VTTI

Advancing Transportation
through Innovation

It all started with **15**.

In 1988, the Virginia Tech Transportation Institute (VTTI) began as the Center for Transportation Research with 15 employees poised to become a resource for intelligent vehicle/infrastructure research. Researchers at this new Virginia Tech-based center were interested in human factors that addressed the growing concerns about the acceptance of emerging smart car technology. When legislators initiated discussions about a "smart road" equipped to facilitate real-world testing of intelligent transportation systems, the Center for Transportation Research became the natural candidate to house such an initiative.

That road today is synonymous with VTTI. Our researchers have logged more than 22,000 hours of use on the formally titled Virginia Smart Road, pilot testing nearly every major research endeavor, from pavement sustainability to enhanced lighting safety, and from student-led hybrid vehicle studies to advanced vehicle technology.

But the Smart Road is only one example of what VTTI is now. Today, the Institute has developed a world-class $110 million infrastructure.

VTTI has grown to become, by most metrics, the largest U.S. university-level transportation institute, with more than 475 employees. We were named one of only three national Intelligent Vehicle/Highway System Research Centers of Excellence; we are the leader of the Tier 1 Connected Vehicle/Infrastructure University Transportation Center; we opened the affiliated Global Center for Automotive Performance Simulation, which houses the world-renowned National Tire Research Center and Southern Virginia Vehicle Motion Labs; we house the National Surface Transportation Safety Center for Excellence; we are a member of TranLIVE, a Tier 1 University Transportation Center led by the University of Idaho; and we are a member of the Mid-Atlantic Transportation Center. We have built six buildings and have accumulated more than one-third of a billion dollars in sponsored program research expenditures. We annually support 150 graduate and undergraduate students who work here gaining hands-on experience to become the next generation of researchers.

VTTI has pioneered and continues to enhance groundbreaking naturalistic driving studies made possible by data acquisition systems developed in-house; these systems allow drivers to be observed as they go about their lives on national roadways. The results of such studies have made a significant impact on transportation policies at the local, state, and national levels. With our partners, we completed the Second Strategic High-

way Research Program Naturalistic Driving Study (SHRP 2 NDS), the largest light-vehicle study ever conducted with more than 3,500 drivers across six data collection sites in the United States. The data set has already facilitated new analyses of driver risk factors published in such high-impact journals as the Proceedings of the National Academy of Sciences. Results from the study were also included in a new book we published entitled "Survive the Drive," the first driving guide of its kind in which years of research, anecdotes, and personal experience have been distilled into one publication written for teen to adult to senior drivers, as well as motorcyclists and professional drivers. VTTI now supports access to the SHRP 2 NDS data set—the largest crash-only database, with 1,600 crashes and minor collisions identified—for users across the globe who wish to determine the greatest risk factors faced by drivers and to create effective countermeasures.

VTTI researchers have provided congressional testimony about the dangers of distracted driving. We were invited to the White House summit on distracted driving, the result of which was a national call to end distracted driving that has thus far influenced 46 states, the District of Columbia, Puerto Rico, Guam, and the U.S. Virgin Islands to ban text messaging for all drivers. We are currently conducting the largest naturalistic studies to date for trucks, motorcoaches, and motorcycles. Our revolutionary studies are also being conducted on a global scale, with research efforts under way in China, Canada, and Australia. In 2016, we began collecting data for the first naturalistic marijuana driving study in an effort to better inform the transportation community about the effects of THC on driving.

While our research is aided by the evolution of "big data"—the capacity to process thousands of hours of data streams—VTTI also continues to leverage its capabilities in the realm of connected-automation. Using such resources as the Smart Road and the Virginia Connected and Automated Corridors in Northern Virginia, Institute researchers are working with government entities, auto manufacturers, and suppliers to perform studies that examine the potential benefits of connected and automated vehicles, as well as advanced vehicle systems. Projects are being performed integrating our naturalistic driving study method to determine real-world driver interaction with new automated-vehicle models. In the coming years, we will expand our capabilities in the connected-automation domain by creating a new test bed that will answer industry needs and open new opportunities in the testing of multiple automated-vehicle platforms.

To become what we are today, VTTI has had to grow in size and complexity. However, we are still a family at our core; we are a community committed to conducting cutting-edge research to save lives, save time, save money, and protect the environment.

This is the story of how we began, where we are now, and where we're going.

- Tom Dingus

Director, VTTI

Director, VTT, LLC

Newport News Shipbuilding Professor of Engineering

Honored at the White House as a 2013 Champion of Change

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THE MAKING OF AN INSTITUTE

By the mid-1980s, the interstate highway system was almost complete, and how transportation funds would be used became a subject of debate, according to the history of the Intermodal Surface Transportation Act of 1991 written by Richard F. Weingroff. He reported that, in early 1987, the Federal Highway Administration formed a task force, known as the Futures Group, which concluded that "the federal role is justified by four main responsibilities: national defense, interstate commerce, equity, and uniformity and efficiency," and that "some activities, such as research and implementation programs and dissemination of information, can be more economically carried out by the federal government than by each state or local government."

Meanwhile, the scientific community had a firm vision of how to advance the field of transportation. The National Transportation Board was established in 1920 as a division of the National Research Council, the principal operating agency of the National Academies. This board created the University Transportation Centers program in 1987 for the purpose of establishing university-based transportation centers that would receive grants from the U.S. Department of Transportation to educate the future transportation workforce and to conduct research.

> "Tom [Dingus] built the center, now institute, from a $2 million program into a $40 million program in 10 years. He built relationships with engineering and automotive companies, focusing on human factors. That was the go-to area in transportation research. I told him when he was honored by the White House as a Champion of Change, that the whole point – the objectives – of the Smart Road had been met. Actually, they have long since been met."
>
> – Ray Pethtel, University Transportation Fellow

Thus, with a will and a way having been created for federally funded transportation research, Virginia Tech leapt at the opportunity. "In 1988, Tony Hobeika said he wanted to start a transportation center," said Ernie Stout, former associate vice president for research at Virginia Tech. Hobeika, a professor of civil engineering, presented information about research partnerships and support. The center was approved as one of only 10 university-wide centers.

"It was a university center because transportation research is not just based in civil engineering," said Wayne Clough, department head at the time and later dean of the Virginia Tech College of Engineering. "There was always a division of civil devoted to transportation … divided between transportation materials and transportation systems. When smart technologies began to appear to have a real future in transportation, it was clear that while civil had some of the knowledge base in the systems area, it lacked skills like electronics, heads-up displays, sensor technology, and recognition technologies. These other skills were needed if smart roads and smart vehicles were to be integrated into transportation systems. That was the reason that a center that reached beyond civil was needed: to build a base that would accommodate all of the skill sets required."

A handful of faculty members and students worked out of offices at 106 Faculty St. in Blacksburg, Va., but with access to an interdisciplinary base, the Center for Transportation Research gained stature as it became a member of the national region III University Transportation Center. According to the Roanoke Times, early research included moving hazardous materials, the effectiveness of evacuation plans around Virginia nuclear power plants, and the

LOGAN WALLACE

reduction of traffic chaos during emergencies. Research totaling nearly $650,000 was supported by grants from Virginia Power, NASA, the Virginia Department of Transportation (VDOT), and the U.S. Department of Transportation.

Support for the Center for Transportation Research continued as the General Motors Foundation agreed in 1992 to give Virginia Tech $250,000 during the next five years for students to study smart highway systems.

A $1.37 million grant from the Federal Highway Administration to Virginia Tech, Hughes Aerospace, Bell Atlantic, and JHK & Associates was awarded to support Rural Applications of Advanced Traveler Information Systems. The project would assess traveler needs, identify technologies, and develop and test systems designed to improve the safety and efficiency of rural traffic.

By 1993, other Center for Transportation Research projects that would grow into major programs in the years to come included:

- Truck safety research, including investigating causes of crashes such as icy roads and mechanical malfunctions, evaluating sensor technologies for early detection of crash causes, and assessing means for transmitting and displaying warnings.
- Passenger Information Systems Research, which included vehicle location technology such as GPS and GIS to report bus locations.
- Adaptive cruise control, including early-stage simulations and evaluations of car-following algorithms.
- Incident detection and management, including developing new sensing systems such as lasers, video image processing, and acoustic and cell phone technologies designed to improve the quality of traffic data from traffic control centers. The aim was to develop a comprehensive incident database to facilitate timely decision making.
- Human factors projects, including in-vehicle electronic display legibility and usability evaluations, auditory signal design, and driver mental workload assessment.
- Real-time diversion strategies, an ongoing project since 1988 to develop a comprehensive traffic diversion deployment system to relieve congestion.

The Center for Transportation Research was eventually named one of three national Intelligent Vehicle/Highway System (IVHS) Research Centers of Excellence by the Intelligent Transportation Society of America. These centers were charged with serving as "internationally recognized university-based organizations that aggressively develop and implement activities that advance the state of the art in IVHS." The award brought $5 million during the next five years, with $3.5 million in matching funds from public and private affiliates.

> "In 1996, the Virginia Department of Transportation and the Federal Highway Administration were our largest sponsors. Now we have more than 100 public and private-sector sponsors."
>
> -- Tom Dingus, director of VTTI

From a Center to the Institute

Innovation requires transformation, and significant change occurred within the Center for Transportation Research beginning in 1996, when Thomas A. Dingus was named its new director. He earned his B.S., M.S., and Ph.D. in industrial and systems engineering specializing in human factors and safety engineering, with his graduate degrees from Virginia Tech. He was founding director of the National Center for Transportation at the University of Idaho and had been associate director of the Center for Computer-Aided Design at the University of Iowa since 1993. He began doing transportation research in 1984 and developed the first comprehensive analysis of the safety and usability of an advanced in-vehicle navigation system, the Etak navigator.

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In 1999, the Center for Transportation Research moved into new offices at the Virginia Tech Corporate Research Center. The number of employees required use of only one suite. "We could all fit into one small conference room," said Brian Daily, software developer at the Institute. "I remember Tom saying he wanted to make this a place that people would make a career of."

The name change from the Center for Transportation Research to the Virginia Tech Transportation Institute (VTTI) occurred during 2000 and "represents the interdisciplinary nature of our organization and differentiates us from other 'transportation centers' in the country," Dingus wrote in the annual report. That same year, the Institute opened the Virginia Smart Road to testing.

"Our evolution was surprisingly tactical," said Dingus. "We looked for opportunities and created opportunities. You need four things to start a research area: capability, opportunities for research funding, societal need – something we have all been interested in – and a niche where you can compete," he said. "There might be lots of opportunity and funding, but if there are already a lot of other universities and companies in the space, then it is not your niche."

One of the first niches VTTI tackled was becoming a facility for testing and developing vehicle technology. "Car companies, automotive suppliers, and even the government would have systems they wanted tested to make sure they were safe and effective. We would test them on the Smart Road to determine their safety benefits, whether there were unintended consequences, and how drivers really use a system compared to how engineers thought it would be used," Dingus said.

"For example, we did a lot of testing of innovative headlights, like UV headlights. They were developed so drivers could see pedestrians better," Dingus explained. "If you are familiar with black lights, you understand the concept. Pedestrians wearing clothing washed in phosphorescent detergent should be more visible with UV light. It turned out to be too difficult to get enough UV light onto the road."

> "Research into human factors is trying to make driving safer and save lives."
>
> -- Andy Petersen, director,
> VTTI Center for Technology Development

On the other hand, a successful product is collision warning systems. "Backup warnings, blind spot warnings, and assisted braking are now on many new cars, and forward collision warnings are becoming more prevalent in newer vehicle models. All of these systems were tested at VTTI for a decade," said Dingus.

General Motors, Ford, and Nissan all invested in research by VTTI into user acceptance of such systems. General Motors sponsored numerous projects through a blanket agreement. Ford Motor Company provided funding to graduate students through a University Research Program.

"In general, research into human factors is trying to make driving safer and save lives," said Andy Petersen, director of the VTTI Center for Technology Development. "Tail lights are an example." VTTI researchers have been testing various tail-light configurations to grab the attention of a distracted driver. "Even a half a second faster braking can avoid a lot of rear-end crashes. That saves lives. That is a direct application of human factors research," said Petersen.

With a strong foundation of experience and significant interest from sponsors and partners, VTTI rapidly grew over the years to emerge as the leading university-level transportation institute in the country. Dingus' initial approach to growing the Institute still holds sway today, with the VTTI community continually challenged to leverage its capabilities, seek new funding opportunities and avenues, address ever-evolving needs of the transportation community, and discover areas in which the Institute can do what it does best: innovate in the name of safety.

RICK GRIFFITHS

VTTI **Today**

In 2016, the Virginia Tech Transportation Institute (VTTI) was named "Best of R&D in Virginia" by Southern Business & Development magazine, as selected by a group of approximately 50 economic developers, educators, economists, site consultants, and chief executive officers in the south.

The accolade speaks to the energy and passion the Institute as a whole puts into producing results that make a measurable impact on society. "For nearly three decades, we have worked tirelessly to create and enhance research and development efforts within the transportation community, with a forward-thinking approach that has allowed us to anticipate the needs of not only our sponsors and partners, but the public as a whole," said VTTI Director Tom Dingus.

"We have more than 475 employees and students who are dedicating their lives to the objective of advancing transportation through innovation," said Jon Hankey, director of research at the Institute. "With over 300 active projects performed with about 100 sponsors and partners—including government agencies, auto manufacturers, and suppliers—we are helping find answers to today's transportation challenges on state, national, and international levels while discovering opportunities for tomorrow."

Those projects—which are conducted in a variety of settings that range from test tracks to labs to public roadways—include naturalistic driving studies and access to resulting data, pavement, mobility, lighting, tire and vehicle modeling and simulation, and the development and deployment of the next generation of vehicular technology: connected and automated vehicles.

The Virginia Smart Road

During the late 1980s, national interest in smart cars and smart technology was growing. A 1990 Richmond Times-Dispatch article quoted U.S. Rep. Rick Boucher as saying Virginia was the first state to apply for federal funds to build a smart highway, which VTTI (then named the Center for Transportation Research) would design. The highway would be equipped with fiber optic sensors that used navigational computers to warn drivers when they were getting too close to the vehicle in front, when they were veering off the road, when they were approaching a hazard, and when it was okay to pass.

During the summer of 1991, the Roanoke Times reported, "A U.S. House of Representatives committee has approved Rep. Rick Boucher's request for $10 million for construction of a 'smart road' between Blacksburg and Roanoke." It was November by the time the proposal worked its way through the system and $5.9 million was awarded for a "smart road demonstration project." In December, President George H. W. Bush signed the Intermodal Surface Transportation Efficiency Act of 1991 with approximately $660 million authorized to intelligent vehicle/highway systems during the next six years.

In early 1992, the Montgomery County Board of Supervisors approved the smart road, which was also endorsed by the Town of Blacksburg, the Greater Blacksburg Chamber of Commerce, Roanoke City, Roanoke County, the Roanoke Regional Chamber of Commerce, the New River Alliance, and the Roanoke Times.

By the time the Smart Road was officially opened in 2000, it was in high demand for research purposes. Interest in the capabilities of the road have not waned, with more than 22,000 hours of research logged on the 2.2-mile closed test track. This research includes assessing the benefits and potential problems of a large number of advanced vehicle systems, such as active safety systems.

For more than a decade, the technologies tested on the Smart Road have ultimately been placed in vehicles. "One of the most rewarding aspects of this career is seeing technology that we had a role in improving on production vehicles," said Hankey. Such research continues today. For example, connected- and automated-vehicle technology is tested on the Smart Road prior to deployment in the real world to assess the potential for safety benefits while minimizing driver distraction and information overload.

