Shanghai, China. This project provides opportunities to evaluate the logistical and technical challenges of conducting a collaborative international naturalistic driving study and to investigate variations between international driver behaviors and traffic conditions. The three-year data collection effort will include:

- Up to 90 participants
- Five vehicles

KIM PETERSON

Canada Naturalistic Truck Driving Study

Conducted in conjunction with the ongoing Canada Naturalistic Driving Study and funded by Canada's Deputy Ministers Responsible for Transportation and Highway Safety and Transport Canada, this field study will focus on collecting naturalistic commercial motor vehicle data in Saskatoon, Saskatchewan. The 12-month project is expected to cover:

- 20 trucks
- 20 to 24 drivers
- More than 370,000 vehicle miles traveled

Drowsy Driver Warning System Field Operational Test

Designed to determine the safety benefits and operational capabilities, limitations, and characteristics of a drowsy driver warning system, this National Highway Traffic Safety Administration-funded project marked the largest naturalistic commercial vehicle study undertaken. The results include more than 12 terabytes of video, kinematic, and audio data for:

- 103 commercial motor vehicle drivers, aged 24 to 60, from three for-hire companies in Virginia and North Carolina
- 46 trucks, including line-haul and long-haul operations
- Nine to 11 weeks of driving per participant
- 46,000 driving hours
- 2.4 million vehicle miles traveled
- More than 1,500 safety-critical events
- Approximately 195,000 hours of actigraph data*

Field Demonstration of an Advanced Heavy-vehicle Indirect Visibility System

The National Highway Traffic Safety Administration and the Federal Motor Carrier Safety Administration collaboratively funded this project designed to evaluate whether providing drivers with enhanced vision information resulted in improved situational awareness and a reduction in safety-critical events. Both commercially available and advanced camera/video imaging systems were installed on trucks that operated in a revenue-producing environment. Data were collected during the four-month driving phase for:

- Six trucks
- 12 drivers
- 278,000 vehicle miles traveled
- 338 safety-critical events

Field Study of Heavy-vehicle Crash Avoidance Systems

Sponsored by the National Highway Traffic Safety Administration, this ongoing project is designed to evaluate heavy-vehicle collision avoidance systems. VTTI is working with two suppliers, Bendix® and Meritor WABCO, to evaluate

* An actigraph is a wristwatch-type, activity-monitoring device used to assess a participant's quantity and quality of sleep.

VTTI captures continuous naturalistic driving data from a variety of vehicles, from tractor-trailers to motorcycles and bicycles.

system reliability during operation on up to:

- 150 trucks traveling across the continental United States
- 160 drivers, each operating his or her normal schedule for one year

FMCSA's Advanced System Testing utilizing a Data Acquisition System on the Highways (FAST DASH)

The objective of this ongoing Federal Motor Carrier Safety Administration-funded study is to perform three independent and quick turnaround evaluations of promising safety technologies designed for commercial vehicle operations. For the three evaluations, data collection is expected to cover:

- Up to 65 drivers
- More than 40 tractor-trailers
- More than three million miles of driving

Impact of Local-/Short-haul Operations on Driver Fatigue

This Federal Motor Carrier Safety Administration-funded project was designed to determine objectively, via a field study, if fatigue was a safety issue among local-/short-haul operators. The resulting data included:

- Two local-/short-haul companies
- Four types of local-/short-haul trucks
- 42 drivers, with an average age of 31, who worked their typical delivery routes for approximately two weeks
- Nearly 250 safety-critical events
- More than 400 days of actigraph data*

Impact of Sleeper Berth Usage on Driver Fatigue

This Federal Motor Carrier Safety Administration-funded study was the first of its kind to examine drivers' sleeping habits and drowsiness relative to crash risk. Two Class 8 tractor-trailers were instrumented and loaned to trucking companies for data collection, which covered:

- 56 drivers, aged 28 to 63
- Up to 240 driving hours
- Four for-hire commercial trucking companies in eight U.S. cities

Naturalistic Truck Driving Study

This Federal Motor Carrier Safety Administration-funded project was undertaken to investigate commercial motor vehicle crash risk by identifying safety-critical events, including crashes/near-crashes, illegal maneuvers, and unintentional lane deviations. The resulting 6.2 terabytes

(14,500 driving hours) of video, kinematic, and audio data cover:

- 100 participants, aged 21 to 73, from four trucking fleets in seven locations
- Eight trucks
- 735,000 vehicle miles traveled
- 3,000 safety-critical events
- Approximately 65,000 hours of actigraph data*

Onboard Monitoring System Field Operational Test

This ongoing project is sponsored by the Federal Motor Carrier Safety Administration and will determine whether an onboard monitoring system will reduce at-risk behavior and improve driver safety performance among commercial drivers and bus operators. The resulting data, collected during an 18-month period, are expected to include:

- 270 participants from fleets in Florida, Louisiana, Michigan, North Carolina, California, Texas, Pennsylvania, and New Hampshire
- 206 heavy trucks and 43 motorcoaches
- Nearly five million vehicle miles traveled

