

# VTTI25



VirginiaTech®  
Transportation Institute

# 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. Therefore, 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 16,500 hours of use on the formally titled Virginia Smart Road, pilot testing nearly every major research endeavor from pavement sustainability to enhanced lighting safety to student-led hybrid vehicle studies.

But the Smart Road is only one part of our history.

During our 25 years, VTTI has grown to become the second largest U.S. university-level transportation institute with more than 350 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 National Tire Research Center in Southern Virginia; 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 Penn State-led Mid-Atlantic Universities Transportation Center. We have built six buildings and have accumulated more than one-quarter of a billion dollars in sponsored program research expenditures. Since 1996, we have funded more than 1,000 students who work here gaining hands-on experience to become the next generation of researchers.

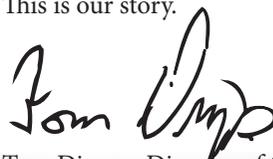
VTTI has pioneered groundbreaking naturalistic driving studies made possible by internally developed data acquisition systems that allow drivers

to be observed as they go about their lives. The results of such studies have made a significant impact on transportation policy at the local, state, and national levels. 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 39 states and the District of Columbia to ban text messaging for all drivers. We are currently conducting the largest naturalistic studies to date for light vehicles, 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.

While our research continues aided by the evolution of “big data” – the capacity to process thousands of hours of data streams – VTTI is once again ramping up its research endeavors. Using such resources as the Smart Road and an instrumented test bed opened in Northern Virginia, our researchers are leading studies that examine the potential benefits of the next wave of transportation innovation: connected and automated vehicles.

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 our story.



Tom Dingus, Director of the Virginia Tech Transportation Institute  
Honored at the White House as a 2013 Champion of Change



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# THE ROAD TO THE FUTURE

Twenty-five years ago, there was a dramatic change in national transportation priorities. The focus shifted from a national highway system to an exploration of new technologies and the consideration of human factors. Virginia Tech was ready, and the Center for Transportation Research (now the Virginia Tech Transportation Institute [VTTI]) was created to respond.

## Changing Focus for the National Highway System

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 Transporta-

tion Board was established in 1920 as a division of the National Research Council, the principal operating agency of the National Academies.

The 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., 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 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.

## Evolution of the Smart Road

A closer link between Roanoke and Virginia Tech was becoming a leading topic among legislators, and Gordon Willis Sr., president of

Rockydale Quarries Corp., formed and chaired a private organization called the University Connection to promote this link.

When Virginia Governor Gerald Baliles announced construction of critical highways as an initiative, Southwest Virginia legislators and business people advanced a “university connector” between Roanoke and Blacksburg as a critical highway that would be an economic development aid by improving access to intellectual resources for businesses in Roanoke and by shortening the commute to the airport for university staff.

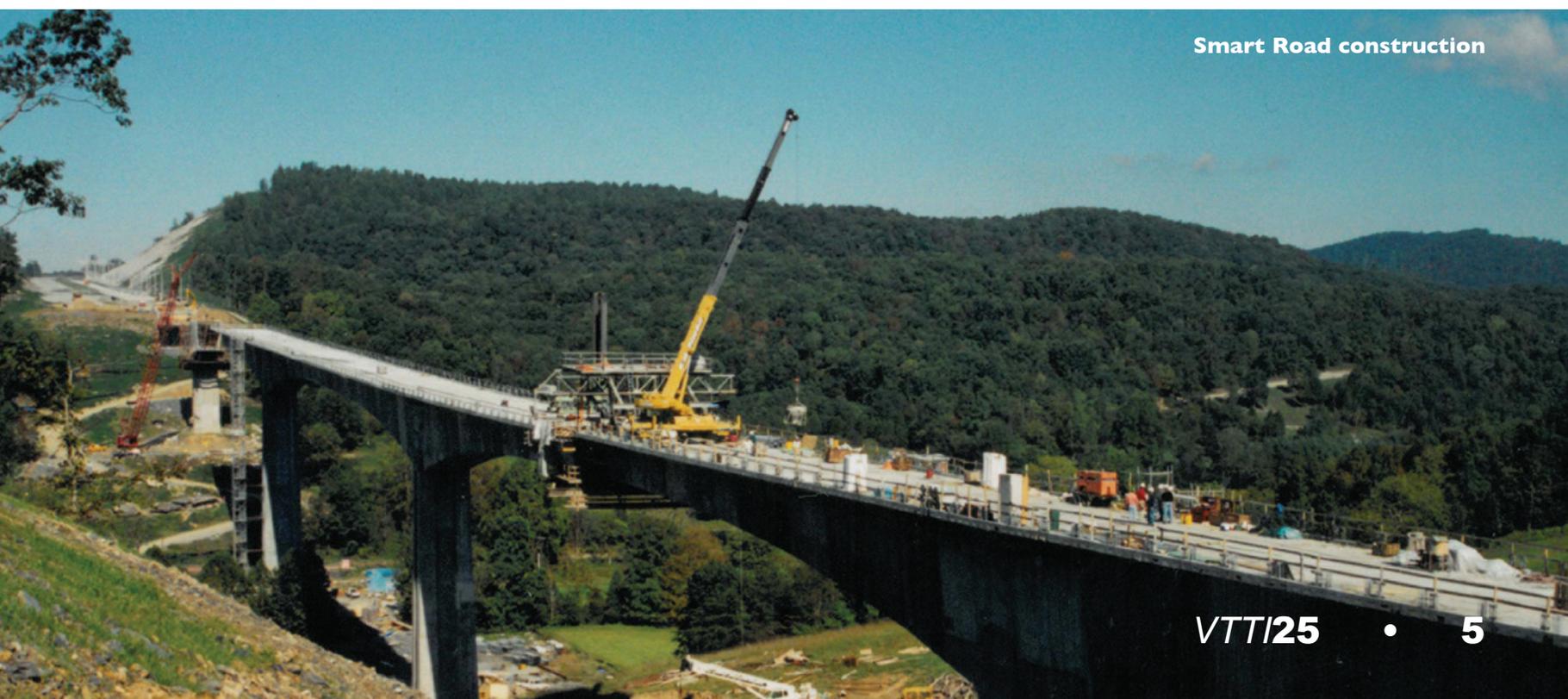
On August 15, 1988, the Virginia Tech Board of Visitors passed a resolution affirming its support for the direct link between Interstate 81 and Blacksburg. The proposal was presented to the Commonwealth Transportation Board, which Ray Pethtel chaired. “We put it on our list, but it was not a high priority in that form,” said Pethtel.

Then, in June 1989, Roanoke County Supervisor Dick Robers proposed linking smart road technology with the Roanoke-to-Blacksburg highway, according to the Roanoke Times. Robers persuaded his colleagues that companies interested in developing and testing technologies would set up businesses in the area.

“The connector gained new momentum,” said Pethtel. “Steve Muselwhite, the member of the transportation board from the Salem district, brought the idea back to me, and we discussed it with local people. I was excited and thought it would put the commonwealth in the forefront of transportation technology. In 1990, the transportation board put the road into the six-year plan. [Virginia Delegate] Dickie Cranwell played an important part in the support and promotion of the concept.”

It was actually seven years before ground was broken for this smart road, but support grew in the meantime.

“The smart road consumed the local discussion, but there was already national interest in smart cars and smart technology,” said Clough. “There needed to be a place to test that technology.”



