MDOT State Highway Administration

Connected & Automated Vehicle (CAV) Strategic Action Plan

A Strategic and Operational Outlook on the Impacts of CAV

December 2017

Larry Hogan Jr.
Governor

Boyd Rutherford
Lt. Governor

Pete Rahn
MDOT Secretary

Greg Slater
SHA Administrator

MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

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Message from the Administrator

On behalf of Maryland Governor Larry Hogan and Maryland Department of Transportation (MDOT) Secretary Pete Rahn, thank you for your interest in Maryland's transportation system. With the Governor's focus on Changing Maryland for the Better, the Maryland Department of Transportation's State Highway Administration (MDOT SHA) is focused on providing a balanced, reliable, safe, efficient and affordable transportation system to all of Maryland's citizens and businesses.

We continue to invest in roads to reduce gridlock, improve safety, and reliably transport people and goods. Our focus includes a recognition that changing technology and advances in mobile computing are rapidly changing the landscape of transportation in Maryland – and around the nation. Governor Hogan's recent initiatives such as the "Smart Signals" program and the "Innovative Congestion Management" project along Interstate 270 are just a few examples of leveraging next generation technology to provide benefits to hundreds of thousands of Maryland travelers every day.

Technology isn't just changing on the roadways, it is also rapidly advancing in the vehicles that utilize our facilities. This evolution is captured in what the industry refers to as Connected and Automated Vehicles (CAVs) – technology changing the way we drive, and eventually changing who is driving the vehicle (human vs computer).

The rapid pace of technological innovation with respect to CAV requires owners and operators of roadway infrastructure to adopt policies and programs to accommodate the vehicles of the future. These technologies could improve safety, significantly alter transportation costs, and change traffic patterns and congestion. These safety, mobility, and environmental benefits are directly in line with MDOT SHA's existing goals, policies and plans. But it is important that we keep up with the fast-moving evolution in technology and ensure our facilities, programs, and users are ready for this change.

The emerging CAV industry could also affect local job creation, talent retention, economic development, and improve quality of life throughout the state. We are committed to delivering on the Governor's pledge to be "Open for Business" as the economic vitality of our State, creating jobs and opportunities, is closely tied to transportation.

This CAV Strategic Action plan defines strategy statements that will enable MDOT SHA to achieve the aforementioned safety, mobility, and environmental goals, while acknowledging and working within the uncertain environment that today's technology revolution demands. It establishes a vision whereby we focus on embracing technology and next generation mobility trends to provide safe & reliable travel for people and goods within Maryland. Join us as we journey into the not-too-distant future and set a course for future technology developments in transportation.

Greg Slater
State Highway Administrator

Acknowledgments

The Maryland Department of Transportation's State Highway Administration (MDOT SHA) developed this Connected & Automated Vehicle (CAV) Strategic Action Plan through a comprehensive internal coordination effort led jointly by the Office of CHART and ITS Development and the Office of Planning and Preliminary Engineering. In addition to representation from a broad spectrum of stakeholders within MDOT SHA helping guide the development of this plan, a number of external subject matter experts helped execute its development, most notably from WSP USA and the University of Maryland Center for Advanced Transportation Technology.

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Acronyms

AASHTO... American Association of State Highway and Transportation Officials
ACM ....American Center for Mobility
APL.. Applied Physics Laboratory
ATC .... Aberdeen Test Center
ATCMTD.....................Advanced Transportation and Congestion Management Technologies Deployment
ATM .... Active Traffic Management
AV .... Automated Vehicle
BRTB ....Baltimore Metropolitan Planning Region
CATT.. Center for Advanced Transportation Technology
CAV .... Connected & Automated Vehicle
CDOT.. Colorado Department of Transportation
CGI .... Concrete General Inc.
CHART .... Coordinated Highways Action Response Team
CRCS... Connected Road Classification System
CV .... Connected Vehicle
DARPA... Defense Advanced Research Projects Agency
DCCP .... Digital Commerce and Consumer Protection
DMS .... Dynamic Message Signs
DOD .... Department of Defense
DOT .... Department of Transportation
DSRC .... Dedicated Short-Range Communications
EOI .... Expression of Interest
ETP .... Emergency Traffic Patrols
FAST .... Fixing America's Surface Transportation
FHWA.. Federal Highway Administration
FLETC .... Federal Law Enforcement Training Center
GID.. Geometric Intersection Description
HAV.. Highly Automated Vehicles
HSIP .... Highway Safety Improvement Program
ICM .... Innovative Congestion Management
IoT.. Internet of Things
ITE.. Institute of Transportation Engineers
ITS.. Intelligent Transportation Systems
LRTP .... Long-Range Transportation Plan
MAA... Maryland Aviation Administration
MDOT.. Maryland Department of Transportation
MDTA.. Maryland Transportation Authority
MMITSS... Multimodal Intelligent Traffic Signal System
MPA .... Maryland Port Administration
MPO... Metropolitan Planning Organizations
MTA .... Maryland Transit Administration
MVA.. Motor Vehicle Administration
NCHRP... National Cooperative Highway Research Program
NCSL.. National Conference of State Legislatures

NHPP .... National Highway Performance Program
NHTSA .... National Highway Traffic Safety Administration
NSFHP .... Nationally Significant Freight and Highway Projects
NTC .... National Transportation Center
NYCDOT .... New York City Department of Transportation
O&M .... Operations and Maintenance
OBU .... Onboard Unit
PFS .... Pooled Fund Study
POC .... Point of Contact
REL .... Reversible Express Lanes
RSU .... Roadside Unit
RWIS .... Road Weather Information Systems
SAE .... Society of Automotive Engineers
SHA .... State Highway Administration
SOC .... Statewide Operations Center
SPaT .... Signal Phase and Timing
SPMD .... Safety Pilot Model Deployment
STEM .... Science, Technology, Engineering, and Mathematic
TBU .... Transportation Business Units
THEA .... Tampa-Hillsborough Expressway Authority
TIP .... Transportation improvement program
TOC .... Traffic Operations Center
TSM&O .... Transportation Systems Management & Operations
UMD .... University of Maryland
VMT .... Vehicle-Miles Traveled
VPP .... Vehicle Probe Project

Executive Summary

The Maryland Department of Transportation State Highway Administration (MDOT SHA) has developed this strategic action plan for connected & automated vehicles (CAV) to prepare its infrastructure, policy, and operations for the future. The plan will employ a well-informed and well-defined approach to ensure MDOT SHA is prepared and engaged in CAV implementation.

Among other things, the MDOT SHA is looking toward pilot deployments to better understand and support project-level and region-wide programs of the next generation. There are also a number of foundational efforts identified in this plan that will ensure MDOT SHA remains nimble yet grounded in the need to provide ongoing benefits to the citizens of Maryland.

MDOT SHA's CAV program vision and goals are built upon and support the guiding principles and objectives of the agency as a whole:

MDOT SHA VISION for CAV	Embrace technology and next generation mobility trends to provide safe & reliable travel for people and goods within Maryland.
MDOT SHA GOALS for CAV	GOAL 1: Make Maryland an attractive partner for CAV development, testing, and production; Maryland is "open for business." GOAL 2: Begin deploying CAV technology to gain experience through pilot projects, and work with partners to engage in national efforts. GOAL 3: Establish foundational systems to support future CAV deployment – data management, telecommunications, and a robust policy program to enable sustained deployment activity. GOAL 4: Enable CAV benefits for customers—identify ways to add value to your customers today and in the near future during the transitional timeframe of CAV on our roadways. GOAL 5: Look for opportunities to leverage CAV technologies to support existing business processes and objectives such as performance based planning and provide operational benefits to support and enhance other business processes.

Widespread introduction of CAVs could greatly reduce crashes and fatalities on our roadways, improve congestion and provide increased travel options, and result in improvements to fuel economy and air quality. These safety, mobility, and environmental benefits are directly in line with MDOT SHA's existing goals, policies and plans.

This Strategic Action plan defines strategy statements that will enable MDOT SHA to achieve the aforementioned vision and goals, while acknowledging and working within the uncertain environment that today's technology revolution demands.

Strategy Statement	Examples
Implement Pilot Programs to Build Experience and Attract Partners	Examples include a pilot corridor already defined along US 1 in Howard County, future pilot corridors aligned with other programs, and issues surrounding funding and related project efforts.
Get Additional Benefits by Supporting CAV Testing	Examples include partnering with the Aberdeen Proving Ground and the U.S. DOT, while leveraging relationships with various Maryland academic institutions and private companies interested in testing in Maryland.
Foundational Needs of a CAV Program	Examples include an emphasis on a robust telecommunications infrastructure, enhanced road markings and signage, policy & legislative issues, and a focus on data governance.
Outreach Activities	Examples include an internal and external outreach program, and continued involvement in national activities.
Organizational Management of CAV	Examples include an internal MDOT SHA CAV Working Group and active involvement in MDOT's larger working group.

The dizzying pace of technological innovation with respect to CAV requires owners and operators of roadway infrastructure to adopt policies and programs to accommodate the vehicles of the future. These technologies could improve safety, significantly alter transportation costs, and change traffic patterns and congestion. This emerging industry could also affect local job creation, talent retention, economic development, and improve quality of life throughout the state. The anticipated timeframe for a "majority" of vehicles to be CAVs varies greatly and depends on a variety of factors—but most scholars believe even partial implementation could have dramatic impacts on our transportation infrastructure and travel patterns. It is time for government agencies to consider how the potentially substantial changes posed by CAV technology will affect transportation and infrastructure decisions.

Overview

Connected and automated vehicles (CAV) are key components in the quest to achieve the next generation of transportation and mobility. To support the Maryland Department of Transportation State Highway Administration (MDOT SHA), WSP conducted a planning exercise to establish a framework for moving forward. Several internal working group meetings were held—accompanied by one-on-one meetings with specific stakeholders within MDOT SHA—to frame the issues, concerns, and ideas that should be captured in planning for CAV. The result is this strategic action document—roughly described as somewhere in between a master plan and a deployment plan—which combines both elements to provide MDOT SHA with a view of how to best manage this rapidly evolving topic.

The foundation in MDOT SHA's effort was recognizing it is important to outline goals and objectives but also remain nimble so as to rapidly adjust to lessons learned and evolving strategies or technologies. This will be a living document.

DOCUMENT ORGANIZATION

Four different components describe this planning exercise:

- Baseline: What is CAV?
- Planning Activities
- Take Action! Pilot CAV Programs
- Enabling Actions: Build a Support Program

The baseline chapter introduces definitions associated with CAVs, taking care to describe the differences and nuances of the terminology. The different stakeholders involved in CAVs and some of the key infrastructure components of most interest to MDOT SHA are also described. The baseline chapter emphasizes the many different activities happening at the national level—including connected vehicle (CV) pilot programs and deployments, the national Vehicle-to-Infrastructure (V2I) Deployment Coalition, federal automated vehicle (AV) policy, and automated vehicle development, testing, and research—and concludes with a discussion on the rapidly growing Smart Cities & Communities effort.

The planning chapter follows, taking care to describe Maryland's entry into Transportation Systems Management & Operations (TSM&O), and how this strategic action plan incorporates the philosophy and specific elements from the TSM&O activity in progress. The chapter also describes Maryland's Coordinated Highways Action Response Team (CHART) program, guidance from the U.S. Department of Transportation (U.S. DOT) on planning for CAV, and how new CAV developments affect planning for operations and maintenance. The chapter concludes with a vision and goals for a Maryland CAV program, and a set of strategies moving forward.

The most impactful chapter focuses on taking action, with two sections dedicated to tactical actions that are influenced by and will likewise influence strategic planning efforts. Implementing pilot programs to build experience and attract partners is important, and this document discusses several potential opportunities in Maryland:

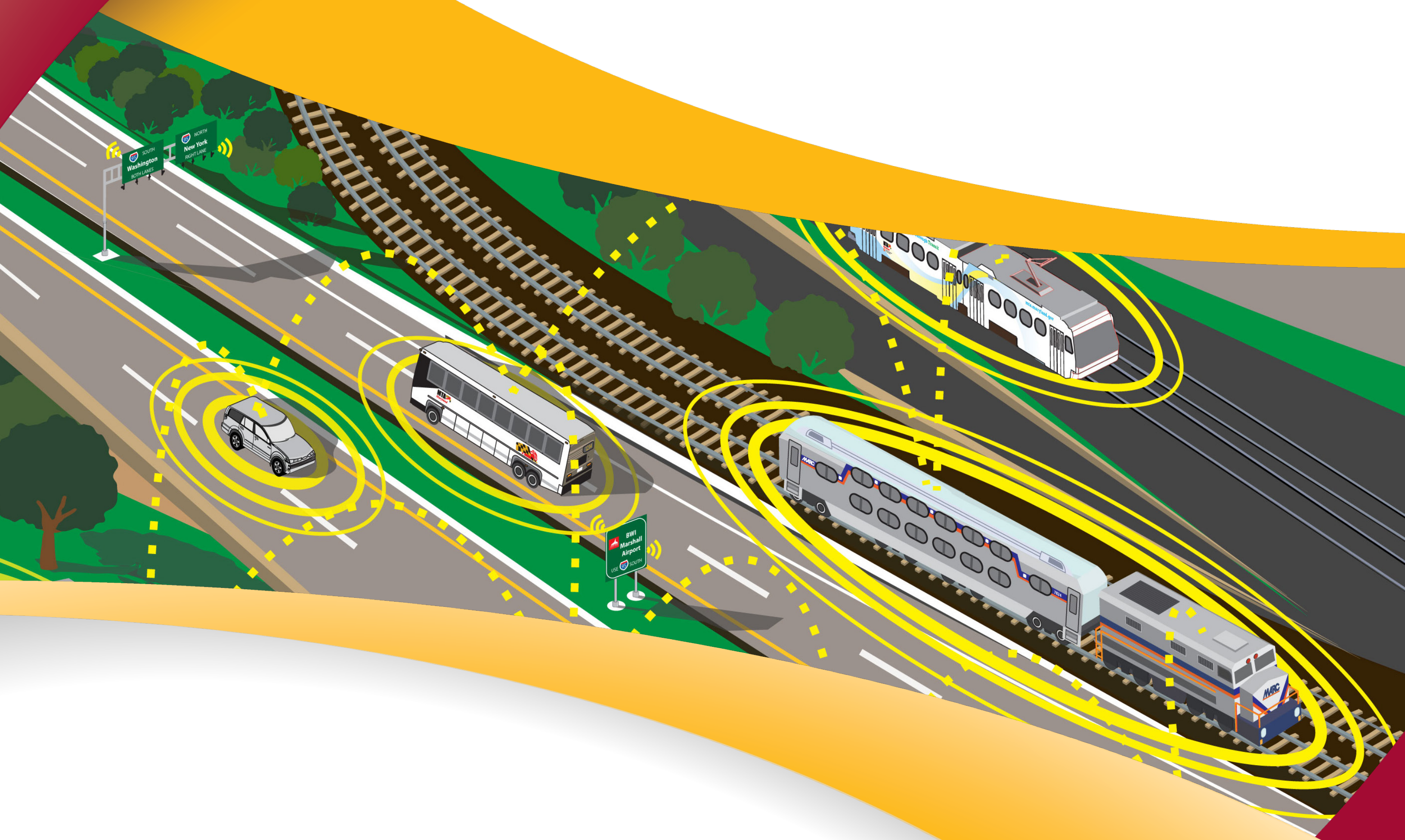
- US 1 Innovative Technology Deployment Corridor
- Future Innovative Technology Deployment Corridors and Process for Identifying New Opportunities
- Federal Grant Opportunities

The "taking action" section also focuses on gaining valuable experience and exposure for MDOT SHA by supporting CAV testing in cooperation with the Aberdeen Proving Ground, U.S. DOT, and the University of Maryland.

Finally, the report rounds out the planning effort by recommending the following enabling activities that will help build a solid program for the future of CAV in Maryland and within MDOT SHA:

- Foundational needs such as telecommunications, enhanced road markings and signage, policy and legislation, data governance, and staffing and skill development
- Outreach for internal, external, and engagement in national activities
- Organizational management of CAV within and among MDOT SHA offices, as part of the greater MDOT and its CAV Working Group.

Baseline:
What Is CAV?



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Baseline: What is CAV?

INTRODUCTION TO CAV

CVs and AVs will likely bring fundamental change to transportation and mobility as we know it today. Technology is not only changing the way we look at transportation, in our increasingly connected society, it is also dramatically changing all aspects of our lives. This chapter explores some of the key concepts that will have an impact on MDOT SHA programs today and in the future.

Terminology

As with any nascent industry, definitions and terminology often evolve as quickly as policy and technology. For example in the case of CAV, the terms connected, autonomous, automated, self-driving, and driverless are often used interchangeably, but in the rush to hype the technology revolution, we often don't get this message—the terms each mean something different:

- A vehicle can be connected by different communication means (e.g., cellular, satellite, dedicated short-range communications) but still be driven like a typical car/truck. The federal government has researched CVs and concluded that many applications and strategies that use Dedicated Short-Range Communications (DSRC) could significantly reduce accidents and roadway fatalities.
- A vehicle can be autonomous and operate purely through the guidance of sensors, cameras, and GPS—being aware of its immediate surroundings but not the bigger picture. The Waymo (formerly Google) autonomous car has logged more than a million miles across several locations around the United States.
- Automated is a more generalized term, referring to the ability to operate with limited human interface. Automated vehicles can combine connected and autonomous technologies to operate in the immediate vicinity but with an awareness of what's going on around the corner, three cars ahead, or a mile down the road. To many industry experts, this is the ideal combination, providing technological convenience alongside maximum safety benefits.
- A vehicle can have self-driving capabilities but require occasional human intervention, or it could be driverless and require no human intervention. There are different "levels of automation" defined by the industry and government that attempt to define these different interactions between human interaction and computer control.

Likewise, there remains an uncertain future in terms of "acronym bundling." Interchangeable use of CAV, C/AV, CV/AV, and even Autonomous and Connected Vehicle (ACV) have further confused those just entering the arena. For the purposes of this document we focus on CAV—recognizing, however, that when referring to a program controlled by others we may refer to it in its given form even though it might mean the same thing.

Further complicating the situation is a frequent merging of different categories and solutions such as low-speed AV shuttles and high-speed CAV interactions. The needs and issues for those two examples are dramatically different: an 8-person 15 mph all-electric autonomous shuttle operating in a closed-loop scenario on a protected right-of-way involves an entirely different set of assumptions, standards, and issues than a personal car with partial automation operating at 65 mph on a crowded freeway alongside vehicles driven by humans. In the rush to embrace the rapidly evolving scene, these exact scenarios are often referred to as one-in-the-same.

The U.S. Department of Transportation (U.S. DOT) has provided some assistance with the Federal Automated Vehicles Policy released in late 2016[1] and updated again in September 2017.[2] This guidance suggests how state or local departments of transportation (DOT) might prepare for the incoming issues surrounding AVs, and more importantly, in terms of definitions. The U.S. DOT adopted the "Levels of Automation" (Figure 1) put forth by SAE International in its J3016 standard.[3]

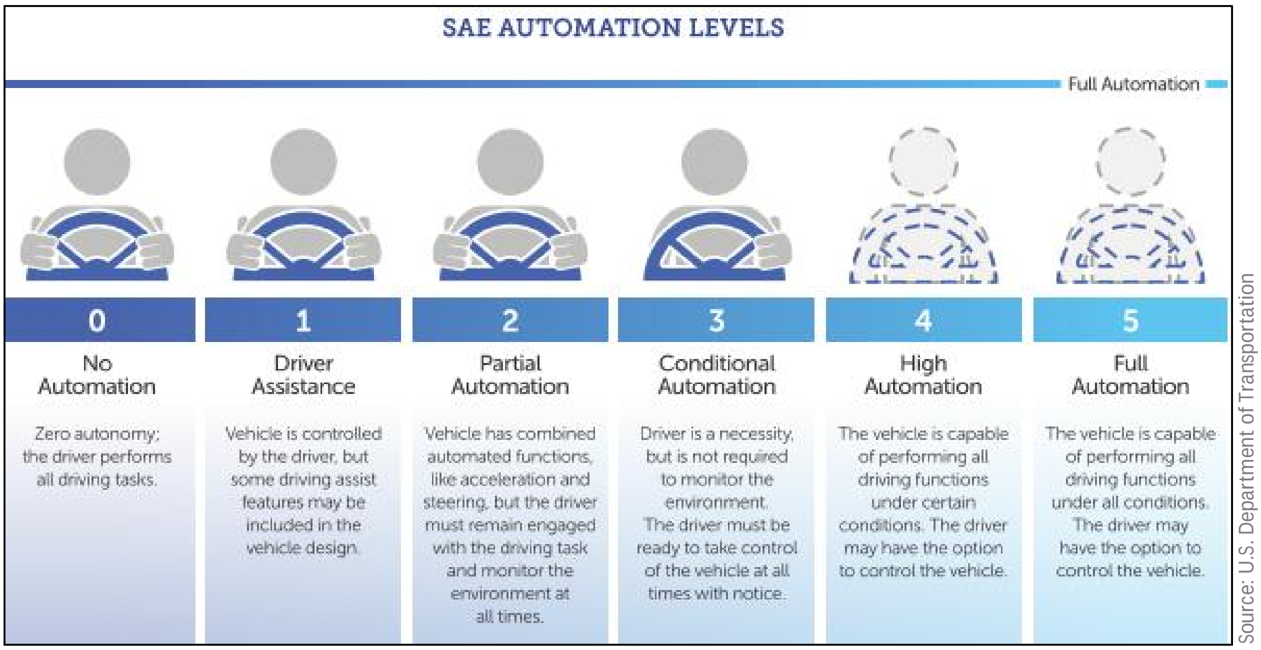

Figure 1: Levels of Automation

The roadmap from here to full automation—as defined internationally by engineers and transportation authorities—locates car users now at level 1, where some of the driving tasks are both automated and assisted. Levels 2 & 3—phasing in over the next several years—will allow the car to take control on certain roads (such as highways) but with the driver ready to retake control when required for other situations. The timing of levels 4 and 5 remains unclear—research, development, and testing are in process at these levels and many promises are being made in the media. Reality, as always, is less clear.

