A Broad Partnership to place Virginia (and VT) as a Global Destination for Intelligent Infrastructure and Smart Cities

Thanassis Rikakis, Executive Vice President and Provost

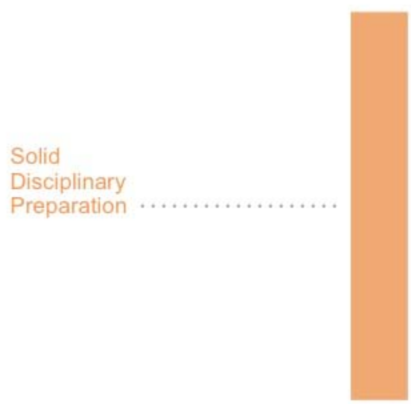
National/Global Prominence Through Differentiation The Leading Destination For VT-Shaped Knowledge

A distinguishing characteristic for Virginia Tech that

- Builds on the university's strengths and tradition
- Allows the university to tackle the complexity of 21st century education, research and engagement in a unique manner
- Facilitates recruitment of talented students and faculty
- Graduates 21st century work force; addresses gaps/needs
- Advances the development of partnerships
- Diversifies our financial portfolio
- Promotes communities of learning

VT-Shaped Individuals

VT-Shaped Framework

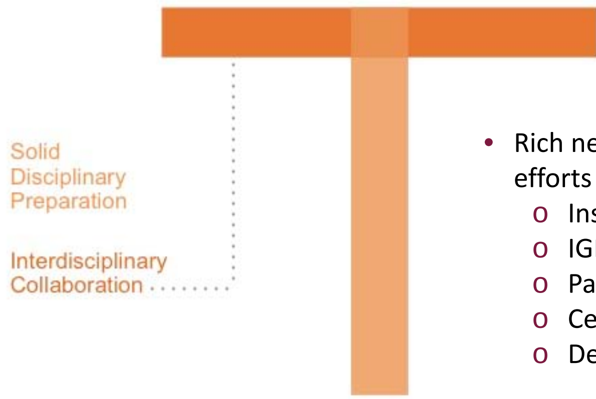


Colleges:

- Customized benchmarking
  - Global leader in select areas of excellence
  - Regional leader in areas of strength
  - Continuous improvement and innovation

- Intelligent Infrastructure a global leader characteristic for many colleges

VT-Shaped Framework



- Rich network of interdisciplinary efforts at VT
  - Institutes
  - IGEPs
  - Pathways Gen Ed Curriculum
  - Centers
  - Destination Areas

Destination Areas Enrich Our Interdisciplinary Network

- Opportunity for collaborations and outcomes of large-scale and scope
  - Student impact
  - Faculty connectivity
  - External support and buy in
  - Societal Impact
- VT excellence network: a three layer network
  - Disciplinary distinction (network nodes)
  - Interdisciplinary distinction
    - Focused interdisciplinary connectivity (centers, institutes, igeps, pathways, etc)
  - Cross cutting approaches to wicked problems (destination areas)

Destination Areas and Themes

Data Analytics and Decision Sciences
- general methodology
- health analytics
- financial resilience analytics
- infrastructure analytics
- security analytics
- social analytics

Integrated Security
- interface between cyber-physical and human agents
- security governance policy and practices
- national security and preparedness

Global Systems Science
- sustainable food systems
- water for health
- contagions and infectious disease

Intelligent Infrastructure for Human-Centered Communities
- autonomous vehicle systems
- smart design and construction
- energy, intelligent/ubiquitous mobility

Adaptive Brain and Behavior
- decision-making
- healthy development
- comparative neuro-oncology

Strategic Growth Areas and Themes

Innovation and Entrepreneurship
- Curriculum available to 10% of our students
- Develop cross-university scholarship in the area

Creative Technologies and Experiences
- Curriculum available to 10% of our students
- Develop cross-university scholarship in the area

Materials
- Focus on additive manufacturing

Policy
- Cross-disciplinary knowledge for meaningful public policy

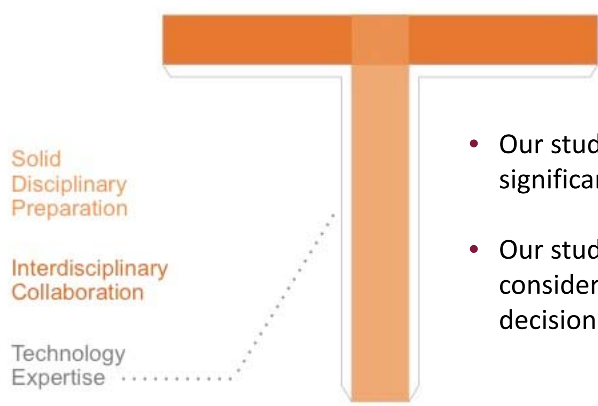
Equity and Social Disparity in the Human Condition
- Pathways Curriculum
- Develop cross-university scholarship in the area

Destination Areas Enrich Our Interdisciplinary Network

Our strategy

1. Explore synergies among strengths of colleges and institutes (completed June 2016)
2. Convene faculty design teams to propose transformational vision and explore participation interest (currently happening)
3. Validate with external audiences (starting by October 2016)
4. Build faculty clusters around areas of greatest synergy and potential for attracting talent globally (starting October 2016 – ongoing)
5. Ensure inclusive representation in faculty design teams and executive committee (starting October 2016 – ongoing)
6. Develop signature cross-cutting research, education, and experiential learning around promising destination area faculty clusters (starting Fall 2016, will take time to mature, schedule to be driven by the faculty/colleges participating)

VT-Shaped Framework



- Our students will graduate with significant technology expertise
- Our students will recognize and consider the human context in decision and action.

VT-Shaped Knowledge Generation Requires Diverse Communities of Learning

- Being where the knowledge and experiences are:
  - Blacksburg
  - Roanoke
  - National Capital Region
  - Extension/Experiment Stations
  - Joint labs with industry
  - Global and regional gateways
- Broad Partnerships: academia, industry, government, community
- Diversity and Inclusion as a key to excellence in 21st century complexity
- Adaptive pedagogy and curriculum

INTELLIGENT INFRASTRUCTURE DESTINATION AREA LEVERAGING EXISTING STRENGTHS

Virginia Tech has many existing strengths at the intersections of the built environment, autonomous systems, and social policy:

8th Ranked Public College of Engineering (USN&WR, 2015)

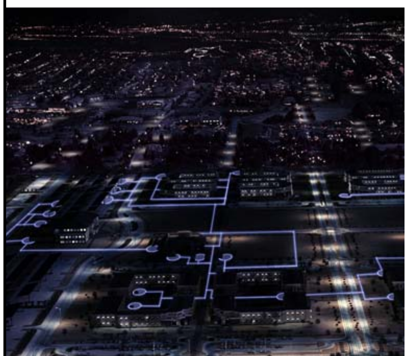
4th Ranked Architecture and Design Program (Design Intelligence, 2015)

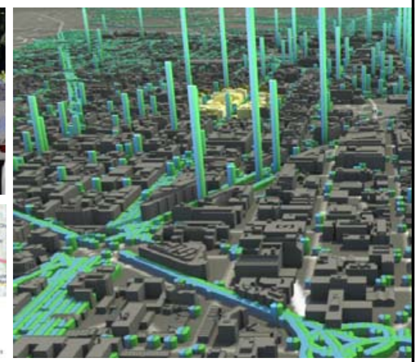
World Class Transportation Institute and Related Centers

Virginia Tech is a comprehensive university that embeds technology and data sciences across its curriculum, including the social sciences and humanities.