Smart Road construction

Virginia was in the race to create that place. The Center for Transportation Research was receiving significant federal funding, and research to improve transportation safety and efficiency continued as a priority.

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 the Center for Transportation Research would design. Center Director Anthony Hobeika told the newspaper that 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 “University Connection.” Other organizations or municipalities that endorsed the road included 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.

## Transportation Research Proceeds

Even while the Smart Road was only on the drawing board, the Center for Transportation Research was advancing its mission of research and education. Support 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:

## Expanding VTTI

During the past 25 years, 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 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 partners have included:

- American Association of State Highway and Transportation Officials
- Battelle Memorial Institute
- Bendix
- Calspan
- Crash Avoidance Metrics Partnership (a consortium of auto manufacturers)
- CUBRC
- Delphi Electronics
- Fairfax County, Va.
- Ford Motor Company
- General Motors
- George Mason University
- Goodyear
- Google
- Halifax County, Va.
- Intelligent Transportation Society of America
- Meritor WABCO
- Michelin
- Montgomery County, Va.
- Morgan State University
- Motorcycle Safety Foundation
- National Academy of Sciences Transportation Research Board
- National Institutes of Health
- National Science Foundation
- Navistar International
- NAVTEQ (now Nokia)
- Nissan
- Norfolk Southern Railroad
- Penn State University
- SAE International
- Texas A&M Transportation Institute
- Toyota
- Travelers
- University of Michigan Transportation Research Institute
- University of Virginia
- U.S. Department of Defense
- U.S. Department of Transportation (USDOT) Federal Highway Administration
- USDOT Federal Motor Carrier Safety Administration
- USDOT National Highway Traffic Safety Administration
- USDOT Research and Innovative Technology Administration
- Virginia Center for Transportation Innovation and Research
- Virginia Department of Transportation
- Virginia Tech Foundation
- Volvo Trucks and Volvo Cars
- Westat



## Smart Road

photo by Michael Kiernan

- 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 are 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 40 sponsors.”

– Tom Dingus, director of VTTI

## A Turning Point for the Smart Road

Since opening, the Smart Road has logged more than 16,500 hours of research. 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 Jon Hankey, senior associate director for research and development at VTTI. Such research continues today. For example, connected-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 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 90 percent of lighting configurations found on U.S. highways could be assessed. 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*

*“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*

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 still 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 Danville. 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.

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



*photo by Logan Wallace*

## VTTI Profile:

### Walter Wierwille,

Paul T. Norton Professor Emeritus  
of Industrial and  
Systems Engineering

More than 100 undergraduate and graduate students annually receive hands-on training at VTTI. Researchers at the Institute not only dedicate themselves to saving lives through transportation innovation; they also actively engage the next generation of researchers.

But who initially engaged VTTI researchers?

For many here, the answer is Walter W. Wierwille.

Wierwille, the Paul T. Norton Professor Emeritus of Industrial and Systems Engineering, joined the Virginia Tech College of Engineering in 1971 and became director of the vehicle analysis and simulation lab in 1979. In 1998, he became a Senior Transportation Fellow at what was then the Center for Transportation Research (now VTTI). Later, he also became associate director.

“At the time I started at Virginia Tech, there were almost no electronics in vehicles, and definitely no computers,” said Wierwille. “But the U.S. government was becoming concerned about emissions. By 1976, there were catalytic converters on many vehicles, but it was another year or more before cars had computers, and even then it was only for control of the engine for pollution control.

“When Jon Antin [now the director of the VTTI Center for Vulnerable Road User Safety] and Tom Dingus [now director of VTTI] were both my students—in approximately 1983 and 1984—we had to add whatever instrumentation we needed. Jon worked on a way to investigate instantaneous mental workload for his 1984 master’s degree research, and Tom worked on detection of drowsy drivers for his 1985 master’s degree. Both did their Ph.D. research on the attention demands of in-car navigation systems, even though cars didn’t even have LAN [local area network] yet.”

Many other current VTTI researchers were also students in Wierwille’s classes, and his influence has continued through his work. For instance, Dingus chaired the Ph.D. committee of Richard Hanowski, whose 2000 dissertation, “The impact of local/short haul operations on driver fatigue,” cited Wierwille’s work. Hanowski now directs the VTTI Center for Truck and Bus Safety. Less than a decade after earning his Ph.D., Hanowski and others in his center co-authored papers with Wierwille.

Wierwille’s research has included in-field deployments of drowsy driver detection and countermeasure systems, the study of enhanced rear-lighting configurations to reduce the number of rear-end crashes, the improvement of understanding driver error, and the use of automated instrumentation to gather naturalistic driver data with a particular emphasis on eye-glance behavior during lane changes. He developed a method for rating driver drowsiness known as the Observer Rating of Drowsiness (ORD). An assessment of the driver’s facial tone, behavior, and mannerisms is based on a 100-point continuous scale observed during the 60 seconds of video taken prior to a crash, near-crash, or other trigger event. ORD has subsequently been used to investigate whether drowsi-

ness was a contributing factor during a safety-critical event and to develop driver alert systems.

“Drowsy driver research – to know when that is happening and alert the driver – has been very important,” said Wierwille. “Along with that, there is research to develop unintended lane-change warnings, when a vehicle wanders into another lane without signaling. We began testing that in the simulator when I was in the College of Engineering. Now radar and coherent light are being incorporated.”

While drowsiness continues to be a key driver behavior studied at VTTI, researchers are already examining issues associated with the next wave of transportation innovations: automated and connected vehicles. Current VTTI studies conducted in those domains include modeling of signalized intersections that assume control from vehicles, testing of communication systems on the Smart Road, and field trials run on instrumented test beds that are actual highways in Northern Virginia and Southwest Virginia.

“I started at VTTI when it was still the Center for Transportation Research and before it moved to its own facility,” said Wierwille. “It just continues to grow, largely due to Tom Dingus’ foresight.”

photo by Steven Mackay

# FROM A CENTER TO THE INSTITUTE

Innovation requires transformation. Change was occurring at the Center for Transportation Research in the form of a new director, a new name, and funding for a new research project that would make international news and change laws across the nation.

