
the FUTURE is NOW
ACTIVE • CONNECTED • AUTOMATED
1872
Virginia Tech
Transportation Institute

Since 1988, the Virginia Tech Transportation Institute (VTTI) has been on the cutting edge of transportation innovation. Researchers at the Institute have led national and international projects focused on all aspects of surface transportation, from infrastructure and vehicles to operations. The Institute pioneered the use of and continues to oversee large-scale naturalistic driving studies that allow driver behaviors to be observed in real time thanks to a revolutionary data acquisition system developed in-house. The results of these studies have made measurable impacts on transportation policy across all levels of government and on the design of innovative vehicle-/infrastructure-based products. Each project has been undertaken to address the VTTI mission: to save lives, save time, save money, and protect the environment.

Today, VTTI continues to answer its mission and to serve as a leader within the transportation field by being among the first to oversee projects that delve into the next waves of transportation innovation: connected and

LOGAN WALLACE

automated vehicles and technologies. Researchers at the Institute are already conducting such connected-automation projects at established facilities affiliated with the Institute: the Virginia Smart Road, the Northern Virginia Connected-vehicle Test Bed, and the Virginia International Raceway.

The combined testing capabilities and facilities available at VTTI are unparalleled. They offer researchers, partners, and sponsors the unprecedented opportunity to safely assess emerging technologies and vehicles today. Because of its commitment to thinking beyond current transportation questions and issues, VTTI is fully equipped to directly answer the transportation challenges of tomorrow.

The future of transportation is happening now at VTTI.

The Virginia Smart Road

SCAN FOR MORE IMAGES AND INFO.

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One of VTTI's instrumented motorcycles is displayed for guests, including then Secretary of Transportation Ray LaHood.

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More than 30,000 fatalities occur each year on U.S. highways alone.*

Next-generation vehicles and technologies are being developed, tested, and deployed with the goal of decreasing, and ultimately eliminating, the number of crashes and near-crashes experienced on our nation's highways.

VTTI is working now with industry leaders to help answer this goal through seminal programs designed to aid in the development and assessment of tomorrow's vehicles and technologies.

**National Highway Traffic Safety Administration Fatality Analysis Reporting System*

Automated Vehicle Systems

In 2013, federal agencies released multiple statements and policies in response to the increased pace of automated-vehicle development. Several states have already enacted legislation that includes provisions for the operation of automated vehicles, though only under certain conditions. While there are myriad advantages to the use of automated vehicles—from fewer traffic collisions due to faster reaction times to the potential for increasing the mobility of older drivers and safety of teen drivers—there are many questions that must be answered. Will drivers become too reliant upon an automated system? What happens if the automated system is compromised?

Through the VTTI Automated Vehicle Systems program, Institute researchers are already actively working with such industry leaders as General Motors (GM) and Google to address automated-vehicle topics via the development and testing of next-generation vehicular technologies.

VTTI is also collaborating with commercial vehicle system suppliers Bendix and Meritor WABCO to assess heavy-vehicle automation via a National Highway Traffic Safety Administration project.

Automated Vehicle Systems at VTTI pursues an interdisciplinary approach to studying all aspects related to the automation life cycle in the transportation field. The program is anchored in applied research and is strengthened by collaborations with national and international partners in vehicle automation.

Partners of the Automated Vehicle Systems program include groups involved in the research, planning, policy, and production of automated vehicles. The growth and variety of automated vehicles currently being developed and already implemented globally should be anchored in research. This program offers pragmatic research based on a scientific approach that emphasizes the importance of safety, security, reliability, and user acceptance. The goal is to strengthen the safety benefits of automation across all levels of the transportation industry.

"The Department of Motor Vehicles (DMV) is a forward-looking agency and thus is extremely interested in the future of automated vehicles. We are committed to working with VTTI, as well as with other agencies and with affected stakeholders, to develop responsible but business-friendly rules for the on-road testing of these vehicles--including legislation, where necessary, to present to the General Assembly--so that Virginia will be in the best possible position to meet the challenges of the emerging technologies."

- Richard D. Holcomb
Commissioner, Virginia Department of Motor Vehicles

VTTI is researching driver acceptance of differing levels of vehicle automation.

JESSAMINE KANE-WISELEY

Today, VTTI researchers are working on projects designed to assess and identify fundamental human factors research questions related to automated driving and to enhance the transportation community's understanding of the education, development, deployment, and assessment needs of automated-vehicle systems.

The fundamental objective of automated vehicles is to eliminate the fatalities and injuries occurring on our nation's roadways. VTTI is already making significant strides towards the realization of a zero-injury/zero-fatality surface transportation system by: working with leaders in the field of automation, by partnering with the Virginia Department of Transportation and Virginia Department of Motor Vehicles to ensure the state is a prime location for connected-automation testing, and by facilitating automated vehicle and system testing.