VirginiaTech *Invent the Future*

ENERGY, TRANSPORTATION, DATA





Energy Systems &
Power Electronics

Transportation &
Autonomous Systems

Simulation Science &
Data Analytics

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ROBOTICS

Robotic-Assisted Digital Construction and Inspection



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STRUCTURES AND MATERIALS

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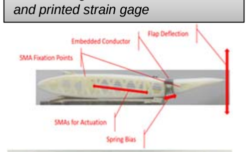
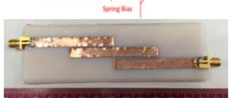
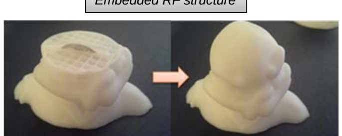
Advanced manufacturing of self monitoring, adaptive, sustainable material

Printed wing with embedded actuator and printed strain gage

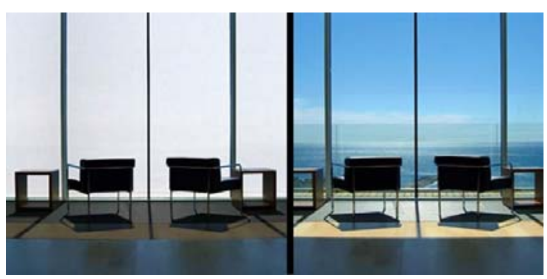


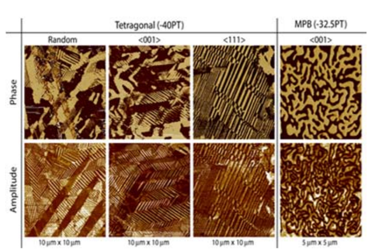


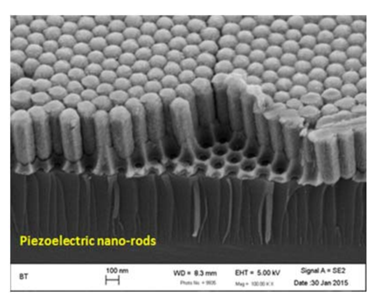
Embedded RF structure



Printed part with embedded RFID tag







FUTURE HAUS

Advanced IoT-Ready Modular 'Cartridges'

Construction with Efficient and Accurate Industrialized Tools and Processes

VISUALIZATION

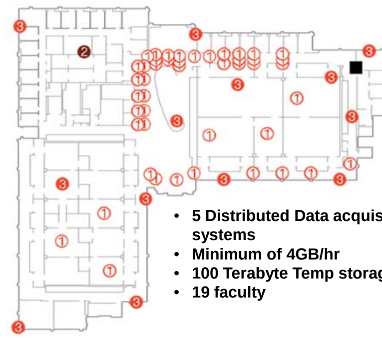
Virtual Reality in Building Design and Construction

Instrumented Buildings

Smart Infrastructure Laboratory (SIL): SIL's mission is to advance research and education in topics that utilize sensor information to improve design, monitoring and daily operation of civil and mechanical infrastructure as well as to investigate how humans interact with the built environment

Major Focus Research Areas

- Security, Emergency Response and Evacuation: Cyber-assisted evacuation through event notification and coordination with authorities can greatly improve high-paced security threats
- Structural Health Monitoring: Use sensor data for long term health monitoring as well as event driven situation such as earthquakes
- Resource Management: Improve energy efficiency by fine-grain analysis of building use with the aid of occupant localization and tracking algorithms
- Smart and Connected Health: Monitoring of health developments in the built environment and events such as fall detection that can improve the quality of life
- Interactive Built Environment: Build fully immersed systems with distributed sensing and actuation for paradigm shift in building interaction
- Network Design: Study different sensor modalities, sensor reduction techniques, optimal placement, and scalability options



- **5 Distributed Data acquisitions systems**
- **Minimum of 4GB/hr**
- **100 Terabyte Temp storage**
- **19 faculty**

212 high sensitivity accelerometers

65,000 feet of cable

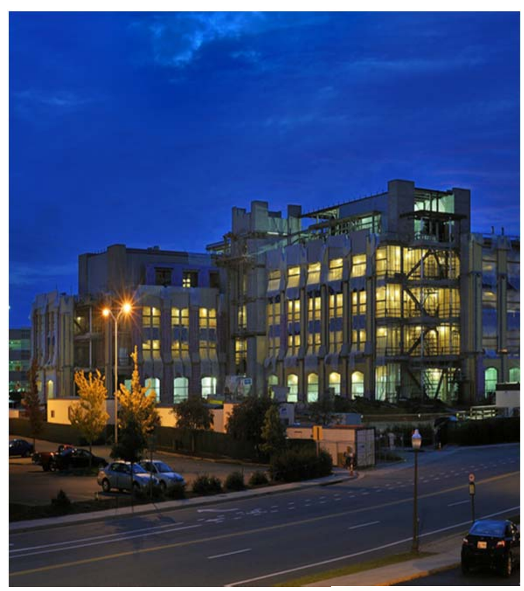
VirginiaTech Invent the Future®

Instrumented Buildings

Goodwin Hall and Moss Arts Center: heavily instrumented living labs for understanding vibration, occupancy, and energy use

Wireless@VT Cognitive Radio Laboratory: world renowned research in dynamic spectrum access and machine learning as applied to wireless communications systems

Center for Housing Research: instrumentation of real world multi-family units across the state for energy consumption and other use patterns



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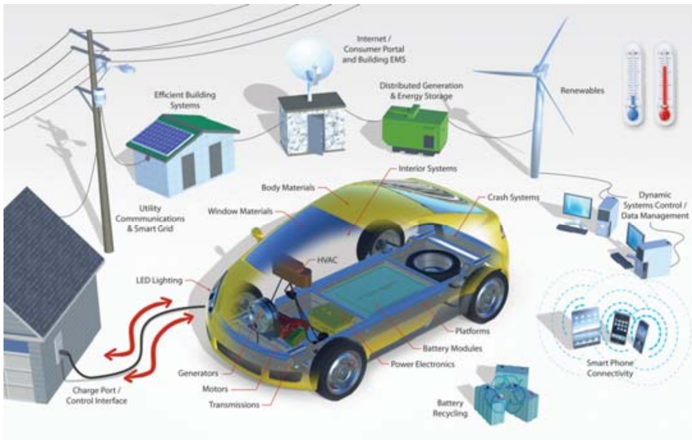
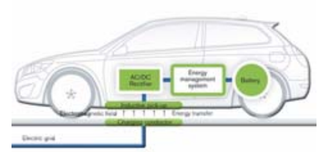
Energy Efficient Built Environments





Energy and Water

Network Dynamics and Simulation Science Laboratory (NDSSL): data modeling and simulation to study integrated systems of energy to include policy and behavior of individuals and organizations

Civil Engineering Networks Dynamics Laboratory:

- developing systems to understand, improve, and predict the dynamics in networks of building occupants
- impact social and physical networks to sustain energy conservation in and across buildings