When combined with its weather-making and highway lighting capabilities, the Smart Road also provides a powerful tool for evaluating visibility. One of the first federal studies to use the Smart Road was the enhanced night visibility project, which was designed to assess alternative light sources ranging from infrared technology to new headlamp designs that enhanced visibility during clear and inclement weather conditions. The Smart Road also served as the first roadway lighting test bed on which more than 95 percent of lighting configurations found on U.S. highways could be assessed. The Virginia Department of Transportation (VDOT) continues to use the Smart Road to measure the visibility of pavement-marking materials during wet weather and at night. The durability of successful pavement-marking materials is also assessed.

"We are providing dynamic solutions that consider the factors that impact visibility on our roadways, such as overhead lighting, pavement markings, and the interaction of vehicle lighting with the roadway. Our results have shown the potential to significantly reduce energy usage on roadways by up to 30 percent. We continue to study pavement delineation in the rain and more efficient methods to highlight roadway curvature."

-- Ron Gibbons, director, VTTI Center for Infrastructure-based Safety Systems

The all-weather testing capabilities offered by the Smart Road have also been essential for pavement friction, splash, spray, and sensor research. Today, different materials, infrastructure, and light sources found on both vehicles and along the roadway are being tested to improve driver performance and safety.

The Smart Road is also used for non-VTTI work. Local law enforcement personnel have conducted emergency maneuver and crash reconstruction classes on the road. Before being unveiled to the world on CBS in 2009, the blind-drivable dune buggy was tested for months on the Smart Road and at the Virginia International Raceway in Southern Virginia. Testing was performed as part of the Blind Driver Challenge during which a Virginia Tech-led team partnered with Blacksburg-based TORC Robotics to develop a technology that can convey real-time information about driving conditions to the blind motorist. In 2013, Google brought its self-driving car to the Smart Road for testing; at that point, it marked the only time Google had run its innovation on a roadway outside of its own facilities.

Heavy-vehicle simulator

"Pavements are the single most valuable asset in terms of patrimonial value within our transportation infrastructure. VTTI research and innovations have contributed to making pavement networks safer and more durable, comfortable, and environmentally friendly. We are enhancing the mobility of people and goods and contributing in this way to the economic development of the region, the state, and the nation."

-- Gerardo Flintsch, director, VTTI Center for Sustainable Transportation Infrastructure

While the Smart Road continues to receive attention from myriad sectors, other innovative VTTI developments are making equally significant impacts on transportation safety.

Naturalistic Driving Studies

VTTI Director Tom Dingus wanted to carve out a new niche at VTTI: to discover human behavior that results in crashes.

“More than 20 years ago, Andy [Petersen] and I were trying to decide how to build instrumented cars so we could observe drivers to determine reasons for crashes,” said Dingus. “The trouble with simulators and test roads is people know they are being tested. You can look at crash databases, but the police really don’t know what the driver was doing leading up to the crash.”

As a result of Dingus’ vision, VTTI has put 4,000 instrumented vehicles on the road and has collected data for nearly 2,000 crashes and minor collisions. But at first there were two vehicles, and instrumentation was a slow process.

Andy Petersen, who started at VTTI one month after Dingus, was his first hire. They had been at Iowa together, where Petersen did all of the hardware.

“Very early, instrumented cars required a lot of hardware. It was labor intensive and ugly,” said Petersen. “Computers, video records, and so on took up the trunk. Wires ran from the trunk to sensors in the console, the steering wheel, the pedals, turn signals, and speedometer … There was a huge glob of wires – a bundle two or three inches around under the carpet and under the vehicle. It took a month to instrument a car. That was how our first two instrumented cars were done.”

When VTTI was given a Volvo truck, Petersen wanted to make the instrumentation simpler. “I worked at home because I had more tools there for electronics. I redesigned the dash with a microprocessor-based, serially networked data acquisition system [DAS]. There was one communication cable from the trunk to the dash, and then we added nodes on the network that ran from the dash. Instrumentation time went from a month to a week,” he said.

“But then Tom said he wanted to do 100 vehicles. I said, okay, I have to redesign the DAS to be more installable. We hired more engineers, and we set a goal of two people doing one car in one day. We applied new technologies, like digital video and a computer designed for the space shuttle. The result was a success; two people could get the install done in a day. That made it possible to get enough funding to support the install time for the 100-Car Study.”

The award came in 2000 for the 100-Car Study, the first large-scale, naturalistic driving study ever undertaken.

The naturalistic driving data collection system that Petersen’s Center for Technology Development created for the 100-Car Study was disclosed as an intellectual property in 2002. The center began installing the instruments that would make it possible to observe real-world driving during January 2003, and the task was completed in June.

One hundred and nine primary drivers and 132 secondary drivers drove instrumented vehicles for 12 to 13 months during 2004 and 2005 in Northern Virginia and Washington, D.C. Researchers collected 42,000 hours of data from about two million vehicle miles of driving. The data covered 15 police-reported and 67 non-police-reported crashes; 761 near-crashes that required a rapid, severe evasive maneuver; and 8,295 incidents that required a less severe evasive maneuver.

The data collection technology included up to five channels of digital, compressed video; up to four radar sensors; machine vision-based lane-tracking systems; GPS; accelerometers; glare sensors; radio frequency detectors; and connections to the auto manufacturers’ in-vehicle networks to obtain other sensor information.

In the meantime, a number of naturalistic truck driving studies were begun at VTTI, including one that used 34 trucks and 102 drivers to develop a drowsy driver warning system. A naturalistic data set from commercial vehicle drivers included more than 200 drivers and three million miles.

The results of the 100-Car Study and of the truck studies were a wakeup call about distracted driving.

The May 2006 news release from the 100-Car Study sponsor, the National Highway Traffic Safety Administration, announced that driver inattention – “driver distraction” that included distraction from a specific source, a random glance away from the roadway, or drowsiness – was responsible for 80 percent of crashes and 65 percent of near-crashes.

The Impact of VTTI Naturalistic Driving Studies

For nearly two decades, the Virginia Tech Transportation Institute (VTTI) has undertaken a range of naturalistic driving studies that help tell the story of our transportation community. The method pioneered at VTTI involves equipping volunteer participants' vehicles with unobtrusive cameras, sensors, and radars that automatically and continuously collect driving parameters—including speed, time to collision, GPS location, acceleration, and eye-glance behavior—from key-on to key-off.

These studies provide a wealth of information, facilitating a direct observation of drivers' performance and behavior during the minutes or seconds leading up to a crash. Such data are continually used by researchers both internal and external to VTTI, government agencies, and automotive manufacturers and suppliers to assess the greatest risk factors faced by drivers, with the ultimate goal of ensuring the safety of the traveling public.

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- and near-crash data from drivers in the Northern Virginia/Washington D.C. area. Comprising more than 240 primary and secondary drivers and 8,300 events that include near-crashes and police- and non-police-reported crashes, the 100-Car Naturalistic Driving Study results became a mainstay in national discussions about driver distraction, error, and impairment. The data are still referenced today, with technical reports resulting from the study cited more than 2,000 times.

Second Strategic Highway Research Program Naturalistic Driving Study

Now considered the largest light-vehicle naturalistic driving study performed to date, VTTI and its partners led this National Academy of Sciences-funded project covering more than 3,500 drivers across six data collection sites in the United States. With more than 1,600 crashes and minor collisions identified in the data set, as well as nearly 3,000 near-crashes, this study marks the first known opportunity to assess driver risks on a large scale. New analyses from the study have already been published in Proceedings of the National Academy of Sciences, and VTTI is supporting more than 100 global users who are accessing study data for separate analyses.

Teens

The Teen Risk and Injury Prevention Group at VTTI was created to enhance the knowledge and understanding of the risks novice teen drivers face and how to apply this knowledge to improve safety. Teen drivers—particularly novice drivers—are overrepresented in our nation's fatality and injury crash statistics, with one out of every five young drivers in the U.S. involved in a crash within the first six months of driving. Under the guidance of Charlie Klauer, the Teen Risk and Injury Prevention Group is dedicated to reducing novice driver's high crash rates and saving teenage lives through research and outreach.

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Global Center for Automotive Performance Simulation: Revolutionizing Tire and Vehicle Testing

In 2010, VTTI publicized plans to move into the realm of tire testing. In 2013, the Institute, Virginia Tech, and the Institute for Advanced Learning and Research announced the opening of the National Tire Research Center located in Alton, Va., nearly a mile from the Virginia International Raceway. Designed to serve as an advanced tire research center and test facility, this unique initiative was created to offer a level and breadth of research, development, and testing currently unavailable anywhere else for automotive and tire manufacturers.

“Tire research, development testing, economic growth, and job creation in Southern Virginia became our mission,” said Frank Della Pia, executive director. “We dedicated ourselves to advancing the tools critical for research and development of tires and how they relate to vehicle performance and energy loss.”

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The hub of the National Tire Research Center is an $11.5 million force-and-moment machine (LTRe) created for passenger-car, light-truck, and motorsport tires. The LTRe is a superior product representing a transformational leap in technology by offering at least twice the capability in major performance areas across current tire test machines.

The National Tire Research Center created additional research and funding opportunities for vehicle manufacturers, tire manufacturers, the motorsports industry, local educational institutions, and government agencies. Transportation industry engineers and scientists work together to conduct research and testing that enable the industry to more rapidly introduce vehicles with newly developed technology.

It was expected that the innovative capabilities offered by the National Tire Research Center would attract other companies in the automotive or racing industries to locate in the Southern Virginia region. An economic study projected that the National Tire Research Center would have an economic impact of $147 million on the Southern Virginia region during its initial 10 years of operation, creating 183 jobs in the region by 2020.

Initial expectations for the center were exceeded; global customers rapidly began joining regional industry leaders coming to Southern Virginia to see this facility and to tap into the unique capabilities offered. As a result, it became apparent that a national center title was a misnomer. Thus, in 2014, the Global Center for Automotive Performance Simulation (GCAPS) was unveiled as a better representation of the expanded capabilities offered in Southern Virginia.

GCAPS comprises not only the National Tire Research Center, but also the Southern Virginia Vehicle Motion Labs, which offers vehicle-related services using a multi-post vertical dynamics test rig, data acquisition capabilities on both track and highway, and hardware-in-the-loop testing; and the Virtual Design and Integration Laboratory, which provides simulation, testing, and modeling support for tires.

Collectively, these initiatives provide the full range of services essential for creating a more dynamic product through both virtual and physical development. Using the technology available at GCAPS, researchers are pursuing the application of innovative materials and design to create a super tire that can adjust on the fly with the car and road without sacrificing wear or traction and can increase fuel efficiency, potentially saving billions of gallons of fuel annually. Researchers have completed numerous projects for major automotive manufacturers and aftermarket companies, using on-road or track data and vehicle response and suspension metrics to develop vehicles via subjective evaluations.

According to results of the truck studies, "Tasks that significantly increased risk included texting, interacting with a dispatching device and dialing a cell phone." A staggering finding was that texting while driving increased the risk of a safety-critical event among truck drivers by 23 times, said Rich Hanowski, director of the VTTI Center for Truck and Bus Safety.

The issue of cell phone use, particularly texting, began to be covered in leading newspapers such as the Wall Street Journal and the New York Times. The Times' series, "Driven to Distraction," received a 2010 Pulitzer for National Reporting for its coverage that was credited with laws and policies banning texting in many states.

Whether or not a result of New York Times' coverage, the "23 times" message helped lead U.S. Transportation Secretary Ray LaHood and the U.S. Department of Transportation to issue a call to end distracted driving. Dingus appeared before U.S. Congressional Subcommittees to testify about distracted driving and was an invited panelist at Secretary LaHood's Distracted Driving Summit. As a direct result of the summit, President Obama issued an Executive Order banning all text messaging for four million federal employees while driving government-owned vehicles and while driving any vehicle on official government business. The order also banned using mobile devices issued by the government while behind the wheel.

Currently, 46 states, the District of Columbia, Puerto Rico, Guam, and the U.S. Virgin Islands have banned text messaging for all drivers. Fourteen states, D.C., Puerto Rico, Guam, and the U.S. Virgin Islands prohibit drivers of all ages from using handheld cell phones while driving.

"The 100-Car Study was the first study large enough that you could statistically figure out what behavior was safe and what was unsafe," said Petersen. "You could see whether eating a hamburger was safer than talking on the cell phone."

"One thing that surprised us was that 70 to 90 percent of the time, crashes occur when drivers look away and something unexpected happens," said Dingus. "We were surprised it was that high. Looking away can be because the driver is distracted or because they are asleep," he said.

In particular, the study shined a light on teens' risky behavior, resulting in follow-up naturalistic driving studies with teens. A 40-teen study showed that, "A vast majority of teens' poor driving is due to a lack of judgment," said Dingus.

"We found that teen drivers know how to drive well, and when an adult is with them, the teen drives like an adult – following rules and not engaging in distracting tasks. But when there is no adult in the car with them, all that goes away," said Dingus.

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He favors delaying licensing or installing monitoring systems that give the teen immediate feedback when a rule is broken or the teen becomes distracted. The system would also report to the teen's parents. It would be like having a virtual adult in the car. Development of such a monitor was recently completed at VTTI and has been implemented in studies by the Teen Risk and Injury Prevention Group, led by Charlie Klauer. She points out that VTTI studies have revealed that crash/near-crash rates among novice drivers are nearly four times higher than for experienced drivers. "Newly licensed novice drivers are at a particularly high crash risk, in part because driving is a complicated task and novice drivers are still learning what constitutes a roadway hazard and what are appropriate and safe responses to these hazards," said Klauer.

But 100 cars cannot answer all questions. For example, the sample of people who do not always use seat belts was almost too small to provide a pattern. Wanting to extend findings with a larger sample of drivers and more robust demographics, Dingus told Petersen he wanted to instrument 5,000 cars.

"That eventually was about 3,300 vehicles," said Petersen. "But the DAS needed to be cheaper, more capable, and even quicker to install. So we went fully customized on two circuit boards."

The Center for Technology Development updated the software package installed in the DAS with modular, more easily configurable software. The update makes data more easily transferable from the DAS to data reduction systems. The center also developed machine vision and lane-tracking software for this next-generation DAS, aptly named the NextGen.

> "We try to do impactful research. We have 250 people doing safety research and more than 300 projects under way at any one time."
>
> -- Tom Dingus

"This second generation DAS was roughly the size of a book," said Petersen. "The cost went from $10,000 each to $4,000 each, and installation went to four hours for one person. That made the new study – the Second Strategic Highway Research Program Naturalistic Driving Study – possible."

The VTTI-developed MiniDAS

In 2007, the Transportation Research Board announced that VTTI was the prime contractor for the planning phase of the Second Strategic Highway Research Program Naturalistic Driving Study, the largest naturalistic light-vehicle study ever conducted. The planning phase would be the first stage of a multi-phase project. The VTTI-led research team, which included the University of Michigan Transportation Research Institute and the Battelle Memorial Institute, was chosen for this project largely due to its experience with the 100-Car Study, advanced DAS technology, and a comprehensive database.