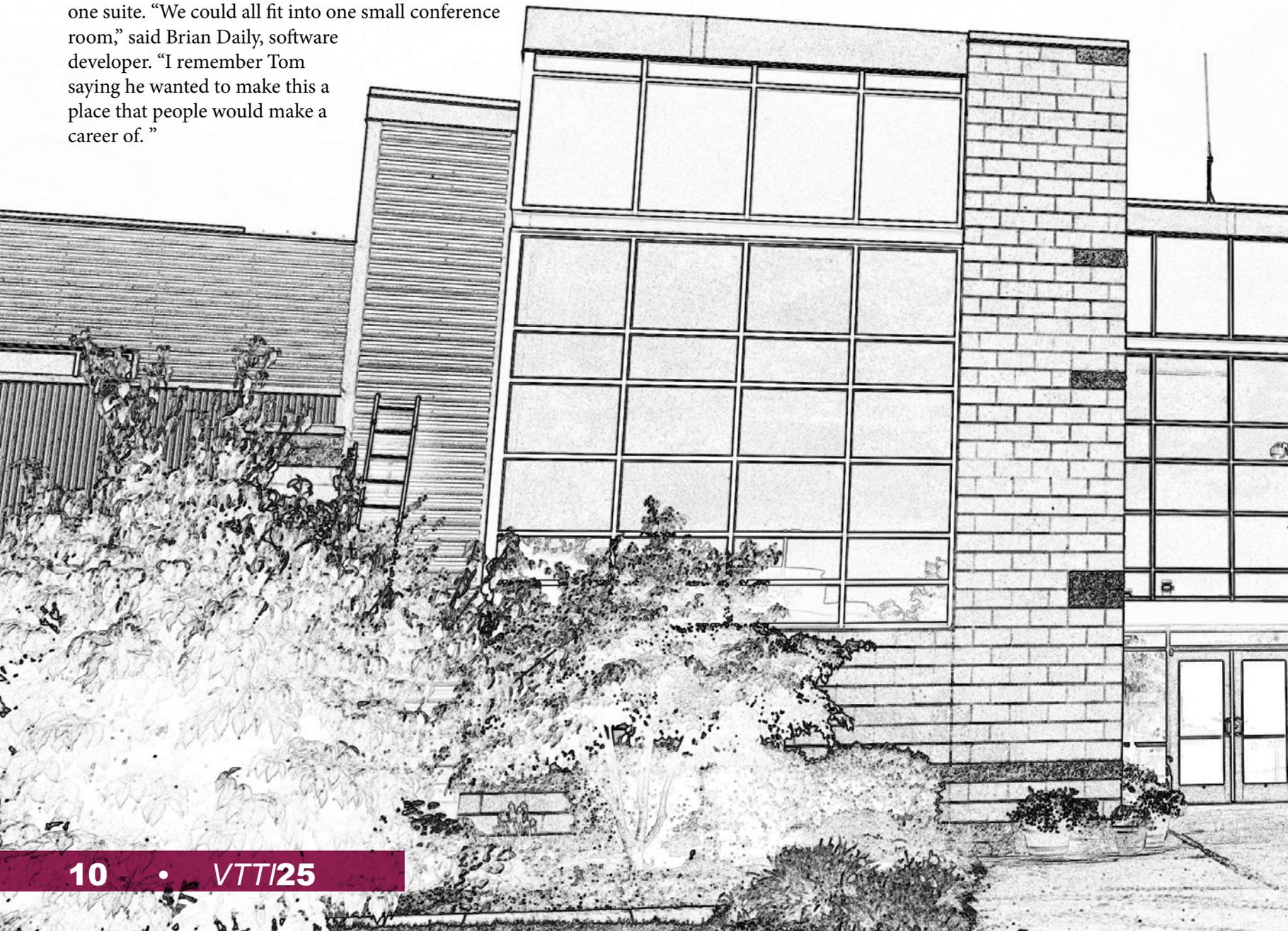
In 1996, Thomas A. Dingus was named the new director of the Center for Transportation Research. He earned his B.S., M.S., and Ph.D. in industrial and systems engineering specializing in human factors and safety engineering, with his graduate degrees from Virginia Tech. He was founding director of the 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.

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. “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.

How did the institute evolve? “It 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, parts suppliers, and even the government would have systems they want-



ed to market or that 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 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.”

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 on some. All of them were tested at VTTI for a decade,” said Dingus.

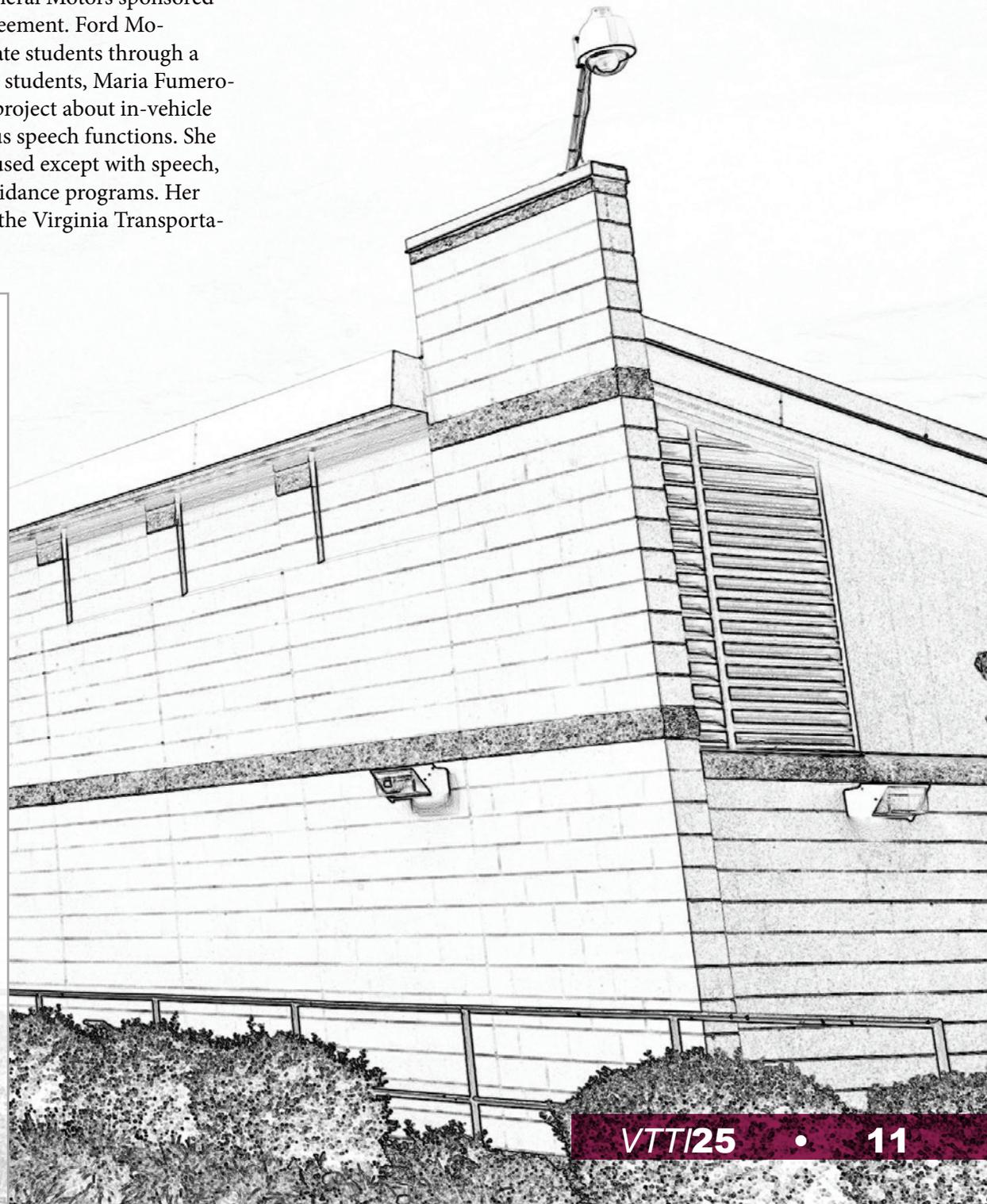
General Motors, Ford, and Nissan all invested in research by VTTI into user acceptance of such systems. General Motors sponsored numerous projects through a blanket agreement. Ford Motor Company provided funding to graduate students through a University Research Program. One of the students, Maria Fumero-Aguila, conducted a three-year research project about in-vehicle information presentation using text versus speech functions. She found that visual displays should not be used except with speech, which is the format now used in route guidance programs. Her research won the student paper award at the Virginia Transportation Conference.