VTTI is working with such industry leaders as General Motors and Google to assess automated vehicles. Shown here is Google's 2013 visit to the Virginia Smart Road, located at VTTI and owned/maintained by the Virginia Department of Transportation.

STEVEN MACKAY

II

Vehicles and Systems for Connected-Automation: VTTI Capabilities

Connected Vehicles

Since its inception, VTTI has been a forerunner of intelligent transportation systems. Initial projects undertaken at the Institute focused on evaluating the application of emerging technologies using the Virginia Smart Road. During its first three years of operation, VTTI was named one of only three national Intelligent Vehicle/Highway System Research Centers of Excellence.

VTTI has only grown as a leader in intelligent transportation systems by expanding its capabilities, particularly in the area of vehicle connectivity. Connected-vehicle technology facilitates a system whereby vehicles, infrastructure, and devices communicate wirelessly to alert the motoring public of such travel challenges as impending collisions, congestion, potential roadway hazards, and inclement weather conditions.

VTTI is a leader in testing and evaluating connected-vehicle technologies.

VTTI researchers and collaborators are leading a multitude of connected-vehicle-based projects designed to advance transportation safety through the application of innovative research. VTTI is currently working with the Crash Avoidance Metrics Partnership (CAMP) Vehicle Safety Communications 3 (VSC3) to test connected-vehicle safety technology. The CAMP VSC3 comprises a consortium of eight major automobile manufacturers: Ford Motor Company, General Motors (GM) Company, Honda, Hyundai-Kia, Mercedes-Benz, Nissan, Toyota, and Volkswagen-Audi. Other VTTI researchers are refining

short-range communication technologies mounted on various vehicle types and worn by construction-zone workers to emit alerts when an on-foot worker is in danger of being struck. Institute researchers are also assessing the use of connected-vehicle communications to provide following traffic with in-vehicle notifications of a stopped school bus, especially when the bus is stopped over a hill or around a blind curve.

According to the National Highway Traffic Safety Administration*, one in seven fatalities occurring on our nation's roadways is a motorcycle rider. In an effort to mitigate and ultimately eliminate such fatalities, VTTI became the first to equip motorcycles with connected-vehicle technology that will be used during the development and assessment of crash warning systems for the rider.

Connected vehicles equipped by VTTI demonstrate next-generation technologies.

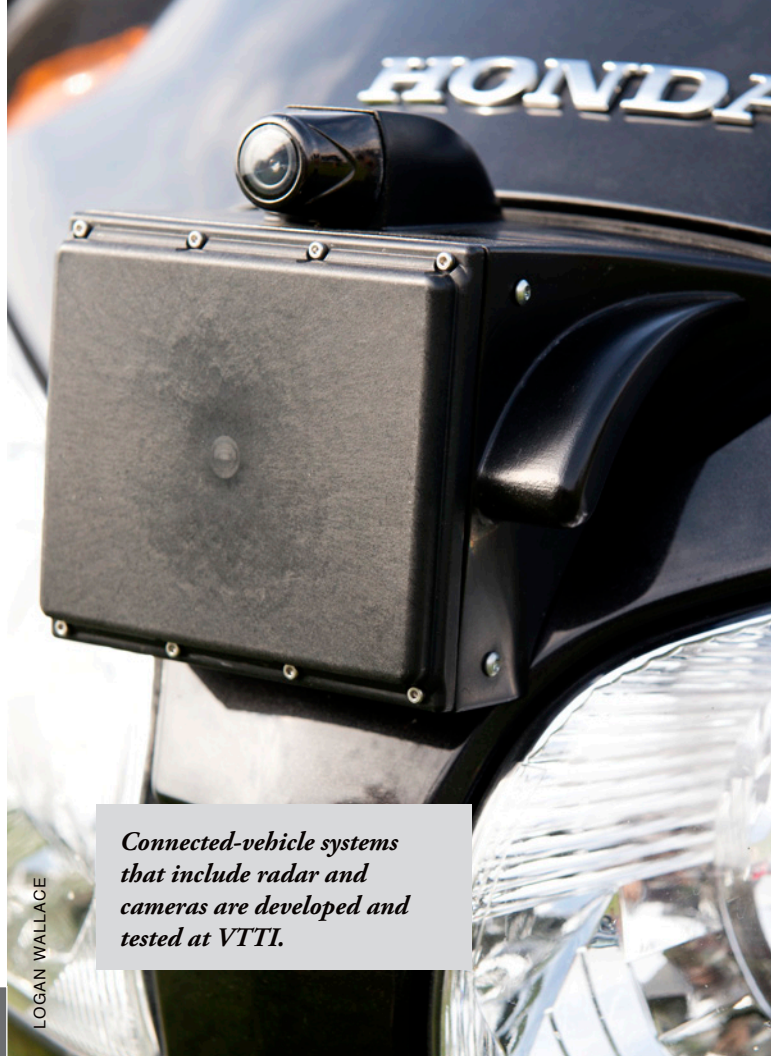
In addition to its connected motorcycles, VTTI is instrumenting and has deployed a range of connected vehicles, including SUVs, sedans, a motorcoach, and a tractor-trailer. The vehicles are equipped with forward collision, road-departure, blind-spot, lane-change, and curve speed warning systems and advanced GPS. They also feature sophisticated recording devices that download to VTTI so researchers can

observe conditions in real time and accumulate data for transportation analyses.