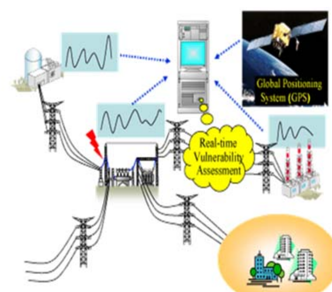
Sustainable Facilities Infrastructure Laboratory: policy, operational, and technological innovations for sustainability over the built environment life cycle

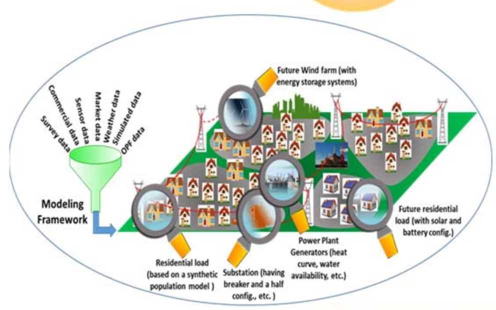
Center for Power Electronics: improving electronic processing and distribution of electrical energy that impact systems of all sizes

ICTAS Energy and Materials Initiative (EMI):

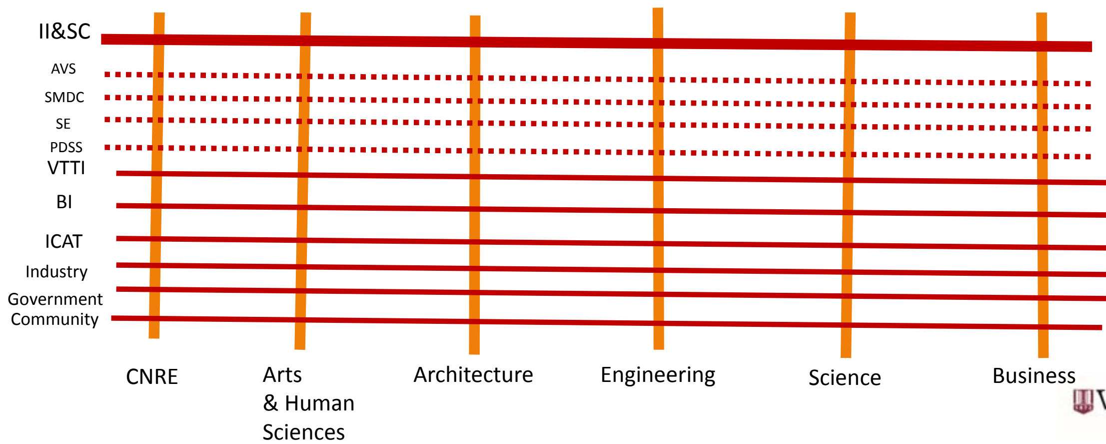
- food, energy, and water nexus
- wasted food to electricity generation and reuse of water

Center for Renewable Energy and Aerodynamic Testing (CREATE): experimental and computational research in wind turbine aerodynamics and aero-acoustics as well as hydrokinetic energy





Intelligent Infrastructure and Smart Cities



VirginiaTech Invent the Future

Intelligent Infrastructure and Smart Cities

- **Infrastructure as Cyber-physical Systems**: Opportunity to lead the development of sustainable materials with sensors and instruments providing on-demand data about performance and efficiency resulting in systems that are smart, adaptive and self-healing; from bridges and roads to buildings and utilities
- **Virtual Design and Smart Construction:** Based on modern production principles, and the emergence of virtual, digital, tools, and semi-autonomous systems, reshaping the planning, design, materials, construction of buildings and structures. Emphasis on interdisciplinary cross proficiency and integration. Emphasis on modular, robot assisted, embedded systems construction.
- **Pervasive decision support systems**: Based on advances in HPC, data sciences, modeling and simulation to develop novel decision support and policy informatics environments.
- **Autonomous Transportation Systems**: Lead the development of self-driving, interconnected transportation systems (land, air and water) with a focus on human safety and wellness. Issues of policy and ethics are interspersed in the development of such systems.
- **Integrated energy systems**: Distributed Smart Energy, focused on developing on-demand energy through a combination of highly efficient and environmentally friendly conventional and renewable energy sources.

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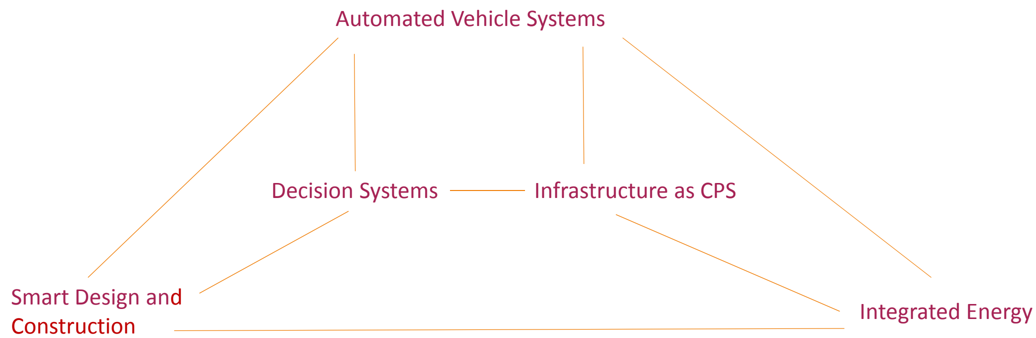
Intelligent Infrastructure and Smart Cities
a systems approach