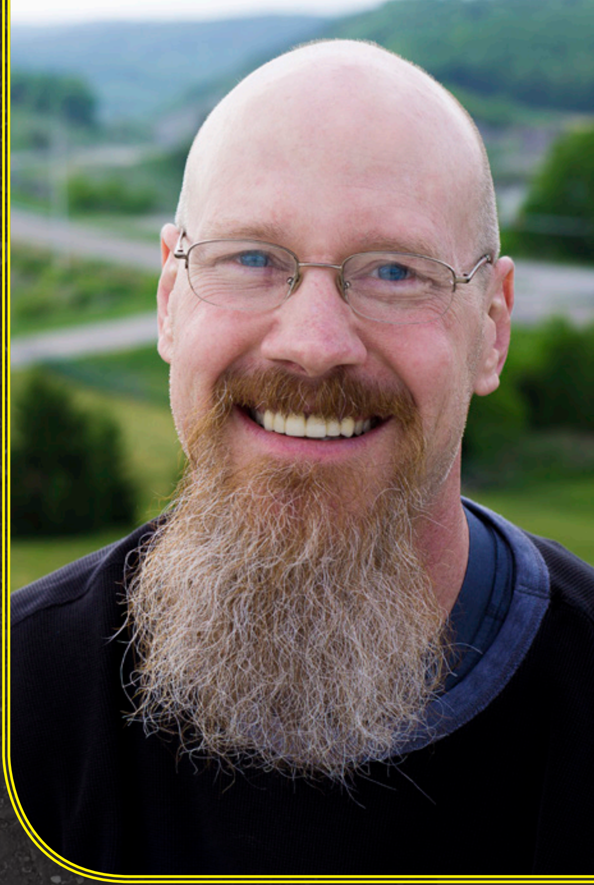
The Second Strategic Highway Research Program study resulted in data from more than 3,500 drivers, 4,000 data years, and 1,600 crashes and minor collisions. With the completion of the study, the Institute is further positioned to help fellow researchers, government agencies, automobile manufacturers, and suppliers more definitively assess the role of driver behavior and performance in crashes and near-crashes. New analyses using this study data set have already had a tremendous impact on the current understanding of crash risk factors such as distraction, impairment, and driver errors, with findings published in such high-impact journals as the Proceedings of the National Academy of Sciences.

The updated technology created for the Second Strategic Highway Research Program study also provided VTTI the capability to undertake the largest naturalistic truck study, the largest naturalistic motorcycle study, and opened the doors to international research. VTTI is currently conducting naturalistic driving studies in Canada, China, and Australia, with plans to expand data collection within these countries and to add new countries to its international efforts of improving transportation safety.

VTTI continues to develop and enhance the capabilities of its data collection system to answer the demands and challenges of subsequent studies. The latest iteration is the MiniDAS. "It is about the size of a hamburger and takes 30 minutes to install," said Petersen. For example, "a camera once the size of an apple is now the size of a pencil eraser," he said. The MiniDAS is being used in teen driving studies, in heavy trucks to observe the use of other advanced technology, and on motorcycles and bicycles.

Andy Petersen

Director of the Center for Technology Development



What brought you to VTTI?

Tom Dingus and I worked together at the Center for Computer-Aided Design at the University of Iowa. Tom was associate director, and I was the hardware group lead. When he became director of VTTI and needed a hardware guy, he asked me to come to VTTI. I felt comfortable coming here because I knew Tom was a rainmaker and soft funding would not be a problem.

How has your work evolved?

When I arrived, the center had a tape measure, a hammer, and a screwdriver. I worked out of my home for the first three years because I had the tools suitable for electronic design.

The hardware group enables research. We evolved the data acquisition system [DAS] to be more easily instrumented and better tailored to do human factors research. Tom's ability and my ability to play off of each other's strengths has resulted in custom hardware for human factors research that is pretty unique.

The DAS used in the 100-Car Study was about the size of a piece of carry-on luggage. Our group built the circuit boards and used PC hardware from the space program, which is pretty old technology now. The most recent technology, the MiniDAS, is about the size of a sandwich. In some ways it does more, although it has two cameras instead of four.

What are some other technologies your center has created?

We have created a number of technologies for use on the Smart Road. If a car company wants to test a warning system's impact on a driver, you want the test to be on a closed test course in case the driver is startled and steers off the road. A golden scenario is when the driver is looking away from the road and you trigger an event in front of them. We have all kinds of fun toys to create "startle events" for drivers: a surrogate target (a fiberglass shell of the rear of a car that is on bicycle wheels and is towed behind another car), fake bollards that pop unexpectedly out of the roadway, automated remote control inflatable deer that run out in front of you, and boxes that suddenly fall off trucks. The researcher distracts the driver in the following car by asking him or her to tune the radio, and then the startle event occurs in front of them, and they must react. Looking at this response is what our research is about. The experiment can be used to test brake lights, forward collision warning systems, and/or drivers' responses. If there is a collision, little damage is done.

The hardware group gets to build all of these things and figure out how to make them work – it's great fun.

What projects are next for your center?

A lot of research and development remains to be done on automated vehicles, such as: How does the human take over control? What should be done in emergency situations? How do you compensate for non-automated vehicles driving around you? Reliable pedestrian/animal/object detection needs to be developed. Does the car steer around a hazard or just pop out of automated control to let the human deal with the hazard? All these topics and more need to be studied and design guidelines and standards developed, then reliable technologies need to be invented to ensure the safe designs and implementation of full automation in vehicles. It's VTTI's desire to be on the cutting edge of this new human-machine interface design problem.

What do you enjoy most about being at VTTI?

I like the atmosphere. It is fun to be part of a research group that's at the cutting edge. And personally, I enjoy the mechatronics of it all: computer control, moving motors with computers, and looking at and analyzing the data.

Big Data

The numerous naturalistic driving studies conducted at VTTI obviously result in copious volumes of data—more than 2.5 petabytes so far. The Institute has become home to nearly 90 percent of continuous naturalistic driving data in the world, making it a "big data" leader.

Big data has become the next frontier for innovation, competition, and productivity, according to the McKinsey Global Institute. A New York Times article called data scientists "magicians" and emphasized the potential of enormous amounts of data created by modern technologies. Data scientists "crunch the data, use mathematical models to analyze it, and create narratives or visualizations to explain it, then suggest how to use the information to make decisions," the Times reported.

"VTTI has been doing big data for more than a decade," said Brian Daily, software developer for the Institute.

When Daily arrived at VTTI in 1995, it was still known as the Center for Transportation Research and was housed in one suite in a building at the Virginia Tech Corporate Research Center.

Daily was hired as systems administrator and a software developer. He had received a B.S. in electrical engineering with a minor in computer science from Virginia Tech in 1992, and he was glad of the opportunity to get back to Blacksburg. As data grew, he became a full-time software developer and database administrator for VTTI research databases.

Connected-vehicle applications

The first projects to create large databases were the 511 project and the 100-Car Study.

VTTI began work on the Travel Shenandoah project in 1999 as an advanced traveler information system that would be available on the web and by cell phone. Daily and former VTTI employee Aaron Schroeder wrote the software and created the website.

Daily built the voice XML system – the interactive voice dialogs between a human and a computer. "People can ask for information on a range of topics," he said.

Travel Shenandoah became the statewide 511 service. Virginia was among the first states to have 511. Initial support came from Shentel, VDOT, the Virginia Tourism Corporation, and the Intelligent Transportation Systems Implementation Center. As the program evolved, it was supported by VDOT. The VTTI Center for Technology Development completed data provisions for the 511 project in 2004 and evaluated the project with focus groups and surveys. The project was renewed, and as of today, the VTTI Smart Road operations group serves as the primary quality assurance/quality control agency for the VDOT 511. It is a solid tool that assists travelers in avoiding congestion and negotiating roadways made dangerous by bad weather. Services include the website, an interactive voice response phone system with information for 400 roads, VA511 Alert emails, and message boards at nine welcome centers.

The stunning results of the VTTI-led 100-Car Study and subsequent demand for naturalistic driving studies created an increased need for data analysis. VTTI responded by further refining existing internally developed tools to facilitate data mining, providing easier visualization and manual extraction of data. Formal data reduction labs were developed with the primary purpose of extracting valuable information from existing data sets. All data are stripped of personally identifying information, such as participants' names.

Sponsors were quick to realize the potential for using existing data to answer a multitude of research questions. Automotive manufacturers and researchers from the National Highway Traffic Safety Administration, the Federal Highway Administration, and VDOT were among the first to see the value of using 100-Car Study data. The findings would aid in the development of collision avoidance systems and give car companies an opportunity to design safety systems that can be tailored to drivers.

The agencies also wanted to study specific distraction factors, such as what tasks related to the use of cell phones and other handheld devices are the riskiest and what other behaviors are distracting. In other words, sponsors wanted an in-depth analysis of driver inattention to establish direct relationships between driving distraction and crash/near-crash involvement. They also wanted to examine such factors as driving while impaired, instances of aggressive driving, illegal maneuvers, and the age and experience of the driver.

Where the roadway infrastructure was a contributing factor in crashes, there were questions about alignment, delineation, traffic control devices, weather, and visual obstructions. When crashes were rear-end collisions, the questions concerned following distance.

In 2004, the Federal Motor Carrier Safety Administration funded further analysis of data from the 2003 VTTI Drowsy Driver Warning System study. The original study, which was to take three years, was created to evaluate the effectiveness of a particular device. But the Federal Motor Carrier Safety Administration asked that the data also be analyzed to assess light-vehicle/heavy-vehicle interactions, crash and near-crash incidents with countermeasure recommendations, driver alertness as related to lane keeping and speed, driving patterns, and characteristics of high-incident drivers.

VTTI began its next set of naturalistic driving studies during 2006. With this ramp up of new data and increasing sponsor interest, VTTI saw the need to further develop its data-mining capabilities. In 2008, Clark Gaylord was hired as chief information officer to lead the information technology efforts and to build VTTI data-mining and analysis capabilities to a new level. "VTTI is poised to become the national repository for naturalistic driving data that will change the way safety research is conducted," VTTI Director Tom Dingus wrote in the annual report. "As the national repository, we expect to be the source of data for international and national researchers for at least the next 20 years."

By 2010, VTTI was the recognized leading expert for in-vehicle, real-world transportation data collection; in 2012, VTTI was the recipient of the CIO Magazine "CIO 100" award for the innovative and effective use of large-scale, data-intensive, and high-performance computing infrastructure.

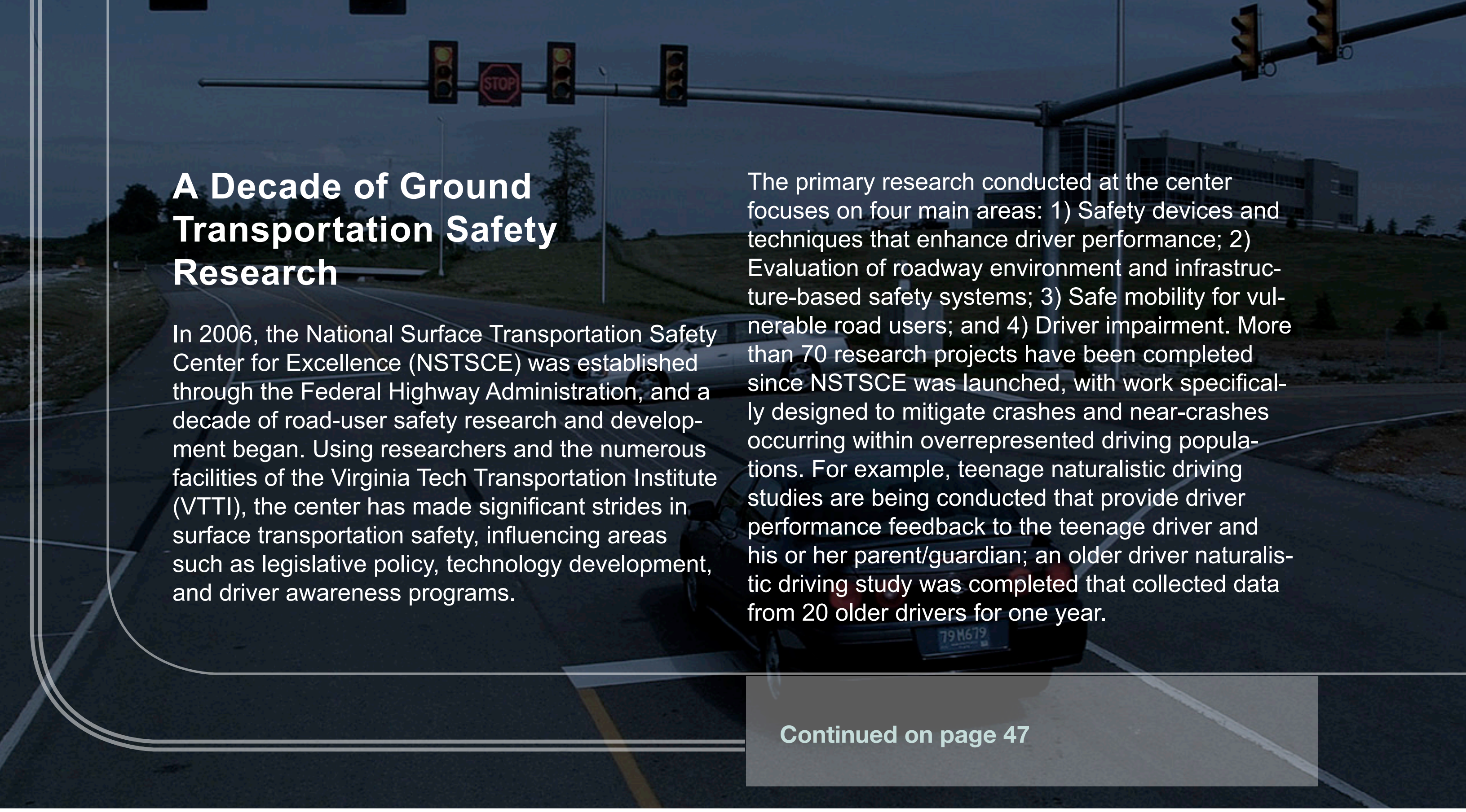
The Institute's Smart Data Center burgeoned from 40 terabytes to 100 terabytes with an expectation of further growth to 1.5 petabytes because of the Second Strategic Highway Research Program Naturalistic Driving Study. The data center continued to service national and international researchers while starting to provide data sets for public

Clark Gaylord

Chief Information Officer

Clark Gaylord is the chief information officer and director of data center operations for VTTI. Throughout his career as an IT professional, he has led many efforts supporting scientific research and advancing the high-performance networking, computing, and information security of the campus environment. Since 2008, he has led the strategic direction for information technology, data center infrastructure, and big data management and analysis at the Institute. He is the principal architect of the VTTI Scientific Data Warehouse, integrating high-performance computing, parallel database, and peta-scale file system technologies to enable data-intensive scientific research.

In addition to his work at VTTI, Gaylord works closely with his peers across campus to design the networks, storage systems, and clusters supporting the greater research computing missions of Virginia Tech. He continues to be involved with his peers in the Internet2 community and is a member of the network security team for SCinet—the high-performance network of the SC supercomputing conference. With his background in mathematics and statistics, he has always held a keen interest in advancing science through data analysis, and the VTTI data-intensive program is an ideal fit for his expertise.



A Decade of Ground Transportation Safety Research

In 2006, the National Surface Transportation Safety Center for Excellence (NSTSCE) was established through the Federal Highway Administration, and a decade of road-user safety research and development began. Using researchers and the numerous facilities of the Virginia Tech Transportation Institute (VTTI), the center has made significant strides in surface transportation safety, influencing areas such as legislative policy, technology development, and driver awareness programs.

The primary research conducted at the center focuses on four main areas: 1) Safety devices and techniques that enhance driver performance; 2) Evaluation of roadway environment and infrastructure-based safety systems; 3) Safe mobility for vulnerable road users; and 4) Driver impairment. More than 70 research projects have been completed since NSTSCE was launched, with work specifically designed to mitigate crashes and near-crashes occurring within overrepresented driving populations. For example, teenage naturalistic driving studies are being conducted that provide driver performance feedback to the teenage driver and his or her parent/guardian; an older driver naturalistic driving study was completed that collected data from 20 older drivers for one year.

Continued on page 47

download. Development and maintenance of these public data sets were funded by the National Surface Transportation Safety Center for Excellence. Based on its increasing size and importance within the research community, the Smart Data Center was renamed the International Center for Naturalistic Driving Data Analysis at Virginia Tech.