CAV Stakeholders

The universe of organizations involved in CAV is broad and includes stakeholders not typically identified with standard transportation projects. Or, looking at this from a different perspective, Maryland's

1 *https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf*
2 *https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf*
3 *http://standards.sae.org/j3016_201609/*

successful entry into the CAV arena can't be accomplished without a willingness to consider the following broader spectrum of stakeholders present:

- MDOT SHA Internal – Most Intelligent Transportation Systems (ITS) programs to date have been led by the Office of CHART and ITS Development (CHART), with support from the Office of Traffic & Safety and Office of Maintenance. A successful CAV program requires a much broader internal coalition, including the Office of Planning & Preliminary Engineering, Office of Policy Research, Office of Highway Development, strong participation from each of the MDOT SHA districts, and unwavering support from the administrator and deputy administrators.
- MDOT Internal – While the CHART program has shown the benefit of coordinating incident management and traffic operations issues across multiple transportation business units (TBU) within MDOT, the CAV program will eventually require significant additional collaboration of TBU staff and leadership. This document is laid out for MDOT SHA, but the engagement and pursuit of joint efforts with the Maryland Transportation Authority (MDOT MDTA) and Maryland Transit Administration (MDOT MTA) will be frequent and an important factor to the future success of their CAV program. Additional involvement of Motor Vehicle Administration (MDOT MVA), Maryland Aviation Administration (MDOT MAA), Maryland Port Administration (MDOT MPA), and The Secretary's Office are also important.
- Other State Government Agencies – Unlike almost any other "traditional" transportation project, CAV efforts could affect the state government branches such as the Governor's Office of Homeland Security, Maryland Department of the Environment, Department of Information Technology, Maryland Energy Administration, and Department of Health.
- Business Development – The Maryland Chamber of Commerce, select local chambers of commerce, the Maryland Economic Development Commission, and other groups within the Maryland Department of Commerce have proven to be critical components in other successful programs nationwide, in recognition of the huge benefit that CAV could bring to the state and the incredible level of involvement they could bring to the table.
- County & Municipal Government – Transportation will be affected at all levels, and the state can and will play a huge role in assisting county and municipal governments in adapting to and supporting the rollout of CV and AV programs. Whether the agency has one traffic signal or 100, there will be an impact. And from an economic development perspective, a safer and more efficient transportation network facilitates jobs; those jobs affect all levels of government.
- Metropolitan Planning Organizations (MPO) – MDOT coordinates with seven different MPOs across the state, and CAV will affect all of them in some fashion. MPOs are charged with developing a 20-year long-range transportation plan and a short-term (usually 2–6 years) program called the transportation improvement program for each of their respective regions, which makes coordination in terms of CAV critical.
- Law Enforcement – Engaging law enforcement during every stage of the development is a critical factor in our future success—everything from understanding how to train first responders to

appreciating the changes in responsibility/authority between human drivers and computer-operated vehicles. And just as we need to consider the state DOT in addition to county and municipal DOTs, the same can be said for the law enforcement community. Not only the Maryland State Police (MSP), MDTA Police, and MTA Police, but also county and local agencies will be affected by CAV activities.

- Academic – Maryland ranks first in the nation with 16 higher-education institutions designated by the National Security Agency and Department of Homeland Security as National Centers of Academic Excellence in Cyber Defense education and research. The University of Maryland Center for Advanced Transportation Technology (UMD CATT) is one of the largest transportation research and development centers in the world, with more than 100 engineers, software developers and researchers. UMD CATT develops technology and designs software for innovative transportation systems that are used by both the military and private companies such as Google. In addition to the UMD CATT, the Johns Hopkins University Applied Physics Laboratory (APL) is engaged in supporting military systems development for automated technology, and the National Transportation Center (NTC) at Morgan State University advances U.S. technology and expertise in transportation, research, and technology transfer, focusing on transportation as a key to human and economic development.
- Private Automotive Industry – Automobile manufacturers and their supplier communities are applying technology to transportation and mobility. Every major automaker has publicly stated goals about offering "driverless" cars or functionality (and are heavily engaged in research and development), and the community is an active participant in U.S. DOT research and collaborative efforts to advance the state of the practice within the vehicle as well as the infrastructure.
- Private Technology and Communications Companies – The consumer electronics industry has flirted with transportation and mobility for several decades, but the rapid advances in mobile communications and the internet have been game-changers. Wireless providers like Verizon and AT&T are now involved in CAV research and development—leading-edge technology companies like Apple, Intel, and Google/Waymo are entering the vehicle and systems marketplace—and a host of new entrepreneurial interests are popping up around the nation as this nascent industry explodes on a seemingly daily basis. The universe of stakeholders is growing rapidly, and private-sector involvement in the CAV ecosystem is critical to future success; this is not always going to be a traditional design-bid-build environment.
- Private Consulting – Traditional architecture & engineering (A/E) firms have long been a staple in the DOT cupboard, providing additional manpower, bringing state-of-the-art ideas to bear, and helping bring national lessons-learned down to the local level. In a fast-moving scenario such as the CAV one that is currently unfolding, the role of the consultant has ramped-up from a "want" to a "need," and the diversity of skills needed far exceeds what any reasonable state agency can maintain.

CAV Infrastructure

The issues, concerns, and opportunities in CAV are diverse, but for this document MDOT SHA is primarily concerned with the impacts on its infrastructure. And in the short term, that means emphasizing the CV environment, which will encompass four basic foundations: supporting infrastructure, equipped vehicles and/or motorists, data and applications, and the communications network needed to support the system.

The following key technology components define the CV ecosystem:

- Roadside Unit (RSU) are devices that send messages to, and receive messages from, nearby vehicles. The RSU operates from a fixed position or a portable device, and includes a processor, data storage and communications capabilities on a secure channel with other equipped vehicles. RSUs use DSRC or other wireless communications technologies.
- Onboard Equipment (OBU) are devices located in the vehicle either as standard equipment or as an aftermarket device. OBUs process, store, and provide communications functions necessary to support CV operations. Using DSRC or other alternative wireless technologies, OBUs interface with the standard equipment or aftermarket safety devices to communicate information to the driver.
- Nomadic Devices are used by travelers—whether a pedestrian, bicyclist, or wheelchair user—which provides information to the vehicle drivers.
- Traffic Signal Controller allows the traffic signal to communicate between motorized and non-motorized users, utilizing data streams to maximize safety and flow through the intersection.
- Backhaul Communications are a secure communications network between the highway agency and roadside unit to disseminate accurate and useful information to the driver.
- Vehicle-to-Vehicle (V2V) Communications is a wireless exchange of data among vehicles that are close to each other.
- Vehicle-to-Infrastructure (V2I) Communications is a wireless exchange of critical safety and operational data between vehicles and the roads they use.

Communicating with Connected & Automated Vehicles

CVs have the ability to continuously transmit vehicle position, direction, and speed. Imagine someone's vehicle telling your car that it's turning or putting on the brakes. These communications will enable safety functions—such as collision avoidance and work zone warnings—as well as applications to improve mobility and the environment, such as providing optimal travel speeds to go through multiple intersections on a green signal. There are many potential mediums by which vehicles will be able to communicate with each other, with the roadside, and with mobile devices. Satellite, cellular, Wi-Fi and other short-range communications all represent methods by which vehicles today are already connected, and the vehicles of tomorrow will become increasingly connected.

DSRC is one of the primary areas of research and development for a network exclusively for transportation-related uses. It is anticipated that DSRC will be used for both V2V and V2I communications. The spectrum is seen as particularly useful, because it can support very low-latency, secure transmissions; fast network acquisition; and, in general, the ability to handle rapid and frequent handovers that are inherent in a vehicle environment; as well as being highly robust in adverse weather conditions.

DSRC is a two-way, wireless communication that permits secure and fast messaging needed for safety applications, where "short range" is approximately 300 meters (984 feet), depending on the surrounding environment. These communications occur in a 75 megahertz (MHz) band of the 5.9 gigahertz (GHz) spectrum, which has been allocated by the Federal Communications Commission (FCC) for ITS vehicle safety and mobility applications. This band affords a relatively clean operating environment with very few preexisting users, allowing for a relatively unimpeded and interference-free communication zone.

Sources: Lear, Savari, WSP USA

Figure 2: Example Pictures of Roadside Units for Dedicated Short-Range Communications Broadcast

The National Highway Traffic Safety Administration (NHTSA)—as the federal agency with authority over motor vehicle safety—has been researching V2V communication technology for more than a decade, in partnership with others in the U.S. DOT, the automotive industry, and academic institutions.

DSRC-based devices can be installed directly in vehicles when originally manufactured, after initial manufacture via an “aftermarket” installation, or carried into vehicles by drivers in the form of a handheld device (and perhaps eventually, as a function on a smartphone).

The U.S. DOT has identified more than 40 use cases for V2I technologies, such paying for parking and tolls wirelessly; identifying when a car is approaching a curve too quickly and alerting the driver; adjusting traffic signals to accommodate first responders in an emergency; and alerting drivers of conditions such as road construction, among others.

According to the *National Connected Vehicle Field Infrastructure Footprint Analysis*[4] report conducted by the American Association of State Highway and Transportation Officials, CV infrastructure deployment is expected to leverage technologies that include cellular and Wi-Fi as well as DSRC and would typically include the following:

- Roadside communications equipment and enclosures, mountings, power, and network backhaul
- Traffic signal controller interfaces for applications that require signal phase and timing data
- Systems and processes to support management of security credentials and ensure a trusted network
- Mapping services that provide highly detailed roadway geometries, signage, and asset locations
- Positioning services for resolving vehicle locations to high accuracy and precision

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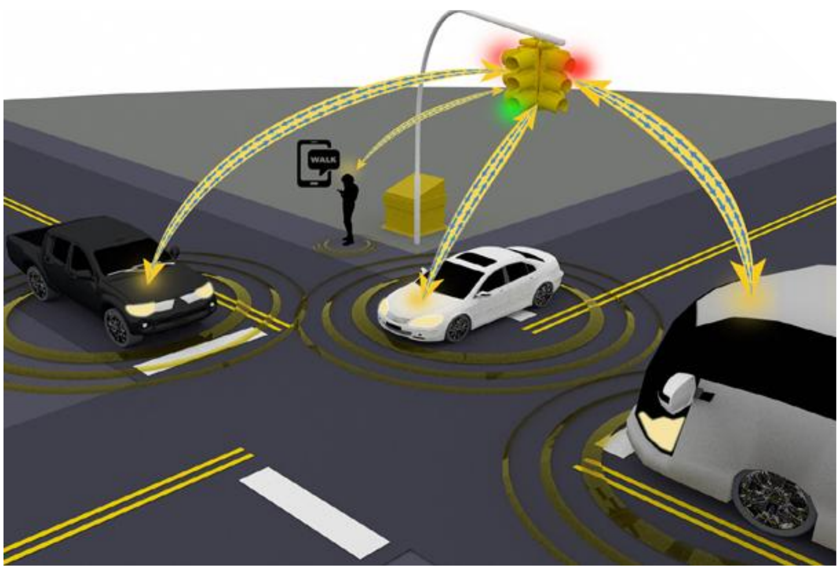
[4] *https://ntl.bts.gov/lib/52000/52600/52602/FHWA-JPO-14-125_v2.pdf*

- Data servers for collecting and processing data provided by vehicles and for distributing information, advisories, and alerts to users

Broadcasting Infrastructure Data

Key data sets are of value to the CAV, including road weather conditions, extreme road geometry, incidents & accidents, pavement condition, and of course traffic signal status. Broadcasting traffic signal phase and timing (SPaT) can open the door to critical safety applications in vehicles, with a potential to significantly reduce and/or eliminate crashes at intersections.

Broadcasting SPaT data is complicated by the lack of nationwide uniformity of traffic signal equipment and still evolving standards. Many existing traffic controllers already run software that supports common communication protocols (e.g., National Transportation Communications for ITS Protocol), but they are designed to monitor and control actuated and coordinated intersection timings from a central location over a communications link, at a time granularity measured in seconds. These protocols were not designed to notify vehicles of real-time signal phase count-down, which is needed for the safety-focused signal violation countermeasures, over a high bandwidth connection and at a frequency measured in fractions of a second. In other words, they were not designed to specifically broadcast SPaT data as defined in the national challenge. In addition to the need for a standard message broadcast for signal timing data, this output cannot be interpreted by a vehicle without additional contextual information in order to recognize what part of the signal phase information applies to the vehicle's approach to the intersection.



Source: U.S. Department of Transportation

Figure 3: Graphical Representation of SPaT Data Broadcast

To convert the data for use in V2I applications, the data must be formatted into the SPaT data format as defined by the SAE J2735 standard. SAE J2735—also known as DSRC Message Set Dictionary—is an industry standard intended for application developers, equipment manufacturers, and system integrators to support interoperability among DSRC applications using standardized message sets, data frames, and data elements. Within the standard, specifications for SPaT have been defined to share data for use in V2I applications.

SAE J2735 defines SPaT as a complex set of four messages:

- Signal Phase and Timing (SPaT) describes the signal state of the intersection and how long this state will persist for each approach and lane that is active. The SPaT message sends the current state of each phase with all-red intervals not transmitted. Movements are given to specific lanes and approaches by use of the lane numbers present in the message.
- Map Data (MAP) describes the static physical geometry of one or more intersections (i.e., lane geometries and the allowable vehicle movements for each lane) and introduces the idea of "intersection data frame" to describe barriers, pedestrian walkways, shared roadways, and rail lines that may affect vehicle movements. Within SAE J2735, the contents of this message are at times referred to as the Geometric Intersection Description (GID) layer. The MAP (or GID) layer is static, whereas the other three messages could be dynamic.
- Signal Request Message requests preempt or prioritize services for public safety and transit applications. The current signal preemption and priority status (e.g., when active) are also sent. This is not absolutely necessary for intersection safety applications but is important for mobility and in particular transit applications.
- Signal Status Messages describes the internal state of the signal controller and provides a more complete summary of any pending priority or preemption events. Again, this is not absolutely necessary for intersection safety applications but is important for mobility and in particular transit applications.

Some newer controllers can already make the data available in the standardized SPaT format; however, many do not, and third-party vendors must manipulate the data to the accepted industry format. However, not all vendors convert the raw signal data to the SPaT format, since their own applications might not require it. As of now, it is primarily the automotive industry that requires the standardized format; application developers or other third-party vendors may opt to use their own formats.

As noted, automotive applications also require MAP data for each of the intersections, and not all third-party vendors can provide that yet. (At least one has to create it for each intersection, requiring an estimated 2 hours/location.)

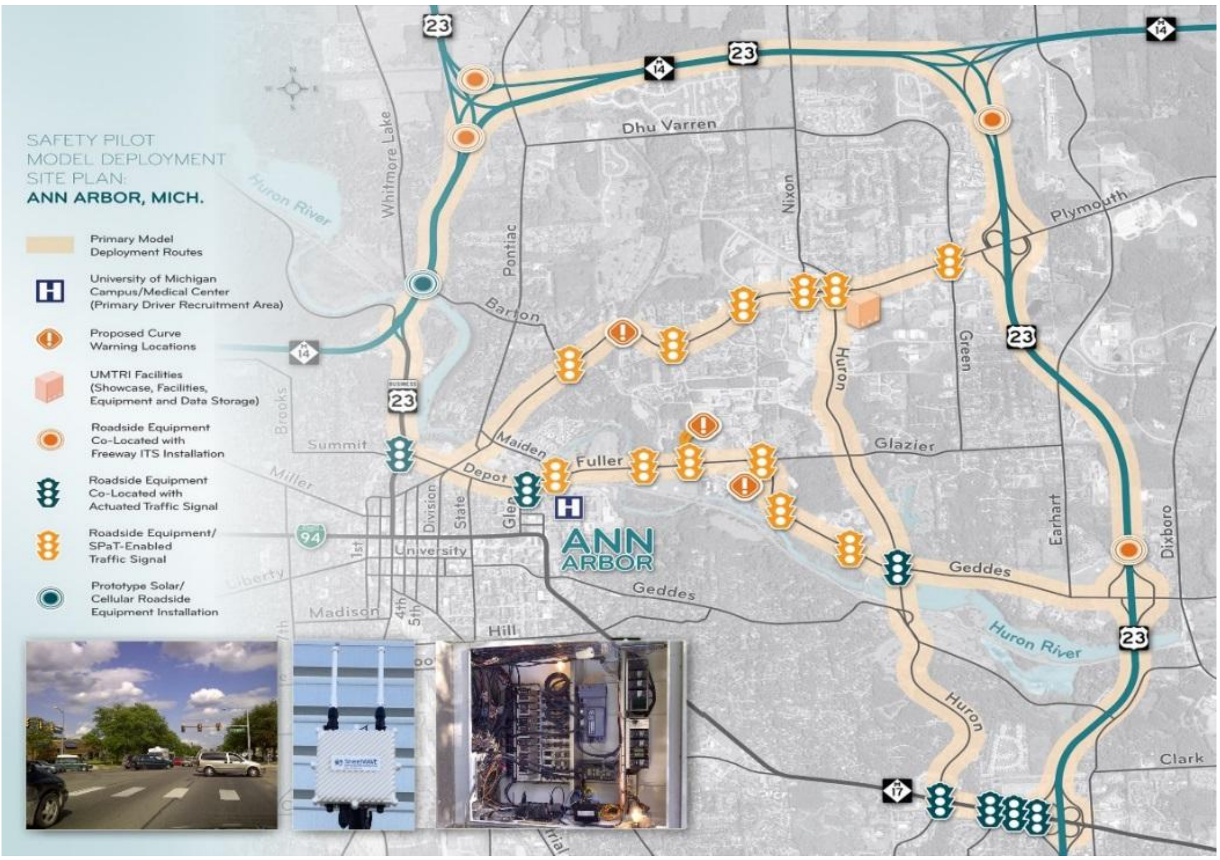
NATIONAL OVERVIEW

CV Pilot Programs and Deployments

During the formative years of DSRC development and CV program evolution, several "proof-of-concept" tests were conducted to verify various components of the CV ecosystem. The foundational project that is often referenced as a critical step in the evolution—and eventually led to proposed federal regulation and larger-scale deployment efforts—was the Safety Pilot Model Deployment (SPMD) program that took place in Ann Arbor, Michigan (Figure 4).

SPMD was a research program that demonstrated the readiness and effectiveness of DSRC-based CV safety applications for nationwide deployment. Originally intended as a one-year pilot, this real-world deployment was launched in August 2012 in Ann Arbor, Michigan. The deployment used CV technology in over 2,800 vehicles and at 29 infrastructure sites to test the effectiveness of the CV crash avoidance systems.

After three years of data collection and analysis, the SPMD was deemed a major success, influencing numerous enhancements to the CV environment, and leading the U.S. DOT to initiate rulemaking that proposes to create a new federal motor vehicle safety standard to require V2V communication capability for all light vehicles and to create minimum performance requirements for V2V devices and messages.



Source: Safety Pilot Model Deployment, U.S. Department of Transportation

Figure 4: Safety Pilot Model Deployment Program, Ann Arbor, Michigan

The SPMD also paved the way for a new federally sponsored pilot deployment program. The CV pilot deployment programs are expected to integrate CV research concepts into practical and effective elements, enhancing existing operational capabilities. On September 1, 2015, the U.S. DOT awarded three cooperative agreements—collectively worth more than $45 million—to initiate a design/build/test phase in three sites: New York City, Tampa (FL), and Wyoming.

New York City

New York City DOT's (NYCDOT) planned deployment provides an ideal opportunity to evaluate CV technology and applications in tightly spaced intersections typical in a dense urban transportation system and is anticipated to be the largest CV technology deployment to date. Approximately 5,800 cabs, 1,250 Metropolitan Transportation Authority (MTA) buses, 400 commercial-fleet delivery trucks, and 500 city vehicles that frequent these areas will be equipped with the CV technology. Using DSRC, the deployment will include approximately 310 signalized intersections for V2I technology. In addition, NYCDOT will deploy approximately 8 RSUs along the higher-speed FDR Drive—to address challenges such as short-radius curves, a weight limit, and a minimum bridge clearance—and 36 RSUs at other strategic locations throughout the city to support system management functions. As a city bustling with pedestrians, the pilot will also focus on reducing vehicle-pedestrian conflicts through in-vehicle pedestrian warnings and an additional V2I/I2V project component that will equip approximately 100 pedestrians with personal devices that assist them in safely crossing the street.

Tampa (FL)

Tampa-Hillsborough Expressway Authority (THEA) owns and operates the Selmon Reversible Express Lanes (REL), which is a first-of-its-kind facility to address urban congestion. The THEA CV pilot program will employ DSRC to enable transmissions among approximately 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians with smartphone applications, and approximately 40 RSUs along city streets. The pilot program will deploy a variety of applications to relieve congestion, reduce collisions, and prevent wrong-way entry at the Selmon REL exit. THEA also plans to use CV technology to enhance pedestrian safety, enhance bus operations, and reduce conflicts between street cars, pedestrians, and passenger cars at locations with high volumes of mixed traffic.