A Pilot Study of a Driver-monitoring System in the Oil and Gas Industry

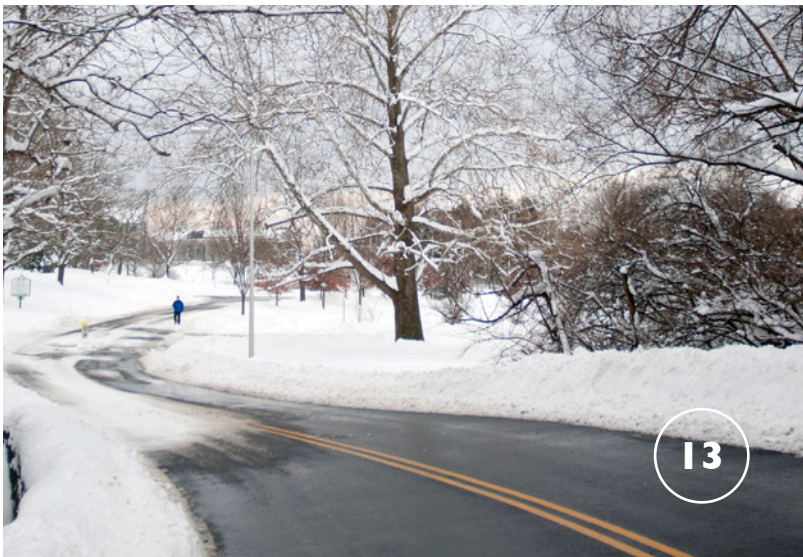
VTTI and the National Institute for Occupational Safety and Health have been tasked by the National Surface Transportation Safety Center for Excellence to perform a quick turnaround, independent evaluation of a promising risk management system installed in an oil and gas industry fleet. Resulting data are expected to include:

- 25 to 30 vehicles equipped with the risk management system; five of these vehicles will be instrumented with the VTTI data acquisition system
- 60,000 vehicle miles traveled

Winter Maintenance

The Minnesota Department of Transportation funded this effort to investigate causes of fatigue in operators during winter emergencies. The naturalistic driving data collection included:

- Four winter maintenance operators from the Virginia Department of Transportation
- More than 365 driving hours, including 338 hours of winter emergency operations
- 92 events, including crashes, near-crashes, and crash-relevant conflicts
- More than 6,600 hours of actigraph data*



* An actigraph is a wristwatch-type, activity-monitoring device used to assess a participant's quantity and quality of sleep.

MOTORCYCLES

The motorcycle naturalistic driving studies conducted by VTTI are the first of their kind to collect real-world data that will aid in the understanding of factors that contribute to the high crash rate experienced by motorcyclists.

The Motorcycle Safety Foundation-sponsored naturalistic riding study was recently completed and covers data for:

- 100 riders between 21 and 80 years of age in California, Florida, Virginia, and Arizona
- Three different motorcycle types (sport, touring, cruiser)

The National Highway Traffic Safety Administration-sponsored study is ongoing and will include data for 160 motorcycles instrumented in Southern California.

LOGAN WALLACE

40-Teen Driver

Funded by the National Institute of Child Health and Human Development and the National Highway Traffic Safety Administration, this 18-month study assessed the effect of driving experience on driving performance. More than 5 terabytes of continuous naturalistic driving data were collected for:

- 42 newly licensed teens and their parents in Virginia's New River Valley
- 275,000 vehicle miles traveled

Driver Coach: Bedford/Montgomery, Virginia Evaluation Project

This project, sponsored by the National Surface Transportation Safety Center for Excellence, the Virginia Center for Transportation Innovation and Research, the National Institutes of Health, and the Toyota Collaborative Safety Research Center, is designed to forward the concept of teen driver coaching and monitoring to eliminate behaviors that can lead to injurious and fatal crashes. Teen drivers are three times more likely to get into fatal crashes than their adult counterparts due to causes that can include: excessive speed, alcohol use, distraction, and failure to recognize hazards. VTTI has been independently approached by two Virginia counties (Bedford and Montgomery) to help design a program to mitigate what they believe is a tragic and growing problem in their communities. This ongoing project is expected to comprise data for:

- 90 teen participants during pre- and post-licensure
- More than 23,000 vehicle miles traveled

Second Strategic Highway Research Program Naturalistic Driving Study: Teen Driver Subset

Comprises 255 drivers aged 16 to 17 and 479 drivers aged 18 to 20. Participants were enrolled in the study for a minimum of four months. See *Light Vehicles* for more information about the Second Strategic Highway Research Program study.

Supervised Practice Driving Study

Sponsored by the National Institute of Child Health and Human Development, this ongoing study is designed to assess factors that are important during the time a teen is driving with a learner's permit. The study includes the nine months of the practice driving phase and the first 12 months of independent driving. Data have been collected thus far for:

- Up to 90 teen participants during pre- and post-licensure
- More than 38,000 vehicle miles traveled

OLDER DRIVERS

Older Driver Naturalistic Driving Study

Under the sponsorship of the National Surface Transportation Safety Center for Excellence at VTTI, this project was the first of its kind to assess a variety of older drivers' functional abilities, specifically visual awareness, flexibility, reaction time, and visual-cognitive ability. Nearly 2.5 terabytes (4,600 driving hours) of continuous naturalistic driving data were collected for 12 months from:

- 20 senior drivers, aged 75 and older, from Virginia's New River Valley
- 131,000 vehicle miles traveled

Older Drivers and Vision Impairment: Naturalistic Driving Studies

This newly awarded project on which VTTI is collaborating with the University of Alabama at Birmingham is designed to examine the relationships between vision and driving performance among older drivers. Approximately 200 participants, aged 70 and older, will be recruited to participate in the study. Analyses will focus on the relationship between vision and safety-critical events observed in the resulting naturalistic driving data. Driver characteristics, functional capabilities, medical problems and medications, and environmental and vehicular factors will be taken into consideration during analyses.