The National Surface Transportation Safety Center for Excellence continues to take advantage of VTTI data-mining skills and capacity. The center comprises a stakeholders' committee that includes General Motors Corporation, VDOT, Travelers, and the Federal Motor Carrier Safety Administration. "This consortium, which serves as an ideal example of collaboration among public and private sectors, is greatly interested in improving transportation safety and understands the value of using big data and naturalistic driving studies to collect such data," said Jon Hankey, director of research at VTTI.

In 2008, the National Surface Transportation Safety Center for Excellence launched a new analysis of the 100-Car Study data to develop statistical models to investigate risk factors associated with crash events, including age, gender, weather, traffic, fatigue, and driver behavior.

The center stakeholders also decided to support a health and fatigue study for commercial motor vehicle drivers. The goal was to determine the need for and potential effectiveness of a diet and exercise guide to encourage a healthy lifestyle and reduce fatigue among this driving population whose work schedules create special challenges. Once again, data mining was the resource. The study examined data sets from the VTTI Drowsy Driver Warning System field test to investigate the relationship between a driver being overweight and the risk of involvement in a crash.

Data from the 2006 VTTI Naturalistic Truck Driving Study continue to be analyzed to assess the relationship between prescription and over-the-counter drug use and involvement in safety-critical events. Volunteer drivers kept logs and reported medications they took, the time of the medication, and the dosage. Data from the same study are also being analyzed to determine the differences in sleep characteristics, cognition, medication use, and crashes categorized by age.

The National Surface Transportation Safety Center for Excellence also funded in part an analysis of data from a VTTI naturalistic teen driving study to examine which driving performance parameters and situations -- such as speeding, hard braking, and following too closely -- should be used to provide feedback about unsafe driving to newly licensed teens, with the goal that the selected measures would be programmed into teen driving monitoring devices.

In 2009, VTTI worked to implement feedback received about its commercial driver monitoring technologies into its hardware and software product concept. The hardware application included a "black box" DAS that could be mounted on commercial trucks to capture a variety of measures that could be used to evaluate the safety and operational performance of the individual driver. The software applications included all of the necessary functions to support efficient transfer of data from vehicles to a data storage center, accurate analysis of the collected data, and access to the data for fleet safety managers.

In 2011, VTTI began a project to further improve its ability to support researchers and general access to data. The Second Strategic Highway Research Program Naturalistic Driving Study—sponsored by the National Academy of Sciences—funded a variety of tools and data sets designed to answer this goal. The project included a data access website called InSight that now houses driver, vehicle, and naturalistic data, and workshops are held that provide technical support for users. Data sets that include trip summary files, crash files, and near-crash files have been placed on the website, with the expectation that such information be used to answer research questions and to provide insight into the most applicable types of data to be mined.

Following the completion of the Second Strategic Highway Research Program study, the National Academy of Sciences awarded a sole-source contract to the Institute to further support use of the study data set housed on InSight. To date, the Institute has contracted with more than 100 users across the globe seeking to access this vast data resource.

In 2013, the VTTI Center for Data Reduction and Analysis Support was created to aid users of naturalistic driving data. This center works closely with researchers internal and external to the Institute to support access to and analysis of numerous data sets housed at the International Center for Naturalistic Driving Data Analysis at Virginia Tech. "As researchers deeply interested in public safety, we understand the need for data-driven and timely decisions," said Miguel Perez, director of the Center for Data Reduction and Analysis Support. "As an Institute, we have committed an unparalleled amount of capital and resources to collecting a vast amount of driving data. Our big data warehouse allows us to leverage those data beyond finding answers to the important research questions of the past and into developing the type of understanding that will yield the traffic safety breakthroughs that our society needs."

As the largest repository of real-life driver behavior data, VTTI is able to provide the information that will ultimately enhance driver safety, including data about applications such as vehicle safety systems and driver training programs. The repository will only continue to grow, with new studies designed to assess the efficacy of emerging technologies, including connected and automated vehicles.

VTTI/Center for Injury Biomechanics Crash Sled Lab

The VTTI/Center for Injury Biomechanics Crash Sled Lab celebrated its grand opening during 2009.

The jewel of this 10,000 square-foot lab is a 1.4 meganewton ServoSled System manufactured by Seattle Safety. The sled is used during the study of transportation-related trauma with primary applications found in the automotive environment. This is the only facility in the world with unique capabilities ranging from high-rate impact testing to high-rate imaging. These tools allow center researchers to be leaders in nationally and internationally funded research.

The crash sled helps center researchers better understand the mechanisms of injury and develop better mitigation schemes and protection systems, thereby saving lives. For example, the system can be used to recreate crash pulses from real-world crashes during which people sustain serious injuries.

"It is the mission of the Center for Injury Biomechanics to reduce the cost to society related to injury and the treatment thereof by providing the basic response data needed to mitigate, if not eliminate, the potential for injury that might exist in all aspects of the human experience," said Warren Hardy, center director.

The facility also allows researchers to answer fundamental questions regarding injury mechanisms specific to the military environment. "We will examine blast-induced brain trauma and mechanisms to reduce the risk of injury to the eyes and facial bones," said Stefan Duma, head of the Virginia Tech – Wake Forest University School of Biomedical Engineering and Sciences.

The lab, which is located in the Virginia Tech Corporate Research Center, is primarily funded by the National Highway Traffic Safety Administration.

Stefan Duma (left) and Warren Hardy

LOGAN WALLACE

Thomas A. Dingus

Director

To be an innovator is to evolve.

To innovate means growing to not only answer new challenges, but to anticipate their arrival and to do so with an understanding of how we arrived at such a point.

Since its inception, that is exactly how the Virginia Tech Transportation Institute (VTTI) has approached the realm of transportation safety.

We have always strived to do better and to be better. Because of our tenacity and unremitting belief in a safer, more mobile, and more sustainable transportation environment, we have made it our goal to help fellow researchers, government representatives, major automobile manufacturers, and suppliers achieve what others perceived to be impossible but what we saw as more than feasible—we saw it as necessary.

When the transportation research community needed to actually observe the greatest risk factors faced by drivers—and not just depend on crash reports or simulations—VTTI filled this research gap by creating the naturalistic driving study method. This method has resulted in thousands of hours and millions of miles of real-world data that have pushed society to come face-to-face with what is causing crashes, from distraction to fatigue to driver judgement and performance errors. Since our first large-scale naturalistic driving studies in the early 2000s, the Institute has been able to inform local, state, and national policies that seek to mitigate dangerous driving behavior. The results of these studies—published more recently in the New England Journal of Medicine and Proceedings of the National Academy of Sciences—continually draw attention to such issues as driver distraction, fatigue, and impairment. To further inform the public of these risk factors, we wrote "Survive the Drive," taking hard statistics and pairing them with personal experiences and stories designed to both educate and entertain.

User needs in a transportation environment have always shifted; they are never stagnant. From that basic understanding, VTTI has looked towards the horizon and worked with collaborators, sponsors, and partners to prepare for what we foresaw. That is why, for nearly three decades, we have worked to study the next generation of vehicular technology: connected and automated vehicles.

Since 1996, the VTTI community has facilitated the development of numerous advanced safety systems--such as forward collision warnings and lane-departure warnings--that once seemed to be a luxury but are becoming more prevalent in newer, affordable vehicles. We have conducted more than $30 million in connected-vehicle projects and are working with industry leaders to develop safe and reliable automated vehicles. In less than two years, VTTI and its partners have unveiled two new initiatives—the Virginia Connected Corridors and the Virginia Automated Corridors—designed to revolutionize the development and deployment of connected and automated vehicles.

Our research is proving the multitude of benefits to be derived from the integration of connected and automated vehicles into the transportation environment. When deployed safely and as intended, the possibilities afforded by these technologies have few limits: they can enable advances in pavement maintenance and sustainability, they can help significantly increase mobility and reduce traffic congestion, they can lead to significant reductions in both cost and environmental impact when it comes to road lighting, and they can mitigate driving in unsafe conditions and crashes overall.

But, while user needs are changing, it remains imperative for us as a research community to ensure new technologies are developed and implemented in a consistent manner that only increases safety and mobility. Thus, the VTTI community works tirelessly as a team across the entire ground transportation spectrum, from the road, to the tire, to the chassis, to the safety systems installed and their impacts on users, to the human factors, to the environment that envelops transportation users as they flow from Point A to Point B. We work collectively to forge the future by understanding the past and today. We know we cannot hastily forego what is intrinsic to current transportation, because we understand that successful innovation happens incrementally.

At VTTI, we do not take lightly our motto "advancing transportation through innovation." We seek every day to embody those words, and we strive as a community to make life on the roads safer for everyone.

Gerardo Flintsch

Director of the Center for Sustainable Transportation Infrastructure, Professor of Civil and Environmental Engineering at Virginia Tech

Since the mid-1980s, Gerardo Flintsch has worked in the areas of asset management, pavement engineering, and sustainability. "When I finished my undergraduate studies in civil engineering, I really enjoyed civil engineering software development and had planned to build a career designing bridges," said Flintsch. "However, I was also working for the National Highway Administration of the Ministry of Transportation and Publics Works in Uruguay and got assigned to lead a new office that was responsible for the development of a pavement management system and the acquisition of state-of-the-art pavement evaluation equipment as part of the agency modernization efforts. I loved the opportunity to use innovative technologies for improving the way we preserve and renew our transportation infrastructure and have been working in that field since then."

While at VTTI, Flintsch has been instrumental to establishing strong partnerships with the Virginia Department of Transportation (VDOT) and the Virginia Transportation Research Council. This collaboration eventually led to the Virginia Sustainable Pavement Research Consortium, which has positioned itself as a world leader in pavement and materials research and education. The consortium is often cited as an example of collaboration between government, academia, and industry. Collaborative efforts initiated during the construction of the Smart Road have also evolved into a strategic, long-term, multimillion-dollar pavement research program that includes an agreement to operate a $2.5 million accelerated pavement machine that simulates the wear and tear induced by repeated passes of heavy trucks on a highway, as well as two nationwide pooled-fund projects focused on pavement surface properties and pavement sustainability.

Flintsch's recent and ongoing pavement research includes projects to improve the ride quality and safety of pavement surfaces; the development of innovative pavement assessment tools using instrumented vehicles and smart tires; the development of robust splash and spray and hydroplaning models for pavements; the development of continuous pavement deflection measuring technologies; and assessing and improving the sustainability of pavement materials, systems, and networks. These projects have already resulted in significant improvements in the quality of the service provided to roadway users and important maintenance and rehabilitation savings not only for VDOT but for transportation agencies around the world.

What attracted you to perform research at VTTI?

In 1997, I had the opportunity to join the Civil and Environmental Engineering Program at Virginia Tech where I have continued to build an academic career aimed at developing innovative, efficient, sustainable, and resilient solutions for designing, constructing, and managing infrastructure facilities, networks, and systems. I'm simultaneously educating the next generation of civil engineers to have a solid academic foundation, be creative and resourceful, and appreciate the social, economic, and environmental impacts of our civil engineering profession.

I joined VTTI just as construction of the Smart Road was beginning. This allowed us to build the Smart Road as the first full-scale pavement research facility in the world, built from the ground up with its infrastructure incorporated into the roadway. We had the opportunity to create the Roadway Infrastructure Group, which has evolved into the Center for Sustainable Transportation Infrastructure [of which Flintsch is director]. The center currently includes state-of-the-art laboratories and field testing equipment and employs five full-time researchers; has ongoing collaborations with colleagues from different departments, colleges, and institutions; and regularly supports 12 to 15 graduate students and a number of undergraduate students.

What does the future hold for pavement research?

My long-term vision is to continue to find innovative and efficient solutions for making our infrastructure more sustainable and resilient. Our goal is to invent and implement the pavement of the future, which we believe must be sustainable, multifunctional, durable, and resilient and provide safe, smooth, and quiet rides for a transportation fleet that is becoming more sophisticated, connected, and automated. To achieve this goal, we are trying to maximize the use of recycled materials into the pavement systems while improving long-term performance where possible, incorporating sustainability and resiliency considerations into infrastructure design and management processes; maximizing the use of existing infrastructure by optimizing how we use our existing systems; and developing, testing, and deploying the materials, multi-functional systems, and networks of the future.

THE ROAD TO THE FUTURE

Beyond the importance of naturalistic driving studies and big data, "there are transportation technology improvements that, if correctly implemented, have a great potential to save lives, save time, save money, and protect the environment. Connected- and automated-vehicle technologies truly have the promise to improve the driving experience from a safety perspective," said Tom Dingus, director of the Virginia Tech Transportation Institute (VTTI).

National opportunities in the intelligent vehicle/highway system arena were the impetus for starting what eventually came to be VTTI, and aspects of vehicle/infrastructure connectivity and automation have been studied at VTTI for nearly three decades. When it was only three years old, VTTI was named one of the three national Intelligent Vehicle/Highway System (IVHS) Research Centers of Excellence.

VTTI and the Virginia Department of Transportation (VDOT) installed modest intelligent transportation systems into the Smart Road during construction, including pavement data acquisition systems (DASs) and magnetic tape for vehicle position location. By the time it was operational for two years, the Smart Road was developed into the first reconfigurable test bed for wireless transportation applications.

In 2001, the Smart Road gained significant infrastructure for an intelligent transportation system initiative. An instrumented intersection was added with signals that could be controlled externally. These technologies allowed for research into intersection decision-making, such as yellow-light responses. VTTI research about driver response to yellow lights presented the concept of the dilemma zone, where the driver can neither stop nor proceed through the intersection before the light turns red. The research earned rave reviews at the 2002 Intelligent Vehicle Initiative national meeting and resulted in a new standard for the timing of yellow lights. Subsequent published research resulted in a $20.9 million award in 2007 to study intersection collision avoidance. The award came from a consortium of vehicle manufacturers known as the Crash Avoidance Metrics Partnership.

By 2010, VTTI had designed, developed, and tested a vehicle/infrastructure integration safety application. The prototype system prevented crashes by predicting stop-sign and signal-controlled intersection violations and warning the offending driver. Instrumented intersections sent messages to the vehicle, which predicted whether or not the driver would stop based on speed and distance. The driver was warned with visual and auditory messages and a brake pulse. Test-track and Smart Road test results were excellent, and the success of this project led to VTTI participation in the Crash Avoidance Metrics Partnership-sponsored Safety Pilot Model Deployment. This large-scale initiative, which was designed to test connected-vehicle systems, required Institute researchers to design, develop, and instrument 72 vehicles with DASs. VTTI then monitored and maintained the condition of every equipped light vehicle.

In 2011, the National Highway Traffic Safety Administration contracted with VTTI to assess safety concerns about the potential for information overload from connected-vehicle applications and

displays. As a result of this and other human factors research, Battelle Memorial Institute and VTTI developed a framework for the Human Factors Guidelines for Connected Vehicles in 2011. Guidelines continue to be updated as research progresses.

Outside of the Smart Road, VTTI started to transform Blacksburg – the hometown of Virginia Tech – into the first real-life test facility in North America. The National Science Foundation provided $750,000 for the revolutionary project, which would allow the study and control of traffic flow, testing of alternative means to disseminate real-time traveler information, evaluations of energy and environmental impacts of transportation projects, testing of emerging intelligent transportation system technologies, and evaluations of surveillance and communication technologies. Resulting data would allow VTTI to compete for additional research.

"Almost 20 years ago, there was an initiative by the U.S. Department of Transportation for automated vehicles. VTTI realized even then the potential for automated vehicles and has been working in that arena ever since," said Andy Petersen, director of the VTTI Center for Technology Development, which creates all of the hardware and software for VTTI instrumented vehicles. "Now the technology is here to support sophisticated connected and automated vehicles. About a decade ago, there were not the Wi-Fi networks, and cell phone range was spotty. Now, applications that were developed for the consumer market are making it to cars."

