Automated Vehicle Research

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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
Virginia Tech Facts

• 32,000 students
• 4th largest College of Engineering in the U.S.
• 140 new engineering faculty in the next 10 years (more than 500 total)
• Allows us to perform completely proprietary and confidential research
  ➢ No disclosure without sponsor approval
  ➢ Vast experience conducting propriety/confidential research
VTTI Facts

• #1 or #2 largest transportation institute in the U.S., depending upon metric
• Largest group of driving safety researchers in the world
• ~100 sponsors; 300+ projects; 475 employees
• State-of-the-art test track (3 additional underway)
• Crash Sled Lab Partnership
• Regional and National University Transportation Centers
• Connected Vehicle and Automated Vehicle Corridors (Virginia)
Today

• Current State of Automated Vehicles (AVs)
• VTTI Differentiation
  • Unique Facilities & Collaborations
  • A Foundation of Human Factors Research
  • Naturalistic Driving Studies
• Factors Affecting AV Adoption
Current State of Automated Vehicles
Self-Driving Features You May Have Already Used

**Collision avoidance**
Radar-, laser-, or camera-based systems that warn of an impending collision. Some systems recognize a person straying into the road. If the driver ignores the warnings, some systems will still apply the brakes.

**Drifting warning**
When your car begins to deviate from its lane, some systems alert the driver with a warning buzzer, light and small counter-steering force to the steering wheel.

**Blind-spot detectors**
Uses cameras or radar to detect vehicles in the driver’s blind spot. Alerts the driver with sounds or warning lights in the rearview mirror or in the car’s pillars next to the windshield.

**Enhanced cruise control**
Maintains a predefined distance to the vehicle ahead. If it slows, your car also slows. If a car moves into your lane, your car keeps its distance. Useful in bumper-to-bumper traffic.

**Self parking**
The car maneuvers itself into a parking spot using cameras or sonar. But the driver usually has to brake and follow commands. It first appeared in 2003 in the Toyota Prius. It is now offered by BMW, Ford and many others.

Illustrations by Guilbert Gates/The New York Times
Five Levels of Vehicle Autonomy

**Level 0**
No automation: the driver is in complete control of the vehicle at all times.

**Level 1**
Driver assistance: the vehicle can assist the driver or take control of either the vehicle's speed, through cruise control, or its lane position, through lane guidance.

**Level 2**
Occasional self-driving: the vehicle can take control of both the vehicle's speed and lane position in some situations, for example on limited-access freeways.

**Level 3**
Limited self-driving: the vehicle is in full control in some situations, monitors the road and traffic, and will inform the driver when he or she must take control.

**Level 4**
Full self-driving under certain conditions: the vehicle is in full control for the entire trip in these conditions, such as urban ride-sharing.

**Level 5**
Full self-driving under all conditions: the vehicle can operate without a human driver or occupants.

Source: SAE & NHTSA
Autonomous Vehicle Fleet Projections
(as a percentage of all vehicles on the road)

- 2020's: Large Price Premiums (01%-02%)
- 2030's: Moderate Price Premiums (10%-20%)
- 2040's: Minimal Price Premiums (20%-40%)
- 2050's: Standard on Most New Vehicles (40%-60%)

Source: GHSA
12 states (at least) have AV testing ongoing or coming soon.

**Ongoing**
Arizona, California, Florida, Michigan, Nevada, Ohio, Pennsylvania, Texas, Virginia, and Washington

**Coming soon**
Massachusetts and Tennessee

Source: GHSA
VTTI Differentiation
More than 24,000 hours of groundbreaking research have been logged on this 2.2-mile test bed.

VTTI officially opened the Smart Road in 2000 co-sponsorship with VDOT.