Second Strategic Highway Research Program Naturalistic Driving Study: Older Driver Subset

Comprises 459 drivers over the age of 75. Participants were enrolled in the study for a minimum of four months. See *Light Vehicles* for more information about the Second Strategic Highway Research Program study.

Cooperative Intersection Collision Avoidance System for Violations

In partnership with the Crash Avoidance Metrics Partnership Vehicle Safety Communications 2, the Virginia Department of Transportation, and the U.S. Department of Transportation, this project involved the design, development, and testing of a prototype collision avoidance system to predict stop-sign- and signal-controlled intersection violations and warn the driver. In total, 214 gigabytes (194 driving hours) of video and radar data were collected at 13 intersections for:

- 87 drivers, aged 18 to 55 and older, in Virginia's New River Valley
- More than 3,100 vehicle miles traveled

The Influence of a Research Method

Data from VTTI naturalistic driving studies have been cited and featured extensively by national and international government agencies, private industries, safety organizations, and media, including:

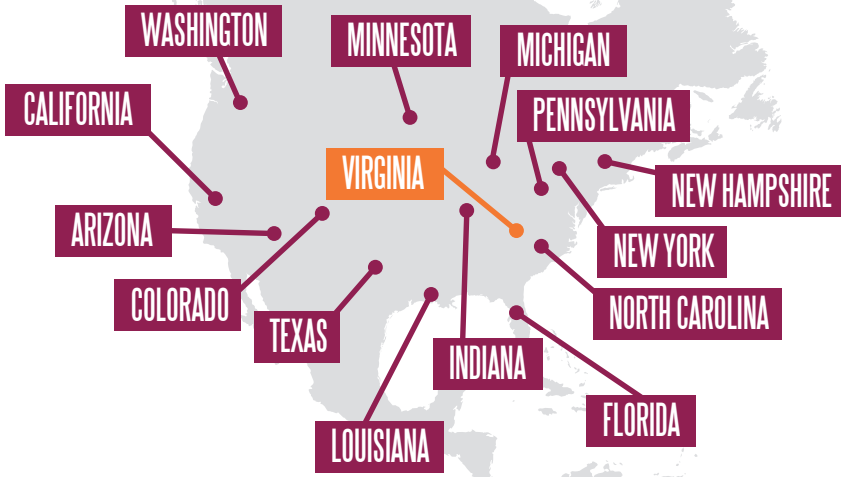
ABC News
American Journal of Public Health
Australia's Keep Your Eyes on the Road Initiative
BBC Affiliates
CBS Evening News
CBS Radio
Centers for Disease Control
CNN Newsroom
Congressional Testimonies
Consumer Reports
Distraction.gov
Edmunds.com
Federal Communications Commission
Federal Highway Administration
Federal Motor Carrier Safety Administration
General Motors
Good Morning America
Huffington Post
Journal of the American Medical Association
Los Angeles Times
National Academy of Sciences
National Highway Traffic Safety Administration
National Institutes of Health
National Safety Council
New England Journal of Medicine
New York Times
NPR
RealClearPolitics
Richmond Times-Dispatch
Time
Travelers
U.S. Department of Transportation
USA Today
Virginia Business Magazine
Virginia Center for Transportation Innovation and Research
Virginia Department of Transportation
Wall Street Journal
Washington Post
Wired

A Global Effort

To date, more than 25 naturalistic driving studies that include a range of vehicle types and drivers have been conducted, or are in the process of being conducted, by VTTI. The groundbreaking methodology was first used on a large scale during the 100-Car Study, which covered participants traveling within Northern Virginia/ Washington, D.C.

Now, VTTI researchers have been tapped to lead naturalistic efforts on a worldwide scale, collecting data that can be used to inform national and international policies, answer new transportation challenges, and help ensure the safety of all transportation users.

VTTI is continually expanding its international efforts, with naturalistic driving studies currently being conducted in China, Australia, and Canada.



CAPABILITIES: INSTRUMENTATION AND FACILITIES

The instrumentation required to undertake naturalistic driving studies has evolved at a relatively rapid pace. Created by the VTTI Center for Technology Development, the data acquisition system (DAS) began as the answer to the question, "How do you build instrumented cars to unobtrusively observe drivers on a larger scale and determine crash causation?"

The first iteration of the DAS was tested on two vehicles. The size of a suitcase, the complex hardware system took a month to install. Then VTTI received the award for the 100-Car Study, the first large-scale naturalistic driving study ever conducted. The project necessitated faster installation times, which meant a more easily installable DAS. New technologies, such as digital video and a computer designed for the space shuttle, were incorporated into a redesign that resulted in an installation time of one day.

Nearly a decade later, the Second Strategic Highway Research Program award meant VTTI and its partners had to instrument more than 2,500 vehicles. The DAS was then modified to be less expensive, more capable, and even quicker to install. Aptly named the Next Generation (NextGen) DAS, this system was fully customized on two circuit boards, the software package became more easily configurable, and machine-vision and lane-tracking software were added. The adjustments made data more easily transferable from data collection systems to data reduction systems. The NextGen was successful: it cost less and took less than four hours to install.

The latest iteration of the DAS, the MiniDAS, includes a connection to the vehicle network, two video channels, GPS, a nine-axis inertial measurement unit (accelerometer, gyro, and magnetometer), is expandable with sensor modules via WiFi or Bluetooth, and is compatible with dedicated short-range communication radios. All of these features fit within a system roughly the size of a sandwich and enable naturalistic studies for all vehicle sizes operating on the roadway, from motorcycles and bicycles to tractor-trailers.