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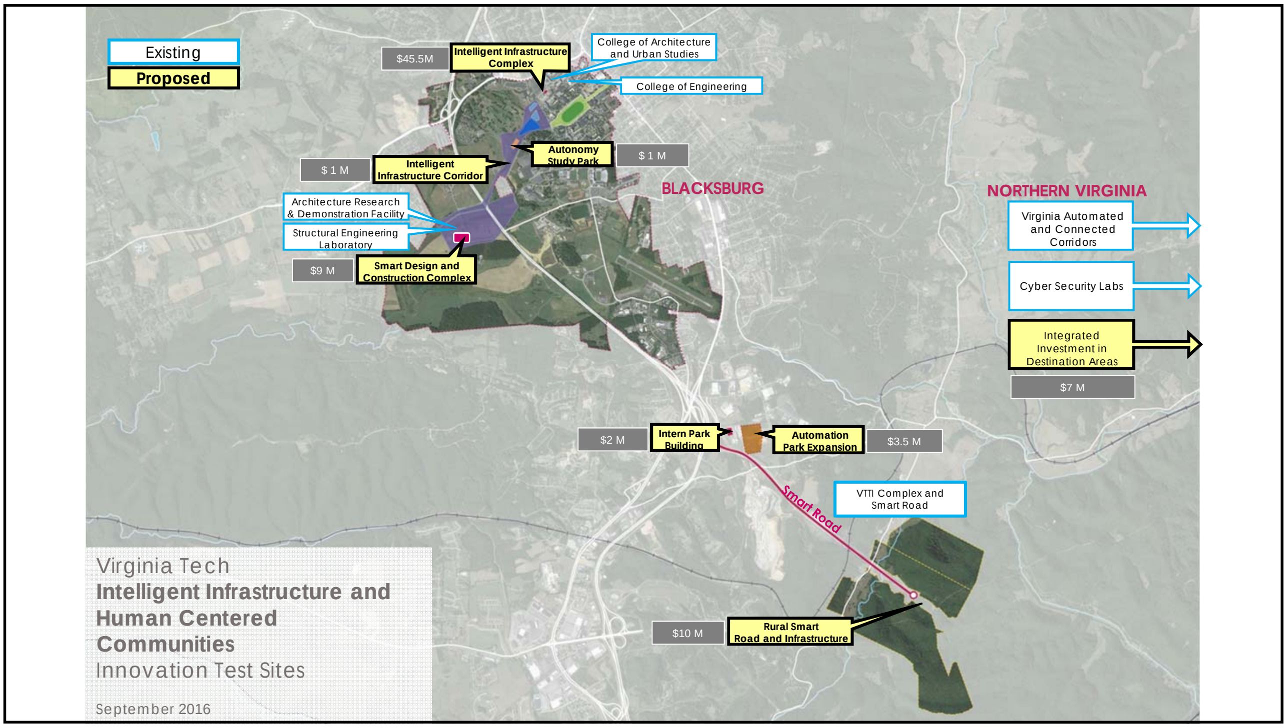
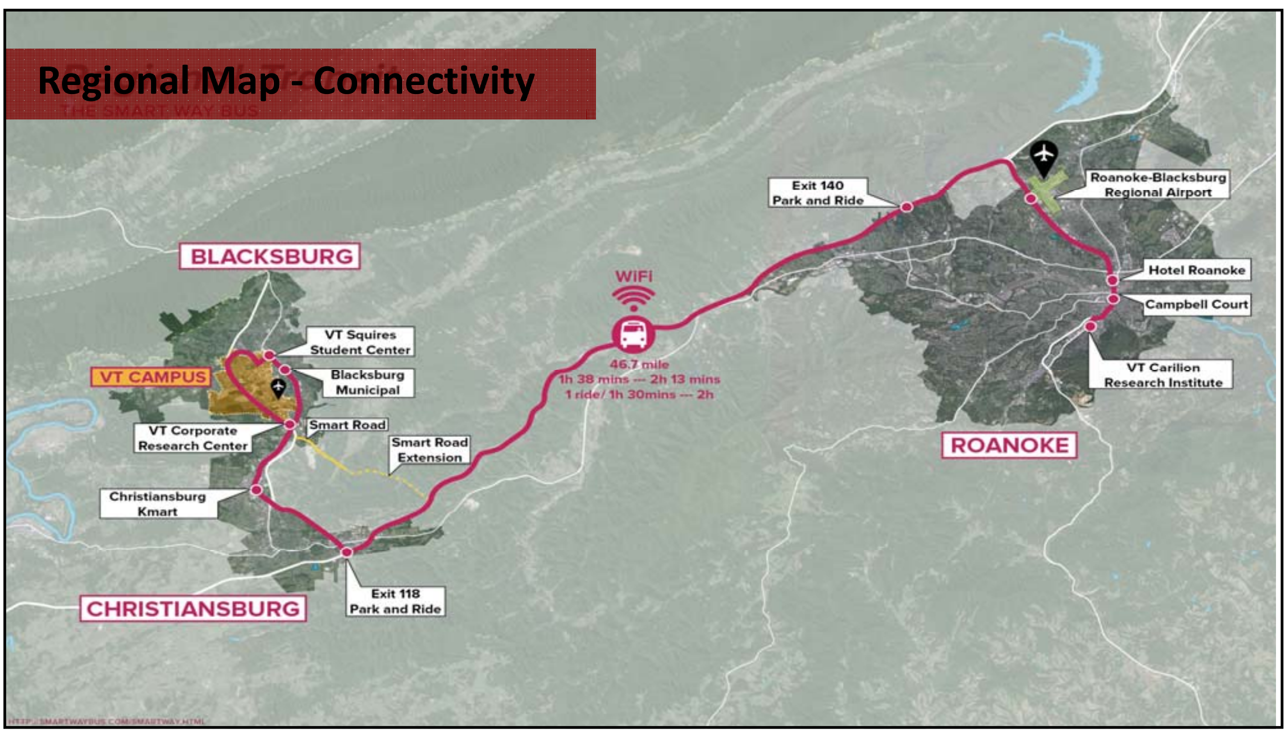
Intelligent Infrastructure Research Locations

Virginia Tech
Intelligent Infrastructure and Human Centered Communities
Innovation Test Sites
September 2016



Existing
Proposed
$45.5M
Intelligent Infrastructure Complex
College of Architecture and Urban Studies
College of Engineering
$ 1 M
Intelligent Infrastructure Corridor
Autonomy Study Park
$ 1 M
BLACKSBURG
Architecture Research & Demonstration Facility
Structural Engineering Laboratory
$9 M
Smart Design and Construction Complex
NORTHERN VIRGINIA
Virginia Automated and Connected Corridors
Cyber Security Labs
Integrated Investment in Destination Areas
$7 M
$2 M
Intern Park Building
Automation Park Expansion
$3.5 M
Smart Road
VTTI Complex and Smart Road
$10 M
Rural Smart Road and Infrastructure
Virginia Tech
Intelligent Infrastructure and Human Centered Communities
Innovation Test Sites
September 2016



Regional Map - Connectivity
BLACKSBURG
VT CAMPUS
VT Squires Student Center
Blacksburg Municipal
Smart Road
VT Corporate Research Center
Smart Road Extension
Christiansburg Kmart
CHRISTIANSBURG
Exit 118 Park and Ride
WiFi
46.7 mile
1h 38 mins --- 2h 13 mins
1 ride/ 1h 30mins --- 2h
Exit 140 Park and Ride
Roanoke-Blacksburg Regional Airport
Hotel Roanoke
Campbell Court
VT Carilion Research Institute
ROANOKE

Intelligent Infrastructure and Smart Cities

- PARTNERSHIPS
  - Industry
  - Government
  - Community

  - Joint Labs
  - Joint Projects
  - Student training and placement collaborations

VA infrastructure becomes the nationally leading test bed
VA has a leading intelligent infrastructure workforce
Industry wants to be here – jobs and economic development
VA as THE destination for 21st century intelligent infrastructure and smart cities

VirginiaTech Invent the Future

Advancing Transportation through Innovation:

VTTI and our role in the Intelligent Infrastructure Initiative

Dr. Tom Dingus

Director of VTTI
President, VTT, LLC
Endowed Professor of Engineering at Virginia Tech