Ubiquitous connected vehicle communications
Optical fiber communication system
Connected-vehicle-compatible intersection controller model
14 pavement sections,
Differential GPS base station
Variable lighting section
- 60 light towers
- Differential spacing
- Height adjustable
- 3 luminaires/poles
- Varying intensities
- Intelligent Transportation Systems (ITS) equipment
- ~95% of lighting configurations found on U.S. highways

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

- Multi-lane flat
- Merges
- Traffic circles
- Complex and blind intersections
- Pick-up / drop off areas

West
• Rural testing
  • Hilly and flat, winding roads
  • Interfering terrain and natural foliage
  • Small bridges and narrow sections
  • Rural intersections
  • Built to older standards

• 3+ miles

Virginia Rural Road Expansion

West

East

Smart Road
Created through a partnership between

VDOT

www.dmvNow.com

transurban

here

Maps for Life

VirginiaTech
Transportation Institute

Safe Drivers · Safe Vehicles · Secure Identities · Saving Lives
Vehicle automation development is progressing at a rapid pace

Pre-deployment testing requires complex vehicle interaction scenarios and real roadway environments

The availability of real-world test environments is extremely limited due to reliability and safety concerns
VAC Test Bed Characteristics

• Smart Road – Controlled test environment with bridge, markings, intersections, weather-making capabilities, variable lighting, roadside equipment
• Virginia International Raceway – Reconfigurable track, operations at higher speeds, elevation changes, complex curves
• HOT lanes in NoVa – Open operational environment, limited-access express lanes
• Real roads in NoVa (I-66, I-495, I-95, rural) – Includes the many details and challenges of public roadway systems
• Potential for expansion to any public roadways to satisfy unique test requirements
# VAC User Options

<table>
<thead>
<tr>
<th>VAC Roadway Environment</th>
<th>Use Case(s)</th>
<th>SAE Level(s) of Automation</th>
<th>Connected via DSRC, Cellular, and HD Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Virginia Highways and Arterials</td>
<td>Freeway Platooning Highway Autopilot Operation in Urban Setting</td>
<td>2-3</td>
<td>Yes</td>
</tr>
<tr>
<td>Town of Blacksburg</td>
<td>Urban Chauffeur Automated Taxi</td>
<td>4</td>
<td>No</td>
</tr>
<tr>
<td>Virginia Smart Road</td>
<td>Closed Test Track</td>
<td>1-5</td>
<td>Yes</td>
</tr>
<tr>
<td>Virginia International Raceway</td>
<td>Closed Test Track</td>
<td>1-5</td>
<td>No</td>
</tr>
<tr>
<td>All Virginia Roads</td>
<td>Many</td>
<td>1-5</td>
<td>No</td>
</tr>
</tbody>
</table>
Visual distraction (eyes off forward roadway) discovered to be the most significant safety issue.

Naturalistic driving data has provided value through discovery, but also through data modeling towards driver support system development (CV, AV).
Naturalistic Driving Research

- Naturalistic driving studies conducted to date provide a wealth of information about driving and transportation
- Continuing to grow the naturalistic database will help answer the greatest transportation challenges of today and into the future
- We will perpetually have 500+ vehicles on the road
- VTTI is expanding naturalistic data collection into next-generation vehicle technologies that have the potential to increase safety and mobility
- We have 2,500 DASs available, including refurbished SHRP 2 DASs
- Advanced vehicle studies planned or underway
Naturalistic Driving Videos

Confidential Videos Shown Here @ Conference (not available for sharing)
Example Public Project

- Mixed Function Automation Study
  - 120 participants in Washington, DC area
  - One month of driving
  - How do people use lateral and longitudinal control systems?
Areas for Investigation

How do **DRIVERS** use their vehicles today and in the future?

How should **AUTOMATED VEHICLES** behave today and in the future?

What is the best **DEPLOYMENT ROADMAP** while considering drivers, AVs, and infrastructure?

How should **INFRASTRUCTURE** be adapted for successful AV deployment?
Factors Affecting Adoption Rates
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• The Human Factor

  Levels 2-4 are difficult to implement
  • Drivers still need to be able to take control under various circumstances
  • Willingness to trust and rapidly engage in secondary tasks, including potential impairment
  • Accurate driver state monitoring may be required

Acceptance

  • >50% report unwilling to fully relinquish control to an automated vehicle
  • Costs may delay broader acceptance
Factors Affecting Adoption Rates

• The Human Factor

We’re being sold on a wide range of safety, eco, and mobility benefits and all are possible, however...
• Most safety and eco benefits won’t begin to be realized until 50-75% of fleet is automated
• May even be early phase dis-benefit with increases in VMT, deadhead trips, security events, etc.