Instrumentation

The VTTI DAS has been designed to collect and store large amounts of continuous detailed data from the driving environment, including video, vehicle network information, and additional sensor information that can include radar, GPS, and acceleration.

The data collected from various onboard systems are processed and stored in the DAS, which is similar to a "black box" unit found in commercial airplanes. The DAS features are configurable and typically include:

- An arm-based core with video processing on a digital signal processor chip;
- Additional sensors, such as accelerometers and gyroscopes;
- Video with H.264 video/audio compression and multi-channel binary data synchronization;
- GPS;
- Doppler-based front and rear radar;
- Controller area network 2.0B, VPW, PWM, and ISO vehicle network interfaces; and
- Removable, high-capacity, shock-resistant hard drives for data retrieval.

Via its cameras, the DAS can collect information about a range of variables. These cameras record multiple views that can include forward, rearward, and internal views (such as over-the-shoulder, face, and pedal areas). Across the sensor package, data parameters can be customized to include such variables as:

- Vehicle network data, such as speed, airbag deployment, brake use, throttle position, turn signaling, and many other elements;
- Environmental factors, such as weather, lighting, glare, and temperature;
- Presence of nearby objects and their relative speed obtained via radar and optical technologies; and
- Other data, such as sound, vibration, acceleration, and turning rate.

Instrumentation Software and Health Checks

The DAS runs custom data acquisition software using a Linux operating system and communicates with a distributed data acquisition network. Other electronic subsystems that use their own microprocessors are applied in an instrumented vehicle to interface with the driver or for specific functions, such as facilitating communication with the existing vehicle onboard diagnostic network.

Each subsystem functions as a node on the data acquisition network. This system configuration maximizes flexibility while minimizing the physical size of the system. Although capable of expansion to 120 nodes, current instrumented vehicles at VTTI

are generally configured with 10 nodes. This process of distributed data acquisition results in an adaptable and maintainable hardware data collection system.

Customized machine-vision software incorporated into the VTTI DAS hardware can include:

- Lane-tracking information and
- Driver's head position.

DAS units can also feature cellular machine-to-machine technology that disseminates software upgrades to installed units, transmits events of interest (such as coachable events and crashes) to project servers; and collects DAS function reports, or what are dubbed "health checks." These combined capabilities ensure that important information is being relayed and that the DAS is functioning properly.

The miniaturized data acquisition system created at VTTI enables naturalistic studies for all vehicle sizes.

Support Facilities

To supplement and support the naturalistic research endeavors of VTTI, a fully staffed and equipped automotive repair and fabrication shop is maintained on site for modification and instrumentation of experimental vehicles and infrastructure. Technicians and engineers use machine shops, welding shops, electronics laboratories, and garage facilities to customize transportation hardware and software that reliably collect vast amounts of data.

Due to differences in vehicle makes and models, network integration systems within the DAS need to be customized for each type of vehicle. VTTI engineers have customized DAS equipment for a variety of vehicle models, from heavy trucks to passenger cars to motorcycles and even bicycles. These systems allow for the instrumentation of participants' personal vehicles, which can then be returned to their original manufactured states after the naturalistic driving studies are completed.

Though naturalistic driving studies can only truly be conducted in everyday driving situations, VTTI pilots its studies and systems using three test beds: the Virginia Smart Road, the Northern Virginia Connected-vehicle Test Bed, and the Virginia International Raceway complex.

Headquartered at VTTI, the Smart Road is a 2.2-mile, controlled-access facility managed by the Institute and owned and maintained by the Virginia Department of Transportation. The road itself is built to Federal Highway Administra-

Using unobtrusive cameras, the VTTI data acquisition system can collect information about many variables recorded from multiple views.

tion specifications and features seven roadside equipment units and two mobile roadside equipment sites that facilitate connected-vehicle communications; an optical fiber communication system; Ethernet fiber transceivers and Ethernet switches; a connected-vehicle-compatible intersection controller model; varying pavement sections and in-pavement sensors; 75 weather-making towers capable of producing snow, rain, and fog; a differential GPS base station for precise vehicle locating; a signalized intersection with complete signal phase and timing control; a wireless mesh network variable control system; and variable pole spacing designed to replicate 95 percent of national highway lighting systems.

The Northern Virginia Connected-vehicle Test Bed was opened during 2013 and supports real-world connected-vehicle/infrastructure research on a larger scale along the most congested roadway in the United States. The test bed is a Virginia Department of Transportation facility developed in partnership with VTTI, the University of Virginia, and Morgan State University as part of the Connected Vehicle/Infrastructure University Transportation Center funded by the U.S. Department of Transportation. The facility features: 43 wireless roadside equipment units that enable connected-vehicle communications along Interstate 66, Interstate 495, U.S. 29, and U.S. 50 (with plans to add 25 wireless roadside units during 2014); two mobile roadside equipment sites; and variable traffic conditions and roadway types, including four major merge/diverge locations, two metro stations, high-occupancy toll lanes, and major roadway construction.