This connected-vehicle fleet can facilitate VTTI projects that include studying the 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.

Connected-vehicle implementation has the potential to improve the overall safety of the transportation community, and VTTI is leading the charge to ensure this promise can be met.

** National Highway Traffic Safety Administration Traffic Safety Facts, 2012*



Connected-vehicle systems that include radar and cameras are developed and tested at VTTI.

LOGAN WALLACE

CONNECTED-VEHICLE FLEET AND EQUIPMENT *AT A GLANCE*

TWO CHEVROLET TAHOES

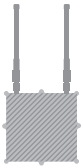
FOUR MOTORCYCLES

THREE CADILLAC SEDANS

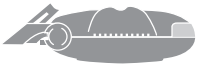
ONE INFINITI SEDAN

ONE MOTORCOACH

ONE FREIGHTLINER TRUCK



60+ PORTABLE ROADSIDE SYSTEMS WITH DSRC & TWO PORTABLE TRAILER-MOUNTED ROADSIDE UNITS



220 PORTABLE DATA ACQUISITION SYSTEMS WITH CELLULAR CAPABILITIES & PROTOTYPE V2X BICYCLE SYSTEM & 50 PORTABLE DSRC SYSTEMS

Active Safety Systems

Since 2000, VTTI has worked with myriad vehicle manufacturers and suppliers to test and aid in the development of active safety systems. While many vehicle models now come equipped with such features as forward collision alerts and lane departure warnings, testing and user acceptance of many of these systems began at VTTI.

Institute researchers study, develop, and evaluate the next generation of automotive systems in an effort to improve the safety and efficiency of the national transportation system. VTTI actively researches crash warning/avoidance/mitigation systems, advanced technology specific to connected and automated vehicles, and driver-vehicle interfaces.

VTTI researchers are working with major automotive companies, suppliers, and governmental agencies on a variety of active safety system projects. The Institute is an integral part of the U.S. Department of Transportation Safety Pilot Program, which seeks to prove the feasibility of using connected-vehicle communications in real-world scenarios and to assess resulting driver acceptance and performance. VTTI researchers are also working with industry leaders in the arena of automated vehicles to address the real-world applications and concepts of vehicle automation and technologies.

For more than a decade, VTTI research results from active safety system projects have made a profound impact on governmental regulations. For example, Institute researchers were among the first to assess safety systems designed to mitigate the widespread problem of drowsy driving in the trucking population. The results of such studies have helped inform federal hours-of-service rules, such as the Federal Motor Carrier Safety Administration's decision to reduce by 12 the maximum number of hours a truck driver can work within a week.

VTTI researchers provided custom instrumentation support for eight vehicle manufacturers participating in the CAMP VSC3 connected-vehicle Safety Pilot Program.

DAN BOICH

Vehicles and Systems for Connected-Automation: VTTI Capabilities

Such research continues today as VTTI works with the Federal Motor Carrier Safety Administration to provide ongoing support for the assessment, advancement, and commercialization of safety technologies.

Active safety systems are an ever-evolving aspect of vehicular design, and VTTI facilities and research endeavors are developed and expanded to ensure industry leaders can test and assess the viability of these technologies now.

“Virtually every General Motors (GM) active safety feature is impacted by the team at VTTI, from the actual design to researching user acceptance. VTTI helps us learn a tremendous amount that can aid in design decisions and in building the confidence to market new systems. They provide us with a better understanding of the causes of accidents and ways to evaluate the countermeasures implemented, which help us create a safety system that we know will work.”

- John Capp

Director, Electrical and Controls Systems Research and Active Safety Technology Strategy

General Motors Research and Development

Wireless roadside units that facilitate connected-vehicle communications are installed along the Virginia Smart Road.