Wyoming

The Wyoming DOT (WYDOT) CV pilot program site focuses on the needs of the freight commercial vehicle operator in Wyoming and will develop applications that use V2I and V2V connectivity to support a flexible range of services from advisories, including roadside alerts, parking notifications, and dynamic travel guidance. WYDOT will equip around 400 vehicles—a combination of fleet vehicles and commercial trucks—with onboard units (OBUs). Of the 400 vehicles, at least 150 will be heavy trucks that are expected to be regular users of I-80. In addition to the 400 OBU-equipped vehicles, 100 WYDOT fleet vehicles, snowplows, and highway patrol vehicles will also be equipped with OBUs and mobile weather sensors.

National V2I Deployment Coalition

Nationwide deployment, operations, and maintenance of V2I applications will require long-term cooperation, partnership, and interdependence between the infrastructure owners and operators (state, county, and local level transportation agencies); the automobile industry original equipment manufacturers, and aftermarket manufacturers; and a variety of other stakeholders. The Vehicle-to-Infrastructure Deployment Coalition (V2I DC) began as a concept to create a single point of reference for all these stakeholders to meet and discuss V2I deployment related issues.

To accomplish this concept, the U.S. DOT asked the American Association of State Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the Intelligent Transportation Society of America (ITS America) to collaborate on organizing and managing the coalition. The V2I DC project team (consisting of members from AASHTO, ITE, and ITS America) then created a vision, mission, and set of objectives that would guide the coalition. This original concept was presented to U.S. DOT for input and guidance leading to the formation of the coalition.

The V2I DC launched in 2015, and during its first 18 months of existence, the technical working groups created within the coalition accomplished the following key national milestones:

- Engaging a unified coalition with common messages and discussion
- Narrowing initial focus for V2I deployments
- Defining research activities to support V2I deployment
- Developing a standards context diagram and recommendations for further standards development
- Creating the SPaT Challenge
- Creating a forum for collaboration between infrastructure owners/operators and automakers

Phase 1 of the V2I DC concluded at the end of 2016, and the considerable momentum established is now initiating Phase 2 for the coalition. Some internal restructuring of technical working groups is underway during the early part of 2017, and some initial goals for ongoing activity have been established:

- Provide input to U.S. DOT on V2I deployment guidance and products
- Support the SPaT Challenge
- Engage the automobile manufacturers
- Serve as a mechanism for peer exchange, information sharing, and public outreach.

National SPaT Challenge

AASHTO, ITE, and ITS America—working together through the V2I DC—have challenged state and local public-sector transportation infrastructure owners and operators to work together to deploy roadside DSRC 5.9 GHz broadcast radio infrastructure to broadcast SPaT real-time at signalized intersections on at least one road corridor or street network (approximately 20 signalized intersections) in each of the 50 states by January 2020. This is commonly called the 20/50/20 Challenge or, more simply, the SPaT Challenge.

The National Highway Traffic Safety Administration (NHTSA) is in the process of requiring all new light vehicles sold in the United States to be equipped with DSRC radios, which can continuously and anonymously transmit basic information about the location, speed, and critical operation of the vehicles. These radios will also be able to receive agency transmitted data, such as SPaT, with the intent to support safer, more efficient operations.

The V2I DC is leading the SPaT Challenge. The AASHTO Board of Directors passed a formal resolution of support and is working with the V2I DC through their AASHTO Connected and Autonomous Vehicles Working Group.

CV Pooled Fund Study

As owners and operators of the nation's surface transportation infrastructure, state and local transportation agencies are at the core of the CV infrastructure. While automakers and device manufacturers will dictate availability of vehicular equipment, transportation agencies will deploy and operate roadside infrastructure and incorporate CV technologies into infrastructure applications (e.g., traffic signal control). In response to this environment, a group of state and local transportation agencies and the Federal Highway Administration (FHWA) created a pooled fund study (PFS)—the Program to Support the Development and Deployment of Connected Vehicle Applications—to conduct the work necessary for infrastructure providers to play a leading role in advancing the CV systems. With the Virginia DOT as lead agency and the University of Virginia Center for Transportation Studies as technical leadership coordinator, the following transportation agencies participated:

- California DOT
- Delaware DOT
- Florida DOT
- Georgia DOT
- Maricopa County (AZ)
- Maryland DOT
- Michigan DOT
- Minnesota DOT
- New Jersey DOT
- New York DOT
- Ohio DOT
- Pennsylvania DOT
- Tennessee DOT
- Texas DOT
- Transport Canada
- Utah DOT
- Washington DOT
- Wisconsin DOT

The CV PFS has completed projects ranging from technical and economic research to its ground-breaking design and development of a software and hardware system that services multiple modes of transportation, including general vehicles, transit, emergency vehicles, freight fleets and pedestrians. This multimodal intelligent traffic signal system (MMITSS) is the next generation of traffic signal systems that provide a comprehensive traffic information framework to service all modes of transportation, including general vehicles, transit, emergency vehicles, freight fleets, and pedestrians and bicyclists in a CV environment.

The MMITSS applications "bundle" incorporates the following arterial traffic signal applications:

- Intelligent Traffic Signal System – Using high-fidelity data collected from vehicles through V2V and V2I wireless communications as well as pedestrian and non-motorized travelers, this proposed application seeks to control signals and maximize flows in real time. This application also plays the role of an overarching system optimization application, accommodating transit or freight signal priority, preemption, and pedestrian movements to maximize overall network performance.
- Transit Signal Priority – This proposed application allows transit agencies to manage bus service by adding the capability to grant buses priority based on a number of factors. The proposed application allows transit vehicles to communicate passenger count data, service type, scheduled and actual arrival time, and heading information to roadside equipment via an onboard device.
- Mobile Accessible Pedestrian Signal System – This application integrates information from roadside or intersection sensors and new forms of data from pedestrian-carried mobile devices. Such systems will be used to inform visually impaired pedestrians when to cross and how to stay within the crosswalk. This application could accommodate safe and efficient pedestrian movement of a more general nature.

- Emergency Vehicle Preemption – This proposed application, while similar to existing technologies, will integrate with V2V and V2I communication systems. The application would account for non-linear effects of multiple emergency responses through the same traffic network.
- Freight Signal Priority – This application provides signal priority near freight facilities based on current and projected freight movements. The goal is to reduce delays and increase travel time reliability for freight traffic, while enhancing safety at key intersections.

Federal Automated Vehicle Policy

In late 2016 the NHTSA released a policy document on highly automated vehicles (HAV) that sets out a proactive safety approach to safely bring lifesaving technologies to the roads while providing innovators with the space needed to develop new solutions. The policy was rooted in U.S. DOT's view that AVs hold enormous potential benefits for safety, mobility and sustainability.

In September of 2017 an update was produced called Automated Driving Systems 2.0 – A Vision for Safety.[5] This document replaces the Federal Automated Vehicle Policy released in 2016.

It's helpful to note that the term Automated Driving Systems (ADS) replaces 2016's phraseology of Highly Automated Vehicles (HAV). ADS is part of the SAE J3016 taxonomy of definitions and continues USDOT's closer alignment with industry (similar to the prior version adopting SAE's six levels of automation). The term ADS applies to Levels 3, 4, and 5 vehicles.

The new document is significantly shorter by way of removing regulatory discussion contained in the first version. In this update, NHTSA has outlined a "nonregulatory approach to automated vehicle technology safety."

In Section 1: Voluntary Guidance for Automated Driving Systems (Voluntary Guidance), NHTSA sets out to support the automotive industry and other key stakeholders as they "consider and design best practices for the testing and safe deployment" of Automated Driving Systems (ADS).

The 2017 update outlines 12 safety elements that are "generally considered to be the most salient design aspects to consider and address when developing, testing, and deploying ADSs on public roadways." All 12 safety elements were included in the 2016 version but in differing levels of detail. Version 2.0 provides minor updates to each of them.

1. System Safety
2. Operational Design Domain
3. Object & Event Detection & Response
4. Fallback (minimal risk condition)
5. Validation Methods
6. Human Machine Interface
7. Vehicle Cybersecurity
8. Crashworthiness
9. Post-Crash ADS Behavior
10. Data Recording
11. Consumer Education & Training
12. Federal, State, and Local Law

[5] *https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf*

In the second chapter, NHTSA acknowledges that vehicles operating on public roads are subject to both Federal and State jurisdiction, and States are beginning to draft legislation to safely deploy emerging ADSs. As a result, Section 2: Technical Assistance to States, Best Practices for Legislatures Regarding Automated Driving Systems (Best Practices), seeks to "clarify and delineate Federal and State roles in the regulation of ADSs," as depicted in Figure 5. The chapter also provides Best Practices for Legislatures, which "incorporates common safety-related components and significant elements regarding ADSs that States should consider incorporating in legislation."

In addition, the section provides Best Practices for State Highway Safety Officials, which offers a framework for States to develop procedures and conditions for ADSs' safe operation on public roadways. It includes considerations in such areas as applications and permissions to test, registration and titling, working with public safety officials, and liability and insurance

NHTSA'S RESPONSIBILITIES	STATES' RESPONSIBILITIES
• Setting Federal Motor Vehicle Safety Standards (FMVSSs) for new motor vehicles and motor vehicle equipment (with which manufacturers must certify compliance before they sell their vehicles)[33] • Enforcing compliance with FMVSSs • Investigating and managing the recall and remedy of noncompliances and safety-related motor vehicle defects nationwide • Communicating with and educating the public about motor vehicle safety issues	• Licensing human drivers and registering motor vehicles in their jurisdictions • Enacting and enforcing traffic laws and regulations • Conducting safety inspections, where States choose to do so • Regulating motor vehicle insurance and liability

Source: U.S. DOT, NHTSA, September 2017

Figure 5: Delineation of Federal and State Roles for ADSs

AV Development, Testing, and Research

While the U.S. DOT is leading the development and testing of CV technology and applications, activity related to testing autonomous and automated vehicle technology and vehicles is increasing. The universe of stakeholders that might be testing is broad—established large technology companies, automakers, state and local DOTs, the federal government, small entrepreneurial companies, and more. Much of the testing begins in the laboratory and on closed locations such as parking lots and areas without interaction of other traffic, but testing on "public roadways" and with potentially "mixed traffic" will become commonplace before much of the technology and vehicles are up for public consumer purchase.

The U.S. DOT solicited applications in late 2016 for test sites to be part of a "federally designated AV proving ground" network. The intent was for the U.S. DOT to have some involvement in test locations, encourage data sharing and lessons learned among sites, and provide an incentive for some locations to more thoroughly prepare for the potential mix of computer-operated vehicles alongside human-driven vehicles. The U.S. DOT selected the following 10 sites as officially designated AV proving ground locations:

- City of Pittsburgh and the Pennsylvania Transportation Institute
- Texas AV Proving Grounds Partnership
- U.S. Army Aberdeen Test Center
- American Center for Mobility (ACM) at Willow Run
- Contra Costa Transportation Authority (CCTA) & GoMentum Station
- San Diego Association of Governments
- Iowa City Area Development Group
- University of Wisconsin-Madison
- Central Florida Automated Vehicle Partners
- North Carolina Turnpike Authority

No federal funding was promised as part of this designation, although there is legislation moving through Congress that proposes a funding set-aside for the sites.

The U.S. Army Aberdeen Test Center is located in Maryland. Additional discussion concerning the opportunities for MDOT SHA participating in testing activities at this location is provided later in this document.

AV testing is not limited to freeways and toll roads (high-speed interactions). Lower speed AV shuttles are also being tested and evaluated in locations around the country. The parameters surrounding low-speed shuttle testing are dramatically different than high-speed interactions, and the U.S. DOT recently started a “working group” to likewise encourage data-sharing and lessons-learned.

For example, at Santa Clara University (California) an autonomous shuttle built by Auro Robotics will traverse an almost 1-mile loop route with five designated stops with a safety engineer onboard. The vehicle itself is an off-the-shelf $30,000 four-person electric vehicle called the Polaris GEM that has been upgraded with cameras, LIDAR, GPS sensors, and controls for brakes and steering—all connected to deep-learning software. And in Las Vegas, an autonomous electric shuttle pilot test that moves about the city’s Fremont Street alongside normal traffic from 10:00 a.m. to 6:00 p.m. daily was completed in early 2017. The NAVYA ARMA vehicles could hold up to 12 passengers and reach speeds of up to 27 mph, although their trips up and down Fremont Street were limited to 12 mph for the trial. A NAVYA representative estimates that the monthly service cost is roughly $10,000.

Here in Maryland, in southern Prince George’s County at the National Harbor development, a private company called Local Motors has introduced Olli, a 3D-printed, autonomous, electric shuttle that is partially recyclable. Local Motors says that it’s the first vehicle to use the IBM Watson’s car-focused cognitive learning platform: Watson Internet of Things (IoT) for Automotive. Local Motors is preparing to give autonomous vehicle rides around National Harbor and at the company’s new National Harbor campus. The facility is part 3D printing demo lab and part inventor playroom, including a new Science, Technology, Engineering, and Mathematic program for kids that demonstrates recycling of printed cars. A timeline for the demonstration pilot is not yet firm, but they have set up shop at the National Harbor and will definitely bring low-speed AV shuttle technology to our doorstep in the near future.

Source: Business Insider Magazine

Figure 6: Local Motors' Olli Electric AV Shuttle

NCHRP 20-102 Impacts of CV/AV on State & Local Transportation Agencies

The National Cooperative Highway Research Program (NCHRP) addresses issues integral to the state DOTs and transportation professionals at all levels of government and the private sector. The Transportation Research Board administers the program, which is also sponsored by the member departments (i.e., individual state DOTs) of AASHTO, in cooperation with the FHWA. Contractors conduct individual projects with oversight provided by volunteer panels of expert stakeholders.

One program of great importance to this planning exercise is NCHRP 20-102 – Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies. The objectives of this task-order contract include identifying critical issues associated with CVs and AVs that state and local transportation agencies and AASHTO will face; conducting research to address those issues; and conducting related technology transfer and information exchange activities.

There are four "teams" of consultants and academics working on tasks under this program:

- Almost Complete
  - 20-102(01) Policy & Planning to Internalize Societal Impacts of CV/AV Systems into Market Decisions

  - 20-102(02) Impacts of Regulations and Policies on CV/AV Technology Introduction in Transit Operations
  - 20-102(03) Challenges to CV and AV Application in Truck Freight Operations
- In Progress
  - 20-102(05) Strategic Communications Plan for NCHRP Project 20-102
  - 20-102(06) Road Markings for Machine Vision
  - 20-102(07) Implications of Automation for Motor Vehicle Codes
  - 20-102(08) Dedicating Lanes for Priority or Exclusive Use by CVs and AVs
  - 20-102(09) Providing Support to the Introduction of CV/AV Impacts into Regional Transportation Planning and Modeling Tools
- Planned
  - 20-102(10) Cybersecurity Implications of CV/AV Technologies on State and Local Transportation Agencies
  - 20-102(11) Summary of Existing Studies on the Effects of CV/AV on Travel Demand
  - 20-102(12) Business Models to Facilitate Deployment of CV Infrastructure
  - 20-102(13) Planning Data Needs and Collection Techniques for CV/AV Applications
  - 20-102(14) Data Management Strategies for CV/AV Applications for Operations
  - 20-102(15) Understanding the Impacts of the Physical Highway Infrastructure Caused By the Increased Prevalence of Advanced Vehicle Technologies
  - 20-102(16) Preparing TIM Responders for Connected Vehicles and Automated Vehicles
  - 20-102(17) Deployment Guidance for CV Applications in the OSADP
  - 20-102(18) Data for Planning Analysis of the Mobility and Reliability Impacts of Connected and Autonomous Vehicles
  - 20-102(19) Minimum Safety Data Needed for Automated Vehicle Operations and Crash Analysis
  - 20-102(20) Update AASHTO's Connected Vehicle/Automated Vehicle Research Roadmap

Additional tasks are being formulated at Transportation Research Board conferences and committees throughout the year, providing the 20-102 organizing panel with updated input to constantly changing research needs. The results of these tasks will provide fundamental guidance and input to state and local DOT's as they continue operating in this fast evolving space.

Beyond the 20-102 program, under the NCHRP 20-24 program (Administration of Highway and Transportation Agencies), a new project was recently advertised that is designed to help infrastructure owner/operators understand the level to which they intend to equip their roadways for the impending rollout of CAVs. NCHRP 20-24(112) focuses on developing a consensus Connected Road Classification

System that will be useful to state and local DOTs and MPOs that are planning or implementing CAV-compatible infrastructure.

The project is based on the premise that an important decision facing each infrastructure owner/operator is the level to which they intend to equip their roadways for the impending rollout of CAVs. Recognizing this, the Colorado Department of Transportation (CDOT) has proposed a road classification system with six levels that relate to the roadway's ability to support CAVs:

- Level 1: Unpaved and/or non-striped roads designed to a minimum level of standard of safety and mobility.
- Level 2: Paved roads designed to AASHTO's standards with MUTCD signage. There is no ITS equipment or infrastructure to collect connected vehicle data (Dedicated Short Range Radio). Access to cellular date service may be available.
- Level 3: There is ITS equipment operated by a Traffic Operation Center (TOC) and/or, one-way electronic data share between DOT/Vehicle/User and/or, mixed-use lanes.
- Level 4: Roadway or specific lane(s) have adaptive ITS equipment (i.e., smart signals hold for vehicles, highway lighting that turn on for vehicles, etc.) with TOC override only, and/or two-way data share between DOT/Vehicle/User, and/or lanes designated for vehicle levels 3 & 4 only.
- Level 5: (Advance Guide-Way System) roadway or specific lane(s) designed for vehicle level 4 only with additional features that may include inductive charging, advance/enhanced data sharing, etc. Additionally, no roadside signs are needed as all roadway information is direct to vehicles' onboard systems.
- Level 6: All lanes on a roadway designed for only vehicle level 4 systems—no signs, signals, striping needed.

The intent of this research project is to build on CDOT's efforts to develop a uniform classification system. This will help agencies designate their roadways based on the degree and level of readiness to accommodate CVs and HAVs and plan their deployment of needed infrastructure.

Smart Cities & Communities

In December 2015, the U.S. DOT launched their Smart City Challenge, asking mid-sized cities across America to develop ideas for an integrated, first-of-its-kind smart transportation system that would use data, applications, and technology to help people and goods move more quickly, cheaply, and efficiently. The Smart City Challenge generated an overwhelming response: 78 applicant cities shared the challenges they face and ideas for how to tackle them. From that initial response, seven finalists were selected and worked closely with the U.S. DOT to further develop their ideas.

The Smart City Challenge provided a spark for cities looking to revolutionize their transportation systems. Through the Smart City Challenge, U.S. DOT committed up to $40 million to one winning city—Columbus, OH. In response, Columbus leveraged an additional $90 million in private and public funding to help make their Smart City visions real. And in October 2016, the U.S. DOT announced an additional $65 million in grants to support community-driven advanced technology transportation projects in cities across America, including four of the finalists in the Smart City Challenge.

According to the U.S. DOT website,[6] "the Smart City Challenge aimed to spread innovation through a mixture of competition, collaboration, and experimentation." But the Smart City Challenge was about more than just technology, because in many locations it brought to light the opportunities that technology, data, and transportation could provide in terms of improving quality of life. It helped spawn bold new solutions that could change the face of transportation in our cities by meeting the needs of residents of all ages and abilities, and bridging the digital divide so that everyone, not just the tech-savvy, can be connected to everything their city offers.

Recent advances in information and communications technologies could transform cities and communities across the nation and globally. By using these technologies to improve existing infrastructure and enable new systems and services, cities and communities aim to improve efficiency and reduce costs, create new economic opportunities, enhance sustainability, improve quality of life, and meet other needs for their residents and businesses.

6 *https://www.transportation.gov/smartcity*

Planning Activities

MARYLAND DEPARTMENT OF TRANSPORTATION

STATE HIGHWAY ADMINISTRATION

Planning Activities

PLANNING FOR CAV IN MARYLAND

Planning in transportation is often rooted in time-honored models and a heavy reliance on historical data. In this instance, we have no historical comparison for CAV, thus providing a unique set of challenges in terms of scenario development. Further complicating the planning task is the rapid evolution of technology and society—changes in how people use transportation, changes in views toward vehicle ownership, and even changes in who might be able to manage transportation going forward. As a result of all this diversity in challenges, the planning task—more than ever before—will require immense flexibility, fast action reactivity, and awareness of factors often outside the typical transportation field.

Transportation Systems Management & Operations

MDOT SHA recognizes the role of a TSM&O program as a key component to fulfill its core mission. A TSM&O program leverages technology solutions, innovations, and partnerships to maximize the use of existing capacity thereby making the system safer, reliable, and more efficient. It's about making it easier for customers to travel reliably from point A to point B; it's about creating a world-class transportation system that attracts businesses to the state; it's about using new sources of data to make better and more informed decisions on transportation investments; it's about all of these and more.

In 2014, MDOT SHA received an FHWA SHRP2 implementation assistance grant to administer the L06 program – Institutional Operations to Improve Systems Operations and Management. The SHRP2 L06 program undertook a comprehensive examination of the way MDOT SHA should organize to execute operations programs successfully to improve travel time reliability. One of the outcomes of this effort was a Maryland TSM&O Strategic Implementation Plan. This effort was led by the MDOT SHA Office of Planning & Preliminary Engineering in strong coordination with the Office of CHART & ITS Development and the Office of Traffic & Safety. The UMD CATT and Cambridge Systematics also supported the development.