The National Highway Traffic Safety Administration also 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 will be updated as research progresses.

“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.

“Research into human factors is trying to make driving safer and save lives.”

– Andy Petersen, director,  
VTTI Center for Technology  
Development



## Naturalistic Driving Studies

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

“Twenty 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 now has 4,000 instrumented vehicles and has collected data for 1,000 crashes and 10,000 near-crashes. But at first there were two vehicles, and instrumentation was a slow process.

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 dash 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 Peters-

en’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.

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 by 23 times, said Rich Hanowski, director of the VTTI Center for Truck and Bus Safety.

The rest is history.

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.

## VTTI Profile:

# 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 is 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, 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 needs 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 implantation 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.

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, 39 states and the District of Columbia have banned text messaging for all drivers.

to the teen's parents. It would be like having a virtual adult in the car. Development of such a monitor is under way at VTTI 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 is 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.



**U.S. Secretary of Transportation Ray LaHood visits VTTI**  
*photo by Logan Wallace*

"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 is 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.

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

"That eventually was 2,500," 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.

"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 2,500-Car Study possible."

"We try to do impactful research. We have 200 people doing safety research and 100 projects under way at any one time."

– Tom Dingus

In 2007, the Transportation Research Board announced that VTTI was the prime contractor for the planning phase of the Second Strategic Highway Research Program 2,500-Car 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 includes 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 naturalistic study will result in data for more than 3,000 drivers, 4,000 data years, and 1,000 crashes. This technology 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.

"We try to do impactful research," said Dingus. "We have 200 people doing safety research and 100 projects under way at any one time."

## Studying Teen Driving: Preserving our Nation's Youth

Crash rates are highest among teen drivers, especially during the first six months and 1,000 miles of independent driving. Crash rates decline with experience. However, no prior research demonstrated the effect learning could have upon driving performance.

That is, until VTTI undertook such an assessment during its 40-teen study.

Initial funds were provided by the National Institute of Child Health and Human Development to instrument 24 cars of teen-aged drivers. Then, as part of a National Highway Traffic Safety Administration project, the number of vehicles in the naturalistic teen driving study was increased to 42.

VTTI purchased forward radars, which were installed on all 42 vehicles to obtain forward range and time-to-collision data. The increase in the number of vehicles added statistical power to this study, and the addition of radars provided key information about teen driving behaviors and insight into traffic conflicts.

All 42 teen volunteers plus one parent each were tested on the Smart Road at the beginning of the study and then again 12 months later. Continuous naturalistic driving data were col-

lected on the teens—and some parents—for 18 months. Vehicles were instrumented within three weeks of licensure to ensure that driving data were captured during the earliest possible period of independent driving. Data collection began in June 2006 and continued through September 2008, with several add-on projects following.

VTTI researchers found that:

- Novice drivers engage in high-risk secondary tasks more frequently over time.
- Novice drivers who drive their "own" vehicle tend to travel faster than the speed limit more frequently over time, whereas novice drivers who share the family vehicle maintain infrequent speeding behavior.
- The crash/near-crash risks for secondary tasks are higher for novice drivers. This may be due to their inexperience and their inability to appropriately assess roadway hazards.

To enhance the knowledge of the risks that novice drivers face and to improve novice driver safety, VTTI formed the Teen Risk and Injury Prevention group. Group researchers work to educate the public about teen driving risks and the best methods of alleviating these risks. Partnerships have been formed with local public county school districts, and group representatives participate in Parent/Teen Safe Driving Meetings during which parents and teenaged drivers receive information about the safety benefits of developing a Parent/Teen Driving Contract. Group researchers are currently working on the development of a system designed to provide immediate feedback to teenaged drivers when they engage in risky driving behavior.



**VTTI Teen Driver Safety Days** (photo by John McCormick)

# A Retrospective: The Impact of VTTI Naturalistic Driving Studies

## Teens

**2003** - The National Institutes of Health sponsored a teen driving study, which was conducted on the Smart Road. The researchers observed that teens engage longer with cell phones, even when approaching intersections, and lack situational awareness compared to experienced adults. The researchers suggested that driver education curricula be revised and cell phones be discouraged or outlawed.

**2006** - VTTI began the 40-Teen Naturalistic Driving Study to assess the effect of experience on driving performance. Researchers instrumented the autos of drivers who had received licenses within three weeks of the start of data collection to capture behavior during the earliest possible stages of independent driving. Resulting data continue to be analyzed.

**2013** - The newly formed Teen Risk and Injury Prevention group, part of the VTTI Center for Vulnerable Road User Safety, is developing a teen driving program that provides real-time monitoring, immediate feedback to the teen driver, and post-trip feedback to the teen's guardians using an adaptation of the MiniDAS.



VTTI Teen Driver Safety Days (photo by John McCormick)

## Trucks

**1999** - Using local-/short-haul driver participants, VTTI led a naturalistic driving study 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.

**2001** - 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. 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.

**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. Multiple agencies funded this study for three years.

**2003** - The VTTI data acquisition system 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).

**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 734,731 miles of real-world driving data. Drivers also wore actigraph watches to monitor their sleep and filled out daily activity logs.

**2010** - VTTI filed five Virginia Tech Intellectual Property disclosures for the drowsy driver monitor and alert system developed by the Center for Truck and Bus Safety. In addition to video-based driver monitoring, the comprehensive safety system includes forward collision and roadway departure warnings.

**2012** - Using VTTI naturalistic data, the Federal Motor Carrier Safety Administration enacted a ban on hand-held cellular phone use among truck and bus drivers.

## Motorcycles

The number of motorcyclists killed and injured has increased while fatalities and injuries for other road users have decreased. With support from the VTTI National Surface Transportation Safety Center for Excellence stakeholders and using a derivative of the Next Generation data acquisition system, 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



photo by Logan Wallace

motorcycle study to date. VTTI has 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 will instrument 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 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 could help with the develop-

ment 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 unimaginable by previous generations.”

## 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.

**VTTI researcher Ron Gibbons studies bicycle visibility**  
*photo by Jim Stroup*





# *BIGDATA*

Big data is 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.

The new buzz word is old news to the Virginia Tech Transportation Institute (VTTI). “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.

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, the Virginia Department of Transportation (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. Original equipment 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 hand-held 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 recom-

mendations, 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, the position of chief information officer was added 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.