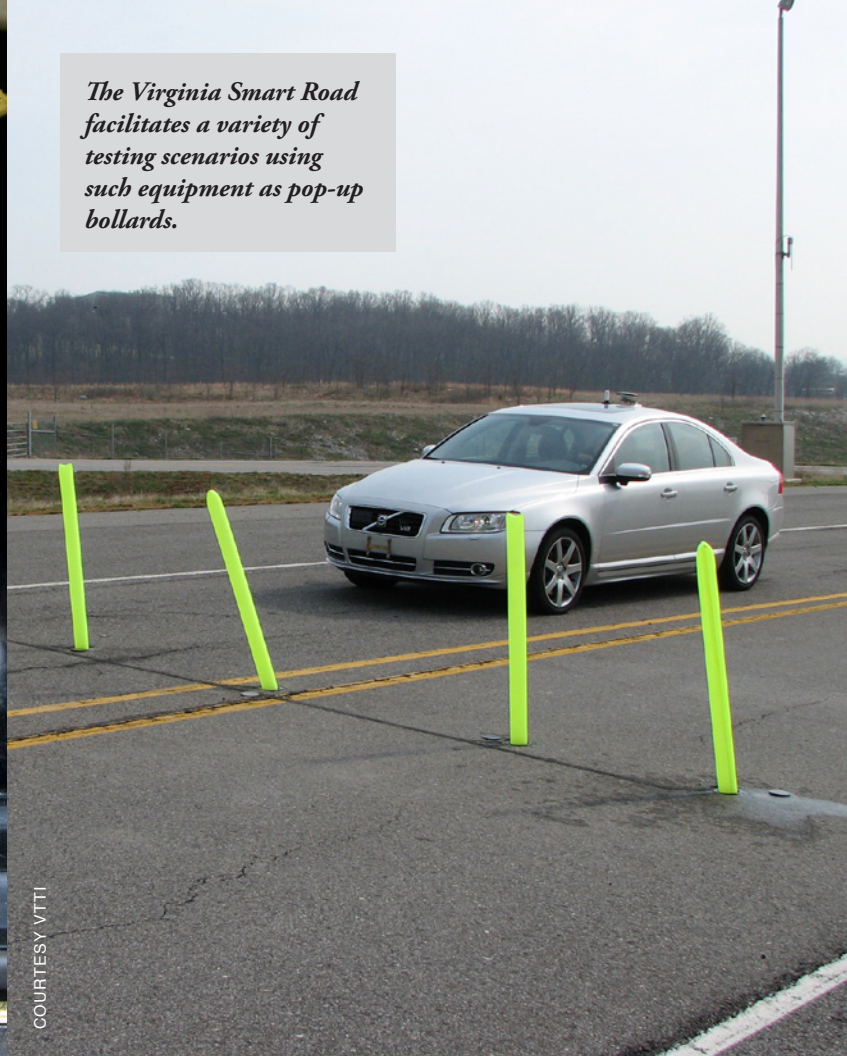
JESSAMINE KANE-WISELEY

Vehicles and Systems for Connected-Automation: VTTI Capabilities

Connected-vehicle hardware designed by VTTI.

COURTESY VTTI

The Virginia Smart Road facilitates a variety of testing scenarios using such equipment as pop-up bollards.



COURTESY VTTI

VTTI testing facilities include the Virginia International Raceway, home to the National Tire Research Center.

LOGAN WALLACE

MICHAEL KERNAN

VTTI is testing the technologies of the future today along one of the most congested highway systems in the United States.

Vehicles and Systems for Connected-Automation:

VTTI Facilities

Before next-generation vehicles and technologies can be deployed, they must be developed and piloted in a testing environment that allows each vehicle and/or system to be safely assessed.

Industry leaders today are using a range of established facilities available to VTTI to evaluate the vehicles and systems of the future.

Virginia Smart Road

Headquartered at VTTI, the 2.2-mile, controlled-access Virginia Smart Road was first envisioned as the answer to a national call to study new transportation technologies. This revolutionary highway was originally slated to 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 safe to pass.

Since its opening, the Smart Road has rapidly evolved beyond these earlier sensors to meet the changing needs of VTTI researchers and the transportation community. More than 18,000 research hours have been logged on the Smart Road thus far. Managed by VTTI and owned and maintained by the Virginia Department of Transportation (VDOT), the road itself is built to Federal Highway Administration specifications. Groups internal and external alike take advantage of the unique capabilities of this facility, including weather-making towers that can generate rain, snow, and fog; a variable lighting test bed capable of replicating 95 percent of roadway lighting found in the U.S.; variable pavement markings and textures; and signalized intersections.

Using the Smart Road, VTTI plays a sustained role in testing emerging technologies. Major automotive companies and suppliers, such as Bendix, Ford Motor Company, General Motors (GM), Google, Honda, Hyundai-Kia, Mercedes-Benz, Meritor WABCO, Nissan, Toyota, and Volkswagen-Audi, travel to Blacksburg to assess connected-automation technologies and vehicles, active safety systems, and driver acceptance. During 2012, the Smart Road was equipped with wireless roadside units as part of a concerted effort to expand the connected-vehicle testing capabilities of the Institute. These units facilitate communication between vehicles, infrastructure, and devices. VTTI has also hosted industry leaders who use the closed test-track environment of the Smart Road to assess the performance of and safety issues related to automated vehicles and technologies.