TSM&O Strategic Implementation Plan Mission Statement

"To establish and maintain a TSM&O program and implement supporting projects within MDOT State Highway Administration, improving mobility and reliability for all people and goods through planned operations of transportation facilities."

The TSM&O Strategic Implementation Plan resulted in four primary goals:

- GOAL 1 – Develop and Implement a Sustainable TSM&O Program at SHA
- GOAL 2 – Improve travel time reliability for both people & freight, on both freeways & arterials
- GOAL 3 – Develop data- and performance-driven approaches to support TSM&O planning, programming, implementation and evaluation decisions
- GOAL 4 – Improve the traveling public's experience on Maryland highways by enabling customers with information and choices

For each of these goals, the TSM&O Strategic Implementation Plan includes specific objectives, strategies, actions, responsibilities, and implementation time frames.

Specific to Goal 2, the following strategy has direct implications for this CAV strategic action plan:

Strategy 2.1d. Work with MDOT MDTA, MDOT MVA, and the private sector to develop and implement a connected and automated vehicle program in Maryland

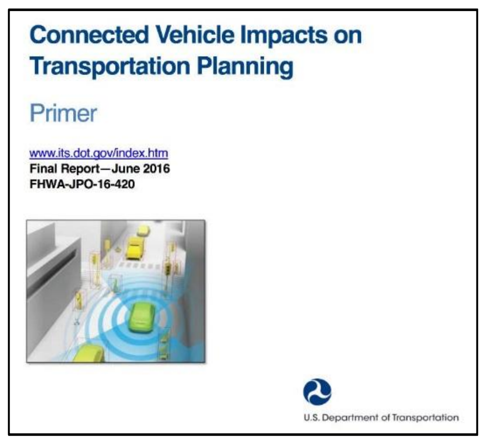
The following action items were associated with this strategy:

- 2.1d.I. Organize a C/AV Taskforce
- 2.1d.II. Research C/AV facets that will immediately impact Maryland's transportation system
- 2.1d.III. Compose C/AV Program Plan
- 2.1.d.IV. Implement Program Plan

So far MDOT SHA has made significant progress toward these goals, in that it has organized an internal CAV Working Group and held several meetings; it has made great strides in understanding CAV readiness and how they need to view future ITS- and transportation-related projects; and this document represents the CAV Program Plan as specified in the TSM&O effort.

Planning and CAV

In June 2016, the FHWA published *Connected Vehicle Impacts on Transportation Planning* (FHWA-JPO-16-420). This report comprehensively assesses how CVs should be considered across the range of transportation planning processes and products developed by states, MPOs, and local agencies throughout the country.


Connected Vehicle Impacts on Transportation Planning

Primer

www.its.dot.gov/index.htm
Final Report—June 2016
FHWA-JPO-16-420

U.S. Department of Transportation

While it focuses on CV technology, the report notes that to incorporate the full range of planning products and activities, AV should be considered as well; thus, the subject of this effort was broadened to include CAV in many instances.

The project conducted four distinct types of analysis to comprehensively assess the impact of CAV technology on transportation planning:

- Identify how CAV technology should be considered in transportation planning processes and products under a variety of circumstances.
- Develop illustrative scenarios of CAV planning, based on real-world planning environments that highlight the various ways that CAV's can be addressed in planning processes and products.

- Identify new or enhanced tools, techniques, and data to support various CAV planning activities and approaches for how to develop them.
- Identify the roles and responsibilities of stakeholders and organizational and workforce skills, expertise, and capabilities needed to carry out CAV planning.

The report identifies a wide range of issues relevant to planners. And while much of the guidance provides specific assistance at various levels, the report identifies a "high level list of key findings that planners should take away from these documents" including the following:

- In the short term, CAV deployment will likely take the form of small-scale pilot projects that planning agencies will need to incorporate into their transportation improvement plans.
- Agencies will need a level of technical knowledge adequate to evaluate these investments and will need to educate their board members and stakeholders on the benefits and costs of the technology.
- In the medium-to-long term, CAV deployments are likely to become a standard strategy, with large-scale investments over multiple funding cycles.
- CAV technologies provide a great opportunity for agencies to enrich their sources of planning data, particularly in the areas of traffic and asset management. This may require new skills in data science; the development of relationships with new stakeholders may be required to address issues of privacy and data ownership.
- CAV technologies provide opportunities to enhance the mobility and safety of non-automobile users—including transit riders, bicyclists, and pedestrians—by providing improved information and enhancing motorist awareness of vulnerable users.
- New CAV data will be available for use in long-range metropolitan transportation plan alternatives analyses and will help to better understand new land use, transportation facility use, socioeconomic impacts that result from CAV.
- In addition, the report includes a healthy amount of guidance and knowledge by presenting case studies—illustrative scenarios of CAV impacts in transportation planning, based on real-world planning products and environments.

As society moves toward a future where more and more vehicles feature CAV technology, how and how often people travel by car and other transportation modes could change—perhaps significantly. Transportation planners rely heavily on predictions of vehicle-miles traveled (VMT) as a guide for decision-making, while also looking to land use policies to influence their work. According to another relevant report *Planning for Connected & Automated Vehicles*, prepared for the Greater Ann Arbor (MI) Region, VMT could either increase or decrease, depending on a number of factors that today we don't know enough about to accurately predict.[7]

Some of the factors that might increase VMT include the following:

[7] *http://www.cargroup.org/wp-content/uploads/2017/03/Planning-for-Connected-and-Automated-Vehicles-Report.pdf*

- Increased travel demand – CAVs promise to make transportation more convenient and affordable, particularly within car sharing or self-driving taxi programs.
- Zero-occupancy VMT – If CAVs perform empty trucking backhauls (return trips without cargo or passengers), VMT could increase.
- Reduced trip chaining – CAVs could lower incentives for making stops on the way to another destination by making zero-occupancy trips possible.
- Location of parking facilities – CAVs could make onsite parking obsolete because vehicles will be able to park themselves outside of downtown or other congested areas.
- Increased mobility of non-drivers – CAVs could offer underserved populations— such as those under age 16, senior citizens with difficulties driving, and persons with disabilities—with greater opportunity to travel. While this has many benefits for society, it would also increase VMT.

While CAVs could increase VMT, they also are likely to affect some factors in the opposite direction, thereby reducing VMT. Some of these factors include the following:

- Pay-per-use self-driving vehicle programs – Providing car sharing, taxis, and ride hailing services via CAV could discourage unnecessary travel, because people would have to evaluate the added value of each trip and pay for each one taken.
- Lower car ownership – If people own fewer vehicles due to a proliferation of car sharing options, unnecessary travel could be reduced.
- Increased vehicle occupancy – CAVs in car sharing or taxi fleets are likely to have technologies that make carpooling more convenient.
- CAVs used as first-and-last-mile solution in combination with public transportation – If CAVs are used as feeder services to transit routes and not to replace entire trips that could be completed with transit, travel may be reduced.
- Less travel related to searching for parking – One of the features that CAVs are likely to offer is the ability to easily locate available parking, eliminating miles spent looking for it.

Connected and automated vehicles could also have complex and as-yet-undetermined impacts on land use in the long term. Different deployment scenarios could lead to varied land use outcomes, and policymakers should consider how CAVs could affect planning and zoning decisions. For example, because people would be able to engage in other activities while traveling, they could accept a longer work commute to live in a more affordable home or in a more personally desirable location. Conversely, CAVs in a shared-use scenario could reduce onsite parking needs and enable road diets, especially in urban cores. This would free valuable space that could be used for redevelopment, which would then increase density and walkable developments and encourage a less car-centric lifestyle. We don't yet know the anticipated changes that will occur, but recognize that CAVs could either encourage more sprawl or greater density, depending on how the vehicles are used and how the technology interacts with other factors.

Maryland's CHART Program

A strong transportation operations program within an agency is often a foundational need to enable and in some instances respond to rapid changes in CAV development. In Maryland, such a program exists: Coordinated Highways Action Response Team (CHART).

CHART is a joint effort of the MDOT SHA, MDOT MDTA, and the Maryland State Police, in cooperation with other federal, state and local agencies. CHART's mission is to improve "real-time" operations of Maryland's highway system through teamwork and technology. This program started in the mid-1980s as the "Reach the Beach" initiative, which focused on improving travel to and from Maryland's eastern shore. It has since expanded statewide

CHART is focused on the following principles:

- Monitoring and responding to incidents.
- Disseminating traveler information.
- Monitoring traffic and roadway conditions.
- Using its systems, communication network, and advanced technology to support related MDOT SHA functions.

The program is directed by the CHART Board, consisting of senior technical and operational personnel from MDOT SHA, MDOT MDTA, MSP, FHWA, the UMD CATT, and various local governments. The board is chaired by the MDOT SHA Chief Engineer for Operations.

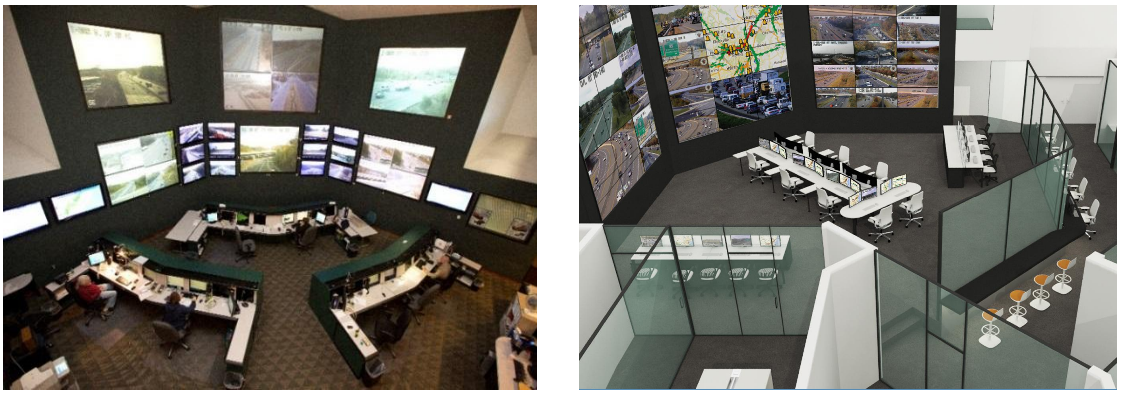
To support CHART operations, many field devices are deployed, including a closed-circuit television (CCTV) system for traffic monitoring and incident verification, as well as a variety of advanced speed and weather detection systems. MDOT SHA also has an extensive arsenal of dynamic message signs (DMS), Traveler Advisory Radio transmitters, and the 511 Highway Advisory Telephone system.

This operational program is managed by a hub-and-satellite architecture with the statewide operations center (SOC) at the center and several satellite TOCs located near College Park, Baltimore, Rockville, and Annapolis. The SOC is the "heart" of the CHART system, functioning 24/7; but the "arms and legs" of the program are clearly the emergency traffic patrols (ETP), which have been helping broken-down motorists and assisting police at incidents along Maryland's interstates and highways since the early to mid-1980s. The ETPs also operate 24/7 in the Baltimore/Washington metropolitan area, from 5:00 a.m. to 9:00 p.m. in the western region (Washington and Frederick Counties, and western Carroll and Howard Counties), and seasonally on the eastern shore and in western Maryland. CHART operates 43 ETP vehicles, covering more than 2,000 lane miles of Maryland roadways. Although they have assigned routes, the ETPs are available to assist with traffic incidents anywhere they are needed in the state.

CHART has access to more than 800 total video feeds available to the SOC operators (from all jurisdictions). More than 300 can be manipulated by CHART operations staff, with the remaining 500+ being view-only and owned by other jurisdictions. Additionally, CHART recently added advanced cameras on all 74 CHART emergency response technician vehicles that can be controlled remotely from CHART's SOC and three satellite TOCs.

In addition to cameras, the CHART infrastructure of devices has grown to include the following:

- 89 MDOT SHA-owned DMSs
- 34 MDOT SHA-owned highway advisory radios
- 57 MDOT SHA-owned weather stations
- 315 MDOT SHA-owned traffic detection devices



Existing

Mock-up of future configuration

Figure 7: CHART Statewide Operations Center – Existing and Future

UMD has developed a yearly assessment of the CHART program since 1999. The CHART program—sometimes in conjunction with other programs and agencies—has made a beneficial difference, especially in the incident management arena. The most recent available report[8] covered calendar year 2015, and notes that the average response time to incidents in 2015 was 11.70 minutes. According to data collected from the NHTSA's Fatality Analysis Reporting System, the average emergency response time of every state is 15 minutes 19.2 seconds. The UMD report comments that "in view of the worsening congestion and the increasing number of incidents in the Baltimore-Washington region, it is commendable that CHART can maintain its performance efficiency."

In addition to faster detection and response, the CHART program has had a noticeable impact on the duration of an incident/lane closure. The duration of incidents managed by CHART response units averaged 23.54 minutes, which is shorter than the average duration of 33.18 minutes for those incidents managed by other agencies in Maryland. On average, CHART operations in 2015 reduced the average incident duration by about 29 percent. It's safe to say that CHART operations by MDOT SHA in 2015 have yielded significant benefits by assisting drivers, and by reducing delay times and fuel consumption, as well as emissions.

[8] *http://chartinput.umd.edu/reports/R-CHART_2015_Performance_Report.pdf*

Planning for Operations & Maintenance

The CHART program owes a large amount of its success to a strong focus on operations and maintenance (O&M). ITS technology is deployed to support incident management and roadway monitoring, maintenance activities and lane closures are coordinated through the CHART software, and in general the planning and policies that govern CHART are made with operations in mind. Even the CHART Board, which directs the overall activities, is led primarily by O&M personnel.

While key performance metrics of response time and incident duration are the public-facing measures, internally the program remains strong because it also measures other O&M factors such as device availability and mean time to repair. This adherence to operational availability is a fundamental strength that MDOT SHA will need to carry forward as it begins engaging in CAV pilots and operational deployments for the longer term.

As planning efforts continue forward for CAV deployment, consideration should be given to maintainability, device standardization, staff expertise, and most importantly operational outcomes. Just because you CAN place a device in a location doesn't always mean you SHOULD—what are the operational outcomes desired, what applications can be enabled, and what impacts might this have on other device deployments (e.g., the communication backhaul for DSRC could also enable other ITS device transmissions such as CCTV or detection).

One key to establishing a maintenance program is initiating a basic asset management system that includes, at minimum, an inventory of devices along with approximate age, life expectancy, regular maintenance needs, and notes such as frequency and impact of failures. In an increasingly high-tech environment, configuration management is also a necessity. Keeping track of software and firmware versions, upgrade needs, and firewall/connectivity issues is just as important as the physical characteristics of the devices. Such information is useful not only for managing equipment, but for making a business case for assigning resources for a more robust maintenance program.

CAV PROGRAM GOALS FOR MDOT SHA

MDOT is a "customer-driven leader that delivers safe, sustainable, intelligent, and exceptional transportation solutions in order to connect our customers to life's opportunities." Therein lies the mission statement of MDOT, and the guiding principle of MDOT SHA planning and operations activities. Building on that foundation, this document sets forth a vision, goals, and strategies to advance MDOT SHA's CAV program going forward.

Vision and Goals

MDOT SHA's TSM&O Strategic Implementation Plan has a very simple vision statement: Maximize mobility and reliable travel for people and goods within Maryland by efficient use of management and operations of transportation systems. That same simplicity and direct focus is applied in terms of establishing a vision statement for MDOT SHA's CAV program:

MDOT SHA Vision for Connected & Automated Vehicles
"Embrace technology and next generation mobility trends to provide safe & reliable travel for people and goods within Maryland."

With this vision in mind, and with the rapid pace of development of CAV technologies in front of us, MDOT SHA needs a well-informed and well-defined approach to be prepared and engaged in CAV technology. This approach will recognize that MDOT SHA's CAV program vision and actions are built upon and support the guiding principles and objectives of the agency as a whole.

To support MDOT SHA's CAV vision, the following program goals have been identified:

- GOAL 1: Make Maryland an attractive partner for CAV development, testing, and production – Maryland is "open for business" and through a combination of assets, human capital, and experience will attract leading-edge companies to locate here.
- GOAL 2: Begin deploying CAV technology and engaging in national activities – MDOT SHA will gain experience in deploying CAV technology through pilot projects, and work with partners to engage in national efforts.
- GOAL 3: Establish foundational systems to support future CAV deployment – MDOT SHA will deploy foundational systems and standards, such as data management, backhaul communications, and a robust policy program to enable sustained deployment activity.
- GOAL 4: Enable CAV benefits for customers – MDOT SHA will identify ways to add value to their customers today and in the near future during the transitional timeframe of CAV on our roadways.
- GOAL 5: Look for opportunities to leverage CAV technologies to support MDOT SHA business processes and objectives – Explore ways to leverage CAV data for performance-based planning, and maximize safety and operational benefits to support and enhance other business processes.

Strategy Statements

Table 1 presents the strategic actions identified to achieve the established objectives for the CAV program. These actions reflect a range of ongoing activities and future priorities for MDOT SHA to fulfill the program mission.

Table 1: Strategies for Consideration in MDOT SHA's CAV Program

Strategy	Description
Implement Pilot Programs to Build Experience and Attract Partners	
Implement the US 1 Innovative Technology Deployment Corridor	MDOT SHA's arterial traffic management efforts, CAV readiness efforts, and a planned arterial CCTV project have converged from a timing perspective. This is an ideal opportunity to combine efforts and demonstrate multi-office collaboration with MDOT SHA in pursuit of a next-generation deployment.
Implement Future Innovative Technology Deployment Corridors	There are several potential opportunities that have been discussed by the internal CAV working group, and additional priorities will emerge (in some instances unexpectedly) as the program matures.
Coordinate with Ongoing Major Projects	A completed I-270 ICM deployment will open the door to new and unique CAV applications to assist drivers in moving through the corridor. In addition, a hard shoulder running project is being planned along I-95 between Baltimore and Washington that could open the door to future opportunities as well.
Pursue Federal Grant Opportunities	Fixing America's Surface Transportation (FAST) Act provides long-term federal funding for surface transportation infrastructure planning and investment. In addition to regularly authorized federal funds, the FAST Act has introduced new grant programs that may be of interest to MDOT SHA in pursuit of advancing CAV initiatives.
Get Additional Benefits by Supporting CAV Testing	
Partner with the Aberdeen Proving Ground	MDOT SHA has been meeting with Aberdeen Test Center (ATC) personnel to explore potential collaborative efforts for CAV testing. The FHWA and other companies will conduct testing on closed-loop courses contained in the ATC, but potentially wish to expand that test to include "real world" roadways and even the potential for mixed traffic situations on public roadways in Maryland.
Partner with the U.S. DOT	The FHWA Office of Operations Research and Development, located at the Turner Fairbank Highway Research Center in Northern Virginia, has ongoing pilot programs and field operational tests concerning CAV. Virginia DOT has actively marketed the FHWA to conduct testing on their roadways but FHWA has shown a willingness to share with MDOT SHA and also incorporate testing on some of its own roadways and facilities in the future.
Leverage our Relationship with Maryland Academic Institutions	The University of Maryland is a national leader in developing transportation technology, and is already an MDOT SHA partner. Likewise, nearby Johns Hopkins University Applied Physics Laboratory, and the National Transportation Center (NTC) at Morgan State University are important partners.

Table 1: Strategies for Consideration in MDOT SHA's CAV Program (continued)

Strategy	Description
Foundational Needs of a CAV Program	
Install a Robust Telecommunications Infrastructure	A comprehensive telecommunications plan and architecture should be mapped out with the future of CAV in mind. It should include an analysis of the technological challenges and opportunities, and operations/policy issues such as maintenance and relationships with Network Maryland. In parallel, MDOT SHA should also work to build provisions of this approach into all roadway projects going forward, such as conduit for fiber optic/wired communications and additional physical cabinet space at ITS and traffic signal installations.
Enhance Road Markings and Signage	MDOT SHA should monitor national research and lessons learned from other states such as Caltrans, and periodically discuss the merits of making changes to existing road marking and signage programs. The MDOT SHA CAV Working Group should visit this topic annually with the Deputy Administrator/Chief Engineer for Operations.
Track and Influence Policy & Legislation	To accommodate the fact that this is a quickly evolving space, frequent communication between MDOT and legislators is recommended. Education on the various components of CAV, testing opportunities, and the impacts on economic development for the state would go a long way toward helping policymakers better understand the impacts of their actions.
Develop a Robust Data Governance Plan	As proliferation of CAV technologies and public awareness increases, both the volume of data and public data requests will escalate. To prepare for this, a formal data governance plan should be developed. MDOT SHA's data governance plan would address data privacy and security, procedures for storing data, sharing policies surrounding signal timing data, fulfillment of public information requests, and other data-related policies.
Pay Attention to Staffing & Skills Development	In a CAV ecosystem, there are expected technology deployments that MDOT SHA will support. Ensuring staff training and skills for each of these is a minimum starting point for agencies to consider, and it begins by fostering an overall culture of embracing technological change.