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 2,500-Car Naturalistic Driving Study. The data center continued to service national and international researchers while starting to provide data sets for public 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 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 the Federal Highway Administration, General Motors Corporation, VDOT, Travelers, the Federal Motor Carrier Safety Administration, and the Virginia Center for Transportation Innovation and Research. "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, senior associate director for research and development 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

# VTTI 25 YEARS



**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.



**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.

**1989**

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

**1997**

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



**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).

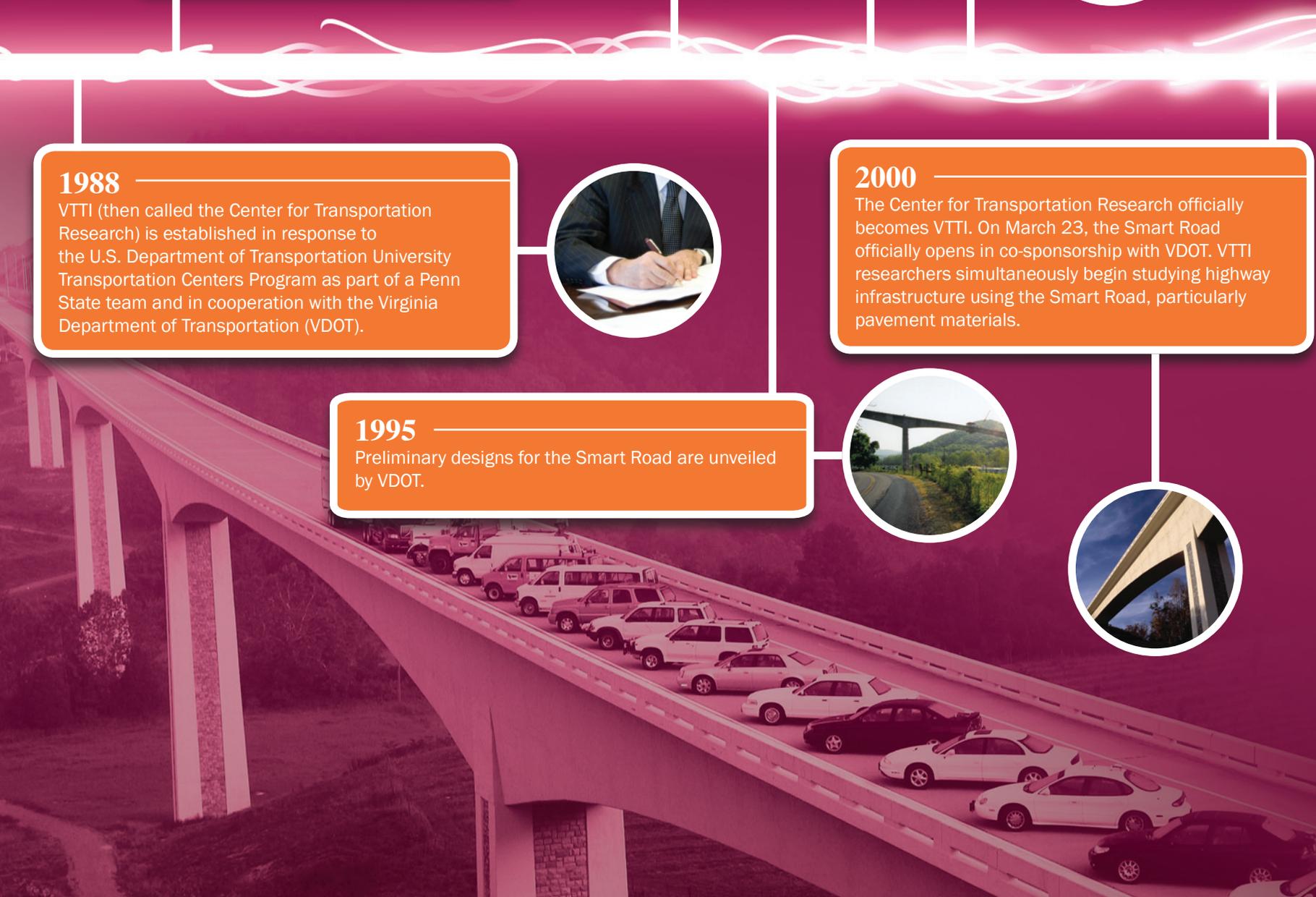
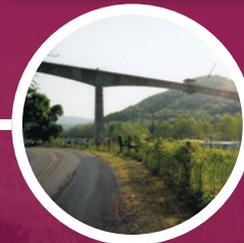


**2000**

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.

**1995**

Preliminary designs for the Smart Road are unveiled by VDOT.





## 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.

## 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).



## 2009

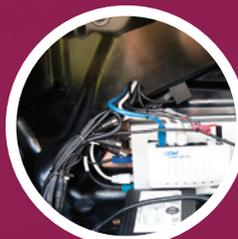
The VTTI Center for Injury Biomechanics brings online the crash sled laboratory, resulting in research awards nearing \$5 million.

## beyond 2013

VTTI is conducting research into the greatest transportation challenges of the future, including automated and connected vehicles.

## 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.



## 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.

## 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.

## 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 2,500-Car Naturalistic Driving Study, which will total \$30 million in funding.



## 2013

Dingus is named a White House Champion of Change in the field of transportation. VTTI spearheads the opening of the Virginia Connected Test Bed in Fairfax, Va., and the National Tire Research Center officially begins tire testing operations. The Institute now comprises more than 350 faculty, staff, and students and has more than \$43 million in research expenditures.

overweight and the risk of involvement in a crash.

Data from the 2006 VTTI Naturalistic Truck Driving Study are being analyzed to assess the relationship between prescription and over-the-counter drug use and involvement in safety-critical events. Voluntary 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. It is anticipated that the selected measures will 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 2,500-Car Naturalistic Driving Study funded a variety of tools and data sets designed to answer this goal. The project includes a data access website that houses driver, vehicle, and naturalistic data, and workshops have been held that provide technical support for users. Data sets that include trip summary files, crash files, and near-crash files are being designed for placement on the website. It is expected that these data sets can be used to answer research questions and to provide insight into the most applicable types of data to be mined. As the largest repository of real-life driver behavior data, VTTI is able to provide such information that will ultimately enhance driver safety, including data about applications such as vehicle safety systems and driver training programs.

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.”



VTTI is continually expanding its international efforts to improve transportation safety. Institute researchers are conducting naturalistic studies in China, Australia, and Canada, with plans in the near future to conduct studies in France and New Zealand. Researchers are often invited to keynote international conferences and symposia.

- |     |           |     |                      |
|-----|-----------|-----|----------------------|
| 1.  | Australia | 15. | Israel               |
| 2.  | Austria   | 16. | Italy                |
| 3.  | Canada    | 17. | Japan                |
| 4.  | Chile     | 18. | Mexico               |
| 5.  | China     | 19. | New Zealand          |
| 6.  | Colombia  | 20. | Portugal             |
| 7.  | Ecuador   | 21. | Qatar                |
| 8.  | Estonia   | 22. | Saudi Arabia         |
| 9.  | Finland   | 23. | South Africa         |
| 10. | France    | 24. | Sweden               |
| 11. | Germany   | 25. | United Arab Emirates |
| 12. | Greece    | 26. | Uruguay              |
| 13. | Honduras  |     |                      |
| 14. | Hungary   |     |                      |

# RESEARCH CENTERS



**Warren Hardy, director  
of the Center for Injury  
Biomechanics**  
*photo by Logan Wallace*

## **CENTER FOR ADVANCED AUTOMOTIVE RESEARCH (CREATED IN 2013; DR. ZACHARY DOERZAPH, DIRECTOR)**

The center focuses on the research, development, and evaluation of next generation automotive systems to improve the safety and efficiency of our nation's transportation system. Primary research areas include crash warning/avoidance/mitigation, connected vehicles, driver-vehicle interfaces, crash causation, and vehicle automation. The center comprises the Advanced Product Test and Evaluation group and the Connected Vehicle Systems group.