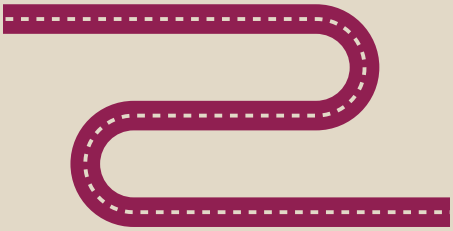
The Virginia International Raceway in Alton, Va., was established as a cooperative agreement through which VTTI can conduct projects in a multi-use testing environment that includes both closed-course and open traffic conditions. On site at the raceway is a resort that features a 12-unit complex of residential villas, a lodge, a club house, a full-service restaurant and tavern, administrative offices, and a spa. The raceway track can be configured to five different courses ranging from 1.1 miles to 4.2 miles and includes such topography as hairpin curves and blind passes. The Virginia International Raceway is also home to the Virginia Motorsports Technology Park, which contains the Southern Virginia Vehicle Motion Labs and the National Tire Research Center, an affiliated company of VTTI and the globe's premier force-and-moment tire test facility.

Hard drives from the VTTI data acquisition systems are swapped for data retrieval.

VTTI Data *at a Glance*

More than **4,000 drivers** across ages (teen, adult, older) and genders

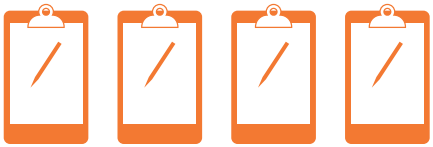
More than **40,000,000 miles** of continuous naturalistic data