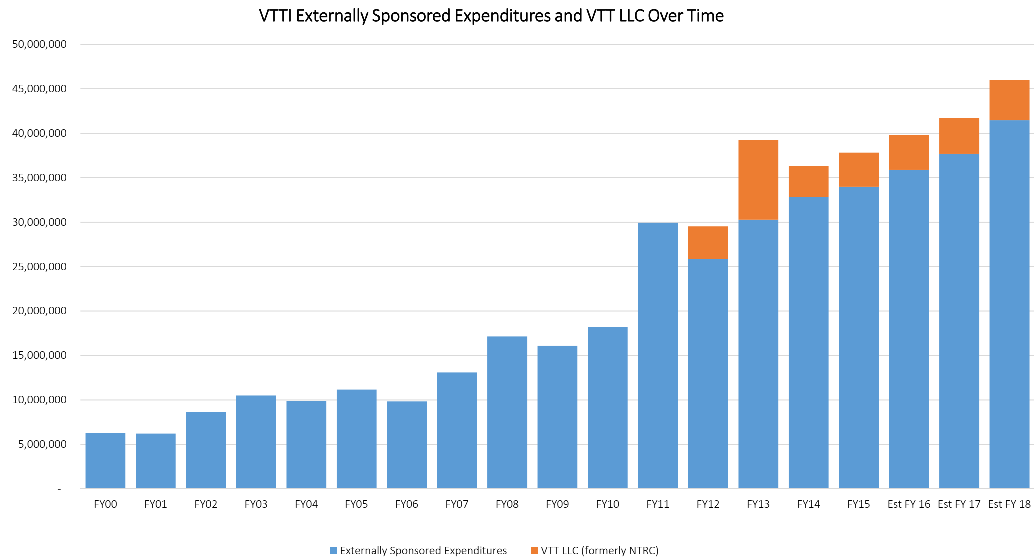
What does it mean to advance transportation through innovation?

It's not just a motto

- We are innovators
- We anticipate the needs of our partners and sponsors and work to create real solutions that enhance safety
- We are pioneers; examples:
  - ➢Smart Road
  - ➢Sled Lab
  - ➢Naturalistic driving studies
  - ➢Global Center for Automotive Performance Simulation

VTTI Facts

- #1 or #2 largest transportation institute in the U.S., depending upon metric
  - ➢#1 in federal grants and contracts
  - ➢#1 in private-sector contracts
- ~100 sponsors; 300+ projects
- 475 employees (almost 300 FTE)
- More than 150 grads/undergrads supported annually
- Projected to grow 25% during the next three years



VTTI Organizational Structure

14 Research Centers/Initiatives/Groups *(~10-40 employees in each)*

- Advanced Automotive Research — Zac Doerzaph, Director (VTTI)
- Automated Vehicle Systems — Shane McLaughlin, Director (VTTI)
- Data Reduction and Analysis Support — Miguel Perez, Director (VTTI)
- Infrastructure-based Safety Systems — Ron Gibbons, Director (VTTI)
- Center for Partnerships, Public Policy and Outreach — Myra Blanco, Director (VTTI)
- Injury Biomechanics — Warren Hardy, Director (ME)
- Sustainable Mobility — Hesham Rakha, Director (CEE/VTTI)
- Sustainable Transportation Infrastructure — Gerardo Flintsch, Director (CEE)
- Technology Development — Andy Petersen, Director (VTTI)
- Technology Implementation — Mike Mollenhauer, Director (VTTI)
- Truck and Bus Safety — Rich Hanowski, Director (VTTI)
- Vulnerable Road User Safety — Jon Antin, Director (VTTI)
- Motorcycle Research Group — Shane McLaughlin, Group Leader (VTTI)
- Global Center for Automotive Performance Simulation — Frank Della Pia, Executive Director (VTT, LLC)

3 Nationally Known Centers

- Connected Vehicle/Infrastructure UTC — Tom Dingus, Director (BEAM/VTTI)
- National Surface Transportation Safety Center — Jon Hankey, Director (VTTI)
- National Tire Research Center — Jon Darab, Director (VTT, LLC)

VTTI Major Historical Milestones:
Development of a World-class $110M Infrastructure

- Smart Road opened in co-sponsorship with VDOT (2000)
- International Center for Naturalistic Driving Data Analysis at Virginia Tech (2006)
- National Surface Transportation Safety Center for Excellence (2006)
- Crash Sled Laboratory Partnership (2009)
- Global Center for Automotive Performance Simulation (Created in 2010; Opened in 2013)
- https://youtu.be/9PUPb-ks0Q4
- Connected Vehicle/Infrastructure University Transportation Center (2012); Northern Virginia Connected-vehicle Test Bed (Opened 2013); Virginia Connected Corridors initiative (2014)
- Center for Automated Vehicle Systems (2013); Virginia Automated Corridors initiative (2015)
- Centers for Public Policy, Partnerships, and Outreach; Technology Implementation (2016)
- Smart Road Expansion (planned for 2016)

Virginia Smart Road

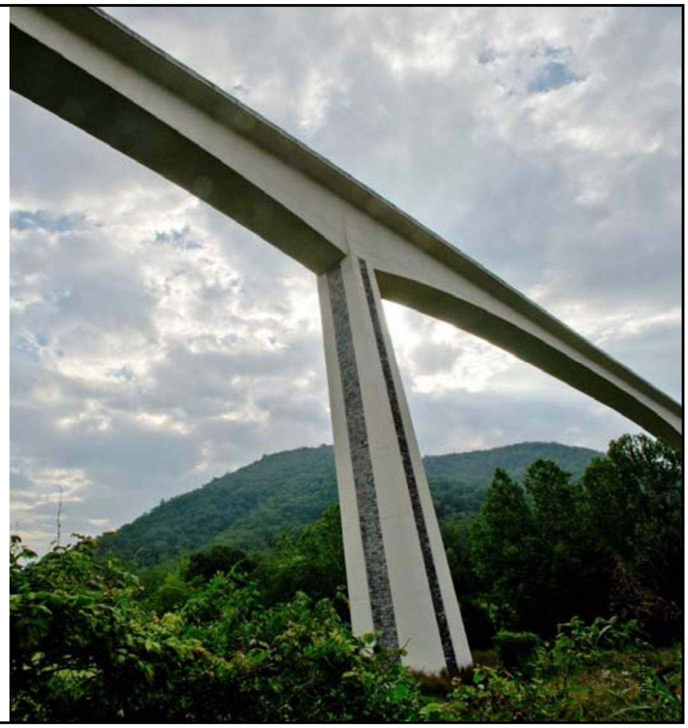
An active, connected, automated test bed for 16 years

The test bed is used more than 2,000 hours per year

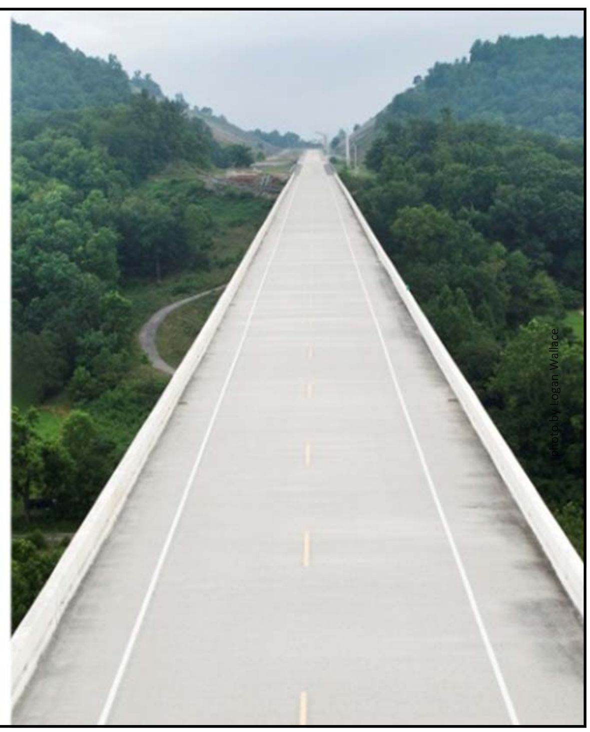
VirginiaTech Transportation Institute

On March 23, 2000, VTTI officially opened the Smart Road in co-sponsorship with VDOT.