"The Virginia Department of Transportation (VDOT) has long recognized the importance of technology in addressing Virginia's congestion and safety challenges. Our investment in the Smart Road at VTTI, the Northern Virginia Connected-vehicle Test Bed, and the facilities and scientists at VDOT's Virginia Center for Transportation Innovation and Research are testaments to our commitment to ongoing research and development of the most promising technologies. We believe that connected vehicles will provide near-term benefits for both safety and mobility, and that automated vehicles may generate even greater improvements. With our test beds, our university partnerships, and strong support from VDOT, Virginia is well-positioned to contribute to the advancement of these important technologies."

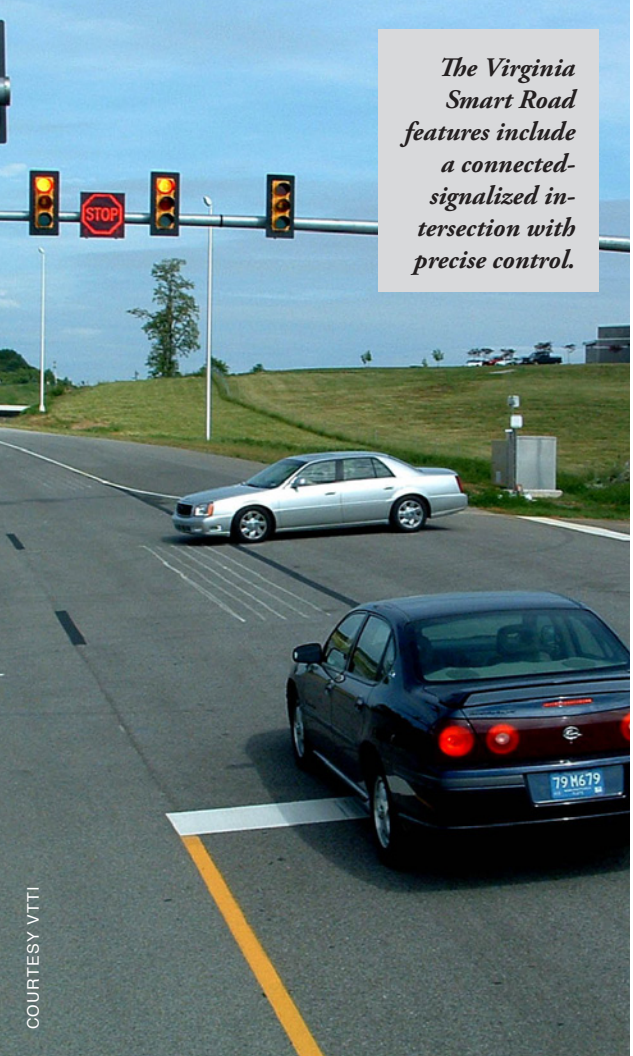
- Catherine McGhee

Associate Director for Safety, Operations and Traffic Engineering

Virginia Center for Transportation Innovation and Research, Virginia Department of Transportation

Fog creation on the Virginia Smart Road, owned and maintained by the Virginia Department of Transportation.

RICK GRIFFITHS



The Virginia Smart Road features include a connected-signalized intersection with precise control.

COURTESY VTTI

VIRGINIA SMART ROAD: FEATURES

- Roadside equipment that facilitates connected-vehicle communications, installed along seven locations at an approximate spacing of 2,000 feet
- Two mobile roadside equipment sites
- An optical fiber communication system
- Ethernet fiber transceivers and Ethernet switches
- Connected-vehicle-compatible intersection controller model
- Fourteen pavement sections, including an open-grade friction course
- In-pavement sensors that detect such factors as moisture, temperature, strain, vibration, and weigh-in-motion
- Zero-crown pavement section designed for flooded pavement testing

- An American Association of State Highway and Transportation Officials-designated surface friction testing facility
- Seventy-five weather-making towers
- Artificial snow production of up to four inches per hour (based on suitable weather conditions)
- Production of differing intensities of rain with varying droplet sizes
- Fog production
- Two weather stations, with official National Oceanic and Atmospheric Administration weather available within one mile
- Variable pole spacing designed to replicate 95 percent of national highway lighting systems
- Multiple luminaire heads, including LED modules
- Wireless mesh network variable control
- Differential GPS base station for precise vehicle locating
- Signalized intersection with complete signal phase and timing using remote controls

Northern Virginia Connected-vehicle Test Bed

Opened during 2013, the Northern Virginia Connected-vehicle Test Bed enables real-world connected-vehicle/infrastructure research on a larger scale. The test bed features a variety of roadway types and targets a transportation system that experiences one of the highest rates of congestion in the U.S. and increased crash rates.

The test bed is a Virginia Department of Transportation facility developed in partnership with VTTI, the University of Virginia, and Morgan State University as part of the Connected Vehicle/Infrastructure University Transportation Center funded by the U.S. Department of Transportation.