## **CENTER FOR DATA REDUCTION AND ANALYSIS SUPPORT (CREATED IN 2013; DR. MIGUEL PEREZ, DIRECTOR)**

The center supports standardized access to and analysis of numerous naturalistic driving study data sets housed at VTTI for researchers internal and external to the Institute. 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; DR. RON GIBBONS, DIRECTOR)**

The center focuses on vehicle/infrastructure cooperative safety systems, roadway delineations, and roadway and vehicle lighting. The center is conducting research into myriad topics such as increasing active sign legibility during foggy conditions; evaluating the impact of lighting source, type, and power on driver performance; assessing airport garage lighting; and determining the durability of pavement markings. The center comprises the Virginia Green Highway Initiative, which is conducting studies that include 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. The center received a large Federal Highway Administration Indefinite Quantity Contract that reflects growth in the area of infrastructure safety.

## **CENTER FOR INJURY BIOMECHANICS (CREATED IN 2006; DR. WARREN HARDY, DIRECTOR)**

The center 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. The center is conducting an in-depth study of 1,000 road-departure crashes at 24 sites across 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, 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.

## VTTI Profile:

### Hesham Rakha,

Professor, Charles E. Via, Jr. Department of Civil and Environmental Engineering at Virginia Tech  
Director, VTTI Center for Sustainable Mobility

#### 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 direc-

tor 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 are being added to Interstate 81 between Roanoke and Christiansburg, Va.

Most recently, we have been developing eco-routing systems to recommend the most fuel-efficient routes and eco-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 working with VDOT to predict travel times between Richmond and Virginia Beach four hours into the future.

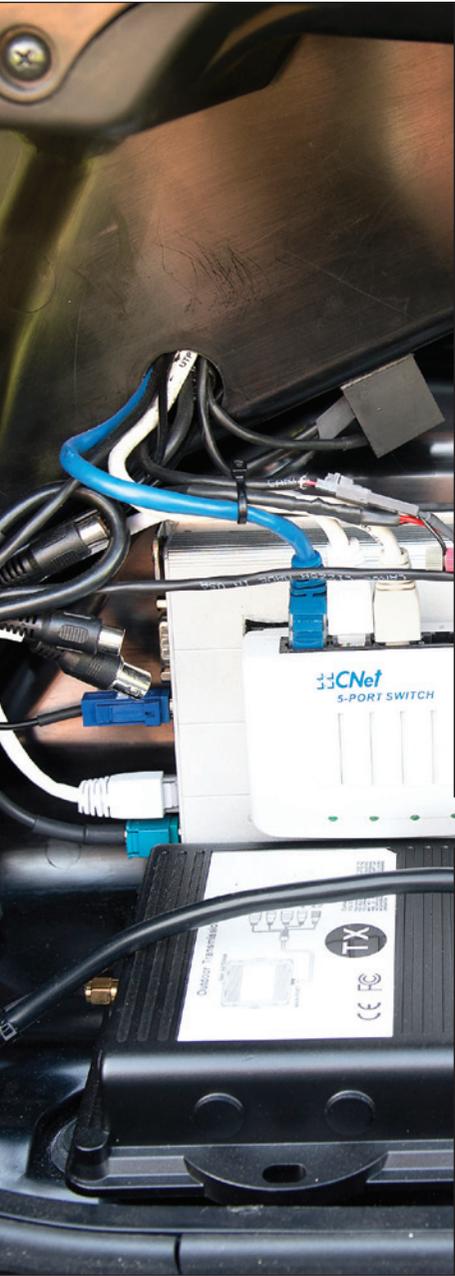
#### Why do you do this research?

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.



photo by Jim Stroup

# RESEARCH CENTERS



**Connected-vehicle hardware designed by Center for Technology Development**

*photo by Logan Wallace*

## **CENTER FOR SUSTAINABLE MOBILITY (CREATED IN 2004; DR. HESHAM RAKHA, DIRECTOR)**

The center addresses two of the focus areas recommended by the Transportation Research Board special report, “Strategic Highway Research: Saving Lives, Reducing Congestion, and Improving Quality of Life.” These strategic focus areas are “Reliability: Providing a highway system with reliable travel times” and “Capacity: Providing highway capacity in support of the nation’s economic, environmental, and societal goals.” The center has worked on projects for the Mid-Atlantic Universities Transportation Center, including 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. The center is developing eco-routing strategies that combine energy and emission models with navigation programs to help consumers make “greener” choices about their routes.

## **CENTER FOR SUSTAINABLE TRANSPORTATION INFRASTRUCTURE (CREATED IN 2006; DR. GERARDO FLINTSCH, DIRECTOR)**

The center focuses on pavement design, analysis, rehabilitation, and safety; infrastructure management; civil engineering materials; nondestructive testing; and life-cycle cost analyses. It 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. Examples of research include testing a product that extends the life of the road surface and retains de-icing chemicals on the surface, thus providing road crews time to deploy during inclement weather. The center also developed a way to include the environmental impact of road materials in the decision process for road construction.

## **CENTER FOR TECHNOLOGY DEVELOPMENT (CREATED IN 2003; MR. ANDY PETERSEN, DIRECTOR)**

The center 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 TRUCK AND BUS SAFETY (CREATED IN 2005; DR. RICHARD HANOWSKI, DIRECTOR)**

The center conducts research and development efforts to advance the state of knowledge in the truck and bus safety domains and provides pragmatic solutions to real-world problems. The center comprises the Advanced Systems and Applications Group, the Behavioral Analysis and Applications Group, and the Safety and Human Factors Group. 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 researchers are conducting the largest field test of an onboard monitoring system designed to record truck and bus driver behavior with the aim of improving driver safety performance.

## **CENTER FOR VULNERABLE ROAD USER SAFETY (CREATED IN 2013; DR. JON ANTIN, DIRECTOR)**

The center conducts research and outreach designed to enhance safety for all vulnerable road users, including senior and teen drivers, bicyclists and other vehicle riders, 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-related 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. One outreach initiative is designed to provide recommendations for coordinating public and private services for the aged, disabled, and indigent populations. The Center for Gerontology at Virginia Tech is a partner in this project.

## **CONNECTED VEHICLE/INFRASTRUCTURE UNIVERSITY TRANSPORTATION CENTER (CREATED IN 2012; DR. THOMAS A. DINGUS, DIRECTOR)**

Virginia Tech/VTTI, the University of Virginia, Morgan State University, and the Virginia Center for Transportation Innovation and Research 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 competitiveness, livable communities, and environmental sustainability. The center operates two test beds. The Southwest Virginia test bed resources include the Smart Road for closed-circuit testing and Route 460 in Montgomery County for real-world testing. The Northern Virginia test bed includes portions of I-66 in Fairfax County and Routes 29 and 50, all of which are equipped with wireless roadside communication technology. There are 43 instrumented intersections as part of the route. Research projects 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.

## **NATIONAL SURFACE TRANSPORTATION SAFETY CENTER FOR EXCELLENCE (CREATED IN 2006; DR. JON HANKEY, DIRECTOR)**

The center was established by the Federal Public Transportation Act of 2005 to develop and disseminate advanced transportation safety techniques and innovations in rural and urban communities. Research focus areas are safety devices and techniques that enhance driver performance, evaluations of the built roadway environment and infrastructure-based safety systems, safe mobility for vulnerable road users, and solutions to driver impairment. The center is supporting research projects that include an analysis of the effectiveness of visibility aides for bicycles and pedestrians, automated detection of driver drowsiness and driver attention away from the forward roadway, and improving the health of commercial motor vehicle drivers. The center includes a stakeholders' committee that shares a vision for improving road-user safety locally and nationally. The committee comprises the Federal Highway Administration, General Motors Corporation, the Virginia Department of Transportation, the Virginia Center for Transportation Innovation and Research, the Federal Motor Carrier Safety Administration, and Travelers.