To date, more than 22,000 hours of groundbreaking research have been logged on this 2.2-mile test bed.



- Wireless roadside units that provide ubiquitous connected-vehicle communications (including 2 mobile RSEs)
- Optical fiber communication system: sensor/data acquisition access every 60 meters
- Connected-vehicle-compatible intersection controller model
- 14 pavement sections, including an open-grade friction course
- Differential GPS base station
- Built-in road features to facilitate crash avoidance research (e.g., wide clear zones)



- Inclement weather testing (snow, fog, rain)
- 75 custom towers
  - Supported by a 500,000-gallon water tank
  - ½ mile of roadway

VirginiaTech Transportation Institute

- Variable lighting section
  - 60 light towers
  - ~95% of lighting configurations found on U.S. highways
  - Differential spacing
  - Height adjustable
  - Intelligent Transportation Systems (ITS) equipment
  - 3 luminaires/poles
  - Varying intensities

Economic Development

More than 500 jobs have been created by VTTI in Montgomery, Arlington, and Halifax counties

Virginia Tech Transportation Institute

- VTTI has created more jobs in Montgomery Co. than any other public or private entity since the Smart Road opened
  - 500 direct and indirect jobs in Montgomery, Arlington, and Halifax counties
- The VTTI-affiliated Global Center for Automotive Performance Simulation will have an economic impact of $147M on Southern Virginia during first 10 years of operation
  - 183 jobs in the region by 2020
  - More than 30 global customers

Virginia Tech Transportation Institute

Automated-vehicle Systems

- VTTI is actively working with NHTSA, OEMs, and suppliers on groundbreaking automated-vehicle studies
- Recently awarded IDIQ worth up to $25M across five years

VirginiaTech. Transportation Institute

NHTSA IDIQ Contract

- Awarded June 2014
- $25M across five years to research three key areas:
  - Electronics Safe Reliability
  - Cybersecurity
  - Vehicle Automation (Levels 2 & 3)
- 32 teaming members

Mixed-function Automation Naturalistic Driving Study

- Sponsors: NHTSA & ITS JPO
- Investigate driver interaction with market-ready Level 2 systems through a naturalistic driving study (NDS)
  - Investigate how wide variety of drivers interact with L2 systems
  - Investigate how L2 systems operate when controlled by a variety of drivers
  - Monitor vehicle data relevant to targeted functions
- 120 drivers from the Northern Virginia/Washington, D.C. region
  - Equal number of males and females; younger and older groups
  - Each participant will drive a study vehicle for 4 weeks

VirginiaTech Transportation Institute

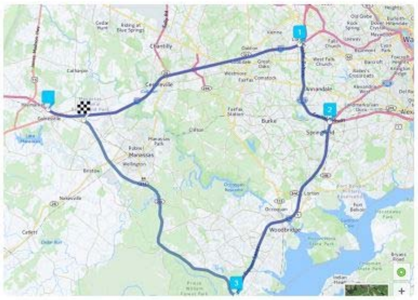
Virginia Automated Corridors

- Part of the Urban Lab concept in Northern Virginia
- In June 2015, VTTI partnered with VDOT, Virginia DMV, Transurban, and HERE to unveil the VAC
- Goal of VAC is to provide an automation-friendly environment that multiple suppliers and developers will use to test and certify their systems
  - Solidify institutional buy-in and support from VDOT, VA State Police, and other key partners
  - Build upon VTTI facilities and VDOT's existing connected-vehicle infrastructure and systems via the Virginia Connected Corridors (VCC)
- VAC allows users to develop test and certification protocols
  - Provide a system migration path from test-track to real-world operating environments for multiple projects
  - Incorporate an operational environment (NoVA) that features myriad transportation challenges
  - Provide realistic and modern connected-vehicle infrastructure environment

VirginiaTech Transportation Institute

Driverless Transportation

About Articles News Events



Va Tech Leaves 'Em Eating Its Dust in the Race to be the Top Driverless Test Track

0 Comments / in Article, Government, Impact, Industry, University

Burney Simpson

Competition among the major driverless car testing grounds came to the fore last week when Virginia Tech Transportation Institute (VTTI) announced it had created the **Virginia Automated Corridors**, 70 miles of real roads near Washington, D.C., that will soon be available for the testing of autonomous vehicles.

VirginiaTech Transportation Institute

Rural Smart Village

(part of the VT Smart Village concept)

VirginiaTech Transportation Institute

Proposed Village

- A large, contiguous area (300+ acres, including Smart Road)
- Encompasses current research and industry leaders
- Full range of test scenarios and conditions (all “edge and corner” cases)
  - Highway
  - Two-lane
  - Long multi-lane flat
  - Weather generation
  - Complex rural roads
  - Off-road
- Educational and secure storage buildings
- Safe and private

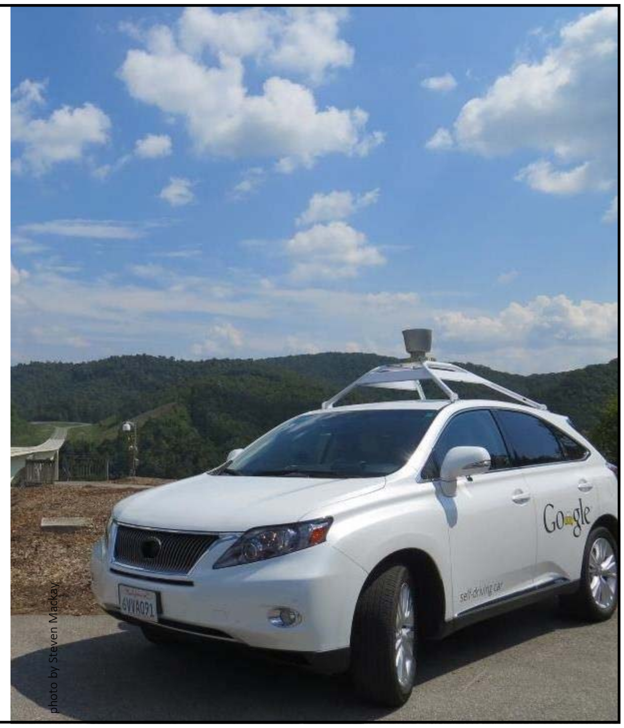
VirginiaTech Transportation Institute

A dramatic shift in mobility is occurring:

- Silicon Valley car companies
  - Apple, #1 in value: $647 billion
  - Google, #4 in value: $453 billion
  - Uber: $51 billion in value (fastest to $50 billion)
  - Tesla: $30 billion (only OEM?)
- Current non-U.S. car companies
  - Toyota, #15 in value: $239 billion
  - VW, #48 in value: $125 billion
  - Daimler, #73 in value: $103 billion
- Detroit car companies
  - Ford: $58 billion
  - GM: $49 billion
- Major global suppliers (none in the U.S.)
  - Bosch: $60 billion
  - Denso: $43 billion
  - Continental: $41 billion