Table 1: Strategies for Consideration in MDOT SHA's CAV Program (continued)

Strategy	Description
Outreach Activities	
Internal Awareness of CAV	Awareness within MDOT SHA, across the various transportation business units (TBU), and at MDOT headquarters itself, is paramount to ensuring the department speaks and acts with one voice. There are tools that can be used to brief employees, assuring them that their own agency is not only aware of the fast-changing evolution in CAV – but actively engaged as a leading-edge organization.
External Outreach & Education	Educating the general assembly on the various issues involved, confusing definitions, and activities of our neighboring states would be helpful in securing a stronger relationship with MDOT; and ensuring new legislation isn't introduced that could be contrary to the goals or plans of MDOT and its TBUs. The business community is another stakeholder group worthy of targeted outreach. Other states have started to engage their economic development groups, and Maryland should make it clear that it's "open for business" and wants to attract CAV development.
Involvement/Visibility in National Activities	MDOT SHA recently engaged in the CV Pooled Fund Study. It is a great opportunity to begin expanding their understanding of other activities nationally. In addition, there are additional opportunities for MDOT SHA to engage in. It is also important that MDOT SHA map out who engages in these activities, ensuring a broad representation from the agency is included and that through the internal MDOT SHA CAV Working Group those experiences can be shared even more broadly.
Organizational Management of CAV	
MDOT SHA Offices and Engagement in CAV	The internal MDOT SHA CAV Working Group serves as a clearinghouse for knowledge, a coordination point for collaboration, and an opportunity for everyone within MDOT SHA to contribute. Executive management should periodically receive briefings from the internal working group, strongly support its efforts, and annually review whether or not the current internal organizational structure is meeting the needs of the program.
Support the MDOT SHA CAV Working Group	MDOT SHA currently has a seat at the table and is actively involved in Working Group activities – from both the policy and technical perspectives. This group represents a great opportunity to garner feedback from other sectors of the industry, impact legislative activity, and connect with other TBUs in effectively communicating MDOT's vision for CAV.

Table 2 illustrates the alignment between these strategies and the program goals, to show the relationship between the two and how goals are anticipated to be achieved.

Table 2: Alignment of Strategies and Goals

STRATEGIES:	Goal 1: Make Maryland an attractive partner for CAV development, testing, and production	Goal 2: Begin deploying CAV technology and engaging in national activities	Goal 3: Establish foundational systems to support future CAV deployment	Goal 4: Enable CAV benefits for users	Goal 5: Look for opportunities to leverage CAV technologies to support SHA business processes
US 1 Innovative Technology Deployment Corridor	X	X	X	X	
Future Innovative Technology Deployment Corridors	X	X	X	X	
Other Major Projects	X			X	X
Federal Grant Opportunities		X			
Aberdeen Proving Ground	X	X		X	X
U.S. DOT	X	X		X	X
University of Maryland			X		X
Telecommunications	X	X	X		
Road Markings and Signage	X		X	X	X
Policy & Legislation	X		X		X
Data Governance Plan	X	X	X		X
Staffing & Skill Development	X		X		
Internal Awareness of CAV		X	X		X
External Outreach & Education	X		X	X	
Involvement/Visibility in National Activities	X		X	X	
MDOT SHA Offices and Engagement in CAV	X	X	X		X
MDOT SHA CAV Working Group	X		X		X

Take Action!

Pilot CAV Programs

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

Take Action! Pilot CAV Programs

IMPLEMENT PILOT PROGRAMS TO BUILD EXPERIENCE AND ATTRACT PARTNERS

As new technology and strategy begins to form around CAV, it is important for agencies like MDOT SHA to gain experience and anticipate (as much as possible) future needs. Pilot programs are an excellent opportunity to provide some immediate benefits to citizens and consumers of transportation, while simultaneously building experience with next-generation technology, new partners, and future operational scenarios.

US 1 Innovative Technology Deployment Corridor

As noted previously, an outcome of Maryland's TSM&O planning exercises was to embark on an aggressive campaign to begin plotting a course that would eventually integrate freeway and arterial traffic management. A report was commissioned that would recommend MDOT SHA conduct a Pilot Project to deploy arterial CCTV along the US 1 corridor in Howard County (MD 32 to MD 100). The planning report was delivered in November of 2016.

While that report was being finalized, the new MDOT SHA CAV Working Group was preparing the administration (and MDOT at large) for the emergence of CAV technology, recognizing the incredible safety, mobility, and environmental benefits it might unlock. The MDOT SHA CAV Working Group acknowledged that MDOT SHA's "CAV Readiness" is an important component for the future, and all projects should begin to consider how they contribute to this going forward.

Timing, as they say, is everything. MDOT SHA's arterial traffic management efforts, TSM&O culture shift, CAV readiness efforts—combined with national efforts such as Maryland's entry into the CV Pooled Fund Study (PFS) and the national SPaT Challenge—created a convergence from a planning and timing perspective (Figure 8). This became an ideal opportunity to combine efforts and demonstrate multi-office collaboration with MDOT SHA in pursuit of a next-generation deployment. Subsequently, the MDOT SHA CAV Working Group asked the Office of CHART & ITS Development to scope out the possibility of expanding the originally proposed Arterial CCTV Pilot Project, to become the US 1 Innovative Technology Deployment Corridor.

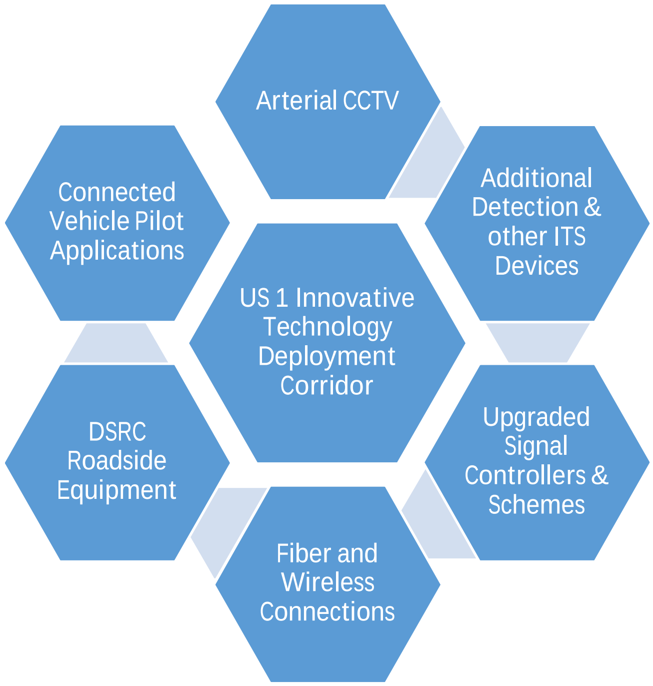


Figure 8: US 1 Innovative Technology Deployment Corridor Elements

Key Elements to be included in the US 1 Innovative Technology Deployment Corridor

- Arterial CCTV to support incident and traffic management
- Additional detection to support arterial travel times
- Upgraded signal controllers to support future CV applications
- DSRC deployment at intersections in support of national SPaT Challenge
- Fiber Optic communication connectivity (with redundancy) to support this and future needs
- Other communication to support field equipment (e.g., point/multi-point or cellular)
- Additional exploration (arterial DMS, localized Road Weather Information Systems (RWIS) deployment, mid-block detection)

Project Geography

- US 1 corridor between MD 32 and I-195.
- Inclusion of key east/west arterial feeders like MD 175.
- Will cover approximately 20 intersections (meeting the SPaT Challenge).
- Explore possible pedestrian CV applications, look at transit for possible CV transit signal priority implementation along corridor, explore park-n-ride locations for possible travel information inclusion, and consider industrial and freight movements along corridor.

In parallel to developing this CAV action plan, a scoping exercise is currently underway to initiate the development, plans, and specifications to make this pilot program a reality. The scoping report will include the following:

- Introduction and Background, including a description of the elements that have led to this
- A Case for Action with emphasis on benefits
- Requirements Document with design elements and communications recommendations
- Other Factors such as operations, maintenance, and costs
- Draft Implementation Schedule to break the project into phases for implementation

Requirements Needs

- Field Review: includes cabinets, communications, current equipment specs, etc. Some of this will be accomplished with as-built drawings and some with a field review where experts physically examine cabinets, document firmware and equipment lists. Existing conditions must be verified.
- Communications/Network Architecture: includes expanding the alternatives analysis that was done for the Arterial CCTV project, introducing the self-healing fiber ring concept, discussing additional communication components that can be utilized, and building a high-level logical architecture that accommodates current and future needs.
- Design Elements: include specifications for some of the equipment, network/communication design, logical and physical architecture. These must be specific and should be requirements not preferences, which will simplify procurement and reduce the risks to integration.

RECOMMENDED ACTION

- Vigorously pursue the US 1 Innovative Technology Deployment Corridor project to establish a solid foundation, demonstrate CAV readiness to private industry, and gain valuable experience in multi-disciplinary projects that include CAV components.

Future Innovative Technology Deployment Corridors

The US 1 Innovative Technology Deployment Corridor will have impacts far beyond the applications and technology that get deployed along the corridor; the policy, planning, design, procurement, and integration efforts that make those applications and deployments possible will in many instances represent new horizons for MDOT SHA. Reviewing and capturing lessons learned throughout the various stages of this project should be a fundamental expectation, and adjustments for future efforts should take those lessons into consideration.

Similar to other efforts within MDOT SHA, lessons learned must be captured in stages and applied “in real time” to the next project, and the next project, and so on. When CHART first began deploying cameras, detectors, and DMS, there were many lessons learned in all facets—early detectors didn’t have proper lightning suppression, early DMS didn’t have walk-in cabinets, etc. These were brand new to MDOT SHA, and over the next two decades the specifications and standards by which the above-mentioned roadside infrastructure was planned, designed, and deployed evolved considerably. So too will CAV technology, making it more important than ever to adequately capture lessons learned at every step along the way.

While it would be advantageous to complete an entire project cycle, gather lessons learned, and THEN start the next project, MDOT SHA can’t afford to wait until the entire US 1 Innovative Technology

Deployment Corridor project is complete and active to begin planning future CAV deployments. In fact, there are already potential CAV deployment opportunities that have been discussed by the MDOT SHA CAV Working Group—and additional priorities will emerge (in some instances unexpectedly) as the program matures.

Aberdeen Technology Deployment Corridor

A high priority was assigned to installing CV roadside infrastructure in locations where dedicated testing is taking place; the most prominent being in support of activities at the Aberdeen Test Center. Soon after the US 1 Innovative Technology Deployment Corridor project scope nears its conclusion, this plan recommends that MDOT SHA immediately develop a scope for the second project—at Aberdeen. This would incorporate I-95, US 1, and US 40 from the Baltimore County/Harford County line on the southern boundary to the Susquehanna River (Tydings Bridge) on the northern boundary. While I-95 in this portion of the state is managed by sister agency MDTA, there is a willingness by both TBUs to partner together in pursuit of advancing the state of CAV in the Harford County region to take advantage of future partnerships with the Aberdeen Test Center. A joint effort with MDTA would meet the One-MDOT vision and would be looked upon favorably by The Secretary's Office.

Connecting all three north-south routes is MD 24, MD 22, MD 543, and several other east-west arterials. MDOT SHA has already replaced most of the signal controllers with state-of-the-art 2070 open architecture controllers (Econolite ASC/3), and has a relatively robust telecommunication connectivity to most signalized intersections in this area (although not a fiber optic connection yet). In addition, there is a robust set of CCTV cameras already deployed in the area, affording the opportunity to combine efforts (and communications) in order to not only install CAV roadside technology, but also maintain and/or fill gaps from other existing CHART roadside infrastructure.

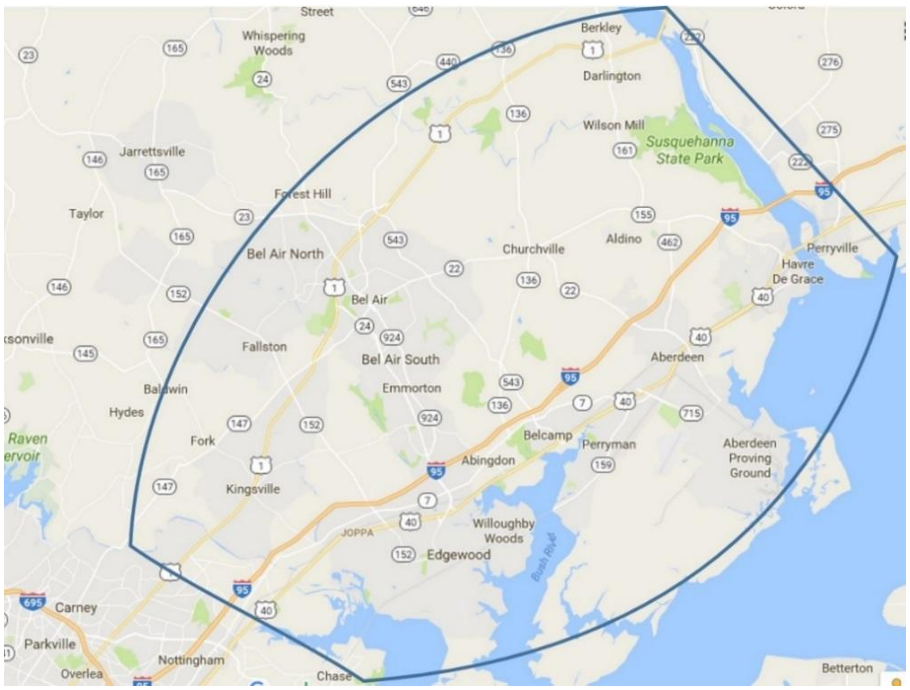
Similar to the US 1 Innovative Technology Deployment Corridor, this report recommends that the Aberdeen Technology Deployment Corridor incorporate upgraded signal controllers to support future CV applications, DSRC deployment at intersections in support of future CAV testing in and around the Aberdeen area, fiber optic communication connectivity (with redundancy), and additional exploration of other ITS field devices that could support enhanced incident management and traffic operations in the region (arterial DMS, localized RWIS deployment, mid-block detection).

As noted, this corridor already features a robust deployment of CCTV, which will speed up the overall concept development and ultimate delivery of benefits. CCTV cameras are located in the scoping area at the following locations:

- I-95 @ MD 152 (south end of interchange)
- I-95 @ MD 152 (north end of interchange)
- I-95 @ MD 24 (south end of interchange)
- I-95 @ MD 24 (north end of interchange)
- I-95 @ MD 543 (south end of interchange)
- I-95 @ MD 543 (north end of interchange)
- I-95 @ MD 22 (south end of interchange)
- I-95 @ MD 22 (north end of interchange)
- I-95 @ MD 155 (south end of interchange)
- I-95 @ MD 155 (north end of interchange)
- I-95 just S of Tydings Bridge
- US 40 @ MD 755

- US 40 @ MD 132 right near APG
- US 40 @ South entrance to Hatem Bridge
- US 40 center span of Hatem Bridge
- US 1 @ Baltimore/Harford County Line
- US 1 @ MD 152
- US 1 @ Conowingo Dam
- MD 24 @ Harford County Mall near US 1
- MD 24 @ MD 924 near I-95
- MD 543 @ MD 136

The Aberdeen Test Center has already indicated a strong interest in having MDOT SHA take this next step as a partner in its future CAV testing and evaluation activities. The applications tested in this region could be significantly different from what is tested along the US 1 corridor in Howard County—offering MDOT SHA a unique opportunity to dramatically broaden its experience, knowledge gained, and value to Maryland drivers.



Source: Google Maps

Figure 9: Scope Area for Aberdeen Region Innovative Technology Deployment

Additional Corridors of Interest

Some additional project areas that have already been discussed by the internal working group include the following:

- College Park/Fort Meade – In the southern portions of the I-95 corridor, US 1 and US 29 are parallel to I-95 and provide access to businesses, industries, and academic institutions, including our key partners UMD and Johns Hopkins University APL. Connecting all three are several arterial and limited access freeways, including MD 32, which runs through Ft. Meade. Most of the signalized intersections in this portion of the corridor also feature some level of telecommunication connectivity and upgraded signal controllers.

- Port of Baltimore – As part of the federal designation for AV testing proposal, and pending approval from homeland security entities for port access, the Port of Baltimore had offered a real-world freight AV testing scenario for both in and out truck operations, as well as drayage opportunities. Specifically, areas of the port—including where MDOT is partnered with Ports America—would provide a ready opportunity for this emerging technology to test and implement freight operations, and the roadways could be equipped in that area with CV roadside infrastructure.

While the Aberdeen project progresses through its scoping effort, the MDOT SHA CAV Working Group should prioritize the next two or three projects. The CHART program has historically produced a Non-Constrained Deployment Plan (NCDP), which is now the Long Range Strategic Deployment Plan (LRSDP), and used that process to "cherry pick" projects for future prioritization and funding. While that same type of effort can be employed for CAV, given the rapid evolution in technology (along with procedural lessons learned), the process should be more flexible and revisited annually instead of every 4 or 5 years.

RECOMMENDED ACTION

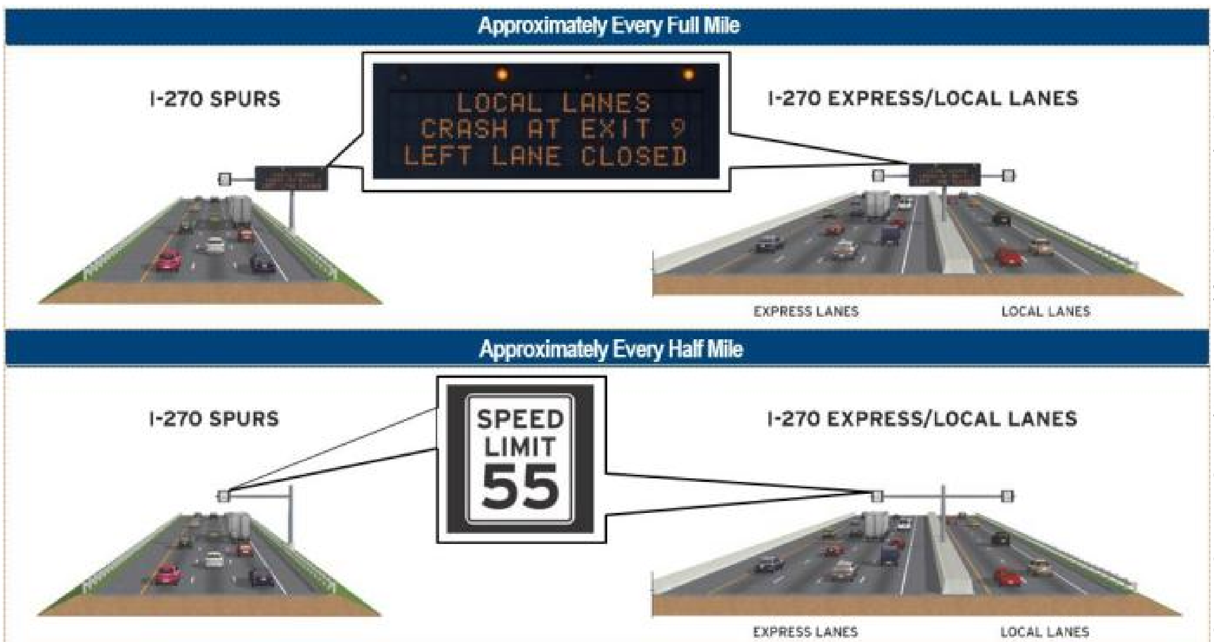
- As soon as the US 1 Innovative Technology Deployment Corridor nears conclusion, MDOT SHA should immediately begin scoping the Aberdeen area project. This will demonstrate to the ATC that MDOT SHA is a ready and willing partner, and will afford the opportunity to partner with MDTA on a scoping effort that will further reinforce the One-MDOT vision.
- Once a year the internal MDOT SHA CAV Working Group should set a meeting with the sole purpose of outlining future deployment corridors. The group should review the progress and lessons learned from the US 1 and Aberdeen deployments, and consider what has changed in the prior months.
- Periodically there will be requests for "one-offs" from companies that want to test in a specific location. The internal MDOT SHA CAV Working Group should seriously entertain all of those interested offers and discuss/explore what might be needed from an infrastructure standpoint.
- At least one other state uses an on-call based deployment contract, so that as individual opportunities arise its value can be assessed internally, and if worthwhile a mechanism to immediately upgrade a specific location can be used to install either permanent or temporary DSRC or other CV communication technology. This approach would allow the state to be more flexible in the eyes of companies looking to potentially engage in testing CAV in the state, and more importantly, it would give MDOT SHA a mechanism to respond and react as technology evolves much faster than any current planning, design, and procurement processes can possibly do.

Ongoing Highway Innovation Projects

There are several ongoing projects that involve implementing current and next-generation ITS solutions and technology. Two in particular—the Interstate 270 Innovative Congestion Management (I-270 ICM) project and the I-95 Active Traffic Management (I-95 ATM) project—are important to monitor and could present future opportunities for leveraging advances in telecommunications and electronic infrastructure.

In mid-April 2017, Governor Larry Hogan announced advancement of the state's $100 million I-270 ICM project. The winning design-build team—led by Concrete General Inc. (CGI) and comprising 16 firms—was selected following a competitive bidding process to determine who could move the most vehicles the fastest and farthest on I-270 between I-70 and I-495. According to CGI's technical proposal (available publicly now that the project has been awarded), 15 roadway improvements will be included, meant to increase capacity and vehicle throughput and address safety deficiencies by strategically eliminating existing bottlenecks. The effort will also include innovative technologies and techniques, comprising adaptive ramp metering, active traffic management, and virtual weigh stations. The project is meant to start construction by the end of 2017 and be completed in 2019.