Saturation will take time
• Average age in the fleet is 12 years
• Automation will likely be rolled out as a luxury option

Commercial trucking may have most compelling value proposition

• The Mixed Fleet
Factors Affecting Adoption Rates

• The Human Factor
• The Mixed Fleet
• Operational Domains

Operational domains are expected to materialize defining where particular systems are expected to function
  • High res mapping, lane markings, V2I, weather conditions, pedestrian controls, unusual features

Where will we start with Level 4+?
  • Dedicated lanes? Freeways? Corridors?
  • Dense urban zones?

Will there be solutions that benefit non-urban users?
  • 34% of roads in US are unpaved with no lines
  • Varied trip lengths affect value proposition

Domains will have regional flavor
Difficult AV Challenges

Safe Drivers · Safe Vehicles · Secure Identities · Saving Lives
Factors Affecting Adoption Rates

• The Human Factor
• The Mixed Fleet
• Operational Domains
• The Big One

Public perception of safety will be key
• One high profile crash could set adoption back 10 years
• Locus of control issues
• Data and privacy concerns

Cybersecurity threats are real and need to be addressed
• This issue is never “solved” and difficult to certify

If trucking adopts rapidly
• Are we ready to accept 80K lb unmanned systems?
Public Perceptions of Automation

Safe Drivers · Safe Vehicles · Secure Identities · Saving Lives
Reddit discussion threads re: self-driving cars

[-] Subvert0 ♂ 15 points 1 year ago
As someone who will only buy vehicles with manual transmissions, I'm not a fan of self driving cars at all. I actually really enjoy driving (hence the manuals), and if my ability to drive my own car is taken away I'd be pretty pissed.

Not to mention the numerous security concerns. Hackers were already able to completely take over control of a Jeep Cherokee through it's wireless internet connection. Imagine what they could do if they got onto the network that controls all self driving cars.

[-] heykidsitiscox 3 points 1 year ago
Not a fan.
I hate having a car that changes gears for me, let alone one that manages the steering wheel.
I enjoy driving, always have and likely always will.

[-] MuslimGoku ♂ 5 points 1 year ago
I drive a mini cooper s with a manual tranny. And I love every second I spend with my car. I love cars, and I love driving. That's why I don't like automatic transmissions, or any of the new stuff peoples do to cars. It's not like you're driving a car anymore. You're just riding in a computer on wheels. Self driving cars are the absolute worst to me.
“When individuals are exposed to involuntary risk (a risk over which they have no control), they make risk aversion their primary goal. Under these circumstances individuals require the probability of risk to be as much as one thousand times smaller than for the same situation under their perceived control (a notable example being the common bias in the perception of risk in flying vs. driving).”

Source: http://capita.wustl.edu/me567_informatics/concepts/riskben.html
Most people believe flying is about 1.75 times safer than driving, when fatality statistics show that it is over 2000 times safer

Using the rough number of 1,000 times more risk tolerant for manual driving vs. autonomous driving = 35 fatalities/year to be perceived as equally safe

Can we get there if we have a perpetual mixed fleet?
Factors Affecting Adoption Rates

- The Human Factor
- The Mixed Fleet
- Operational Domains
- The Big One
- No National Program

Automation has been positioned as the solution to our transportation problems:
- 90% reduction in crashes
- 35% reduction in fuel
- Extended mobility for non-drivers

Currently there is no national program other than guidance:
- Operational domains will vary making product development more challenging
- Rules, legislation, licensing will all vary state by state
- Already seeing variance in state regulation for testing and initial deployments
To Ponder...

• Do autonomous vehicles have to be able to operate at “commercial airline” reliability to be perceived as acceptable and safe?

• Will autonomous vehicles eventually have to operate ubiquitously across state lines and in all roadway, traffic, and weather scenarios?

• Will autonomous vehicles have to perpetually operate in “mixed” traffic?

• How will we protect Autonomous vehicles against ever-evolving cyber attacks?

• Do cars that are not fully autonomous need to not only reliably understand what is going on around them, but also need to understand the state of the driver? - [https://youtu.be/sXls4cdEv7c](https://youtu.be/sXls4cdEv7c)
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