The test bed allows vehicles equipped with connected wireless technology to communicate via wireless sensors installed along the highway infrastructure. The project involves more than 60 roadside equipment devices installed in Fairfax County along Interstates 66 and 495 and state routes 29 and 50.

These roadside units are designed to report road hazards, optimize de-icing operations, warn of congestion and emergency vehicles, and monitor pavement conditions. Connected vehicles instrumented by VTTI and traveling on the 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.

The Northern Virginia Connected-vehicle Test Bed currently facilitates 40 percent of bidirectional information sharing between vehicles and 60 percent of bidirectional information sharing between a vehicle and the roadway. A combination of cellular and dedicated short-range communication channels are used for information sharing.

The dynamic capabilities of the Northern Virginia Connected-vehicle Test Bed allow VTTI researchers and collaborators to assess providing such real-world applications as travel-time estimates, transit bus and parking availability, lane closure alerts, pavement maintenance, and driver decision support.

VTTI's connected vehicles are deployed on the Northern Virginia Connected-vehicle Test Bed, a Virginia Department of Transportation facility.

LOGAN WALLACE

Vehicles and Systems for Connected-Automation: VTTI Facilities

NORTHERN VIRGINIA CONNECTED-VEHICLE TEST BED: FEATURES

More than 60 roadside equipment devices that facilitate connected-vehicle communications

Variable traffic conditions and roadway types:

- Four major merge/diverge locations from the north, south, and west
- Two metro stations/public transport and commuter routes
- I-495 Express Lanes (high-occupancy toll [HOT] lanes that provide drivers faster and more predictable travel options)
- High occupancy vehicle lanes
- A large county hospital
- A fire station
- Multiple schools
- Pedestrian trails
- Mixed-use commercial/residential areas
- Major roadway construction

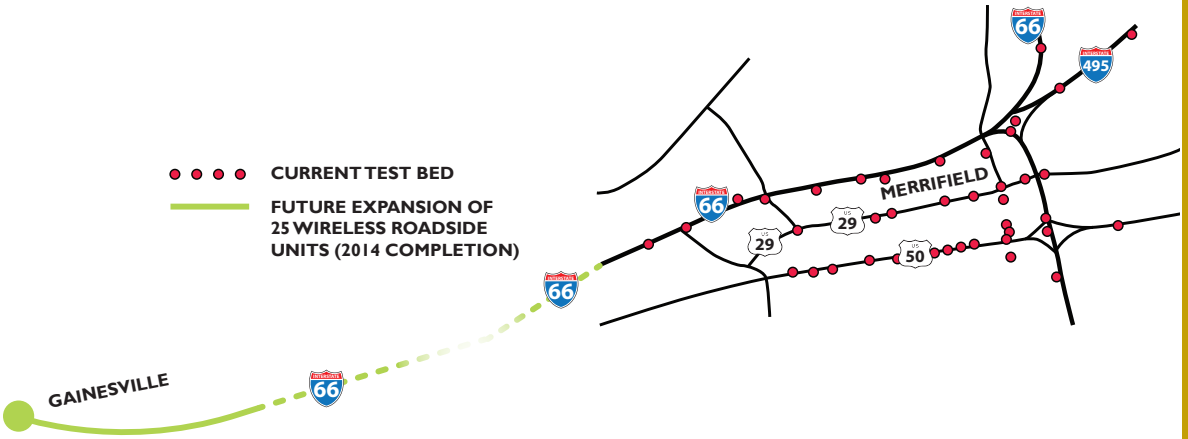
Two mobile roadside equipment sites

LOGAN WALLACE

NORTHERN VIRGINIA CONNECTED-VEHICLE TEST BED: LOCATIONS

The Virginia Department of Transportation currently has 43 wireless roadside units installed along Interstates 66 and 495 and state routes 29 and 50. These units facilitate communication between vehicles, infrastructure, and devices.

Plans are under way to expand the Northern Virginia Connected-vehicle Test Bed, with additional wireless roadside units to be installed westward along Interstate 66 towards Gainesville, Va.



Virginia International Raceway

VTTI has established a cooperative agreement with the Virginia International Raceway to conduct projects in a multi-use testing environment that includes both closed-course and open traffic conditions. When combined with the Virginia Smart Road and the Northern Virginia Connected-vehicle Test Bed, these three facilities create a full suite of testing capabilities for connected-automation and active safety system projects.

Located in Alton, Va., the Virginia International Raceway was opened in 1957 as the first permanent road-racing circuit in the United States.

On-site at the raceway is a resort that features a 12-unit complex of residential villas, a lodge, a club house, a full-service restaurant and tavern, administrative offices, and a spa. Also located adjacent to the raceway is an elite golf course, a skeet shooting range, a karting track, and camping grounds.