VirginiaTech Transportation Institute

During the next five years, automakers and suppliers will spend *$20 billion* globally on automated-vehicle development



There is already fierce competition to attract industry leaders

Mcity (University of Michigan; unveiled in July 2015 and operational):

- 32-acre testing ground/mock suburb in Ann Arbor
- Designed specifically to research self-driving cars
- MI spent $6M to build; additional $4M came from private companies
- 15 companies have already committed to spending $1M each to conduct research, including:
    - ➢Ford
    - ➢GM
    - ➢Honda
    - ➢Toyota

VirginiaTech. Transportation Institute

Automated and Connected Car Test Site at Willow Run (Michigan; in planning stages)

- Proposed $40M test track located in center of MI Smart Corridor; led by TASS International
- Designed to validate components and full vehicles
- Will complement education, research, and advanced engineering capabilities of Mcity
- Will facilitate high-speed, rural, off-road, urban, commercial, user-defined, and residential test scenarios
- Option to extend test site to field test area (e.g., public roads around Willow Run)
- Initial 2014 workshop attended by major OEMs (e.g., Chrysler, GM, Nissan, VW) and Tier 1 suppliers

VirginiaTech Transportation Institute

- GoMentum Station (California)
  - Connected-/automated-vehicle test bed featuring 20 miles of paved, city-like roadway grids; buildings; urban infrastructure
  - Led by Contra Costa Transportation Authority, in collaboration with OEMs, suppliers, tech companies, researchers/academia, and public agencies
  - Honda is already using the station to test automated-vehicle technologies
- Florida DOT is planning for deployment of autonomous and connected vehicles with Florida Automated Vehicles initiative
  - Create framework for implementation
  - Develop research and pilot projects
  - Create awareness of new technologies
- In July 2015, Texas was able to obtain the first on-road self-driving test vehicles from Google

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Smart Village

Rural Smart Village Concept

Phase 1. Virginia Automation Park: $3.2M (procured and underway)

- Residential/suburban layout
  - “Portable” reconfigurable buildings and other infrastructure elements
  - Example: Facades attached to our current semi trailers
- Roundabout/stop-controlled intersections
- Automation-compatible pavement markings
- Connectivity to the Smart Road
  - Highway layout
  - Signalized intersection
  - Weather and lighting generation

Phase 2. Intern Village: $2.5M (FY19, self-funded)

- Future building
  - Company-funded internships for students working with VTTI faculty
  - Company interest in having “hands-on” experience during senior year and/or first-year master’s
  - Goal would be 10 companies funding $100k-200k/year (each)
  - Building could be self-funded, CRC debt-serviced, 20,000 sq. ft.

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Economic Impact

- The IMPLAN economic impact model was used to determine the economic impact of the proposed Rural Smart Village on the New River Valley
- The Village is projected to have an economic impact of more than $365 million on the New River Valley region during its initial 10 years of operations (2017 - 2026)
- It is also projected that the Village will create 225 jobs in the region by 2026
  - 107 direct jobs
    - 20 jobs resulting from company relocation
  - 118 indirect jobs

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Concept Images: Phases 1 and 2

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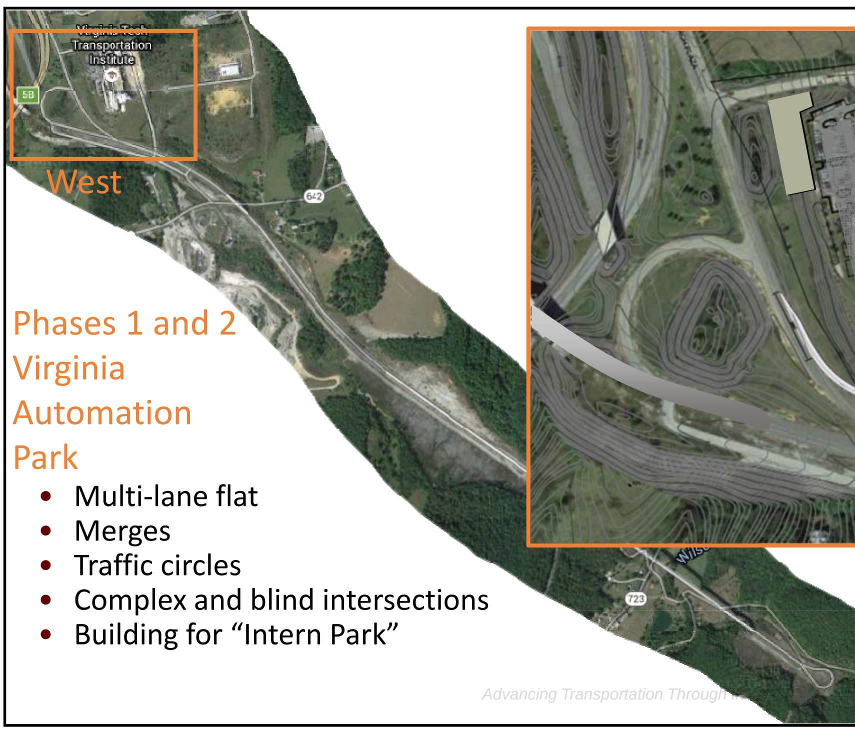

Phases 1 and 2 Virginia Automation Park

- Multi-lane flat
- Merges
- Traffic circles
- Complex and blind intersections
- Building for “Intern Park”

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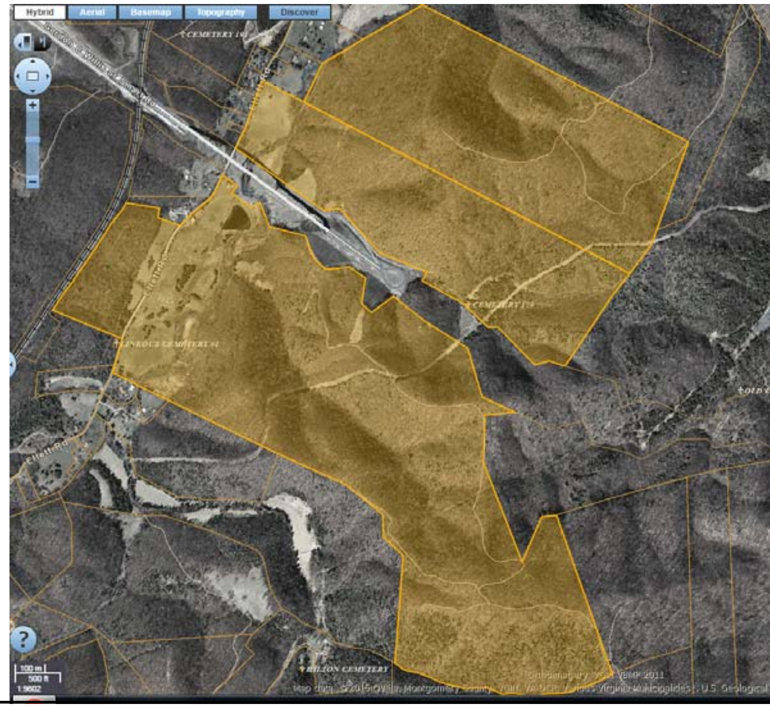
Phase 3: FY19 (Land purchased; concept phase)