More than **1,000 crashes and minor collisions**

More than **10,000 near-crashes**

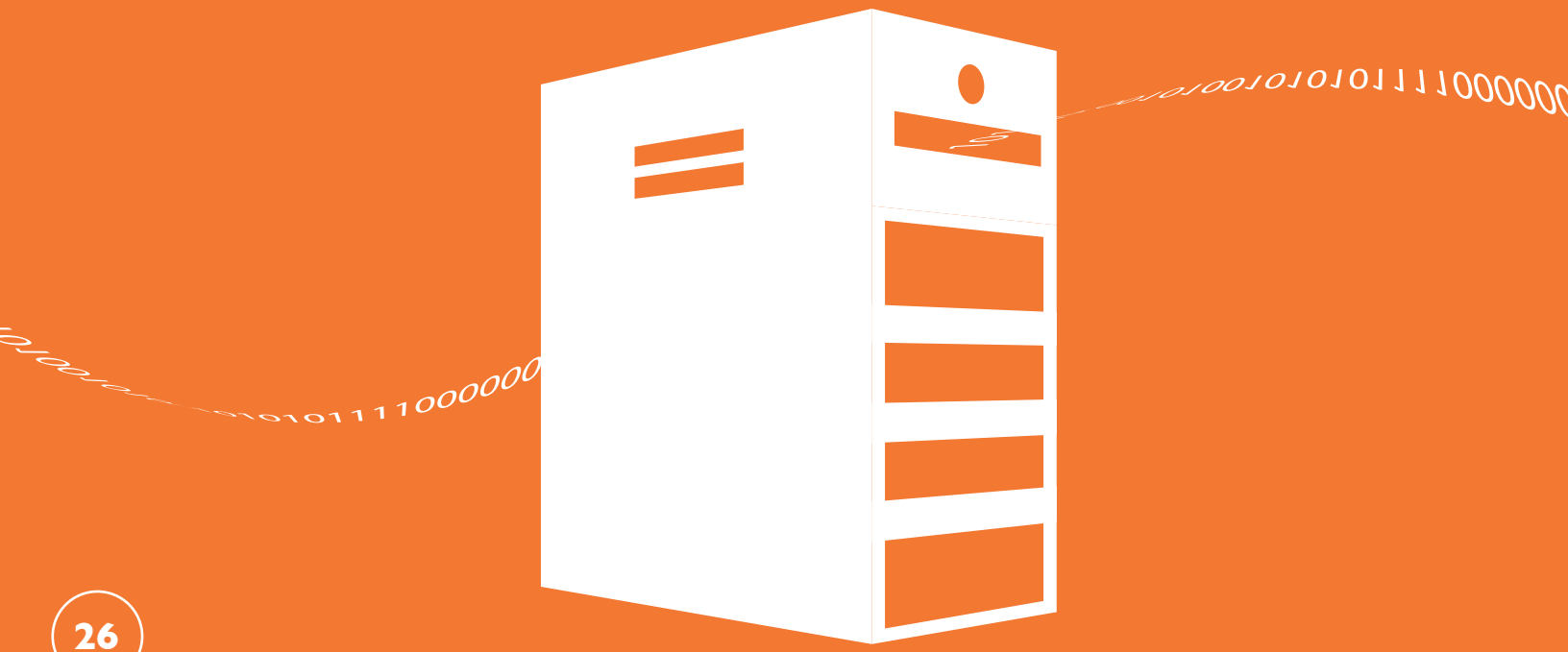
More than 20 **data collection sites**



DATA: REDUCTION, ANALYSIS, AND SUPPORT

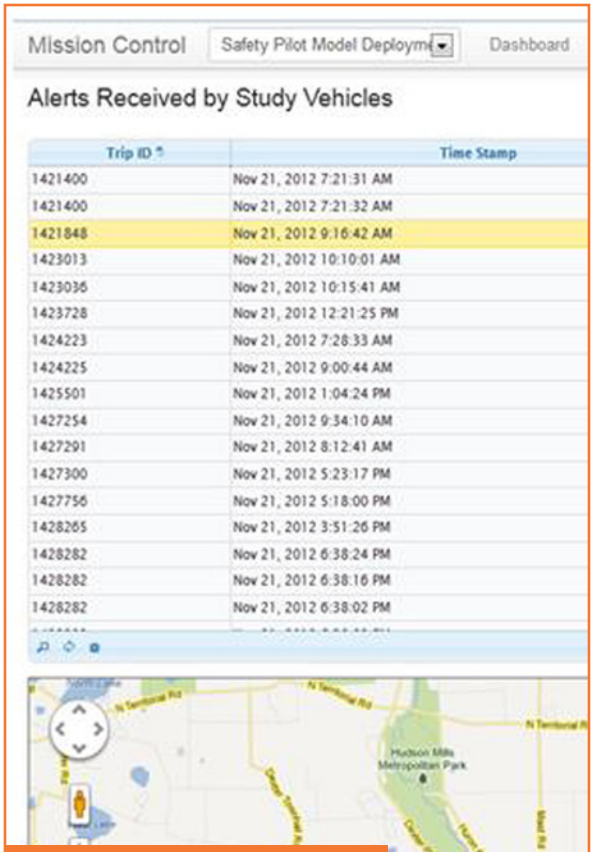
Original equipment manufacturers and researchers from the National Highway Traffic Safety Administration, the Federal Highway Administration, and the Virginia Department of Transportation were among the first to use the 100-Car Study data to aid in the development of collision avoidance systems and other safety systems designed to protect drivers. Today, existing VTTI data continue to be mined by various clients to answer a multitude of research questions.

VTTI data also allow clients to study specific driving performance factors that can include distraction, impairment, fatigue, aggressiveness, illegal maneuvers, and the impact of age. VTTI clients seek an in-depth analysis of driver behaviors, user acceptance, and vehicle performance, and the vast amount of data collected by VTTI across different age groups, vehicle models, and locations can help provide the foundation to accurately assess the greatest issues affecting driver safety.



International Center for Naturalistic Driving Data Analysis at Virginia Tech

The International Center for Naturalistic Driving Data Analysis incorporates Virginia Tech's petabyte-scale, high performance data storage system into the VTTI data infrastructure. This allows data from multiple naturalistic driving studies to be analyzed using high performance computational systems to perform more complex computational algorithms and data mining.



Customized software at VTTI captures a variety of naturalistic data.

The 48-node compute cluster of the Institute moves data between the field and the data center, decrypts data, prepares data files for ingestion to a 500-terabyte scientific data warehouse, processes video files, and provides a platform for advanced analytical processing. A peta-scale archive file system will ultimately facilitate the long-term storage of numerous petabytes of data while maintaining data in an online state.

VTTI data center features include a computational cluster, the application of the Virginia Tech High Performance Computing Storage System, and a significant upgrade to the storage system supporting the scientific data warehouse environment at VTTI. These systems compose the foundation for data-intensive scientific research programs conducted at VTTI, particularly the Second Strategic Highway Research Program Naturalistic Driving Study.

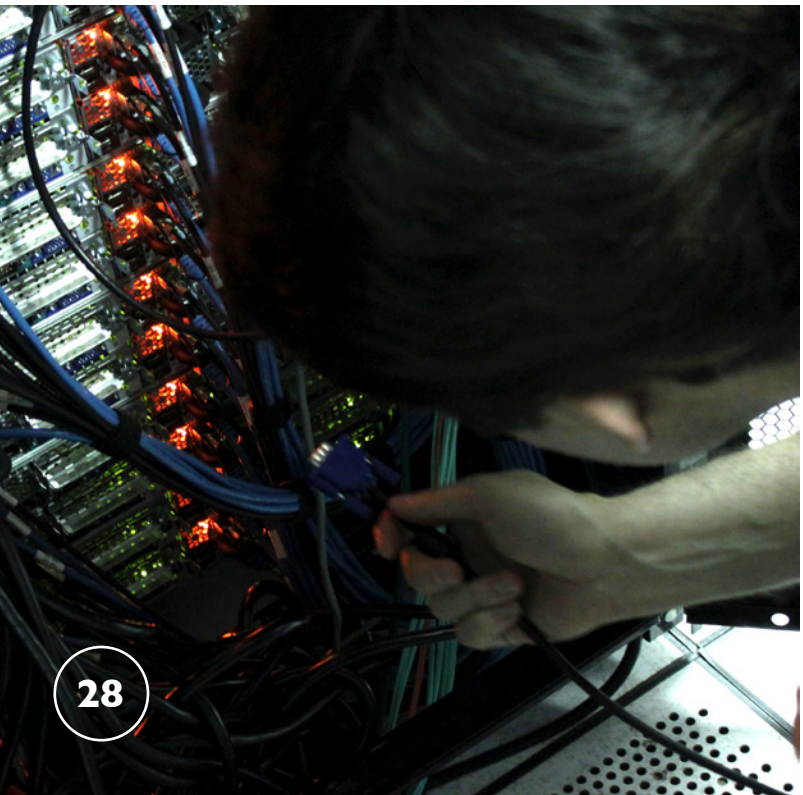
Data Reduction and Analysis Support

VTTI houses close to 90 percent of national and international naturalistic driving data in the world. With on-site data reduction labs and extensive analysis experience, the Institute realized the role it could play in helping others mine and reduce its data to answer subsequent research questions about driver behavior and performance.

Thus, in 2013, the Center for Data Reduction and Analysis Support was created to add value to existing driving data at VTTI. The center serves not only the internal needs of the Institute but those of its strategic partners, supporting standardized access to and analysis of numerous naturalistic driving study data sets held at VTTI.

The center's services include coding video and audio data, data quality assurance, data standardization, data mining, event selection, and data analysis. The center also actively supports data analysis collaborations with external institutions.