The Virginia International Raceway is also home to the Virginia Motorsports Technology Park, which contains the National Tire Research Center. Opened during 2013 and featuring the Southern Virginia Vehicle Motion Labs, the center is an affiliated company of VTTI and is the globe's premier force-and-moment tire test facility specializing in testing complementary activities performed by major tire and vehicle manufacturers.

The full capabilities of the Virginia International Raceway offer VTTI researchers the opportunity to test connected-automation vehicles and technologies in both real traffic conditions and on closed test road conditions. The raceway course itself is up to six miles long and encompasses a range of topography, such as varying hills and curves. Using up to five different raceway configurations, vehicular and system performance can be tested on such roadway layouts as blind passes and hairpin curves. VTTI researchers also have the option to use the full raceway facility for testing purposes.

VIRGINIA INTERNATIONAL RACEWAY: *TRACK CONFIGURATION*

Grand Course: 4.20 miles (6.76 km)

Full Course: 3.27 miles (5.26 km)

North Course: 2.25 miles (3.62 km)

South Course: 1.65 miles (2.66 km)

Patriot Course: 1.10 miles (1.77 km)

Front Straightaway: 3,000 feet (914.5 m)

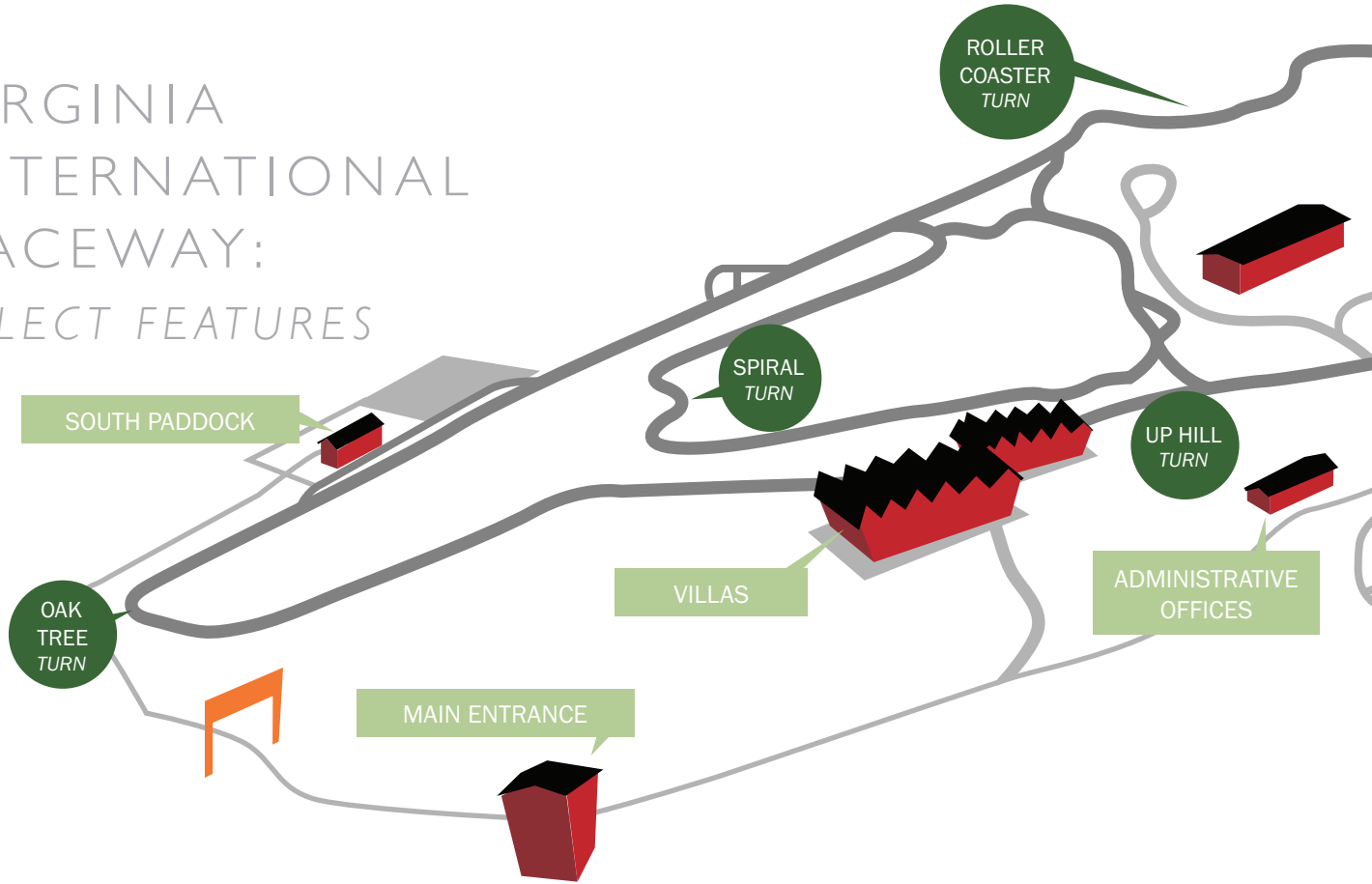
Back Straightaway: 4,000 feet (1,219.2 m)