"There are hundreds of connected- and automated-vehicle applications that will save lives and make roads more efficient," said Dingus.

Myriad projects assessing next-generation vehicular technology are being performed at the Institute. Since 2005, the Institute has conducted more than $30 million in connected-vehicle research and facility development. Researchers have worked with multiple automotive manufacturers and suppliers to develop, test, and help deploy driver assistance systems and automated and connected vehicles. The VTTI-affiliated Center for Injury Biomechanics completed a project for the Centers for Disease Control and Prevention that looked at automated collision notification systems being used as event data recorders, which would help during crash response. The recorders could predict the likelihood of injury and severity to help emergency personnel make decisions about response needs even before such personnel arrive at the scene of a crash. The center developed algorithms allowing event recorders to process impact information in terms of injury potential.

The VTTI Center for Sustainable Mobility is working on vehicle-to-vehicle communication at intersections; another center project includes the development of the eco-cooperative adaptive cruise control system that essentially assists the driver in—or fully automates—the action of slowing or accelerating a vehicle according to the traffic light ahead.

On the automation side, Institute researchers are working with such industry leaders as General Motors (GM) and Google to conduct human factors testing of automated vehicles. The Institute was also awarded a master contract through the National Highway Traffic Safety Administration worth up to $25 million across five years to study the human factors of automation and cybersecurity issues. The contract comprises 32 teaming members, including BMW, Carnegie Mellon, GM, Google, TORC, and the Virginia Tech-based Hume Center and Virginia Center for Autonomous Systems.

Today, real-world, large-scale connected-vehicle/infrastructure research is under way in a bigger city and on

Connected and Automated Testing

Virginia Connected Corridors (unveiled in 2014): Smart Road, Interstates 66 and 495, U.S. 29 and 50

- A developer-friendly environment that supports third-party application development and deployment
- Data exchange services, including data warehouse and clearinghouse implementations
- Free application program interfaces and reference applications to simplify the development of connected-vehicle applications
- Access to more than 60 roadside equipment units installed on a mix of freeways and arterials that are connected to a low-latency backhaul network
- A phased test and deployment process that supports the migration of safety-critical applications from test tracks to live public roadways
- A corridor visualization application that supports situational awareness for deployed application functions
- An integrated vehicle instrumentation and data acquisition system to support post-deployment safety assessments of applications

Virginia Automated Corridors (unveiled in 2015): Smart Road; Interstates 66, 495, and 95; U.S. 29 and 50; Virginia International Raceway

- Access to dedicated high-occupancy toll lanes in conjunction with Transurban, which develops and manages more than 40 miles of express lanes located along the corridors
- Pavement markings implemented in conjunction with the Virginia Department of Transportation, which will maintain standards for both completeness of markings and retro-reflectivity properties
- High-definition mapping, real-time traffic and incidents, intelligent routing, and location cloud technology for automated and connected vehicles supported by HERE
- Ubiquitous 1 cm accurate localization facilitated by a multichannel, high-precision global navigation satellite system with real-time kinematic corrections, an inertial navigation system providing dead-reckoning, and an update rate up to 100 Hz
- Sophisticated, unobtrusive data acquisition systems that record time-synchronized data to the nearest millisecond using multiple (i.e., two to six) cameras and sensors
- Remote monitoring and data streaming
- Existing connected-vehicle infrastructure and systems installed along the Virginia Connected Corridors
- Access to the Virginia International Raceway, which features blind passes and curves
- No bond required for automation testing in Virginia; licensing and insurance provided through the Commonwealth, with Institutional Review Board approval and certification for safe human research involvement facilitated via VTTI

Virginia Smart Village (plans underway)

- Residential/suburban layout with real buildings, "portable" reconfigurable buildings, and other infrastructure elements
- Roundabout/stop-controlled intersections
- Automation-compatible pavement markings
- Two rural road test sections, with many horizontal and vertical curves
- Connectivity to the Smart Road, which includes a highway layout, signalized intersection, and weather and lighting generation
- More than 140 acres of additional space (300 total) for testing

faster, more congested roads. In 2014, VTTI partnered with VDOT to expand upon its connected-vehicle capabilities with the unveiling of the Virginia Connected Corridors. This initiative facilitates the real-world development and deployment of connected-vehicle applications using more than 60 roadside equipment units—which essentially allow vehicles to "talk" to other vehicles, infrastructure, and devices—installed along the Smart Road and in Northern Virginia. Envisioned to enhance mobility, increase sustainability, and save lives, connected-vehicle technology has been lauded by the U.S. Department of Transportation and is expected to decrease crash risk by up to 70 percent.

Using the Virginia Connected Corridors, VTTI is working with the University of Virginia and Morgan State University through the Tier 1 Connected Vehicle/Infrastructure University Transportation Center to perform more than 20 active projects designed to assess connected applications. For example, in cooperation with Virginia Tech faculty, VTTI researchers have developed short-range communication technologies mounted on vehicles and worn by workers in work zones to alert the workers and vehicle operators when an on-foot worker is in danger of being struck.

Another connected-vehicle project is anticipated to reduce school bus and vehicle collisions. Buses are particularly susceptible to being struck from the rear because of frequent stopping. Connected-vehicle communications could be used to provide following traffic with in-vehicle notifications of a stopped bus, especially when the bus is stopped over a hill or around a blind curve.

Other projects include safety and human factors aspects of adaptable stop/yield signs; the development of a connected-vehicle-compatible motorcycle helmet; connected-vehicle applications for adaptive lighting; intersection management using an in-vehicle speed advisory; eco-speed control; emergency vehicle-to-vehicle communication; freeway merge management; infrastructure safety assessment; infrastructure pavement assessment; and connected-vehicle/infrastructure application development for addressing safety and congestion issues related to public transportation, pedestrians, and bicyclists.

Future research projects include optimized routing, road hazard reporting, optimized de-icing, creating beacons for at-risk pedestrians, and vehicle-to-vehicle communication to enhance rear signaling.

"The Virginia Connected Corridors experience the very real and significant transportation challenges in terms of congestion, safety, and environmental impacts that are of concern nationwide," said University of Virginia Consortium Leader Brian Smith, professor and chair of the department of civil and environmental engineering. "Through this test bed, our research team has the opportunity to develop, test, and demonstrate tangible connected-vehicle applications that will have a positive impact on the travelers' experience."

The connected-vehicle fleet at VTTI, which includes six cars, four of the only connected motorcycles yet in existence, a semi-truck, and a bus, has forward collision, road-departure, blind-spot, lane-change, and curve speed warning systems and advanced GIS. The fleet also features sophisticated recording devices that download to VTTI so researchers can observe conditions in real time and accumulate data for later transportation analyses.

Zac Doerzaph, director of the VTTI Center for Advanced Automotive Research, explained that instrumented vehicles traveling on the connected test bed are alerted if they are at risk of a crash, and critical roadside information is communicated directly for the driver to see on the dashboard. The technology can also communicate car and road information such that alerts can be sent to other drivers. For instance, detection of slick pavement or the presence of roadway debris could be gathered from one vehicle, sent to the roadside detector, and quickly disseminated to other vehicles on the system.

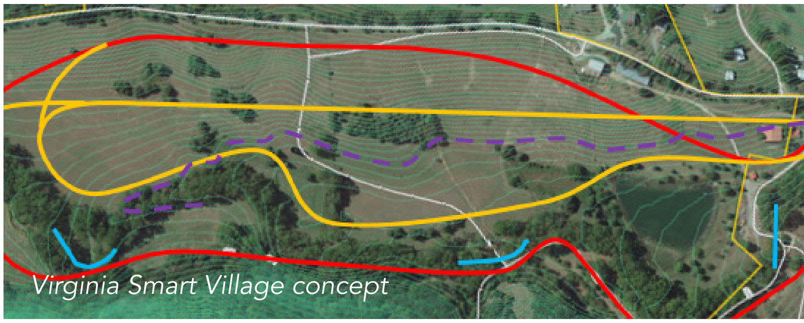
As part of the Virginia Connected Corridors, the Smart Road provides a closed environment on which experimental procedures can be tested. Instrumented portions of Montgomery County add to the variety of road types and topography that are part of the project.

On the automation end, the governor of Virginia released a proclamation in 2015 declaring the Commonwealth "open for business" for automated-vehicle work, naming the VTTI Center for Automated Vehicle Systems the leader in automated-vehicle research and partnership development. In response to this proclamation, VTTI partnered with VDOT, the Virginia Department of Motor Vehicles, Transurban, and HERE (a high-definition mapping business) to create the Virginia Automated Corridors.

The Virginia Automated Corridors—which build upon the capabilities of the Virginia Connected Corridors and comprise the Smart Road; Interstates 66, 495, and 95; and U.S. 29 and 50—will provide an automation-friendly environment that government agencies, automotive manufacturers, and suppliers can use to test and certify their systems via a system-migration path from test-track to real-world operating environments. The automated corridors will leverage extensive experience in on-road safety research to provide efficient solutions to automated-vehicle testing.

The Institute is now working towards the creation of a new Virginia Smart Village, which will eventually cover more than 300 acres—including the Smart Road—that will facilitate multiple testing scenarios across numerous automated-vehicle platforms. The village is envisioned to encompass a residential/suburban layout that features real buildings and reconfigurable buildings, roundabout/stop-controlled intersections, automation-compatible pavement markings, hills and curves, and connectivity to the Smart Road. The village will be developed in consultation with campus representatives and industry stakeholders.

With such a robust past and present as its foundation, and with a future that is markedly strong, VTTI is poised to continue filling that niche its director identified more than two decades ago: saving lives, saving time, saving money, and protecting the environment through innovative research endeavors that make a positive impact on society.


Virginia Smart Village concept

DEVELOPMENT OF A $110 MILLION INFRASTRUCTURE

1988

VTTI (then called the Center for Transportation Research) is established in response to the U.S. Department of Transportation University Transportation Centers Program as part of a Penn State team and in cooperation with the Virginia Department of Transportation (VDOT).

1989

Discussions begin to build a "smart road" alongside a proposed highway between Blacksburg and Roanoke.

1994

Virginia Tech is part of a consortium headed by General Motors awarded a $150 million federal grant to develop a prototype for the high-tech roads of the future.

1995

Preliminary designs for the Smart Road are unveiled by VDOT.

1996

Thomas A. Dingus is named director of the Center for Transportation Research. He oversees a $2 million annual budget and a full-time staff of 18. The Center for Transportation Research is designated as one of three Federal Highway Administration/Federal Transit Administration Intelligent Transportation Systems Research Centers of Excellence.

1997

Groundbreaking occurs for the first 1.7-mile part of the Smart Road.

2000

The Center for Transportation Research officially becomes VTTI. On March 23, the Smart Road officially opens in co-sponsorship with VDOT. VTTI researchers simultaneously begin studying highway infrastructure using the Smart Road, particularly pavement materials.

2001

The Smart Road is dedicated on May 30. Institute researchers begin transforming Blacksburg into the first instrumented city in the United States. The project is designed to monitor traffic flow, traffic safety, noise, and air pollution.

2002

VTTI tops $8.6 million in research expenditures. The Institute begins to conduct the largest data collection effort to date: the 100-Car Naturalistic Driving Study.

2005

VTTI is designated as a Center for Excellence in the 2005 transportation bill Safe, Accountable, Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

2006

The National Surface Transportation Safety Center for Excellence is formally awarded to VTTI through the Federal Highway Administration. Sen. John Warner attends the dedication.

2007

VTTI proposal awards received jump by 231 percent over Fiscal Year 2006. VTTI refines the next-generation data acquisition system (DAS) to collect real-world driving information. VTTI is named the prime contractor for the planning phase of the Second Strategic Highway Research Program Naturalistic Driving Study, which is anticipated to total $30 million in funding from the National Academy of Sciences.

2009

The VTTI Center for Injury Biomechanics brings online the crash sled laboratory, resulting in research awards nearing $5 million.

2011

The National Tire Research Center is launched with $2 million in equipment expenditures towards a state-of-the-art tire development and testing system to be located in the Virginia International Raceway Motorsports Technology Park in Alton, Va.

2012

VTTI collaborates with the University of Virginia and Morgan State University to be named the Tier 1 Connected Vehicle/Infrastructure University Transportation Center by the U.S. Department of Transportation. The center conducts research that will advance surface transportation through the application of innovative connected-vehicle research, with more than 20 active projects conducted to date.

2013

Dingus is named a White House Champion of Change in the field of transportation. The National Tire Research Center officially begins tire testing operations. The Institute launches the Center for Automated Vehicle Systems, which is designed to support the development, testing, and deployment of automated vehicles. The Institute now comprises more than 350 faculty, staff, and students and has more than $43 million in research expenditures.

2014

In partnership with VDOT, the Institute unveils the Virginia Connected Corridors. Comprising both the Smart Road and Interstates 66 and 495, as well as U.S. 29 and 50, the corridors support the design and deployment of vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-device systems. The Global Center for Automotive Performance Simulation is launched as an affiliated company of VTTI and comprises the National Tire Research Center, the Southern Virginia Vehicle Motion Labs, and the Virtual Design and Integration Laboratory. This world-class facility is designed to support testing, modeling, and simulation for both the vehicle and tire.

2015

VTTI partners with several entities to unveil the Virginia Automated Corridors, which include the Smart Road; Interstates 95, 495, and 66; and U.S. 29 and 50. Building upon the capabilities of the Virginia Connected Corridors, the Virginia Automated Corridors allow real-world testing of automated vehicles.

2016

VTTI launches two new centers designed to answer the needs of industry partners and sponsors: the Center for Public Policy, Partnerships, and Outreach; and the Center for Technology Implementation.

Beyond **2016**

VTTI will expand its naturalistic driving studies and will continue to lead connected-automation projects that support real-world development and deployment. The Institute is working to create a new Virginia Smart Village that will enhance testing scenarios across multiple automated-vehicle platforms. The village will feature residential and suburban layouts that include real and reconfigurable buildings, roundabout and stop-controlled intersections, automation-compatible pavement markings, hills and curves, and connectivity to the Smart Road in a secure, controlled environment.

VTTI has grown its research portfolio to encompass hundreds of sponsors, partners, and clients from both the public and private sectors.