The Center for Data Reduction and Analysis Support comprises two groups: Data Reduction and Data Analysis Support.

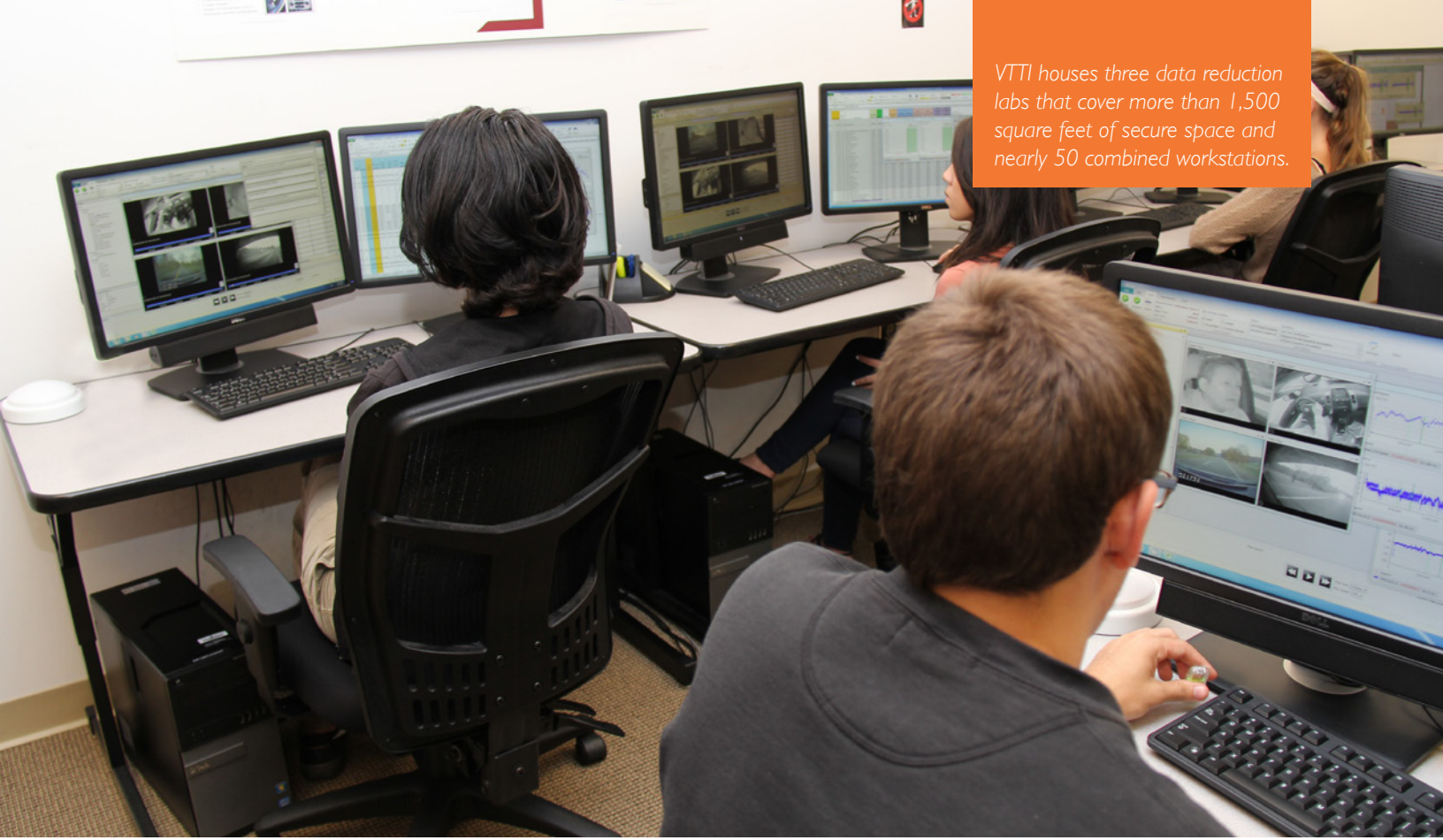


Data Reduction Group

- Includes a group leader, four coordinators, a large staff of data reductionists, and three data reduction labs that cover more than 1,500 square feet of secure space and nearly 50 combined workstations.
- Currently operates six days a week, 60 hours per week to meet project demands.
- Serves clients requiring video and/or audio analyses in the areas of driver performance and behavior metrics, situational analyses, and environmental characteristics.
- Provides efficient, accurate, and comprehensive coding of videos to meet the specific needs of each unique research project.
- Conducts necessary groundwork to prepare a video data set for analysis.
- Works alongside the researcher to develop a data reduction protocol.
- Trains and manages the required data reduction staff, conducts extensive quality control throughout the reduction phase, and prepares final sets of coded data.

Data Analysis Support Group

- Includes experts in data preparation, standardization, mining, and analysis.
- Performs activities and projects that improve the state of and access to the naturalistic driving data sets available at VTTI.
- Removes any roadblocks to efficient data use and analyses.



VTTI houses three data reduction labs that cover more than 1,500 square feet of secure space and nearly 50 combined workstations.

Center personnel also include statisticians experienced in naturalistic data processing, analysis, and visualization. These statisticians are available to provide consulting services and assistance in defining research questions, selecting the proper sample, experimental design, data cleaning, data mining, inferential analysis, and data analysis interpretation.