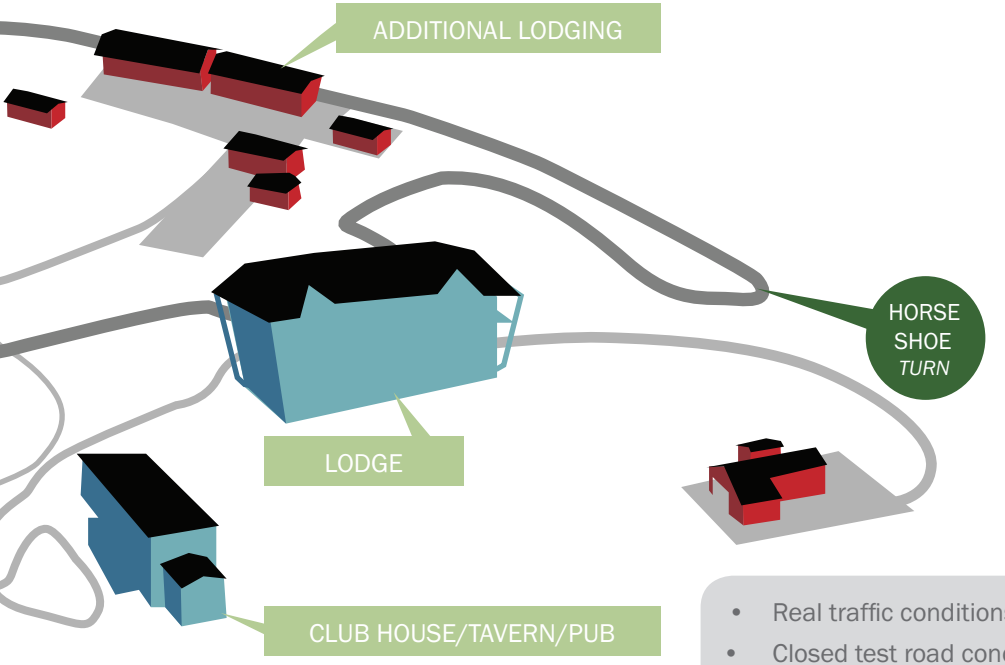
Elevation Change: 130 feet (40 m)

COURTESY VIR

VIRGINIA INTERNATIONAL RACEWAY:

SELECT FEATURES





- Real traffic conditions
- Closed test road conditions
- Horizontal and vertical curvatures
- Five different raceway configurations
- Unique testing environment for such projects as connected-automation, active safety, and active pavement markings

VTTI works with hundreds of sponsors, partners, and clients from both the public and private sectors in the assessment, development, and deployment of next-generation vehicles and technologies designed to enhance the safety of the transportation community. Key VTTI partners in the realms of connected-automation and active safety include:

- American Association of State Highway and Transportation Officials
- Arada Systems
- Auburn University
- Automotive Events
- Battelle Memorial Institute
- Bendix
- Bishop Consulting
- BMW
- Booz Allen Hamilton
- Bosch
- Calspan
- Carnegie Mellon University
- Chrysler
- Continental
- Crash Avoidance Metrics Partnership
- CUBRC
- Delphi Electronics
- DENSO
- DGE Inc.
- Draper Laboratory
- Duke University
- Eaton
- escrypt
- Fairfax County, Va.
- FEV
- Ford Motor Company
- General Motors
- George Mason University
- Goodyear
- Google
- Halifax County, Va.
- Honda
- The Hume Center
- Hyundai-Kia
- Intelligent Transportation Society of America
- Mercedes-Benz
- 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
- Peloton
- Penn State University
- Ricardo
- SAE International
- Savari
- Security Innovation
- SwRI
- Texas A&M Transportation Institute
- TORC Robotics
- Toyota
- Travelers
- TÜVRheinland
- University of Central Florida
- University of Michigan Transportation Research Institute
- University of Virginia
- U.S. Department of Defense
- U.S. Department of Transportation (USDOT) Federal Highway Administration
- USDOT Federal Motor Carrier Safety Administration
- USDOT National Highway Traffic Safety Administration
- USDOT Research and Innovative Technology Administration
- Valeo
- Virginia Center for Autonomous Systems
- Virginia Center for Transportation Innovation and Research
- Virginia Department of Motor Vehicles
- Virginia Department of Transportation
- Virginia Tech Foundation
- Volkswagen-Audi
- Volvo Trucks and Volvo Cars
- Westat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