The I-270 ICM project will feature geometric spot improvements (extending ramps, improving merge areas). It will include a condensed deployment of active traffic management (ATM) tools such as queue warning and variable speed advisory. And it will introduce ramp metering to Maryland roadways, a first of its kind. Figure 10 shows a representation of the ATM implementation.



Source: Concrete General Inc, Proposal for I270 Innovative Congestion Management Project

Figure 10: I-270 Innovative Congestion Management Project Active Traffic Management Deployment

The I-270 ICM project is extremely complex and under intense pressure to deliver a variety of solutions in a short time frame; it will experience maintenance of traffic situations on a rapidly changing basis. Attempting to pilot CAV technology in conjunction with this effort could unintentionally have negative impacts on CGI's ability to complete its task at hand. However, the effort will result in new ITS devices getting deployed along the corridor, and with that will come a more robust communications network along I-270. This will set the stage for future CAV deployment and efforts once the I-270 ICM project is complete. More importantly, a completed I-270 ICM project deployment will open the door to new and unique CAV applications to assist drivers in moving through the corridor.

The I-95 ATM project will also address safety, reliability, and congestion during peak-hour travel, but in this instance by implementing hard-shoulder running. Currently in the planning stages (and not yet funded for construction), the proposed project limits are northbound I-95 between MD 32 and MD 100, and southbound I-95 between MD 100 and MD 175. Requiring ample electronic signage and monitoring equipment to ensure the shoulders are available before being opened to traffic, this project will also require a robust communications network that could enable future CAV-related implementations and applications. Similar to the I-270 ICM project, the maintenance-of-traffic requirements will be complex and attempting to pilot CAV technology in conjunction with this effort could have unintentional negative impacts on measuring the impact of the hard-shoulder running solution.

However, as we progress into a CAV environment, the I-270 ICM project and I-95 ATM project implementations won't be wasted—quite the contrary—the infrastructure-based solutions will complement the introduction of CAV applications. Drivers will have unique potential applications to assist them in moving through the two corridors in addition to the infrastructure-based ITS tools. These applications are not yet available, but potential mobile and/or vehicle-based applications are anticipated, including the following:

- CV-Enabled Queue Warning: consists of a mobile device or vehicle-based warning signal alerting the driver that traffic is stopped or slow ahead. This warning could be coupled with dynamic route guidance to assist the motorist in selecting alternative routes or the most efficient lane.
- CV-Enabled Variable Speed Advisory: consists of a mobile device or vehicle-based advisory alerting drivers to reduce their speeds in advance of downstream congestion. This advisory would need to be closely coordinated with overhead sign delivery of variable speed advisory to ensure mixed messages aren't being delivered to the driver.
- CV-Enabled Lane Closure Advisory: consists of a mobile device or vehicle-based advisory informing drivers of a potential obstruction in the lane they currently occupy or a neighboring lane. The availability of the shoulder would also be included in this advisory message. This would need to be coordinated with overhead lane control signals to ensure mixed messages aren't delivered to the driver.

RECOMMENDED ACTION

- Meet with the project team for the I-270 ICM project and discuss opportunities to include telecommunications (and/or conduit) that could enable future CAV implementation but don't change the scope or schedule of the current project. Similarly, inject future robust communications and conduit plans into the I-95 ACM project planning effort before it is advertised for construction.
- Monitor the progress of the I-270 ICM and I-95 ATM projects, but for the moment allow them to progress before attempting to pilot CAV applications along the two corridors.

Federal Grant Opportunities

Adequate funding is required for a successful CAV program, covering everything from capital improvements, systems maintenance and operations, promotion of services, and staffing. It is recognized that securing adequate funding is an increasing challenge for state, regional, and local agencies. State funding strategies have been successful on some of CHART-related projects, but state funding resources are also stretched thin, and competition for those funds crosses all operational, maintenance, and planning horizons. The FAST Act provides long-term funding for surface transportation infrastructure planning and investment. In addition to regularly authorized federal funds, the FAST Act has introduced new grant programs that may be of interest to MDOT SHA in advancing CAV initiatives.

Information on each grant program is included in the following sections. Since 2017 application information and dates for some of the programs are still in progress, information from the 2016 cycle is included below as an example.

TIGER/U.S. DOT National Infrastructure Investments

These are discretionary grants for capital investments in surface transportation infrastructure that have a significant impact on the nation, a metropolitan area, or a region. This included projects that promoted the Obama administration's Ladders of Opportunity initiative—that is, federal investments that increased connectivity to employment, education, and services; supported workforce development; and/or contributed to community revitalization, particularly for disadvantaged populations.

- Total Funding Available was $500 million, at least $100 million of which must be awarded to projects in rural areas. Individual grants will be $5 million minimum in urban areas and $1 million minimum in rural areas, with a $100 million maximum to projects in a single state.
- Cost Sharing was a maximum 80 percent federal share (up to 100 percent in rural areas). Overmatch is encouraged.
- Eligible Projects were highway or bridge projects, public transportation projects, passenger and freight rail projects, port infrastructure investments, intermodal, and active transportation projects.
- Eligible Applicants were state, local, and tribal governments, including U.S. territories, transit agencies, port authorities, MPOs, other political subdivisions of state or local governments, and multijurisdictional groups applying through single lead applicant.
- Application Criteria included state of good repair, economic competitiveness, quality of life, environmental sustainability, safety, innovation, and partnerships.
- Other Notes of Interest for TIGER:
  - Applications required benefit-cost analysis
  - 2016 Application Deadline: April 29, 2016
  - 2017 Application Deadline: October 16, 2017

Advanced Transportation & Congestion Management Technologies Deployment (ATCMTD) Initiative

The ATCMTD Initiative provides grants to eligible entities to develop model deployment sites for large-scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment.

- Total Funding Available was $60 million total in FY 2016. Five to 10 awards were expected with a $12 million maximum award for a single project.
- Cost Sharing was a maximum 50 percent federal share.
- Eligible projects deployed advanced transportation and congestion management technologies, including:
  - *Advanced traveler information systems* provided real-time, predicted, and individualized information about travel choices, based on data from sensors (traffic, weather), mobile sources (personal portable devices, CVs), and other information systems (public transportation, shared-use mobility, traffic incident management, construction, parking, congestion pricing/tolls or other costs) to allow travelers and shippers to make informed decisions regarding destinations, when to travel, routes, or modes. This information was publicly accessible and not limited to users with smart phones.
  - *Advanced transportation management technologies* assisted transportation system operators in managing and controlling the performance of their systems to provide optimal services or respond to dynamic conditions, including interjurisdictional and intermodal coordination; technologies may include traffic signal equipment, advanced data collection and processing (from sensors, CVs and other mobile sources, other information systems), dynamic lane controls/configurations, and cooperative transportation management algorithms including pricing strategies across jurisdictions/agencies/facilities/modes.
  - *Infrastructure maintenance, monitoring, and condition assessment* technologies and systems that monitored the behavior or assess the condition of transportation infrastructure to allow agencies to better manage their transportation assets through optimizing resource allocation, preventive maintenance processes, and responses to critical conditions.
  - *Advanced public transportation systems* that assisted public transportation system operators or other shared mobility entities in managing and optimizing the provision of public transportation and mobility services.
  - *Transportation system performance data collection, analysis, and dissemination systems* technologies and systems that actively monitored the performance of and interactions between transportation systems and permit agencies and other interested entities to conduct analyses and research, and explore innovative, value-added products and services.
  - *Advanced safety systems*, including vehicle-to-vehicle and vehicle-to-infrastructure communications, technologies associated with autonomous vehicles, and other collision avoidance technologies, including systems using cellular technology.
  - *Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems* that linked information from ITS and other transportation systems with information from Smart Grid and other energy distribution and charging systems to provide users with better information related to opportunities for recharging electric vehicles, and to provide

energy distribution agencies with better information related to potential transportation-user demand.

- *Electronic pricing and payment systems* that permits users to electronically conduct financial transactions for mobility services across jurisdictions and agencies, such as unified fare collection, payment, and tolling systems across transportation modes; or
- *Advanced mobility and access technologies—such as dynamic ridesharing and information systems to support human services for elderly and disabled individuals*—that leveraged data and communications systems to allow public agencies and human service organizations to provide improved mobility services to at-risk users such as elderly, disabled, or other individuals that require transportation assistance.

- Eligible Applicants were state or local governments, transit agencies, MPOs, multijurisdictional groups, or consortiums of research or educational institutions representing a population over 200,000. Public-private partnerships were encouraged.
- Other Notes of Interest for ATCMTD:
  - Evaluation includes a 50 percent score for technical merit, and 50 percent score for ability to staff/support/oversee the deployment
  - 2016 Application Deadline: June 3, 2016
  - 2017 Application Deadline: June 12, 2017

Fostering Advancements in Shipping and Transportation for the Long-term Achievement of National Efficiencies (FASTLANE) Grant Program

The FAST Act established the Nationally Significant Freight and Highway Projects (NSFHP) program to provide federal financial assistance to projects of national or regional significance. The NSFHP program addresses nationally or regionally significant challenges across the nation's transportation system, including improving safety, efficiency, and reliability of the movement of freight and people; generating national or regional economic benefits and increasing U.S. global competitiveness; reducing highway congestion and bottlenecks to enable more efficient intermodal connections; minimizing delays at international borders; and modernizing ports, including connections between ports and their surface transportation systems.

FASTLANE grants are awarded to:

- Improve the safety, efficiency, and reliability of the movement of freight and people.
- Generate national or regional economic benefits and an increase in global economic competitiveness of the United States.
- Reduce highway congestion and bottlenecks.
- Improve connectivity between modes of freight transportation.
- Enhance the resiliency of critical highway infrastructure and help protect the environment.

- Improve roadways vital to national energy security.
- Address the impact of population growth on the movement of people and freight.

Total Funding Available was $759 million total in FY 2016; 10 percent set-aside for "small" freight projects (mainly under $100 million); 25 percent set-aside for projects in rural areas

Cost Sharing may fund up to 60 percent of project costs.

Eligible Projects included highway freight projects carried on the National Highway Freight Network; highway or bridge projects carried out on the National Highway System; railway-highway grade crossing or grade-separation projects; and freight intermodal and rail projects.

Eligible Applicants were state, local, and tribal governments, transit agencies, port authorities, MPOs over 200,000 population, other political subdivisions of state or local governments, and multijurisdictional groups of eligible parties applying through a single lead applicant.

Other Federal Funding Eligibility

Several existing "formula" programs in the transportation authorizations bill included language that expanded the eligibility to now INCLUDE the design and installation of V2I communications equipment. Those programs include the following:

- Congestion Mitigation and Air Quality
- Highway Safety Improvement Program
- National Highway Performance Program
- Surface Transportation Block Grant Program

RECOMMENDED ACTION

- MDOT SHA should have a program in place that will have projects and ideas "on the shelf" with concepts fleshed out. Don't wait for a grant opportunity to be published; most of the grant applications provide a 30- to 60-day window for submittal, but the project conceptualization process can often take 90 to 120 days or even longer if you are lining up partners. Use the internal MDOT SHA CAV Working Group to identify possible projects, and initiate an effort to develop the concepts further in anticipation of future federal grant NOFOs.
- Clarify with the MDOT SHA Office of Procurement and Contract Management the potential role of consultants in developing grant applications or project concepts for grant applications. Given the resource constraints that exist within MDOT SHA, it will be difficult to maintain this on-the-shelf capability without engaging consultants, but current conversations are unclear in terms of eligibility and potential conflict in terms of using consultants.

GET ADDITIONAL BENEFITS BY SUPPORTING CAV TESTING

While pilot programs are excellent opportunities to build experience internally, there are also many opportunities to partner with other organizations already established as research, development, and testing centers. This once again shifts the risk away from MDOT SHA while offering an opportunity to share the reward.

Aberdeen Proving Ground

In Maryland, the ATC is actively engaging in testing and evaluation activities on behalf of the FHWA and will soon include other private-sector interests. The ATC—a unit of the U.S. Army and operating out of the Aberdeen Proving Ground—is focused almost solely on testing and evaluation and not so much on the development side. The ATC is the self-described "Underwriter's Laboratory for the Army," and nearly 75 percent of its work is for the military. However, it has capacity to provide test services to other branches of the government and private industry.

ATC facilities include nearly 50 miles of roadways and road courses that can be used to test vehicles. A huge advantage of working with ATC is its strong commitment to safety (following U.S. Department of Defense requirements) and data confidentiality capabilities for their customers. It is also launching a National Cyber Security Range at Aberdeen.

MDOT SHA has been meeting with ATC personnel to explore potential collaborative efforts for CAV testing. The FHWA and other companies will conduct testing on closed-loop courses contained in ATC, but could expand that test to include real-world roadways and even the potential for mixed-traffic situations on public Maryland roadways. This represents a great opportunity for MDOT SHA to partner with ATC, offering its customers a value-added future expansion to testing while at the same time gaining valuable experience in CAV testing, evaluation, and development in Maryland.

Collaboration with ATC has also expanded into participation by MDOT SHA in a "Community of Interest for DSRC." This working group being led by ATC personnel is exploring the lessons learned, standards issues, and other nuances of working with DSRC among federal and state personnel.

As discussed earlier in this document, the U.S. DOT solicited applications in late 2016 for test sites to be part of a "federally designated AV proving ground" network. No federal funding was promised as part of this designation, but many organizations—including MDOT SHA—recognized the benefits of engaging in CAV testing and evaluation. Accordingly, Maryland submitted an application that included the ATC, along with many other potential stakeholders in presenting an "AV Research & Production Corridor" concept.

Maryland's approach included the I-95 corridor from the Aberdeen Proving Ground region just north of Baltimore, to the Fort Meade and UMD region in the Washington, D.C. metropolitan area. The proposal took advantage of existing development, testing, partnerships, and investment in AV technology that is concentrated along I-95 corridor. It was built on the foundation that our region is already rich with existing AV testing and hardware/software development, related AV cyber innovation, CV testing, and proposed manufacturing sites for CV and AV technology.

"The I-95 Corridor in Maryland is the ideal one-stop-shop for real-world testing and deployment of autonomous vehicles," said Transportation Secretary Pete Rahn in a department press release. "This corridor is strategically positioned along the thriving east coast and combines a wealth of existing facilities, along with unique testing opportunities at the Port of Baltimore and BWI Airport."

Figure 11: Maryland DOT's Automated Vehicle Research and Production Corridor

Maryland's proposal took advantage of existing development, testing, partnerships and investments in AV technology along the I-95 corridor and included existing facilities already developing and testing AV technologies, including the Aberdeen Proving Ground in Harford County, the Center for Entrepreneurship in Howard County, and UMD CATT Laboratory in Prince George's County. The approach included MDOT-owned facilities to provide future simulated and real-world testing environments, including the electronic toll lanes along I-95, the Port of Baltimore for freight operations, and Baltimore-Washington International Airport for passenger shuttle transportation. The proposal also suggested the involvement of private-sector companies already planning development and manufacturing of AV components within the next two years.

U.S. Department of Transportation

In pursuit of developing relationships with the ATC, MDOT SHA staff also uncovered potential opportunities with the FHWA. The FHWA Office of Operations Research and Development—located at the Turner Fairbank Highway Research Center—has ongoing pilot programs and field operational tests concerning CAV. It is conducting tests on vehicles on its campus in McLean, VA (located adjacent to the Central Intelligence Agency's headquarters). There are two intersections "on property" equipped with DSRC and other communication technologies: a large garage where vehicles can be equipped with devices, and several parking lots where small-scale tests and evaluation programs can be run.

Because it isn't a large enough footprint to conduct most research projects, the FHWA expands further into collaboration with the Federal Law Enforcement Training Center (FLETC) in Cheltenham, MD, using the FHWA's urban training simulation areas and short roadways for additional testing. Several mock intersections have been equipped with DSRC equipment, and tests for eco-approach V2I applications are underway at FLETC.

For larger test track needs, the FHWA has recently begun to also now work with the ATC, which has installed DSRC along their large oval track. Testing such applications as cooperative adaptive cruise control and truck platooning, the FHWA Office of Operations Research and Development is interested in future expansion beyond closed-track scenarios to one day include real-world roadways.

The Virginia DOT has actively marketed the FHWA to conduct testing on its roadways and given its McLean, VA, location it lends itself naturally to collaborate. But FHWA has shown a willingness to "share their need" with MDOT SHA and incorporate testing on some of MDOT SHA's roadways and facilities in the future.

Once initial development has been tested and evaluated in laboratories and on closed-circuit tracks, the next logical step is to begin evaluating CAV technologies in real-world conditions. How will the technology function near non-CAV vehicles? Are there specific applications that can be tested on current roadways? How will the systems interface with the infrastructure? Will weather and pavement conditions impact the functionality? Use case studies will need to occur in a semi-controlled environment (compared with a completely controlled environment of the laboratory) and Maryland's I-95 corridor provides the ideal variety of locations and conditions to continue that journey from development to production.

A key reason for FHWA to work with MDOT SHA is that MDOT SHA is not offering just one facility—just one location. TheI-95 corridor in Maryland is truly a "corridor of national significance" that presents numerous transportation scenarios and challenges—a transportation operations engineer's dream come true—where CAV can be tested comprehensively. The corridor includes 5 major north-south routes, 8 major east-west connecting routes, 235 state-owned signalized intersections, a major Post-Panamax port, national security assets, major retail distribution centers, multimodal transit and air operations, plus of course congressional visibility.

In pursuit of developing the MDOT AV testing designation proposal, MDOT SHA staff identified the following locations around the state where CAV testing and evaluation could thrive:

- Federal Law Enforcement Training Center (FLETC) (Cheltenham, MD) – FLETC is already being used by the U.S. Army and FHWA for AV testing and is a 2.2-mile driver training range, including skid control, NEVO, highway response and urban grid.
- Maryland Police and Correctional Training Commissions Public Safety Education and Training Center (Sykesville, MD) – This facility provides mock city and traffic scenarios for testing.
- Race tracks (i.e., Crofton Capitol Raceway) – These facilities are used by the MTA for testing.
- Bainbridge Development Corporation – This is a 1,200-acre site on the corridor and near Aberdeen Proving Ground that could be used for semi-real-world testing.

- Howard County Gateway Facility – This facility is available immediately to support AV testing and has testing planned in next few months. It will allow for a variety of testing scenarios such as parking and other low-speed operations.
- Ellicott City and Columbia in Howard County – The County has proposed real-world and semi-closed AV testing of downtown, mixed-use atmosphere in partnership with its downtown development efforts.
- Baltimore Metropolitan Planning Region (BRTB) – The BRTB is an advanced, high-tech planning agency and a partner in MDOT's data sharing, ITS, and CV testing and implementation. BRTB can assist in urban scenario testing, mostly within Baltimore City but also throughout the corridor since BRTB represents most of the jurisdictions along the corridor.

Private-Sector Testing

At the beginning of 2017, the MDOT Autonomous and Connected Vehicle Working Group began developing an official procedure to allow non-MDOT testing of highly automated vehicles (HAVs) on its facilities. The definition for HAV comes from NHTSA's guidance document addressed earlier in this plan, and the process is focused on keeping the safety of the traveling public as its first and highest priority. However, the process is also designed to foster dialogue with companies or organizations that want to potentially test HAVs and to help MDOT staff to better understand the needs and potential impacts to existing transportation systems.

To begin the process, a company or organization would first fill out an expression of interest (EOI) found on MDOT MVA's website: *http://www.mva.maryland.gov/safety/EOI-test-highly-automated-vehicles-in-Maryland.htm*. The website provides high-level information on the process and support expected. Once the expression of interest is submitted, the following steps will take place:

- The submitter will immediately receive notification that their EOI was received, and additional contact will occur within seven business days.
- The MDOT MVA will designate a Point of Contact to contact the submitter to begin a dialogue and better understand their test situation and infrastructure needs. Expectations on regulatory applicability, public outreach, and safety information will be established during this stage.
- The intent of the dialogue is meant to be collaborative, constructive, and expedient. It is not MDOT's intent to create a burdensome process. However, it is MDOT's responsibility to maintain a safe environment for anyone that uses its transportation facilities.
- Basic rules of this process are set out herein, and each instance will be handled according to its unique circumstances in order to provide the flexibility necessary to accommodate many different testing scenarios. As discussions progress, the submitter will file an Application for Permit to Test HAVs with MDOT MVA. They can expect a written response to the application within 30 business days. Once approved for permitting, the requesting party can begin preparing their test activities.

Additional dialogue with the lead agency will most likely occur as questions arise on either side. A collaborative posture by all parties will result in the most successful execution of tests.

Maryland Academic Institutions

UMD is a national leader in developing transportation technology. MDOT SHA partners with UMD for ITS and data sharing platforms, as well as for research and advancing of ITS systems and concepts. Likewise, nearby Johns Hopkins University Applied Physics Laboratory is engaged in supporting military systems development for automated technology, and the National Transportation Center at Morgan State University advances U.S. technology and expertise in transportation, research, and technology transfer, focusing on transportation as a key to human and economic development.

Autonomous Vehicle Laboratory

The Autonomous Vehicle Laboratory (AVL) is a facility in the UMD Department of Aerospace Engineering. The AVL educates students studying for degrees in the multi-disciplinary area of biologically inspired autonomous robotics. The AVL also pursues applied research, especially in the prototype development of biologically inspired autonomous vehicles for civilian and military applications. The AVL facilities have unique capabilities, including rapid-prototyping facilities for microsystem fabrication and a marker-based visual tracking system that provides direct measurements of vehicle position and orientation for system identification and real-time feedback.