**VTTI works to ensure  
the safety of all  
transportation users**

*photo by Jim Stroup*

# RESEARCH CENTERS



## **NATIONAL TIRE RESEARCH CENTER (CREATED IN 2010, OPENED IN 2013; MR. FRANK DELLA PIA, DIRECTOR)**

The center was created by VTTI in alliance with the Institute for Advanced Learning and Research, General Motors, and the Virginia Tobacco Indemnification and Community Revitalization Commission. A custom-built, force-and-moment tire test machine provides data about torque and braking capabilities, including tire performance on wet road conditions. Lab results can be further tested on the adjacent Virginia International Raceway, a closed-course circuit. General Motors and its suppliers are committed to conducting tire testing at the center for two years from commencement of operation. Allocable machine time beyond these needs is available for third-party or Virginia Tech projects.

## **GROUPS AND INITIATIVES**

photo by Logan Wallace



## **I-81 CORRIDOR COALITION (CREATED IN 2011; MR. KEVIN COLE, INTERIM DIRECTOR)**

The coalition includes state, local, nonprofit, and private organizations committed to making Interstate 81 a safe, efficient, environmentally sensitive, economically viable, and intermodal transportation corridor. Research interests include freight movement, truck safety, intermodal relationships, environmental planning, and corridor-wide information and coordination efforts.

## **AUTOMATED VEHICLE SYSTEMS (CREATED IN 2013; DR. MYRA BLANCO, GROUP LEADER)**

The initiative pursues an interdisciplinary approach to studying all aspects related to the automation life cycle in the transportation field, including planning and policy and the production of automated vehicles. The growth and variety of automated vehicles should be anchored in a scientific approach that emphasizes safety, security, reliability, and user acceptance. Research projects focus on collision warning interfaces, collision avoidance systems, and driver transitioning into and out of automated driving states.

## **MOTORCYCLE RESEARCH GROUP (CREATED IN 2007; DR. SHANE MCLAUGHLIN, GROUP LEADER)**

The group was born from a history in transportation research; concern about increasing numbers 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 are conducting the first large-scale naturalistic motorcycle study, the aim of which is to explore motorcycle crash causation and to develop crash countermeasures.

## **CENTER FOR AUTOMOTIVE SAFETY RESEARCH (RETIRED)**

After serving as the incubator for several VTTI research centers, center directors, and key researchers, the Center for Automotive Safety Research (created in 2005) was retired in 2013. The center specialized in researching the causes of automobile crashes and ways to prevent them. It was also designed to assess advanced vehicle technologies. Within this center, naturalistic driving, on-road, and test-track studies were used in combination with data mining to answer new research questions and improve transportation safety. The size and success of this center led to its retirement and spawned the development of the following three new research centers: the Center for Advanced Automotive Research, the Center for Data Reduction and Analysis Support, and the Center for Vulnerable Road User Safety.

## VTTI Profile:

### Jon Hankey

Senior Associate Director for  
Research and Development

#### 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. Dr. Walter Wierwille 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 15 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 that 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-one 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 over 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 new centers that I believe will grow and produce meaningful research. Today, I am working as the senior associate director for research and development, taking on much 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.



photo by Steven Mackay

VTTI Profile:

**Thomas A. Dingus,**  
Director

I became interested in safety and risk management early during my career while working as a human factors engineer in the aerospace industry. I decided to attend graduate school to learn more about saving lives via human factors engineering. My goal was to eventu-

ally help educate the next generation of engineers in my field. I chose Virginia Tech because it had the best human factors program in the country.

Just after coming to the university, I met Professor Walt Wierwille. Walt had a stellar reputation for conducting groundbreaking research, for moving his students efficiently through the graduate programs, and for giving them opportunities to work as graduate assistants to pay their way through school. As it happens, Walt had some interesting automotive safety work being performed in his labs. While I never planned on studying automotive safety, it quickly became apparent that this field was at the center of injury prevention and risk management. That is, the most injuries occur behind the wheel. Fortunately, I found there is an entire range of data sources and potential countermeasures available to decrease the number of injuries and deaths caused by crashes. As promised, Walt pushed me through the program with an M.S. and Ph.D. in three years while I conducted two projects for General Mo-



tors. My 1985 dissertation was the first on-road safety evaluation of a moving-map navigation system and focused on issues of distraction and attention.

After graduation, I got a teaching job at the University of Idaho. I was able to continue performing automotive research while at Idaho, winning contracts from auto companies and, eventually, the federal government. We conducted the first on-road evaluation of a forward collision warning system during this time, sponsored again by General Motors. After nearly six years, I moved to the University of Iowa to lead the safety research efforts for the National Advanced Driving Simulator. Our team grew to include a group of brilliant students we were able to recruit along the way. After a few years at Iowa, the job of director of VTTI opened, and it gave me the opportunity to come back home to Virginia Tech. I have now been back for almost 18 years, and VTTI has grown from about 15 faculty, staff, and students to become the second largest university-level transportation institute in the U.S. with more than 350 employees.

The students and colleagues I worked with along the way made a significant contribution to this growth, and we have all now been together for many years. That list includes my former students Dr. Jon Hankey (25 years), Dr. Rich Hanowski (22 years), Dr. Mike Mollenhauer (20 years), Dr. Myra Blanco (15 years), Dr. Charlie Klauer (14 years), Dr. Shane McLaughlin (13 years),

and Dr. Zac Doerzaph (12 years) as well as colleagues Mr. Andy Petersen (20 years) and Dr. Jon Antin (intermittently for 30 years). Each now serves as a center director or group leader at VTTI, and they have all been willing to take this ride with me. In turn, each has been instrumental in fostering the next generation of transportation researchers by recruiting students who share our passion for public well-being.

The impact of VTTI has been unprecedented on many levels, from effecting change in state and national laws to enhancing public awareness of important driving issues. Not only have we grown as a research community, we are growing our surrounding area. We have created more jobs in this county than any other private or public entity. The opening of the National Tire Research Center in Alton, Va., will answer the call for not only an advanced tire testing facility but the need to create jobs in the Southern Virginia region. Essentially, we have the capacity to not only increase safety on national roadways but to serve as an economic developer.

For all of these reasons, and more, it has been my privilege to serve as director of VTTI. We have much more to accomplish and new niches to carve in the transportation industry, but we will forever remain dedicated to our most central mission: saving lives.

photo by Logan Wallace



ADVANCING TRANSPORTATION THROUGH INNOVATION  
SMART ROAD CONTROL CENTER

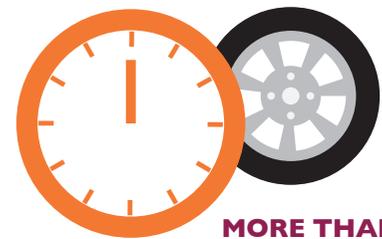
15 EMPLOYEES IN 1988  EMPLOYEES TODAY 350+



# VTTI

AT A **GLANCE**

MORE THAN **140** ANNUAL PUBLICATIONS



MORE THAN **16,500** RESEARCH HOURS ON THE SMART ROAD



MORE THAN **100** GRADS & UNDERGRADS SUPPORTED ANNUALLY



# WHAT'S NEXT?



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-vehicle technology truly has 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 the Center for Transportation Research at Virginia Tech, and aspects of vehicle/infrastructure connectivity have been studied by VTTI for 25 years. When it was only three years old, VTTI was named one of the three national Intelligent Vehicle/Highway System (IVHS) Research Centers of Excellence. But what is happening in recent years makes the early work seem tentative.