The continued success of the Institute and its affiliated company--VTT, LLC--is due in large part to its diverse collaborations with local, state, and national transportation agencies; fellow industry researchers; major automotive companies; and automotive suppliers. Since 1988, some of the key VTTI and VTT, LLC, partners have included:

- AAA Foundation for Traffic Safety
- Alliance of Automobile Manufacturers
- American Association of State Highway and Transportation Officials
- Arete Associates
- Association of Global Automakers
- B&W Pantex
- Battelle
- Bendix
- BMW
- Booz Allen Hamilton
- BP Amoco
- Bridgestone
- Brigham Young University
- Calspan
- Case Western Reserve University
- Cernet Corp.
- Chen Ryan Associates
- City of Flagstaff
- Clanton & Associates Inc.
- Clemson University
- Colorado Department of Transportation (DOT)
- Continental
- Cooper Tire
- Crash Avoidance Metrics Partnership (a consortium of auto manufacturers)
- CUBRC
- Delft University of Technology
- Delphi Electronics
- District DOT
- DMD & Associates
- Drexel University
- DRP Performance
- EMMES
- Enercon
- Engineering & Software Consultants, Inc.
- European Commission
- Fairfax County, Va.
- Ford
- Fugro Roadware
- General Motors
- George Mason University
- Goodyear
- Google
- Halifax County, Va.
- Hankook Tire
- Harmonia
- HERE
- Hoosier Racing
- Hyundai Motor Company
- Illuminating Engineering Society of North America
- Institute for Work Organizational and Transport Research
- Insurance Institute for Highway Safety
- Intelligent Automation, Inc.
- Intelligent Transportation Society of America
- Iowa State University
- Jaguar/Landrover
- Johnson Controls, Inc.
- Korea Advanced Institute of Science and Technology
- Kumho Tire
- Leidos
- Long Road Racing
- Loughborough University
- MaineWay Services
- Meritor WABCO
- Michelin
- Mid-Atlantic Broadband
- Minnesota DOT
- Montgomery County, Va.
- Morgan State University
- Motorcycle Safety Foundation
- National Academy of Sciences Transportation Research Board
- National Institute for Occupational Safety and Health
- National Institute of Aerospace
- National Institutes of Health
- National Science Foundation
- NAUTO, Inc.
- Navistar International
- NEC Laboratories
- Nexen Tire
- Nissan
- Norfolk Southern Railroad
- Oak Ridge National Laboratory
- Office of the Assistant Secretary for Research and Technology
- Ohio State University
- Optimal CAE
- OptimumG
- OSRAM Sylvania
- Pacific Northwest National Laboratory
- Parsons Brinckerhoff
- Penn State University
- Plymouth Rock Assurance
- Qatar National Research Fund
- RoadSafe
- Rowan University
- Rutgers, The State University of New Jersey
- SAE International
- Scitor Corporation
- SEA Limited
- Shandong University
- Southwest Research Institute
- Spire Innovations
- Takata
- TASS
- Texas A&M Transportation Institute
- TORC Robotics
- Town of Blacksburg
- Toyota
- TransAnalytics
- Transport Canada
- Transurban
- Travelers Insurance
- University of Alabama at Birmingham
- University of Idaho
- University of Illinois
- University of Massachusetts Lowell
- University of Massachusetts Medical Center
- University of Michigan Transportation Research Institute
- University of Nevada Reno
- University of New South Wales
- University of South Florida
- University of Utah
- University of Virginia
- University of Washington
- University of Wyoming
- U.S. Army Research Laboratory
- U.S. Department of Defense
- U.S. Department of Justice
- U.S. DOT Federal Highway Administration
- U.S. DOT Federal Motor Carrier Safety Administration
- U.S. DOT National Highway Traffic Safety Administration
- Virginia Center for Autonomous Systems
- Virginia Department of Motor Vehicles
- Virginia DOT
- Virginia Tech Foundation
- Virginia Transportation Research Council
- Volvo Trucks and Volvo Cars
- Wake Forest University
- Washington State DOT
- Wayne State University
- West Virginia State
- Westat
- Western Research Institute
- Wisconsin DOT
- Wyle Laboratories

Hesham Rakha

Director of the Center for Sustainable Mobility; Samuel Reynolds Pritchard Professor of Engineering, Charles E. Via, Jr. Department of Civil and Environmental Engineering at Virginia Tech; Courtesy Professor, Bradley Department of Electrical and Computer Engineering

How did you come to be at VTTI?

My advisor [at Queens University, Canada], the late Michel Van Aerde, offered me a job with M. Van Aerde and Associates after I completed my Ph.D. The first project we worked on involved conducting the system-wide mobility and safety evaluations of the TravTek dynamic route guidance system in Orlando, Fla. This was the first field implementation of a dynamic route guidance system in North America and entailed conducting a system-wide modeling of Orlando. Tom Dingus was doing the human factors evaluation. In 1997, Dr. Van Aerde accepted a faculty position in the civil and environmental engineering department at Virginia Tech and as the associate director of the Center for Transportation Research [now VTTI]. He asked me to join him and work as a research scientist at the center.

What research did you do?

When I first arrived at VTTI, I was involved in a field and modeling evaluation of adaptive cruise control systems. We were tasked with quantifying the safety, mobility, and environmental impacts of such systems. This analysis entailed studying vehicle control algorithms related to gas pedal and brake pedal control—with no control on steering—and driver behavior and adaptation to the system. After that, I got involved with the metropolitan model deployment initiative in Seattle, Phoenix, and San Antonio. As part of this effort, we developed models for adaptive traffic signal control, the use of automatic vehicle identification readers to estimate dynamic travel times that could be displayed to drivers, and the use of roadway closures on driver routing behavior. A key element of our research was the development of safety, fuel consumption, and emission models for use in traffic simulation software.

Afterwards, I started doing work for the Virginia Department of Transportation [VDOT], looking at truck-climbing lanes. We started with data collection on the Smart Road on how trucks handle grades. The result was the truck lanes that have been added to Interstate 81 between Roanoke and Christiansburg, Va. Additional work included developing travel-time prediction algorithms to be used on the VDOT variable message signs and developing speed harmonization algorithms to regulate the flow of traffic approaching freeway bottlenecks.

Recently, we have been developing eco-routing systems to recommend the most fuel-efficient routes and eco-cooperative adaptive cruise control systems, which control the vehicle speed within a range set by the driver while controlling acceleration based on fuel efficiency – climbing hills slowly rather than powerfully, for instance. We are currently working on vehicle automation and the management of automated vehicles in close, dense platoons on highways; the control of automated vehicles at intersections; and traffic signal control strategies to minimize the system-wide delay. Currently, we are developing and field testing eco-cooperative adaptive cruise control systems in the vicinity of traffic signalized intersections.

The Xerox Palo Alto Research Center and the Center for Sustainable Mobility were awarded a major Department of Energy effort to develop the Collaborative Optimization and Planning Transportation Energy Reduction control architecture—a complete solution for the goal of developing comprehensive transportation network modeling, a decision-theoretic approach for system optimization, and explicit human behavior and influence modeling to maximize real-world impact. For this project, the architecture will be evaluated on a multi-modal system model of Los Angeles using VTTI's dynamic traffic assignment and simulation software, which is dubbed INTEGRATION.

Why do you do this research?

I love the research I do. From an environmental standpoint, we have to protect this world we live in. The safety impacts are system-wide across the entire transportation network. And it improves mobility—reduces the time spent commuting, for instance. It is pleasing to see something you did implemented, such as the truck-climbing lanes on I-81. Also, the technology intrigues me—the use of technology to enhance the environment, safety, and mobility.

Rich Hanowski

Director of the Center for Truck and Bus Safety

Rich Hanowski began working at the Virginia Tech Transportation Institute (VTTI) more than two decades ago, when it was then named the Center for Transportation Research. "I started as a graduate research assistant at the time I entered the Ph.D. program in the industrial and systems engineering department at Virginia Tech," said Hanowski. "In 1997, Tom Dingus offered me a full-time position as a researcher, and I accepted that opportunity, though not perhaps fully realizing that it meant I now had two full-time jobs: one as a researcher and the second as a Ph.D. student. After many long days and working through weekends and holidays, I graduated with my Ph.D. in 2000. Despite opportunities to move on to other research institutes and universities, I saw in Tom a drive to develop VTTI into a world-class transportation research institute, which it has become. I'm very glad that I've been able to participate in that success."

Hanowski has served as principal investigator or co-principal investigator on approximately 60 projects, managing more than $40 million in contract research. His research, which includes hours-of-service for truck drivers, driver distraction/texting, and speed limiters for commercial vehicles, has been featured heavily in national discussions about truck driver safety. In fact, Hanowski was selected by the U.S. Department of Transportation to serve as one of six international experts on distracted driving, developing a definition, research agenda, and providing domain expertise.

What drew you to the field of truck and bus safety?

I've been interested in trucking at least since I was a freshman in college. As a way to pay my way through university, I worked summers as a local/short-haul truck driver for a food company. Little did I know then that I would still be involved in trucking 30 years later!

When I began the industrial and systems engineering Ph.D. program at Virginia Tech, I jumped at the opportunity to work with Walt Wierwille, who was teaching in that department, on a project directed at investigating driver fatigue issues in local/short-haul trucking. That study became my Ph.D. dissertation and had a great impact on the U.S. trucking industry; one of my findings led to exempting local/short-haul operations from FMCSA [Federal Motor Carrier Safety Administration] hours-of-service regulations. From that experience, I learned how important and impactful truck safety research can be, and I've been hooked ever since.

What have been your greatest accomplishments while at VTTI?

Over the years, I have had the opportunity to work with and mentor many outstanding students and researchers. At the end of the day, the accomplishment that I'm most proud of is having helped develop young scientists and being able to see their careers flourish.

What lies ahead for the Center for Truck and Bus Safety?

Across the center, we've developed a broad range of capabilities and a portfolio of projects. From studies about crash etiology to research on truck driver health and wellness to testing of new truck safety technologies, and from automated truck technologies to working with naturalistic data, our center is well positioned to meet new challenges in the domain of truck driver safety.

One of the exciting aspects of my job is trying to look ahead at what the next big research area might be. It's not always easy to tell, but I'm confident that with the staff in the Center for Truck and Bus Safety, and more broadly at VTTI, we will be able to take on any new challenges that come our way.

Jon Hankey

Director of Research

How did you come to be at VTTI?

In a word: Tom [Dingus]. I was his first master's student at the University of Idaho to graduate and his first Ph.D. student at the University of Iowa. In 1998, Tom invited me to join VTTI as a research scientist. At that point in my career, I was working for Boeing in their Everett plant and was looking for my next challenge. I had worked with Tom quite a bit in the past and knew he had a unique talent to attract bright, hardworking individuals. Walter Wierwille [the Paul T. Norton Professor Emeritus of industrial and systems engineering at Virginia Tech] was also at VTTI at that point, and I was looking forward to working with someone with that much knowledge and experience. I expected to work for VTTI for two years and then move to my next job. That was nearly 20 years ago.

How has your work changed?

I started working as a research scientist on the Driver Error Project for the Federal Highway Administration [FHWA] under the guidance of Walt. I worked for him on several projects over a two-year period and learned a great deal about everything from conducting research at this level to meeting/exceeding the expectations of sponsors.

GM [General Motors] had a long relationship with VTTI, Walt, and Tom. I was a project manager on another FHWA project in which GM was a research partner looking at enhanced night visibility. As part of this project, GM provided vehicles with new enhanced visibility technology for inclusion in the tests on the Smart Road, such as a Cadillac equipped with a far infrared heads-up display, which shows the heat differential from the foreground and background to increase visibility. When GM saw the road during the night visibility study, they became interested in re-engaging with us. They were concerned about distraction and funded a project on the Smart Road to test five infotainment devices. I was co-principal investigator on this study and took lead on conducting this research. This was a large, complex study that had to be conducted very quickly. At one point, I recall counting the number of people directly working on the study during that hour, and it was 44. The study was a success due largely to a very good team of hardworking individuals who wanted it to succeed.

In 2000, after the project, Tom decided that there was sufficient work to start a new group called the Advanced Product Test and Evaluation Group that would focus on applied work helping original equipment manufacturers and Tier 1 suppliers. Tom named me the leader of this group, and I quickly hired a couple of people who were instrumental to the success of that project: Myra Blanco and Julie Cook. Not long after, the success of the group required us to hire two more researchers, Shane McLaughlin and Ron Gibbons, who have both grown into key researchers within VTTI. This group still exists today and is doing important work under the guidance of Eddy Llaneras and Luke Neurauter.

From there, I eventually became director of the Center for Automotive Safety Research, which grew to one of the biggest centers at VTTI. We retired the center during 2013 and spawned three centers [the Center for Advanced Automotive Research, the Center for Automated Vehicle Systems, and the Center for Vulnerable Road User Safety] that I believe will continue to grow and produce meaningful research. Today, I am working as the director of research, taking on more of an administrative role to support the important research being done at VTTI. When possible, I still like to get my hands dirty and do some of the actual research, though.

What do you like about working at VTTI?

The people. I work with some of the best, smartest people I've ever met. Not many people can say that about their job. On a personal level, it is rewarding for me to see the results of our work being used in vehicles, infrastructure, and policy. I have always been an applied guy, so my greatest joy is seeing our work being used.

STEVEN MACKAY

Myra Blanco

Director of the Center for Public Policy, Partnerships, and Outreach

Myra Blanco began at the Virginia Tech Transportation Institute (VTTI) in April 1998 cleaning cars, making copies, and preparing literature reviews. A master's student in human factors engineering at Virginia Tech, she had volunteered to work at VTTI. By the end of the summer, she had a project for her thesis and support as a graduate research assistant. Her first research project was to help develop guidelines for commercial driver-vehicle interface navigation systems. "We determined what type of information should be included and how it should be presented," she explained.

In 1999, she went to work at Ford as an intern. She returned to VTTI with a project related to meeting Society of Automotive Engineers requirements. The work provided funding for her and several other students.

Blanco completed her master's degree, and in March 2000, Tom Dingus offered her a full-time position at VTTI. When she received her Ph.D. in 2002, she became the youngest research scientist at the Institute.

Blanco initially performed proprietary work on light vehicles for industry until 2005. Then she returned to heavy-truck research and became the leader of the Safety and Human Factors Engineering Group within the VTTI Center for Truck and Bus Safety.

"We worked for the U.S. Department of Transportation Federal Motor Carrier Safety Administration and the National Highway Traffic Safety Administration on technologies that might serve commercial drivers, studies to determine hours of service, and development of simulator-based training for commercial vehicle drivers," Blanco said.

In 2014, Blanco became the director of the Center for Automated Vehicle Systems, where she worked with both light and heavy vehicles and performed the first National Highway Traffic Safety Administration study on human factors aspects of Level 2 and Level 3 automated-vehicle concepts. In 2016, she was named director of the Center for Public Policy, Partnerships, and Outreach, which assists with the needed models of rules and regulations for such advanced vehicles as driver assistance systems and connected and/or automated vehicles.

What are you working on now?

Vehicle automation is now a reality. We have production vehicles that are able to assist the driver with lateral and longitudinal control, and some of them even allow the user to take their hands off of the steering wheel for varying periods of time. We are currently working on the implications for misuse and abuse of these systems, as well as potential training implications.

We also recently finished an automated-vehicle crash rate comparison using naturalistic data. Self-driving cars are quickly moving from prototype to everyday reality. During this transition, the question that is first and foremost on the mind of the public and policymakers is whether or not self-driving cars are more prone to crashes. Existing comparisons based on current data are problematic. Collection methodologies in each state differ, with inconsistent requirements as to what incidents are reported as crashes. Many crashes also go unreported. For this study, we examined national crash data and data from naturalistic driving studies that closely analyze the behavior of 3,300 vehicles driving more than 34 million vehicle miles—to better estimate existing crash rates—and then compared the results to data from Google's Self-Driving Car program.

What changes have you seen in transportation research?

Five years ago, there was much improvement in technology and crash mitigation systems. Now, with the potential for highly automated vehicles in the next decade, I think the next five years are going to be very exciting in terms of vehicle safety. Sensor fusion and other evolving technologies present vehicle automation as a reality. Moreover, all these aspects will reform what states will consider a legal "driver" and will result in potential new takes on insurance and liability.

What opportunities are ahead?

We are at a wonderful stage in the research and development of automated and connected vehicles. I see safe mobility and quality of life as two goals for these technologies. The new generation of mobility will allow people with physical limitations to be free to travel with minimal constraints, if any. It will allow seniors who have ceased driving to emerge as active members of the community again, which will improve their health, allow them to age in place, and potentially prolong a healthier lifestyle. New technologies will assist newly licensed drivers to understand how they could improve their driving, helping their parents win at least one small battle. As newer technology becomes part of our lifestyle, we will learn more about users and how the information could be used to optimize transportation.

STEVEN MACKAY

Zac Doerzaph

Center for Advanced Automotive Research

Zac Doerzaph is the director of the Center for Advanced Automotive Research at VTTI. As center director, Doerzaph coordinates a research program focused on measuring and improving the performance of next-generation vehicle systems. In partnership with the federal department of transportation, state departments of transportation, more than 11 automobile manufacturers, and numerous suppliers, Doerzaph conducts research projects emphasizing safety as it relates to the interactions between driver, vehicle, and infrastructure. His efforts focus on the design, development, and evaluation of connected vehicles, collision avoidance systems, automated driving systems, driver interfaces, and driver behavior monitoring and evaluation. Doerzaph is currently working with his team of researchers on a variety of technologies that will improve transportation for all users in the near-term and far into the future.