UMD Center for Advanced Transportation Technology Laboratory

The UMD CATT Laboratory is the largest transportation data analytics and situational awareness applied R&D laboratory in the world—amassing over 1 trillion transportation data points every day from hundreds of public- and private-sector systems. The laboratory is staffed by an interdisciplinary group of 100+ engineers, software developers, researchers and students with diverse transportation operations, planning, research, and applied/real-world technology skillsets. The laboratory develops innovative technology deployments and user-centered design of software and information visualization systems. These systems and their data are used by nearly 10,000 transportation professionals, the military, leading private-sector firms like Google/WAZE, GM, INRIX, TomTom, and HERE, plus millions of travelers.

UMD CATT laboratory staff are experts in database management systems, big-data technologies like Hadoop, standards, geospatial data management, data processing optimization, and information visualization. MDOT SHA can leverage the UMD CATT laboratory's data and analytical applications to support data sharing and performance metrics for CAV testing. Archived data can also be made available in various analytics tools to help researchers and developers understand the implications of connected and autonomous vehicle technologies while testing various hypotheses.

Maryland Cybersecurity Center

The Maryland Cybersecurity Center (MC2), created in late 2010, is an academic center on the UMD campus that brings together faculty, researchers, and students working in the field of cybersecurity from several schools and departments across campus. Their proximity to the nation's capital enables close interaction with federal agencies, and their location in the Maryland-DC-Virginia region—one of the leading areas in the country for cybersecurity innovation and job growth—makes MC2 an ideal place for technology development and partnerships with industry. MC2—along with UMD CATT laboratory and the National Transportation Center at UMD—are working with the Ford motor company through a strategic partnership agreement on data analytics and cybersecurity related to autonomous vehicles. As a result, an AV cybersecurity lab has already been established for testing on real-world vehicles.

National Transportation Center at the University of Maryland (NTC@Maryland)

NTC@Maryland is one of only five National University Transportation Centers that were selected by U.S. DOT in a 2013 nationwide competition and the only one with a focus on the strategic goal of "Economic Competitiveness." NTC@Maryland focuses on research, education, and technology transfer activities that can lead to (1) freight efficiency and reliability; (2) congestion mitigation with multimodal strategies; and (3) national-level investment and policy analysis. In the AV research area, NTC@Maryland is a leader in studying the impact of AV technology and deployment on travel behavior, traffic flows, and economic development.

Johns Hopkins Applied Physics Lab

The Johns Hopkins University APL supports military systems development for automated technology. Significant advancements are occurring at APL, as well as within the cyber realm. For example, work at APL terrestrial operating domain provides certain advantages as well as particular challenges in comparison to other domains. Perhaps the most visible ground autonomy work in the U.S. Department of Defense today is being done by the Defense Advanced Research Projects Agency as part of the U.S. Army's future combat system. This work has again focused on vehicle design (the Unmanned Ground Combat Vehicle program) and off-road navigation, sensing, and mobility (the Perception for Off-road Robotics program).

National Transportation Center at Morgan State University

The NTC at Morgan State University advances U.S. technology and expertise in transportation, research, and technology transfer, focusing on transportation as a key to human and economic development. The NTC's current areas of research focus are transportation and traffic modeling, safety, economics and equity, transportation funding, and infrastructure's effect on aquatic life. The NTC also works to increase the number of minorities and women working in the transportation field. A key research area for NTC staff is automated technology.

I-95 Corridor Coalition

The I-95 Corridor Coalition is an alliance of transportation agencies, toll authorities, and related organizations, including public safety, from Maine to Florida, with affiliate members in Canada. The coalition provides a forum for key decision and policy makers to address transportation management and operations issues of common interest. MDOT SHA and MDOT MDTA were founding members of the coalition in the early 1990s, and the SHA Administrator at that time was the coalition's first Executive Committee Chairperson.

This volunteer, consensus-driven organization enables its myriad state, local and regional member agencies to work together to improve transportation system performance far more than they could working individually. The coalition has successfully executed dozens of joint collaborative projects, held workshop meetings, and has been a model for regional cooperation and data sharing for the rest of the nation.

One of the coalition's projects has also become a model for gathering and utilizing probe data to support planning and real-time operations. The Vehicle Probe Project (VPP) began in 2008 with the primary goal to provide coalition members with the ability to acquire reliable travel time & speed data for their roadways without the need for sensors and other hardware. The VPP surpassed the original expectations and provided real-time & historical tools for operations and planning. All data, regardless of vendor, is available to each of the participating agencies, providing a truly shared effort.

Specific to CAV, the I-95 Corridor Coalition hosted a conference in June 2016 on connected and automated vehicles – designed to support public agencies in addressing and accelerating the security, safety and operational issues related to the new connected/automated vehicle technologies within their jurisdictions and in coordination with neighboring jurisdictions. The goal was to illuminate and begin a discussion on how these vehicles will affect the coalition members and what actions can be taken to mitigate risk and maximize benefits.

The coalition will continue exploring the issues surrounding CAV, through future workshops and through the exploration of possible pilot programs. As MDOT SHA moves forward with its CAV effort and demonstrates a willingness to engage their resources in support of CAV, the potential to leverage pilot programs up and down the I-95 Corridor grows more likely.

Enabling Actions:
Build A Support Program

MARYLAND DEPARTMENT OF TRANSPORTATION

STATE HIGHWAY ADMINISTRATION

Enabling Actions: Build a Support Program

FOUNDATIONAL NEEDS OF A CAV PROGRAM

Telecommunications

Many external dynamics will affect the nature and timing of the benefits from CAV deployments for state and local transportation agencies. One core enabler of CV applications is providing effective data communications between vehicles and other sources and users of transportation and related data. This communication connectivity could be satisfied by DSRC (as discussed earlier in this document), or it could be through alternative wireless mediums such as satellite, cellular, or other form of wireless ad-hoc network. But in most instances, regardless of wireless protocol, there will need to be communication backhaul capability from nodes, hubs, or central processing points. And it is that communication medium that is most likely planned, installed, and owned by the infrastructure owner and operator (in this case, MDOT SHA).

Backhaul communications need to be high bandwidth to accommodate the unknown (how much data will be exchanged), they need to be reliable (can't afford dropped message packets if vehicle control is involved), and they need to be as close to real time as possible (especially for safety applications). That means latency, reliability, and switching are all critical functions in the network architecture.

It's important to repeat this point—independent of whether V2V and V2I communications are enabled by DSRC, 5G Cellular, or other mediums—some form of backhaul communications will be in play. As far back as five years, ago, the AASHTO Connected Vehicle Infrastructure Deployment Analysis recommended a phased approach of scenarios for deploying CAV roadside technology. This "footprint analysis" as it became known, suggested in 2011 that the communications networks, protocols, and security would be fundamental items of discussion and development for CV research, development, testing, and demonstration. And as a result, a number of state agencies in the US employ the "dig once" philosophy for all their construction projects. The strategies vary by state and location, but many include additional capacity in conduit, or focus on ensuring there is contiguous conduit along key corridors. Some include consideration of locations of hand holds and equipment cabinets/huts based on future CV needs, while others may actually bury dark fiber or other cabling in certain locations for future use.

Successful CV deployments today rely primarily on fiber optic cable for backhaul communications connectivity. It is extremely low-loss, high-speed, high-bandwidth, resistant to electromagnetic interference, lightweight, and in fact is cheaper than the equivalent length of copper (conduit and switching costs, however, are higher for fiber than copper). Fiber isn't the only medium used, and in most CV deployments there is a hybrid communication network that meets important performance standards and is designed for that specific location.

For two decades the deployment of ITS technology has depended on the need in that particular location – and so too has the deployment of communications to support those devices. The same philosophy will be in play for CAV connectivity. A comprehensive communications plan and architecture should be mapped out with the future of CAV in mind, and future projects should all begin to consider how they can contribute to building out this architecture.

This plan should consider not only the network architecture to ensure optimal performance, but also innovative methods for achieving *and* maintaining such a telecommunications foundation. Further, this MDOT SHA plan should be in collaboration with whatever strategic communication planning is being done at the MDOT level, and in concert with other TBUs.

From the perspective of potential private-sector partners (resource sharing), the prospect of a partnership for a corridor-level high-speed telecommunications could be enticing. The financial characteristics of possible shared-resource agreements also may make the interstate system corridor approach more attractive, since in-kind payments to state DOTs rather than cash payments to private land owners mean less well capitalized companies could find these deals more affordable.

RECOMMENDED ACTION

- Develop a strategic telecommunications plan – The effort should include an honest analysis of the technological challenges and opportunities that exist today, acknowledging that we can't possibly predict what the next great evolution in communications might reveal. However, a foundation is needed to take us at least into the next decade, and there are an equal number of technology and policy issues that should be addressed. Those policy issues would also include operations, maintenance, and ownership relationships in terms of SHA vs MDOT vs Network Maryland.
- As a parallel to developing a telecommunications plan and architecture, MDOT SHA should also work to build provisions of this communications infrastructure into all roadway projects going forward to support CAV deployment in the future. Conduit for fiber optic/wired communications should become commonplace, and additional physical cabinet space at ITS and traffic signal installations should be assumed to house future equipment.

Road Markings and Signage

Today's road and highway infrastructure were designed for human drivers, who in many instances have institutional memory and the ability to "judge" in the absence of lane markings. This reality may not be optimal for vehicles driven by computers that are relying on machine vision and specific rules. Thus, the transition from human-driven to computer driven vehicles might require changes to road markings and signage. Future changes in signalization, lane width, road capacity, and access management are also possible, but much further in the future.

Some AVs rely on cameras, radar and laser-mapping tools to determine where they are (GPS, at least for now, is not precise enough to keep cars on the road). Those cameras use striping and other pavement markings to understand their surroundings, but the quality and consistency of those markings can vary greatly. According to a recent article in *Government Technology*, automotive electronics supplier Delphi took its driverless vehicle on a cross-country trip, and despite nominally uniform standards across states, the pavement markings were actually all different.[9]

One of the NCHRP 20-102 projects mentioned previously in this report is dedicated to identifying the performance characteristics of pavement markings that could affect the ability of machine vision systems to recognize them. The results of this research could help to scope guidelines and criteria for road markings and develop common standards in the future.

In July 2017, the California Department of Transportation (referred to as Caltrans) has already started adapting its road markings in anticipation of the needs of machine vision systems. “Because autonomous and semi-autonomous cars use cameras to ‘see’ road markings, those markings are being changed,” Caltrans director Malcolm Dougherty told KPCC Southern California Public Radio. “Today our lane lines are only four inches thick. Now every lane line we lie down going forward is going to be six inches thick. I’ve already started to see some of this transition.” Dougherty also said, “To make California’s 50,000 lane miles of road AV ready, the new markings will be put down during construction projects and the regular re-striping of roadways.”[10]

Many automakers understand that it is unrealistic to expect that all roads will have lane markings in perfect condition all the time. As a result, automakers are exploring other ways to automate lane keeping, such as positioning with respect to the other vehicles, guard rails, and barriers, with input from several sensors and 3D maps. And of course introducing CV technology to also assist in this endeavor. However, improving road markings is considered by some industry leaders to be “low hanging fruit” that could benefit early adoption and accelerate the potential safety benefits of CAVs—recognizing that it may not be necessary in the longer term. More importantly, these improvements would prove useful for human-driven vehicles, cyclists, and pedestrians as well, therefore justifying what could be a potential increase in maintenance costs.

V2I communication and high-definition 3D mapping could replace the functions currently performed by road signs and signals, but that will easily be decades from now. More importantly, pedestrians, cyclists, and human-driven vehicles will still need signs and signals; however, so removing them is not a viable option based on current plans and developments. Traffic signs could be updated to enable V2I applications, or could be enhanced with other retroreflective measures already in play. And in work zones, construction workers or barrels could have wireless beacons that give CAVs instructions from a predetermined list. The same could apply for law enforcement and emergency workers.

RECOMMENDED ACTION

- Monitor national research such as NCHRP 20-102(06) Road Markings for Machine Vision, and NCHRP 20-24(112) Connected Road Classification System, along with lessons learned from other states such as Caltrans, and periodically discuss the merits of making changes to your existing road marking and

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[9] *http://www.govtech.com/fs/infrastructure/States-Fix-Infrastructure-to-Prepare-for-Driverless-Connected-Cars.html*
[10] *http://www.siliconbeat.com/2017/07/17/california-begins-modifying-roads-for-self-driving-cars/*

signage program. The MDOT SHA CAV Working Group should visit this topic annually with the Deputy Administrator/Chief Engineer for Operations.

Policy & Legislation

Each year brings new legislative activity around the nation as this topic gains momentum and policymakers question whether additional regulatory or legislative action is needed.

According to the National Conference of State Legislatures (NCSL), Nevada was the first state to authorize the operation of AVs in 2011. As of early 2017, twelve other states—Alabama, Arkansas, California, Florida, Louisiana, Michigan, New York, North Dakota, Pennsylvania, Tennessee, Utah, and Virginia—and Washington, D.C., have passed legislation related to AVs.[11]

Florida's legislation, passed in 2012, was meant to encourage the safe development, testing, and operation of motor vehicles with autonomous technology on public roads of the state. Michigan's first legislative entry, SB 169, was signed into law by Gov. Rick Snyder in December 2013 and allowed for the testing of driverless cars on Michigan roads. The law included certain stipulations, such as a licensed driver must be behind the wheel at all times and be ready to take over control.

Because this is such a rapidly evolving issue, many of the "early adopters" in legislative activity have already revisited the topic and made adjustments. In 2016, Florida's revised language expanded the allowed operation of autonomous vehicles on public roads and eliminated requirements related to the testing of autonomous vehicles and the presence of a driver in the vehicle. Also in 2016, several updates to Michigan's laws were introduced with strong bipartisan support including:

- Allowing open operation of CAVs beyond testing by repealing the test only restriction.
- Allowing on-demand AV networks to link passengers and various forms of transportation with AVs. Customers will be able to request a ride via a network operator, which will direct a vehicle to the customer location and then onto a desired destination.
- Allowing vehicle platoons where vehicles can travel together with electronically coordinated speeds.
- Establishing the American Center for Mobility at the former Willow Run plant into state law, providing a world-class research facility that will build on the intense activity already seen at MCity, and provide real-world conditions in weather, road conditions, and traffic situations for researchers.
- Penalizing persons who hack or damage AVs to impair the technology or gain unauthorized control of the vehicle.

In Maryland, a bill was first introduced in 2014 (and again in 2015 and 2016) to create a "Task Force to Study Issues Related to the Use of Self-Driving Vehicles." While this bill didn't make it out of committee, it was a key factor in MDOT moving ahead in late 2015 to create the Autonomous and Connected Vehicle (ACV) Working Group as described later in this report. Delegate Pam Beidle (D-Anne Arundel County) was

[11] *http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx*

the sponsor of this legislation and accordingly has been a welcome (and often active) participant of MDOT's ACV Working Group.

Nationally, the beginning of 2017 brought with it a flurry of policy and legislative activity regarding CAV. According to the *NCSL database*,[12] 33 states introduced legislation. This was a significant increase from 2016, where 20 states introduced legislation.

In early 2017, several bills appeared in state legislatures with identical language (GA, MD, TN, IL, AZ, and MI), and there were critics who pointed out that the language was potentially anti-competitive. A report in the Associated Press[13] claimed that General Motors was trying to persuade lawmakers across the country to approve rules that would benefit the automaker while potentially keeping its competitors off the road. Maryland SB 902/HB1013 was one of the GM-sponsored bills that did not make it out of committee. Unfortunately, Maryland still received some negative press as part of a journalistic investigation when the Associated Press article noted that "Maryland State Sen. William Ferguson said he introduced a bill at GM's urging in part because he hoped the automaker would expand its transmission facility near Baltimore, creating jobs. After the Associated Press asked GM about the transmission facility, Ferguson sought to clarify his remarks, saying the automaker didn't explicitly promise to expand its operations."[14]

Also during the 2017 session, Georgia SB 219 started out as the GM bill but was heavily amended through committee, which removed a lot of the manufacturer-restricting language. Georgia SB 219 was signed by the governor late in spring 2017, despite reservations from some in the industry.

North Carolina HB 469 borrowed a lot of the Georgia language and is currently working its way through committee. It has had widespread opposition as well, but one of its sponsors (Rep. Torbett) is intent on moving it forward. It is unclear whether the Senate will support it if eventually passed by the House.

Pennsylvania SB 427 is also working its way through committee, and the latest draft (May 1, 2017) began to strip away some of the general language and focus more on testing. To their credit, the staffers are trying to thoughtfully wade through the issues and arrive at compromise language— but to no surprise they are wrestling with definitions and authority as well.

A recent report by the Governor's Highway Safety Association[15] provided some valuable guidance, including a 5-point recommendation to (1) be informed, (2) be a player in your state, (3) understand the role of states, (4) don't rush into passing laws or establishing regulations, and (5) be flexible—this is a new game. This advice is valuable especially because many agencies and legislators are struggling with definitions: operator vs driver, autonomous vehicle, pilot vs deployment, driverless vehicle, testing

[12] *http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx*
[13] *https://apnews.com/fb906060c89442a3b17cf800f00b3455*
[14] *https://apnews.com/fb906060c89442a3b17cf800f00b3455*
[15] *http://www.ghsa.org/sites/default/files/2017-01/AV%202017%20-%20FINAL.pdf*

requirements and authority, etc. Because the field is so broad and is evolving so quickly, definitions are extremely difficult to reach a consensus.

Note that it is inherently difficult to measure one state against the other in terms of legislative policy because of the lack of standard driving laws and environments from state to state. Since each state has a different format in terms of how their legislature meets (year round, limited time period, periodic sessions) and how their legislature operates (multiple cross-over days, different committee make-up and responsibilities), it is nearly impossible to keep up with the progress in real-time. NCSL has worked hard to keep up, but it is moving quickly.

At the federal level, 2017 has also brought with it a flurry of activity inside the Capital Beltway in Washington, DC. As of October 2017, both the US Senate and US House are considering CAV related language, and while it is not clear how fast it will reach conclusion there is clear activity underway.

The lower chamber was the first to introduce a bill. The House Committee on Energy and Commerce, Subcommittee on Digital Commerce and Consumer Protection, reviewed and marked up a bill entitled, "Safely Ensuring Lives Future Deployment and Research in Vehicle Evolution Act or the SELF DRIVE Act." [16] The bill passed the Subcommittee and subsequently the full Committee, both with voice votes, and was approved unanimously by the full House in September 2017. The language (as it stands now) reaffirms rules designating boundaries between state and federal legal authorities. For more than 50 years, the federal government has led regulation of traditional vehicles, while states and localities have been charged with insuring, titling and registering vehicles, while setting rules of the road, enforcing traffic laws and offering incentives to stimulate private industry. Under the legislation, automakers would be required to demonstrate that a self-driving vehicle "is likely to function as intended and contain fail safe features."

In the upper chamber, the Senate Committee on Commerce, Science, and Transportation recently introduced S 1885, The American Vision for Safer Transportation Through Advancement of Revolutionary Technologies Act or the "AV START Act." At the time of this writing, the bill is going through mark-up and is anticipated to move to a vote sometime during late 2017 or early 2018. The Senate bill has a number of similarities to the House bill, but there are enough differences that a conference committee will be required if/when the Senate passes their bill.

RECOMMENDED ACTION

- Develop a bicameral policy briefing for interested Maryland State Legislators outside of the session (i.e., prior to the start of the 2018 session, and repeat in future years with updates). Secure one or more champions in each house of the assembly, encourage open discussion on potentially restrictive ideas that could be born out of lack of understanding, and discuss whether legislation is necessary.
- Monitor state and federal legislative actions and provide periodic briefs to interested parties. Share lessons learned from other states regularly, and as federal legislation begins to take shape, explore the potential impacts to Maryland and provide updates to give to our federal representatives.

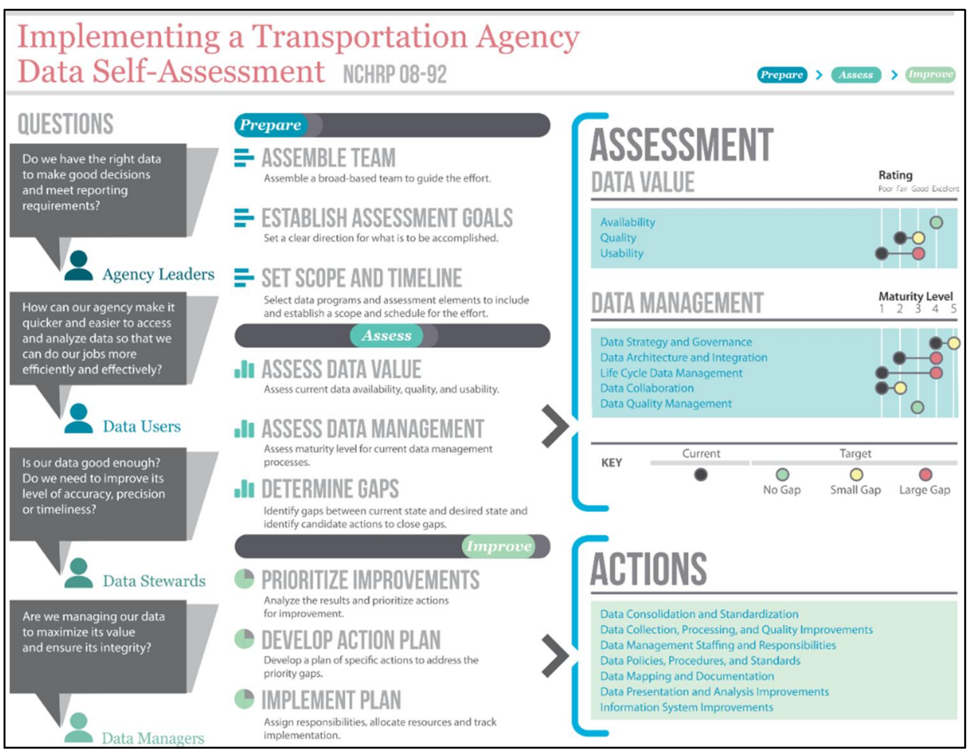
[16] *https://www.congress.gov/115/bills/hr3388/BILLS-115hr3388rfs.xml*

Developing a Data Governance Plan

In 2014, the Transportation Research Board published the final report for NCHRP 8-92 and NCHRP Report 814 – *Data to Support Transportation Agency Business Needs: A Self-Assessment Guide*.[17]. It presents a process akin to the SHRP 2 Organizing for Reliability Capability Maturity Model, though with more detail and conducting an inventory process before holding a workshop. The research includes conducting a self-assessment on 5 dimensions:

- Data Strategy & Governance
- Data Life Cycle Management
- Data Architecture and Integration
- Data Collaboration
- Data Quality

The elements within each are assessed for a maturity level from 1: Initial (ad-hoc and event driven, success due to heroic efforts of individuals) to 5: Sustained (evaluated and improved processes, sustained over time). The structured process also guides participants in identifying gaps, assessing their business impacts, and developing actions to improve performance. This topical information on a wide range of data and data management topics is of great value as agencies address many needs. Figure 12 shows the key elements of the project.