The Center for Data Reduction and Analysis Support manages a Secure Data Enclave where researchers from other institutions and agencies may visit VTTI to view otherwise restricted data. Some clients prefer to use this enclave to perform their own data reduction, while others use the enclave to gain familiarity with data and to prepare data reduction protocols that in-house reductionists at VTTI can then use. Others may visit the Secure Data Enclave after data reduction is complete to gain an understanding of their findings.

The enclave is set up and managed similarly to a data reduction lab, with the same Institutional Review Board certification requirements, network and facility security, and assigned proctors to provide technical assistance and additional security assurance.

Obtaining Access to VTTI's Naturalistic Driving Study Data

If you are interested in using any of the naturalistic driving data sets at VTTI (see *Active Data Sets Available*) to help your organization answer important transportation research questions, please consider obtaining access by taking the following steps:

- Contact datasharing@vtti.vt.edu to determine the specific requirements for the data set in which you are interested.
  - » Note that all data housed at VTTI were collected using voluntary human participants with the approval of one or more Institutional Review Boards. All analyses made using identifying data (e.g., face video, GPS traces) require additional Institutional Review Board approval. Many analyses using de-identified data also require Institutional Review Board approval.
  - » Some data sets require approval of the original sponsor, approval of the original principal investigator, and data-sharing agreements.
- Determine the data you will use and work with VTTI to establish costs, collaboration agreements, access to the Secure Data Enclave, and other analysis needs (e.g., statistical support).

VTTI encourages everyone to explore the Second Strategic Highway Research Program Naturalistic Driving Study InSight website (https://insight.shrp2nds.us/) where qualified researchers can obtain access to large amounts of searchable de-identified data. The Institute has also made publicly available the 100-Car Study and Naturalistic Truck Driving Study data at http://forums.vtti.vt.edu.

Active Data Sets Available

(See *Experience* for more information about each project; please note that some data sets are available pending sponsor approval.)

Light Vehicles

- 100-Car Naturalistic Driving Study
- Canada Naturalistic Driving Study
- The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk
- Light-vehicle Builds and Model Deployment Support for the Safety Pilot Program
- Second Strategic Highway Research Program Naturalistic Driving Study
- Shanghai Naturalistic Driving Study

Heavy Vehicles

- Drowsy Driver Warning System Field Operational Test
- Field Demonstration of an Advanced Heavy-vehicle Indirect Visibility System
- Field Study of Heavy-vehicle Crash Avoidance Systems
- FMCSA's Advanced System Testing utilizing a Data Acquisition System on the Highways (FAST DASH)
- Naturalistic Truck Driving Study
- Onboard Monitoring System Field Operational Test
- Winter Maintenance

Teen Drivers

- 40-Teen Driver
- Driver Coach: Bedford/Montgomery, Virginia Evaluation Project
- Second Strategic Highway Research Program Naturalistic Driving Study: Teen Driver Subset
- Supervised Practice Driving Study

Older Drivers

- Older Driver Naturalistic Driving Study
- Second Strategic Highway Research Program Naturalistic Driving Study: Older Driver Subset

Infrastructure

- Cooperative Intersection Collision Avoidance System for Violations

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VTTI pilots many of its naturalistic studies using a wide range of testing facilities at its disposal, including (from l to r) the Virginia Smart Road, the Northern Virginia Connected-vehicle Test Bed, and the Virginia International Raceway, which is home to the National Tire Research Center.

To conduct its innovative research projects, VTTI has worked with hundreds of sponsors, partners, and clients from both the public and private sectors. The continued success of the Institute is due in large part to its diverse collaborations with local, state, national, and international transportation agencies; fellow industry researchers; major automotive companies; and automotive suppliers. Some of the key VTTI partners include:

- American Association of State Highway and Transportation Officials
- Automotive Events
- Battelle Memorial Institute
- Bendix
- Bishop Consulting
- BMW
- Booz Allen Hamilton
- Bosch
- Calspan
- Carnegie Mellon University
- Chrysler
- Continental
- Crash Avoidance Metrics Partnership (a consortium of auto manufacturers)
- CUBRC
- Delphi Electronics
- DENSO
- DGE Inc.
- Draper Laboratory
- Duke University
- Fairfax County, Va.
- FEV
- Ford Motor Company
- General Motors
- George Mason University
- Goodyear
- Google
- Halifax County, Va.
- Honda
- Hyundai-Kia
- Intelligent Transportation Society of America
- Mercedes-Benz
- Meritor WABCO
- Michelin
- Minnesota Department of Transportation
- Montgomery County, Va.
- Morgan State University
- Motorcycle Safety Foundation
- National Academy of Sciences Transportation Research Board
- National Institutes of Health
- National Science Foundation
- Navistar International
- NAVTEQ (now Nokia)
- Nissan
- Norfolk Southern Railroad
- Peloton
- Penn State University
- Ricardo
- SAE International
- Savari
- Security Innovation
- SwRI
- Texas A&M Transportation Institute
- TORC Robotics
- Toyota

- Travelers
- University of Central Florida
- University of Michigan Transportation Research Institute
- University of Virginia
- U.S. Department of Defense
- U.S. Department of Transportation (USDOT) Federal Highway Administration
- USDOT Federal Motor Carrier Safety Administration
- USDOT National Highway Traffic Safety Administration
- USDOT Research and Innovative Technology Administration
- Valeo
- Virginia Center for Transportation Innovation and Research
- Virginia Department of Motor Vehicles
- Virginia Department of Transportation
- Virginia Tech Foundation
- Volkswagen-Audi
- Volvo Trucks and Volvo Cars
- Westat


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