Doerzaph also serves as the project manager for the Connected Vehicle/Infrastructure University Transportation Center, where he is responsible for developing and articulating the center's approach, objectives, and vision.

Doerzaph began at VTTI in August 2001. As a graduate student seeking knowledge, the Institute attracted his attention with its reputation for high-performance advanced automotive research and rapid growth towards international leadership in transportation safety. After 15 years of engagement, VTTI continues to provide Doerzaph with a unique opportunity to exercise his enthusiasm for automotive engineering while satisfying his desire to positively impact society by reducing injuries and saving lives.

Shane McLaughlin

Center for Automated Vehicle Systems

Shane McLaughlin became the director of the VTTI Center for Automated Vehicle Systems in January 2016. In this role, he leads projects that contribute to the design of advanced systems and automated-vehicle deployment.

For almost 18 years, McLaughlin has supported engineering and design teams using human factors techniques, traditional engineering analyses, and programming. He began his career in industry, working on complex systems, such as adaptive cruise control and navigation. In July 2001, he came to VTTI, drawn to it by his interest in working on research questions across the automotive industry. Since then, McLaughlin and his staff have assisted private and public-sector customers to address each new advance in driver support, considering questions of automation control authority, user behavior, performance capabilities, vehicle dynamics, user monitoring and characterization, user interfaces, and systems specification related to the user.

In 2007, McLaughlin began the VTTI Motorcycle Research Group, which he continues to lead.

Miguel Perez

Center for Data Reduction and Analysis Support

Miguel Perez is the director of the Center for Data Reduction and Analysis Support at VTTI, where he oversees almost two dozen faculty and staff members and up to 100 data coders. He has recently been in charge of efforts related to naturalistic driving study design and analysis, as well as big data standardization, preparation, and mining. His research interests and experience also include driver distraction, human modeling, collision avoidance systems, infotainment systems, and driver performance in test-track and naturalistic environments.

Perez has recently been involved in projects related to the improvement and use of the Second Strategic Highway Research Program Naturalistic Driving Study, the largest study of its kind resulting in more than 35 million miles of continuous naturalistic data from more than 3,500 drivers across six data collection sites in the United States. He has also supported the National Highway Traffic Safety Administration in the development of research plans for portable devices and voice interfaces, performed research used in supporting the draft National Highway Traffic Safety Administration Visual Manual device guidelines, explored how different cell phone use modes affect driver performance, and examined the effects of interface modality in destination entry and navigation tasks. Perez has also been involved in research for the National Surface Transportation Safety Center for Excellence and numerous proprietary research efforts.

In August 2002, Perez began working at VTTI full-time. A graduate from the Virginia Tech industrial and systems engineering Ph.D. program, he was always fascinated by automobiles and enjoyed seeing the immediate application and impact of the work performed at VTTI. Once he began working at the Institute, he was drawn to the people and the culture of the organization, finding them to be dedicated, team-oriented, and ambitious researchers whose character went beyond their work.

Ron Gibbons

Center for Infrastructure-based Safety Systems

Ron Gibbons is the director of the Center for Infrastructure-based Safety Systems at VTTI. He is also the lead lighting research scientist at the Institute and is responsible for lighting- and visibility-associated research projects and projects that consider roadway safety as they relate to infrastructure.

Gibbons is currently the principal investigator on multiple projects, including studies about the impact of lighting design on roadway safety, the impact of headlamp design on safety, wet night visibility, and the performance of alternative light sources in roadway lighting. Gibbons is also the principal investigator on a VTTI contract with the Federal Highway Administration Office of Safety.

Gibbons is the author of several published papers about roadway lighting, photometry, and target visibility. He is a past president of the Illuminating Engineering Society of North America.

ANNE WERNIKOFF

RESEARCH CENTERS

Center for Advanced Automotive Research

(Created in 2013;
Zac Doerzaph, Director)
The Center for Advanced Automotive Research focuses on the research, development, and evaluation of next-generation automotive systems. The center is staffed by a multidisciplinary team of dedicated individuals who are passionate about improving the safety and efficiency of our nation's transportation system. This team strives to solve a broad set of challenges associated with integrating cutting-edge technologies into the vehicles of tomorrow. The primary research areas of the center include crash warning/avoidance/mitigation systems, connected vehicles, driver-vehicle interfaces, crash causation, and vehicle automation.

Center for Automated Vehicle Systems

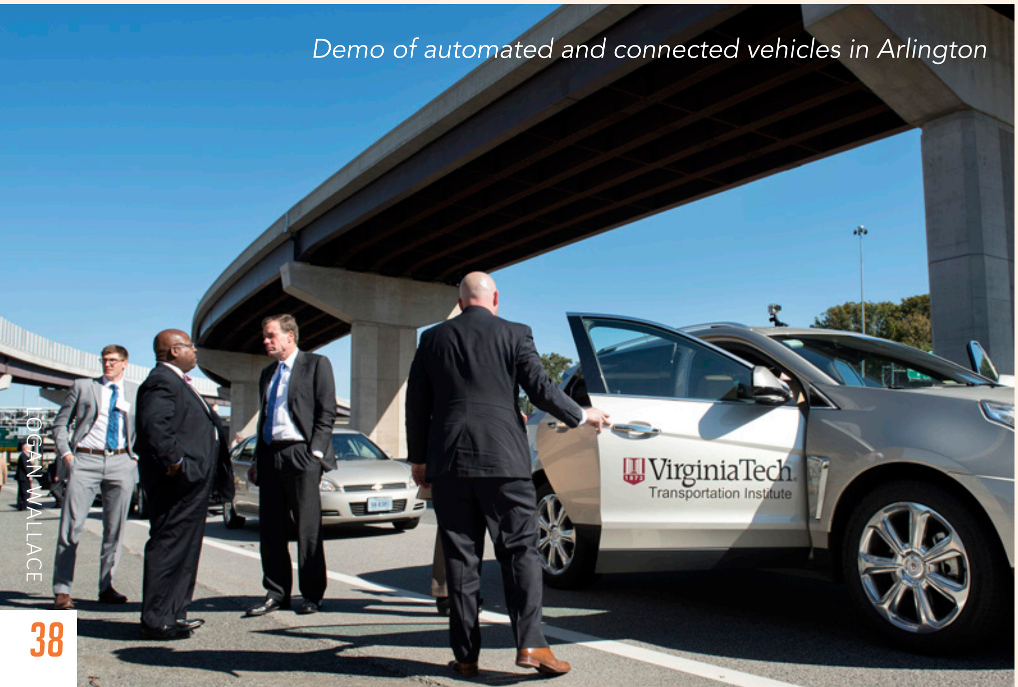
(Created in 2013;
Shane McLaughlin, Director)
The Center for Automated Vehicle Systems uses an interdisciplinary approach to studying all aspects related to the automation life cycle in the field of transportation. The center conducts pragmatic research based on a scientific approach that emphasizes the importance of safety, security, reliability, and user acceptance. The center is anchored in applied research and is strengthened by collaborations with national and international partners in vehicle automation, including Google, General Motors, and other groups involved in the research, planning, policy, and production of automated vehicles. The goal of this center is to strengthen the safety benefits of automation across all levels of the transportation industry.

Center for Data Reduction and Analysis Support

(Created in 2013;
Miguel Perez, Director)
The Center for Data Reduction and Analysis Support provides standardized access to and analysis of naturalistic driving study data sets housed at the Institute; these data sets currently comprise 2.5 petabytes of information about real-world driver behavior and performance. Users include researchers within and outside of the Institute, government entities, and automotive manufacturers and suppliers. Center services include coding of video and audio data, data quality assurance, data standardization, data mining, event selection, and data analysis. The center actively supports data analysis collaborations with external institutions.

Center for Infrastructure-based Safety Systems

(Created in 2010;
Ron Gibbons, Director)
The Center for Infrastructure-based Safety Systems focuses on roadway-based safety systems, such as lighting, visibility treatments, pavement markings, signage, signals, barriers, the interaction of visibility with roadway design,



Demo of automated and connected vehicles in Arlington

LOGAN WALLACE

Lighting research on the Virginia Smart Road

and weather considerations. The center is conducting research into myriad topics that include: increasing active sign legibility during foggy conditions; evaluating the effects of lighting source, type, and power on driver performance; assessing airport garage lighting; and determining the durability of pavement markings. The center contains the Eco-Transportation and Alternative Technologies Group, which is currently conducting an investigation into the potential use of paired types of commercially available vehicle detection technologies designed to reduce false readings at intersections that result in inefficient traffic flow.

Center for Injury Biomechanics

(Created in 2006;
Warren Hardy, Director)
The Center for Injury Biomechanics is a partnership between VTTI, the Virginia Tech Department of Mechanical Engineering, and the Virginia Tech-Wake Forest University School of Biomedical Engineering and Sciences. The center conducts research into injury biomechanics, injury modeling, and transportation-related injury biomechanics. Center work includes an in-depth study of road-departure crashes in the U.S. to determine conditions such as speed and topography. Other transportation-related injury research includes car crash tests, large-scale tissue testing, NASCAR-Indy restraint testing, advanced restraint tests, guardrail evaluations, child seat evaluations, airbag-induced eye injuries, the development of a synthetic eye, elbow joint injuries from side airbags, wrist injuries, upper extremity dummy design, posterior rib fractures from side airbags, child dummy neck evaluations, small female neck interactions with side airbags, airbag out-of-position testing, and the development of a pregnant occupant model.

Center for Public Policy, Partnerships, and Outreach

(Created in 2016;
Myra Blanco, Director)
The Center for Public Policy, Partnerships, and Outreach assists with the needed models of regulations for advanced vehicles, such as driver assistance systems and connected and/or automated vehicles. The center provides research to ensure state and federal policies are based on relevant data, develops partnerships to assist in the advancement of new systems, and enhances the research areas and sponsorship diversity of VTTI. The center works with stakeholders whose interests are affected by governmental decisions on federal, state, local, or international levels in the development and implementation of automated-vehicle systems.

Center for Sustainable Mobility

(Created in 2004;
Hesham Rakha, Director)
The Center for Sustainable Mobility conducts research relevant to society's transportation mobility, sustainability, and safety needs. The center translates the results of research into realistic and workable applications, creates and provides tools needed to apply developed knowledge and processes, and educates qualified engineers to meet today's transportation demands and tomorrow's transportation challenges in the areas of transportation system mobility, sustainability, and safety. The center has worked on projects for the Mid-Atlantic Universities Transportation Center, including a characterization of vehicle dynamics for the enhancement of traffic simulation models and a study of driver behavior at signalized intersections conducted on the Smart Road.

Center for Sustainable Transportation Infrastructure

(Created in 2006;
Gerardo Flintsch, Director)
The Center for Sustainable Transportation Infrastructure focuses on asset management; pavement design, analysis, rehabilitation, and safety; infrastructure management; civil engineering materials; non-destructive testing; and life-cycle cost analyses. The center houses the Infrastructure Management Group and the Sensing, Modeling and Simulation Group. The center initiated a consortium of state highway agencies and equipment manufacturers dedicated to enhancing pavement surfaces. The center also tested a product that extends the life of the road surface and retains de-icing chemicals on the surface, giving road crews time to deploy during inclement weather. The center was instrumental in developing a way to include the environmental impact of road materials in the decision-making processes during road construction. In 2015, VTTI welcomed the first Sideway-force Coefficient Routine Investigation Machine to the United States in a project funded by the Federal Highway Administration; the project objective is to assist states in the development of Pavement Friction Management Programs and demonstrate continuous friction and macro-texture measurement equipment.

Center for Technology Development

(Created in 2003;
Andy Petersen, Director)
The Center for Technology Development specializes in developing, implementing, and maintaining innovative systems for transportation research. The center includes the Mechanical Systems Group, which is responsible for mechanical fabrication to suit the needs of all research projects; the Data Acquisition Group, which is responsible for electronic hardware design; and the Advanced Development Group, which is responsible for software development. The Data Acquisition Group is a pioneer in distributed data acquisition systems. The Advanced Development Group includes specialists in machine vision, road tracking, and data analysis.

Center for Technology Implementation

(Created in 2016;
Mike Mollenhauer, Director)
The Center for Technology Implementation was created to facilitate technology deployment and leverage existing research investments. The center makes it possible for the Institute and its sponsors and clients to participate in early-stage technology implementation programs. Center personnel can help develop a toolbox of modular software solutions that can be applied in new jurisdictions, building smart solutions that combine the best commercial products with customization that can fully address agency goals.

Center for Truck and Bus Safety

(Created in 2005;
Rich Hanowski, Director)
The Center for Truck and Bus Safety focuses on the research, development, and evaluation of heavy-vehicle systems. The center is dedicated to the design, delivery, and implementation of leading-edge research and development efforts aimed at improving the health and safety of heavy-vehicle drivers. The center comprises the Behavioral Analysis and Applications Group, the Human Factors and Advanced System Testing Group, and the Safety and Human Factors Group. Center research includes refining and testing rear-lighting configurations to reduce the number and severity of rear-end crashes, determining safe hours of service for commercial motor vehicle drivers, evaluating causes of drowsiness and providing countermeasures, and developing education programs to keep drivers healthy and alert.

Center for Vulnerable Road User Safety

(Created in 2013;
Jon Antin, Director)
The Center for Vulnerable Road User Safety conducts research and outreach designed to enhance safety for all vulnerable road users, including senior and teen drivers, bicyclists, and pedestrians. Vulnerable road users comprise all age groups and a variety of demographics; their one shared trait is an increased risk of suffering a traffic-relat-

ed crash or injury. The center includes the Teen Risk and Injury Prevention Group and the Senior Mobility Awareness, Safety, and Health Group. Research includes a naturalistic driving study of novice teen drivers with the aim of providing real-time feedback, gathering information for driver training, and keeping teens' parents informed. The center has undertaken outreach initiatives designed to provide recommendations for coordinating public and private services for the aged, disabled, and indigent populations.

Connected Vehicle/ Infrastructure University Transportation Center

(Created in 2012;
Thomas A. Dingus, Director)
Virginia Tech/VTTI, the University of Virginia, Morgan State University, and the Virginia Department of Transportation teamed to develop a Tier 1 University Transportation Center headquartered at VTTI. Robust vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-device communication will enable applications addressing the U.S. Department of Transportation strategic goals of safety, state of good repair, economic competiveness, livable communities, and environmental sustainability. The center conducts connected-vehicle research using the Virginia Connected Corridors, which comprise the Virginia Smart Road and Interstates 66 and 495, as well as U.S. 29 and 50. The corridors are equipped with wireless roadside communication technology. The center has more than 20 active research projects that include in-vehicle notifications of a stopped school bus ahead—especially when the bus is stopped over a hill or around a blind curve—and communication devices installed in safety vests worn by road workers to alert workers and vehicle operators when an on-foot worker is in danger of being struck.

Global Center for Automotive Performance Simulation

(Created in 2010,
Opened in 2013;
Frank Della Pia, Director)
The Global Center for Automotive Performance Simulation is a world-class facility that provides revolutionary services for both vehicle and tire, including testing, simulation, and modeling. The center comprises the National Tire Research Center, the Southern Virginia Vehicle Motion Labs, and the Virtual Design and Integration Laboratory. Collectively, these initiatives provide the full range of services essential for creating a more dynamic product through both virtual and physical development. The center is affiliated with Virginia Tech and VTTI and is located in Southern Virginia.