Source: *http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_814_flyer.pdf*

Figure 12: NCHRP 08-92 Data Self-Assessment Flyer

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[17] *http://www.trb.org/Main/Blurbs/173470.aspx*

There will be a significant amount of data available within the CAV ecosystem, confounding an already rapidly growing data treasure trove emerging in conjunction with an emphasis on performance measurement. As proliferation of CAV technologies and public awareness increases, both the volume of data and public data requests will escalate. To prepare for this, a formal data governance plan should be developed. Data governance refers to the overall management of the availability, usability, integrity, and security of the data employed in an enterprise. A data governance program can include a governing body or council, a defined set of procedures, and a plan to execute those procedures. Specific to the CAV environment, MDOT SHA's data governance plan would address data privacy and security, procedures for storing data, sharing policies surrounding signal timing data, fulfillment of public information requests, and other data-related policies.

CAV data has tremendous potential to not only improve safety and mobility for motorists directly, but to enhance the ability of roadway operators to respond to incidents, re-route traffic, provide traveler information, and gather a wide range of data to support operations, maintenance and long-range planning. As part of the data governance plan, MDOT SHA should further explore how CAV data could be operationalized within a traffic operations center environment. It might be as simple as outlining a roadmap for what data would be most available and usable early in the deployment cycle, and recommending a pilot activity to incorporate some fleet data currently collected into the existing Advanced Traffic Management System in order to explore how it could improve operations.

Also as part of this governance plan, revisiting the topic of data sharing should be considered. The recent Eno Foundation report on CAV[18] suggests that cities and states should establish data sharing agreements "to enhance local transportation planning and operations."

We are truly witnessing the transformation of the automobile from simply a transportation vehicle to now being a node, in a data network, in the IoT.

RECOMMENDED ACTION

- Undertake a comprehensive effort to define a data governance plan. This will be a plan for efficient use of people, processes, and technology, and will link business objectives, programs, and processes to data systems, services and products. It is important to consider the planning and operational characteristics of CAV data. Look for balance between technical and institutional barriers and opportunities, while considering the execution and enforcement of authority over the management of data assets and the performance of data functions.

Staffing & Skill Development

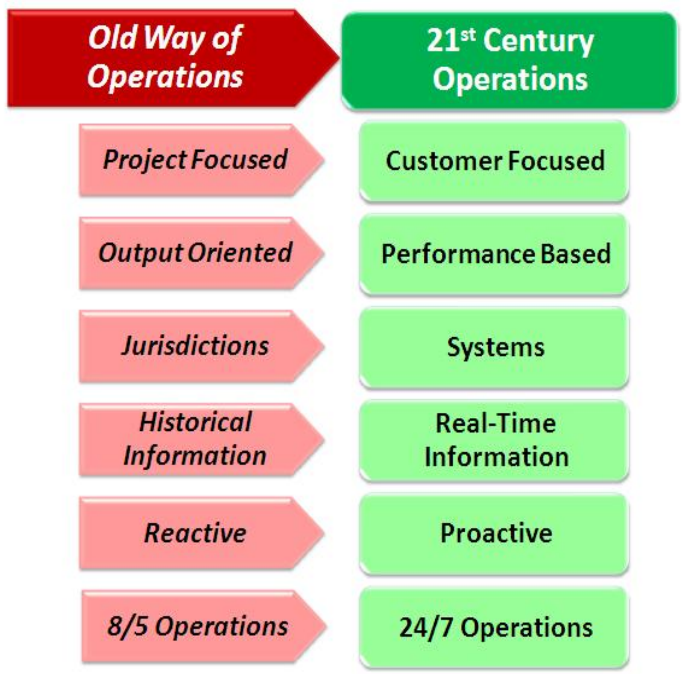
In the report *The Impacts of Future Technology on TMCs* sponsored by the Traffic Management Center PFS, one of the key recommendations for adapting to technology changes is to focus on having a "Nimble Service-Oriented Program Mindset." This aligns with FHWA's guidance on TSM&O that "effectively addressing the congestion problem will hinge on the ability to reshape traditional transportation

[18] *https://www.enotrans.org/etl-material/preparing-a-nation-for-autonomous-vehicles-opportunities-barriers-and-policy-recommendations/*

organizations into 21st century operations agencies using 21st century technologies." Figure 13 summarizes this change in emphasis.

Staffing and skill development will benefit from this focus on a nimble mindset. And it begins by fostering an overall culture of embracing technological change, building on the following concrete steps:

- Involve both operations and maintenance staff in evaluation of potential new technologies.
- Support staff training and time to build familiarity with new technology.
- Establish relationships with related departments within the agency, such as information technology, for consultation.
- Establish relationships with peer agencies embracing technological change.
- Maintain on-call contracts for experts outside the organization to assist with integration and trouble-shooting when needed.
- Recognize that not every well-planned technological change will be successful.
- Identify staff enthusiastic about technology to serve as champions.
- Develop flexible procurement processes, including those for test equipment.
- Develop flexible performance-based specifications where applicable.
- Include training and support with new technology purchases.



Source: Impacts of Technology on TMCs

Figure 13: Changing Emphasis in Operations

Embracing the culture change is valuable in both attracting and retaining staff in a 21st century workforce environment. But the advent of CAV also brings to bear new staff skills in IT, telecommunications, data management, and more. Because much of the equipment with applications to direct safety benefits and implications, it is important for MDOT SHA to have O&M staff who are trained and skilled in the CAV technology that is being deployed—and not have to rely on another department or another agency. Outsourcing some of the support is certainly feasible, but having resident staff who understand the technology and can appropriately supervise the contractors is critical to maintaining the integrity of the system.

Having two-way communications between the infrastructure and vehicles will also create some level of nervousness about security hacks and data privacy. And this concern isn't limited just to automakers. A recent article in *Forbes* magazine[19] claimed that keeping drivers safe won't just be about the car.

> "With increased connectivity and automated driving coming soon, automotive companies will be compelled to implement ways to protect drivers' personal data and to ensure the vehicle, infrastructure and route they (and their driverless vehicles) take cannot be hacked or compromised."

Design and implementation should aim to be service-oriented, quick, and nimble. Strategies to avoid installing obsolete equipment under traditional design-bid-build contracts include a "best value" procurement method, ITS-specific contracts, open and flexible specifications, use of interoperability standards, flexible ITS architectures, and adaptable software.

In a CAV ecosystem there are a number of expected technology deployments that MDOT SHA will support. Ensuring staff training and skills for each of these is a minimum starting point for agencies to consider. The AASHTO National Connected Vehicle Footprint Analysis suggestions that a transportation agency (or an organization operating on its behalf) should provide infrastructure and data supporting the CV environment including, but not necessarily limited to the following:

- V2I roadside equipment (for example, DSRC RSEs)
- Interfaces from V2I roadside equipment to roadside transportation equipment (for example, traffic signal controllers) and/or local roadside networks
- Supporting roadside infrastructure (for example, pole and mounting, power)
- Backhaul from the roadside to network information services
- Data from roadside equipment for DSRC-based applications
- Traveler information and alerts, including advisory speed limits and lane closure information
- Intersection and roadway geometric data
- Signal phase and timing data
- Positioning system and time corrections, if needed
- Network information services as needed by particular applications

RECOMMENDED ACTION

- Periodically review staffing needs and training/skill development needs. Consider the merits of internal growth versus outsourcing, and always maintain the viewpoint that leading-edge support is necessary to foster a culture of innovation among staff and contract support alike. Integrate (where possible) into MDOT SHA's ongoing efforts for organizational modernization analysis.

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[19] *https://www.forbes.com/sites/sap/2016/11/10/8-trends-driving-innovation-in-the-auto-industry/#4df4a2614e2c*

OUTREACH ACTIVITIES

An important outcome from MDOT SHA's TSM&O program was the recognition that its success would depend on effective communication and outreach. An ability to clearly and concisely communicate benefits, educate stakeholders, and gain buy-in for both TSM&O strategies and the TSM&O program can be a lesson learned in the CAV arena as well. The media may be talking about driverless and autonomous vehicles, but a relatively small percentage of internal employees, policymakers, and the traveling public have a good understanding of just how complicated (and near term) connected and AV systems are.

To address the need for education and awareness building, a communications plan should be developed to propose a series of strategies, messages, and tactics to communicate CAV updates and issues among several different stakeholder groups—internal and external to MDOT. This plan should also be done in collaboration with the TSM&O communications plan as they will share many of the same elements.

Internal Awareness of CAV

Awareness within MDOT SHA—across the various TBUs, and at MDOT headquarters itself—is paramount to ensuring the department speaks and acts with one voice. As established at the beginning of this report, there is an abundance of misinformation and confusing definitions on this topic, making it even more important for MDOT employees far and wide to have the latest information and correct interpretation of the environment.

Tools can be used to brief employees, assuring them that their own agency is not only aware of the fast-changing evolution in CAV, but actively engaged as a leading-edge organization. This is indeed an excellent opportunity of the Secretary's Excelerator program in action.

RECOMMENDED ACTIONS

- Develop an internal communications plan for MDOT SHA (with recommendations for MDOT and other TBUs) to propose a series of strategies, messages, and tactics to communicate CAV updates as well as MDOT SHA involvement in CAV efforts and how this fits into the overall TSM&O program.
- Develop and maintain a library of internal materials to support MDOT SHA technical and executive staff in preparing for speaking engagements. This can be offered to other TBUs if interested.
- Get this topic onto the agenda of key internal meetings and gatherings (e.g., CHART Board) among various departments, and offer the opportunity to brief other TBUs.
- Encourage staff participation in local industry associations (ITE, ITS Maryland, ASHE, etc.) where updates of national significance often are shared at the local level.

External Outreach & Education

Internal communication within MDOT SHA and MDOT is important, but other audiences will need to be targeted—in particular—members of the legislative and business communities.

As mentioned previously, there have been several attempts to offer legislation related to CAV over the past few years, some of it resulting in the creation of MDOT SHA's CAV Working Group. There has been occasional involvement from legislators in the meetings, but in general they have not been regularly engaged. Educating the general assembly on the various issues involved, confusing definitions, and activities of our neighboring states would be helpful in securing a stronger relationship with MDOT, and ensuring new legislation isn't introduced that could be contrary to the goals or plans of MDOT and its TBUs.

The business community is another stakeholder group worthy of targeted outreach. Other states have started to engage their economic development groups to the point where funding has even crossed between them and state DOTs. Maryland should make it clear that it's "open for business" and wants to not only attract CAV development, but also provide first-class transportation services for the employees of all business in the state.

As part of this external outreach, development of a public-facing website is valuable to convey opportunities, actions, and most importantly fundamental knowledge and information. Helping to clarify the confusion in definitions and actions will go a long way toward increasing awareness and the attractiveness of working in Maryland.

As part of the external outreach, a branding theme can also be included. For example, Michigan has developed its "Planet M" approach, and a corresponding vision statement: "Michigan. Where big ideas in mobility are born." It uses this thematic approach to present a variety of information on its website (*www.planetm.com*), including links to social media posts, videos, and a variety of definitions and action statements that convey a sense of progress and opportunity.

Maryland Department of Commerce has a website that is rich with facts about Maryland, and why business and industry would wish to locate here. Our external outreach communications should borrow liberally from that treasure trove of data and present it in context to the opportunities that CAV can bring to the state.

RECOMMENDED ACTION

- Develop a bicameral policy briefing for interested Maryland legislators outside of the session (i.e., prior to the start of the 2018 session, and repeat in future years with updates). Secure one or more champions in each house of the general assembly, encourage open discussion on potentially restrictive ideas that could be born out of lack of understanding, and discuss whether legislation is necessary.
- Assess the economic impacts of CAV in Maryland, and develop an economic development outreach strategy. Identify a handful of companies and target outreach/focus group discussions to better understand their needs and concerns.
- Develop a website within MDOT that profiles Maryland's emphasis on technology and transportation. The website can be a portal for companies thinking of doing business in Maryland (to learn more), or can be as simple as reinforcing our posture as a leading-edge high-tech state willing to help all companies and their employees get to where they want to be. Quality of Life is good for all employees.

Involvement/Visibility in National Activities

MDOT SHA recently engaged in the CV PFS. It is a great opportunity to begin expanding its understanding of other activities nationally. In addition to this effort, additional opportunities for MDOT SHA to engage include the following:

- Engagement in other national research activities such as NCHRP 20-102 or by taking part in the annual Automated Vehicle Symposium co-sponsored by the Transportation Research Board and AUVSI.
- Involvement with the national V2I Deployment Coalition, opening the door to increased knowledge and partnership opportunities.
- Engagement in national conferences that highlight technology and operational enhancements, sponsored by groups such as the ITE or ITS America.
- Active involvement and leadership in local chapters of organizations such as ITS Maryland, WDCITE, or ASHE.
- Looking for opportunities to partner with neighboring states and agencies in pursuit of minimizing risks while sharing rewards.

MDOT SHA should map out who engages in these activities, ensuring a broad representation from the agency is included and that through the internal MDOT SHA CAV Working Group, those experiences can be shared even more broadly. Engagement and leadership should not be limited to one department—instead there should be opportunities for others to also engage.

ORGANIZATIONAL MANAGEMENT OF CAV

MDOT SHA Offices and Engagement in CAV

The CAV topic can be led by any number of different individuals or offices within MDOT SHA; right now, that leadership is coming from Office of Planning & Preliminary Engineering with significant involvement from CHART, Office of Traffic & Safety, Office of Policy Research, and the Office of Maintenance. The internal MDOT SHA CAV Working Group serves as a clearinghouse for knowledge, a coordination point for collaboration, and an opportunity for everyone within MDOT SHA to contribute. The tools and principles practiced as part of the TSM&O effort can be replicated for CAV; communication, coordination, and collaboration will pave the road to success.

Now that the internal MDOT SHA CAV Working Group has been established, there is an opportunity to rotate the leadership periodically, ensuring that all MDOT SHA offices and departments have an opportunity to contribute.

Executive management should periodically receive briefings from the internal MDOT SHA CAV Working Group, strongly support its efforts, and annually review whether the current internal organizational structure is meeting the needs of the program. Alternative organizational arrangements—such as creating a dedicated position somewhere within MDOT SHA whose full-time job is focused on CAV coordination—might be a future consideration.

Regardless of how the organization chart is structured, it is critical to encourage interdepartmental coordination and collaboration.

MDOT CAV Working Group

In late 2015, Maryland Transportation Secretary Pete Rahn established the Autonomous and Connected Vehicle Working Group as the central point to develop and deploy emerging autonomous and CV technologies in Maryland. It was later renamed the Connected & Automated Vehicle Working Group (CAV Working Group) and now features multiple sub working groups (Figure 14). MDOT SHA has a seat at the table and is actively involved in the MDOT CAV Working Group activities – from both a policy and technical perspective.

The MDOT CAV Working Group handles strategic planning for MDOT concerning CAVs. The group includes a diverse membership of transportation stakeholders, including elected officials, state and local agency representatives, highway safety organizations, and representatives from the private sector and the automotive industry. The group evaluates the latest research, tracks federal and state laws, policies and programs, and coordinates with other agencies, organizations and businesses to set the course for the future of CAVs in Maryland.

This group represents a great opportunity for MDOT SHA to garner feedback from other sectors of the industry, affect legislative activity, and connect with other TBUs in effectively communicating MDOT's vision for CAV.

The MDOT CAV Working Group holds open (public) meetings and includes representation from a wide variety of stakeholders including:

- The Secretary's Office and all business units within MDOT– MVA, SHA, MTA, MPA, MAA, & MDTA
- Law Enforcement
- County Public Works
- Trucking Industry
- Insurance Administration
- Automakers/Suppliers
- Metropolitan Planning Organizations (WASHCOG and BMC)
- The Departments of Aging & Disabilities
- The Department of Information Technology
- Elected Officials
- Technology Experts
- AAA

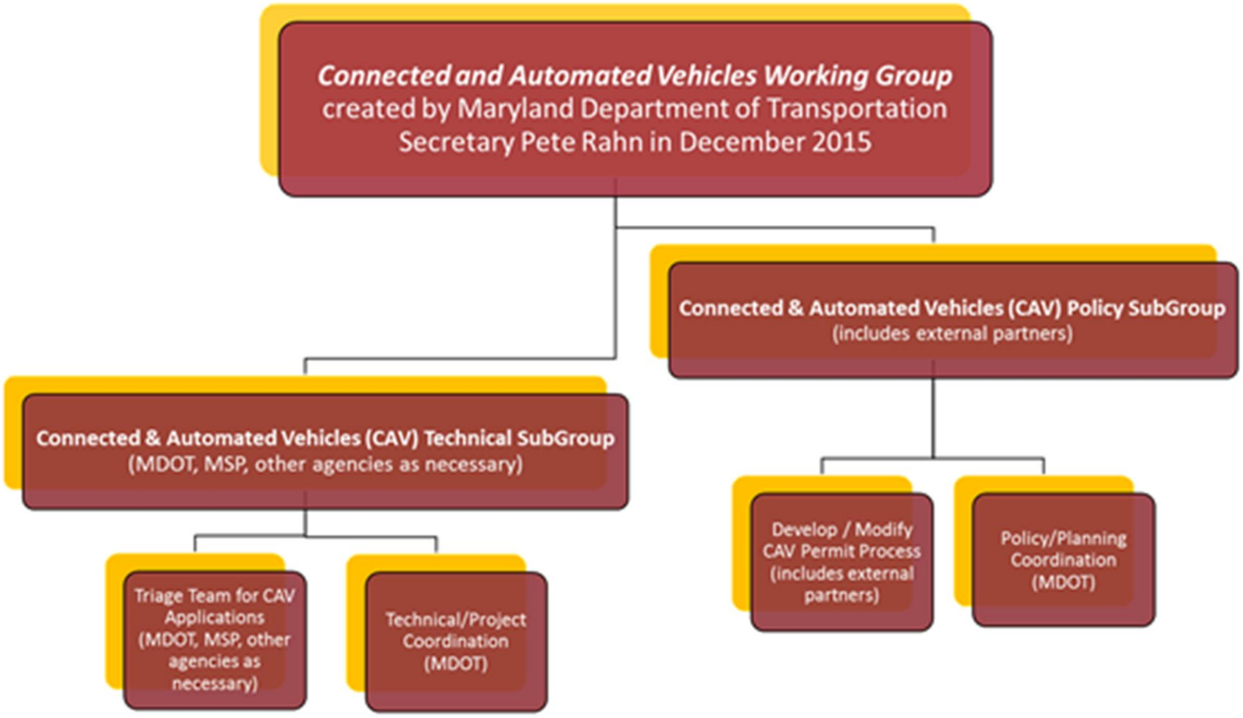

Figure 14: MDOT CAV Working Group

MDOT CAV Policy Subgroup

A subgroup of representatives from the MDOT CAV Working Group will meet as needed to further discuss policy and legislative issues, and to oversee development and maintenance of the processes and policies for test permitting on Maryland-owned infrastructure. This subgroup comprises agency personnel representing the different MDOT TBUs and Maryland State Police. Additional expertise can be engaged to vet issues and pursue solutions, such as the recent effort to develop the application and process for testing HAVs. The overall MDOT ACV Working Group can assign tasks to this subcommittee in order to facilitate actions on open issues, concerns, or ideas.

MDOT CAV Technical Subgroup

A subgroup of representatives from the MDOT CAV Working Group will meet as needed to further discuss technical and operational issues, and to oversee the actual testing of HAVs on Maryland-owned infrastructure. This subgroup comprises agency personnel representing the different MDOT TBUs and Maryland State Police. Additional expertise can be engaged to vet issues and pursue solutions as needed, such as the efforts to develop an operational process for communicating with and engaging appropriate personnel once HAV test permits are approved, and a plan for managing the relevant safety plans for each case. The overall MDOT ACV Working Group can assign tasks to this subcommittee in order to facilitate actions on open issues, concerns, or ideas.

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