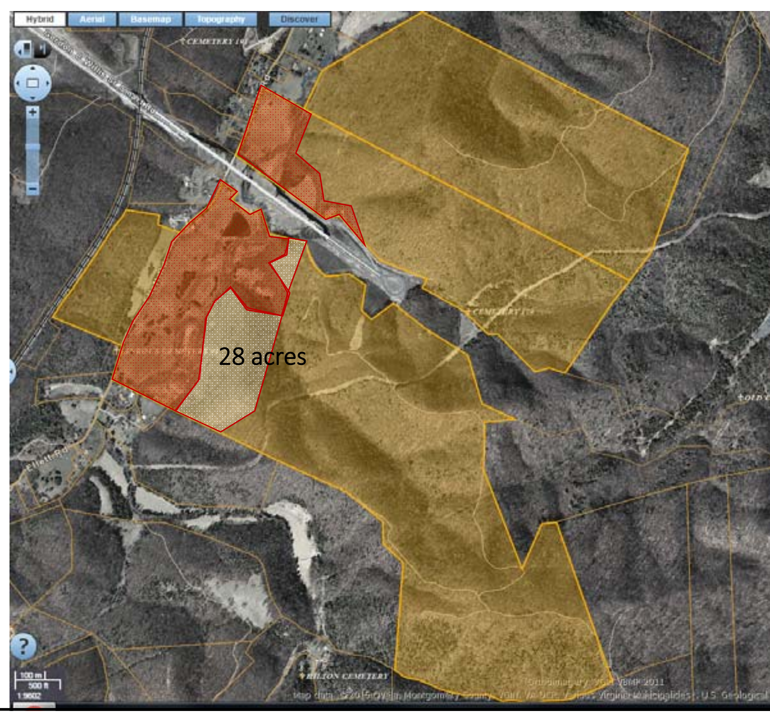
- 615 acres; spans Smart Road right-of-way
- Other uses may emerge as part of the Destination Area process (e.g., military off-road vehicle testing)
- Goal is advanced R&D for connected and automated vehicles
- We want to be the test site for all of the "edge and corner" cases that automated vehicles will have to negotiate
  - Hills and curves of all kinds
  - Trees and limited line of site
  - All weather
- Approximate cost to complete: $8-10M



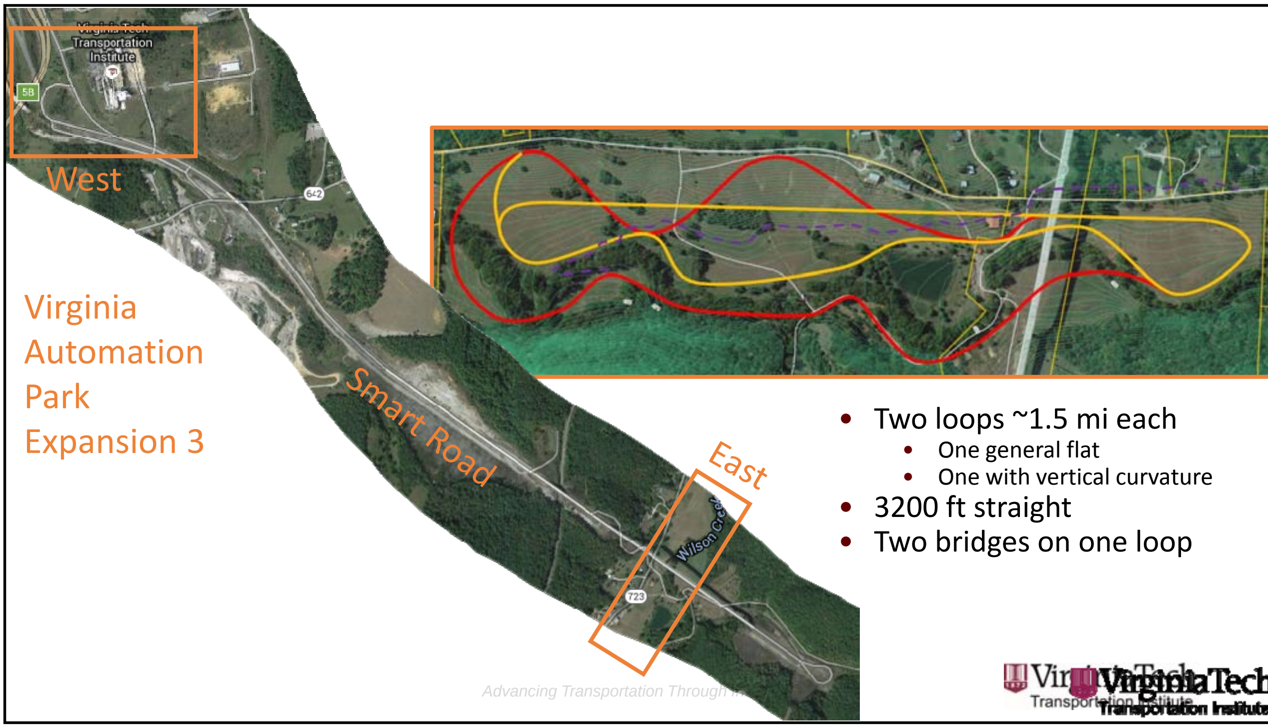
VTTI land commitment

Low Area plus steep hill (103 acres)

1. 75 acres flat cleared lands
2. Plus 28 acres to provide:
   a. Steep hill climb/descent
   b. Rugged terrain



Virginia Automation Park Expansion 3



- Two loops ~1.5 mi each
  - One general flat
  - One with vertical curvature
- 3200 ft straight
- Two bridges on one loop

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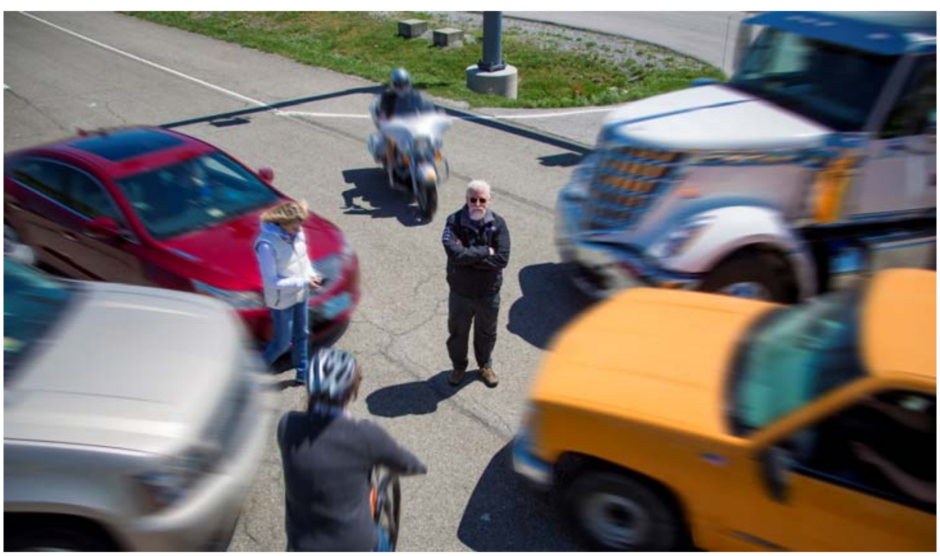
Questions?



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