National Surface Transportation Safety Center for Excellence

(Created in 2006;
Jon Hankey, Director)
The National Surface Transportation Safety Center for Excellence was established by the Federal Public Transportation Act of 2005 to develop and disseminate advanced transportation safety techniques and innovations in both rural and urban communities. Center research focuses on four major objectives: 1) To develop and test transportation devices and techniques that enhance driver performance; 2) To evaluate the roadway environment and infrastructure-based safety systems; 3) To address mobility for vulnerable road users; and 4) To examine driver impairment issues.

Motorcycle Research Group

(Created in 2007;
Shane McLaughlin,
Group Leader)
The Motorcycle Research Group was born from a history in transportation research; concern about an increasing number of motorcyclist fatalities and injuries; and the excitement of a large number of VTTI engineers, staff, researchers, and family who are riders. The group focuses on riders and their machines while considering other factors in the surrounding transportation system. Group researchers have conducted the first large-scale naturalistic motorcycle study, the aim of which is to explore motorcycle crash causation and to develop crash countermeasures.


LOGAN WALLACE

The Impact of VTTI Naturalistic Driving Studies
(continued from page 11)

The group has conducted a series of naturalistic driving studies involving novice drivers: the Naturalistic Teenage Driving Study, the Supervised Practice Driving Study, and the Driver Coach Study. The Naturalistic Teenage Driving Study was the first study of its kind to capture continuous real-world driving behaviors of novice teen drivers during the first 18 months of independent driving. VTTI-developed data acquisition systems (DASs) were installed in the personal vehicles of 42 newly licensed drivers from southwest Virginia; the DASs consisted of sensors, accelerometers, radar, GPS, machine-vision lane tracker, and multiple camera views (forward view, driver face, rearward view, and over-the-shoulder view). Video and driving performance data were collected continuously for 18 months from the 42 teen participants and at least one of their parents.

Results from the Naturalistic Teenage Driving Study found that, compared to adults, novice teen drivers are involved in four times more crashes and near-crashes during the first 18 months of licensure. In 2014, Klauer, along with fellow researchers from VTTI and the National Institutes of Health, co-authored an article published in the New England Journal of Medicine that compared the driving behavior and performance of adult drivers in the 100-Car Naturalistic Driving Study with results from the Naturalistic Teenage Driving Study. The authors found that secondary task engagement while driving increased crash and near-crash risk amongst the teen drivers. The impact of the journal article was almost immediate on a national level, with the article named among the Top 100 most-discussed academic papers in 2014 and among the Top 15 most-read of more than 10,000 studies published by the New England Journal of Medicine.

The Supervised Practice Driving Study collected continuous driving data from 90 novice teen drivers during nine months of the learner's permit phase, followed by 12 months of independent driving. The research objectives of the study were to better understand the quantity and quality of supervised practice driving during the learner's permit phase and how supervised practice driving impacts independent driving. Preliminary results indicate that only 50 percent of all novice drivers obtain the required 45 hours of supervised practice driving with their parents; thus, the quantity of practice driving needs to be higher for novice drivers.

The Driver Coach Study was developed to determine if feedback provided to a teen driver will reduce teen driver crash and near-crash rates. This study recruited 92 newly licensed teen drivers who received instantaneous, real-time feedback when a risky driving event was detected. Further, the teen drivers and parents received post hoc feedback along with driving coach advice. Preliminary results from this study indicate that, if parents are engaged and review the feedback website, teen crash/near-crash rates are lower than if parents do not review the feedback website. Further study methods of driver coaching and feedback that could be more widely deployed for reducing teen driving risks are being considered.

The Teen Risk and Injury Prevention Group is now embarking on a study of novice driver populations that are known to have higher crash risks, such as teenagers diagnosed with ADHD. Additionally, the group has developed the Teen Naturalistic Meta-Database, the largest data set of its kind and comprising the Naturalistic Teenage Driving Study, the Supervised Practice Driving Study, and teen drivers within the Second Strategic Highway Research Program Naturalistic Driving Study. Collectively, these data cover 380 16- and 17-year-old drivers, 12 to 24 months of continuous driving data per teen, 321 crashes and 675 near-crashes, and more than 700,000 trips and 200,000 hours traveled. The group will use the meta-database to further inform the understanding of teen driver risks on an even larger scale, working continuously to help mitigate crash rates among this overrepresented driving population.

Trucks

The Center for Truck and Bus Safety was created in 2005 to undertake the research, development, and evaluation of heavy-vehicle systems. Since its inception, the center has provided numerous results informing national policies designed to regulate safety for heavy-vehicle drivers.

Using local-/short-haul driver participants, VTTI undertook an early naturalistic driving study in 1999 that informed the 2003 Federal Motor Carrier Safety Administration hours-of-service rule. This rule provided a special exemption for local short-haul operators; the sponsoring agency estimated that, without the exemption, the industry would be required to hire a minimum of 48,000 new drivers.

Two years later, VTTI finalized a naturalistic driving study that assessed the impact of truck drivers using a sleeper berth unit for rest. Data were collected from 56 drivers who were on the road up to two weeks at a time. As a result, the Federal Motor Carrier Safety Administration hours-of-service rules now require that property-carrying drivers must get at least 10 hours of rest using a combination of sleeper berth and off-duty time.

In 2002, VTTI began work on an evaluation of a drowsy driver warning system, a dash-mounted device that would detect physiological indications of driver drowsiness and alert the driver. The study involved 34 instrumented trucks and 102 drivers; four months of data were collected for each driver, with multiple agencies funding this study for three years. A year later, the VTTI DAS provided the Federal Motor Carrier Safety Administration with information required to evaluate its hours-of-service regulations, such as off-duty time, on-duty time, breaks, and re-start provisions. In 2005, the Federal Motor Carrier Safety Administration adjusted its hours-of-service safety requirements, reducing by 12 the maximum number of hours a truck driver can work within a week (from 82 to 70 hours).

In 2006, the VTTI Center for Truck and Bus Safety began work to assess a prototype drowsy driver monitoring technology that can reliably assess driver fatigue. The naturalistic driving study involved the instrumentation of nine trucks from four fleets. Data were collected from 100 drivers during a four-month period, resulting in more than 730,000 miles of real-world driving data. Drivers also wore actigraph watches to monitor their sleep and filled out daily activity logs. VTTI filed five Virginia Tech Intellectual Property disclosures for the drowsy driver monitor and alert system in 2010. In addition to video-based driver monitoring, the comprehensive safety system includes forward collision and roadway departure warnings.

Two years later, the Federal Motor Carrier Safety Administration again used naturalistic truck driving data from VTTI, this time to enact a ban on handheld cellular phone use among truck and bus drivers.

The VTTI Center for Truck and Bus Safety is now

conducting multiple projects for the Federal Motor Carrier Safety Administration to assess truck driver performance. The first project will use the naturalistic driving study method to determine such factors as fatigue and distraction among truck drivers. The second project is part of a federally mandated study in which Institute researchers will track and compare truck driver fatigue and safety performance levels for drivers who take two nighttime rest periods during their 34-hour restart break and for drivers who take less than two nighttime rest periods during their restart break. Both projects are ongoing and are expected to inform federal regulations designed to mitigate truck driver risks on the road.

Motorcycles

The number of motorcyclists killed and injured has increased while fatalities and injuries for other road users have decreased. With support from the National Surface Transportation Safety Center for Excellence stakeholders and using a derivative of the NextGen DAS, VTTI demonstrated that motorcycles can be outfitted with equipment that will record rider and machine conditions.

This instrumentation led to the Motorcycle Safety Foundation sponsoring VTTI within the largest naturalistic motorcycle study to date. VTTI instrumented 100 motorcycles in four states to collect data and develop strategies to avoid crashes. A complementary study funded by the National Highway Traffic Safety Administration instrumented 160 motorcycles in Southern California. “These studies will provide the basis for us to address the overrepresentation of motorcyclists in fatalities and injuries,” said Shane McLaughlin, the VTTI Motorcycle Research Group leader. “The technology that VTTI has developed is the first of its kind. We can instrument the motorcycles, send them out, and the riders are doing what they do from day to day for a year at a time. That’s really what sets VTTI apart: we have the capacity to continually record real-world data.”

Older Drivers

A National Surface Transportation Safety Center for Excellence-sponsored project resulted in the completion of an older driver naturalistic data collection effort. The study included instrumentation of 20 vehicles and resulted in the collection of more than 4,600 hours of driving data from more than 29,000 trips. The aim of this pilot effort was to collect the first substantive naturalistic driving database from a senior population to learn about their typical driving patterns and crash-related behaviors and situations. The project was also designed to correlate functional impairment profiles to driving behavior and risk. Results are expected to help with the development of fitness-to-drive models and influence the content of older-driver training programs, development of technological assistance devices, and licensing and restriction protocols. The VTTI Center for Vulnerable Road User Safety is following up with further data-mining efforts, education, and outreach programs.

“There are several inescapable facts that necessitate our research into senior drivers and their mobility. We are aging as a nation, seniors have a greater crash rate per mile driven than all but the youngest and most inexperienced drivers, and seniors are far more likely to suffer a serious injury or fatality,” said Jon Antin, director of the VTTI Center for Vulnerable Road User Safety. “When one considers these factors along with the rapidly transforming transportation infrastructure, tomorrow’s seniors will face personal and transportation-related advantages and challenges unimagined by previous generations.”

With the completion of the Second Strategic Highway Research Program Naturalistic Driving Study, the Center for Vulnerable Road User Safety now has access to an aging driver database comprising nearly 900 drivers and more than 1.3 million trip files. This meta-data set will allow large-scale assessments of such older driver factors as cognition, perception, and the role of physical and psychological health on driving performance.

Data retrieval from the VTTI data acquisition systems

JOHN MCCORMICK

Advanced Vehicles

The next generation of vehicular technology—namely, connected and automated vehicles—is anticipated to provide numerous benefits within the transportation community, including increased driver safety, enhanced mobility and sustainability, and reduced congestion. However, implementation of this advanced technology requires focused assessments of driver interactions with such systems. VTTI researchers are now leading a naturalistic driving study in which 120 drivers will participate three months each to determine the safety benefits and any possible detriments of several multi-function automated vehicles, including Audi Q7, Infiniti Q50, Mercedes-Benz E350, Volvo XC90, and Tesla Model S. The study is expected to result in 140,000 miles of data with driver assessments to include driver-vehicle interaction, user compliance, and driver distraction.

Other Roadway Users

VTTI researchers are conducting investigations designed to enhance the visibility of cyclists and their bicycles. The study will involve placing cyclists into naturalistic settings such as public roads and assessing their visibility using various lighting and reflective methods.

Driver Impairment

VTTI researchers are now conducting the first naturalistic driving study to assess the effects of THC on driving performance. The study involves up to 20 drivers in Colorado who regularly use cannabis, with a three-month data collection period for each driver. The study is anticipated to inform national discussion about how the use of marijuana impacts driving behavior and performance.

International

VTTI researchers led a naturalistic driving study in Canada involving 125 light-vehicle drivers—resulting in more than 290,000 driver trips—and 22 commercial-vehicle drivers covering more than 94,000 driver trips. Study data continue to be analyzed. Researchers are also collaborating on ongoing studies in Australia and China that will assess driver behaviors and performance internationally.

LOGAN WALLACE

Warren Hardy

Center for Injury Biomechanics

Warren Hardy is the director of the Center for Injury Biomechanics and began working with Virginia Tech in December 2007. He has degrees in engineering science (bioengineering), mechanical engineering (biomechanics), and biomedical engineering.

Hardy has been conducting injury biomechanics research for more than 35 years, formerly having appointments at the Wayne State University Bioengineering Center and the University of Michigan Transportation Research Institute. His research includes impact and injury response characterization, mechanical properties and tolerance of biological materials, trauma mechanisms and injury mitigation, physical and numerical surrogate development, and automotive crash testing. Hardy's primary focus is traumatic brain injury.

Hardy's research efforts have attracted more than $54 million in funding, and he has authored more than 60 peer-reviewed publications. He is the editor-in-chief of the SAE International Journal of Transportation Safety and sits on the advisory committee of the Stapp Car Crash Journal. His teaching interests are classic controls, biomedical instrumentation design, experimental methods in impact biomechanics, and trauma biomechanics.

Jon Antin

Center for Vulnerable Road User Safety

Jon Antin is the director of the Center for Vulnerable Road User Safety at VTTI. Antin began working at the Institute in October 2005, having been initially drawn to it because of his friendship and collaboration with VTTI Director Tom Dingus.

Antin recently served as co-principal investigator and project manager for the oversight and integration aspects of the Second Strategic Highway Research Program Naturalistic Driving Study, the largest full-scale study of its kind ever undertaken and the model for similar emerging efforts around the globe. He is currently the principal investigator for several ongoing studies, including a naturalistic driving study conducted in collaboration with University of Alabama at Birmingham researchers, which is focused on seniors with particular visual and information processing capabilities, and the first large-scale naturalistic driving study in Australia, which is looking at normative driving behaviors and interactions with vulnerable road users.

Antin is responsible for more than 70 publications and presentations. He is a member of the Human Factors and Ergonomics Society, the Surface Transportation Technical Group, the Transportation Research Board Committee on Safe Mobility of Older Persons, and is a faculty affiliate of the Center for Gerontology at Virginia Tech. As a member of the Virginia Department of Motor Vehicles Mature Driver Study Group, he helped the agency establish new licensing regulations pertaining to the screening of senior drivers. Antin will also serve as an inaugural member of the editorial board of the journal Innovations in Aging.

Frank Della Pia

Global Center for Automotive Performance Simulation

Frank Della Pia is the executive director of the Global Center for Automotive Performance Simulation, an affiliated company of VTTI. He has more than 40 years of experience across a wide range of leadership positions in the area of engineering and manufacturing in the automotive industry. Della Pia has a long history in motorsports and specializes in leading teams to create transformational methods, processes, and technology.

Della Pia joined VTTI in December 2010. He was attracted to the Institute by the potential to be involved in work that impacts the future of transportation and makes vehicles safer, perform better, and easier on the planet.


LOGAN WALLACE

A Decade of Ground Transportation Safety Research

(continued from page 18)

The development of sophisticated, ruggedized equipment led to a 100-motorcycle study, which finished data collection at four sites (California, Florida, Virginia, and Arizona). Funded by the Motorcycle Safety Foundation and covering more than 500,000 miles of data, this naturalistic driving study was the first of its kind to explore motorcycle crash causation with the goal of developing crash countermeasures. The National Highway Traffic Safety Administration is funding a complementary 160-motorcycle study that is underway in Southern California.

NSTSCE enables large-scale data collection and data sharing efforts on national and international levels. By facilitating the in-house creation of data acquisition system iterations that can be installed across varying vehicle types, the center is ensuring that more data can be collected about myriad transportation users. Such increased data amounts will allow future analyses that seek to answer the greatest issues facing the traveling public.

NSTSCE comprises a committee of stakeholders that help enable research and that directly benefit from the work performed by the center. These stakeholders include the Federal Motor Carrier Safety Administration, General Motors, Travelers, the Virginia Department of Transportation, and VTTI.

Although much has been accomplished in the past 10 years, NSTSCE looks forward to strengthening partnerships and capabilities as it continues to grow and further its impact in surface transportation safety.

Select NSTSCE projects:

- Tips for sharing the road with commercial motor vehicles
- Evaluation of the sleeper-berth provision
- Driver Coach study (teen naturalistic driving study)
- Teen licensing
- Roadway luminance and adaptive lighting
- Cell phone use and distracted driving
- Commercial driver use of over-the-counter and prescription drugs
- Health and wellness programs for commercial motor vehicle drivers
- Older driver fitness-to-drive assessments
- Onboard safety monitoring
- Quiet vehicles and pedestrian/bicyclist safety
- Cognitive distraction
- Older driver risk at intersections
- Rural driving

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