“Fifteen years ago, there was an initiative by the U.S. Department of Transportation for automated vehicles. VTTI was dabbling, but our main focus has been around human factors research,” 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 vehicles. Ten years 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-vehicle applications that will save lives and make roads more efficient,” said Dingus.

An example is a project that the VTTI-affiliated Center for Injury Biomechanics just completed for the Centers for Disease Control and Prevention. The study 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 they arrive at the scene of a crash. The center developed algorithms that will allow event recorders to process impact information in terms of injury potential.

But vehicular connectivity began less dramatically.

## From Intelligent Vehicles to Connected Vehicles

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.

Even before the road opened, the U.S. Department of Transportation awarded the Intelligent Transportation System Implementation Center to VTTI in cooperation with George Mason University and the University of Virginia to evaluate the application of intelligent transportation system technologies. The implementation center was the result of a \$6 million line-item in the Transportation Efficiency Act of the 21st Century. The Act was a response to a 30 percent increase in traffic between 1988 and 1998. An intelligent transportation system was the strategy for solving congestion without building more roads. U.S. Department of Transportation literature explained that such systems would use advanced technologies to make transportation safer and more efficient. The technology would communicate transportation options, conditions, and scheduling information. It would include “smarter vehicles and smarter roads; flexible traffic control; and enhanced fleet management systems.”

VTTI research supported by the Intelligent Transportation System Implementation Center has included cruise control enhanced for fuel efficiency and route guidance systems that offer energy efficient routing as well as shortest or fastest routing options.

In 2001, the Smart Road gained significant infrastructure for the IVHS 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

## VTTI Profile:

# Myra Blanco

## Automated Vehicle Systems Group Leader

Myra Blanco started at 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 M.S. 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 explains.

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."

In 2013, Blanco became group leader of the newly formed Automated Vehicle Systems initiative, working with both light and heavy vehicles.

### What changes have you seen in transportation research?

Five years ago, there was a lot of improvement in technology and crash mitigation systems. Now, with the potential for automated vehicles, 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.

### What do you like best about your work?

Two things: the work environment and the objective.

VTTI has been my family since 1998. It is a better place to work than many places I have seen.

The objective, to save lives, is very pragmatic. We know what we are trying to accomplish – reduce fatalities and injuries. The goal for the new wave of automated vehicles is zero fatalities and zero injuries. It is a really big goal that the transportation industry is trying to achieve.

photo by Steven Mackay

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 is designed to test connected-vehicle systems, requires Institute researchers to design, develop, and instrument 72 vehicles with DASs. VTTI will then monitor and maintain the condition of every equipped light vehicle.

But maybe someday intersection signals will not be necessary. “If all the vehicles are communicating with each other, we might not need lights at all,” said Hesham Rakha, director of the VTTI Center for Sustainable Mobility. “Cars would adjust their approach to an intersection like airplanes adjust their arrival at airport runways.” One of the center research projects is vehicle-to-vehicle communication at intersections.

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.

Now, real-world, large-scale connected-vehicle/infrastructure research is under way in a bigger city and on faster, more congested roads. In 2013, the Virginia Connected Test Bed was launched as a public-private partnership spearheaded by VTTI. The test bed falls under the umbrella of the Connected Vehicle/Infrastructure University Transportation Center, which Dingus also directs. The center is a consortium comprising Virginia Tech/VTTI, the

## 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 crash sled 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 ServoSled System crash sled will help 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, department 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.



**Warren Hardy (left) and Stefan Duma (right)**  
photo by Logan Wallace

University of Virginia, Morgan State University, and the Virginia Center for Transportation Innovation and Research.

The Virginia Connected Test Bed involves vehicles equipped with connected wireless technology that enables them to “talk” to each other via wireless sensors installed along the highway infrastructure. The project involves a total of 43 “connected” intersections located in and around Merrifield, Va., near Fairfax along the Interstate 66 corridor and state routes 29 and 50. Wireless infrastructure devices installed near the road track and receive information from test cars equipped with wireless communication technology. In addition to the Smart Road, VDOT has provided matching funds for the Northern Virginia test bed.

“The Fairfax County test bed experiences 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 will have the opportunity to develop, test, and demonstrate tangible connected-vehicle applications that will have a positive impact on the travelers’ experience.”

The roadside units installed on the Virginia Connected Test Bed report road hazards, optimize de-icing operations, warn of congestion and emergency vehicles, and monitor pavement condition. The instrumented vehicles, which include six cars, four of the only connected motorcycles yet in existence, a semi-truck, and a bus, have forward collision, road-departure, blind-spot, lane-change, and curve speed warning systems and advanced GIS. They also feature sophisticated recording devices that download to VTTI so researchers can observe conditions in real time and accumulate data for later transportation analyses.

Dingus 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.

The Smart Road is also part of the connected-vehicle/infrastructure test bed, providing a place at 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.

VTTI-led connected-vehicle research was under way even before the Virginia Connected Test Bed was officially opened. For example, each year more than 20,000 injuries and more than 100 fatalities occur at road construction zones. In cooperation with Virginia Tech faculty, VTTI is developing short-range communication technologies mounted on vehicles and worn by workers to alert workers and vehicle operators when an on-foot worker is in danger of being struck.

Another connected-vehicle project would reduce school bus and automobile 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; 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, beacons for at-risk pedestrians, and vehicle-to-vehicle communication to enhance rear signaling.

Just imagine what VTTI will be like in another 25 years.



# National Tire Research Center: Advancing Tire Design and the Economy

VTTI has also moved into the realm of tire testing with the opening of the National Tire Research Center located in Alton, Va. Designed to serve as an advanced tire research center and test facility, this unique initiative offers 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 is our mission,” said Frank Della Pia, center director. “We are dedicated to advancing the tools critical for research and development of tires and how

they relate to vehicle performance and energy loss.”

The center encompasses the Southern Virginia Vehicle Motion Labs, which features:

- 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.
- An 8-post Test Rig, Wheel Force Transducers, and two of Cruden’s Simulators. When combined, these tools address virtual components prior to conducting real-world ride and handling tests on the adjacent Virginia International Raceway world-class circuit and designated local roads.

Using this technology, researchers are pursuing the application of innovative materials and design to create a super tire. This tire 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.

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

It is expected that the innovative capabilities offered by the National Tire Research Center will attract other companies in the automotive or racing industries to locate in the Southern Virginia region. A study projected that the National Tire Research Center will 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.

Global customers are already joining regional industry leaders coming to Southern Virginia to see this facility and to tap into the unique capabilities offered.



**Frank Della Pia, director of the National Tire Research Center**  
*photo by Logan Wallace*

The National Tire Research  
Center LTRe machine  
*photo by Logan Wallace*



photo by Anne Wernikoff



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