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16. Abstract

Infrastructure maintenance is very important for ensuring the efficiency of our transportation system. In 2020 alone, US Department of Transportation (DOT) spent a total of $24 billion dollars to preserve our national highway systems. In particular, the mobile and slow-moving operations, such as striping, sweeping, bridge flushing, and pothole patching, are critical for efficient and safe operation of a highway transportation system. Performing the maintenance required for a roadway infrastructure, however, could involve risks. The rapid advancement of Connected and Autonomous vehicle (CAV) technologies is receiving attention from many State DOTs in the niche area of using Autonomous Maintenance Technology (AMT) to reduce DOT worker fatalities in work zones. One specific technology, the Autonomous Truck Mounted Attenuator (ATMA) vehicle, or sometimes referred to as Autonomous Impact Protection Vehicle (AIPV), is a quickly emerging technology and offers a promising solution to eliminate injuries to DOT employees. The objective of this report is to summarize the state-of-the-art, as well as the state-of-the- practice, of the AMT development. A brief review of mobile and slow-moving operation technology is provided first. Then, the Federal and State regulations for autonomous vehicles are reviewed, and how the ATMA system aligns with these regulations is analyzed. The progress from the ATM Pool Fund is summarized in the last section.

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1. Introduction

America's roads are critical for moving an ever-increasing number of people and goods. Unfortunately, the growing wear and tear to our nation's roads have left 43% of our public roadways in poor or mediocre condition, and this number has remained stagnant over the past several years. Overall, our deteriorating roads are forcing the nation's motorists to spend nearly $130 billion each year on extra vehicle repairs and operating costs. Even more troubling is that the number of vehicle miles traveled on roads in "poor" condition has risen from 15% to more than 17% over the last decade. In fact, the United States' infrastructure is so distressed that the American Society of Civil Engineers (ASCE) assigned it a D in its *2021 Report Card for America's Road Infrastructure* – an assessment of conditions and investment needs for public roads in the United States (ASCE 2021).

Infrastructure maintenance is very important for ensuring the efficiency of our transportation system. In 2020 alone, USDOT spent a total of $24 billion dollars to preserve our national highway systems. In particular, the mobile and slow-moving operations, such as striping, sweeping, bridge flushing, and pothole patching, are critical for efficient and safe operation of a highway transportation system. Performing the maintenance required for a roadway infrastructure, however, could involve risks. Nationally, a total of 94,000 crashes occurred in the nation's work zones in 2017 alone, resulting in 37,000 injuries and 809 fatalities. Many of these crashes involved State Department of Transportation (DOT) workers. For example, in the State of Missouri, slow-moving vehicles have been involved in crashes more than 80 times, since 2013, resulting in many injuries to DOT workers (MoDOT 2018). One fundamental issue, that resulted in many DOT worker injuries, were the speeds of mobile and slow-moving vehicles, which generally ranged from 5 mph to 15 mph. Dramatic speed differences were observed when these slow speeds were compared with those of the faster moving general vehicles on a freeway or a highway. As such, drivers of general vehicles are required to take immediate action, when approaching work zones, such as slowing down or changing lanes. If, for reasons like driving under the influence (Harb et al. 2008), such action is not taken in a timely manner, a crash in a work zone is very likely to happen. Research suggests that aggressive or distracted driving does occur very often and is the primary factor in crashes in work zones. Other reasons, such as the faulty performance of heavy vehicles, speeding, and dynamic traffic conditions, may also result in work zone crashes (Meng and Weng 2011, Hu et al. 2018, Ma et al. 2018, Qi and Hu 2018). How to reduce hazards and achieve a safer environment for DOT workers remains an urgent problem.

The rapid advancement of Connected and Autonomous vehicle (CAV) technologies, although potentially years away from wide application to travel for the general public, is receiving attention from many State DOTs in the niche area of using Autonomous Maintenance Technology (AMT) to reduce DOT worker fatalities in work zones. One specific technology, the Autonomous Truck Mounted Attenuator (ATMA) vehicle, or sometimes referred to as Autonomous Impact Protection Vehicle (AIPV), is a quickly emerging technology and offers a promising solution to eliminate injuries to DOT employees. It is anticipated that there is considerable potential for improving transportation infrastructure maintenance safety by removing drivers from risk. While different vendors may have different system designs and hardware/software setups, an ATMA vehicle system usually includes a leader truck (LT), a follower truck (FT), a truck mounted attenuator (TMA) installed on the FT, and a leader-follower system that enables the FT to drive autonomously and follow the LT.

Figure 1 shows photos of an ATMA vehicle system in operation on a roadway, with (a) an overview of the system, (b) a view from above (taken by a drone), and (c) a view from the rear. The leader truck is designed for normal maintenance work, such as roadway striping and pothole fixing, whereas the follower truck is doing autonomous car-following and is serving as a buffer in case a crash occurs. The driving distance between the follower truck and the leader truck ranges from a few hundred feet to half a mile or so, and the follower truck is designed to mimic the behavior of the leader truck and to drive autonomously. The follower truck is capable of, not only speed control (e.g., acceleration, deceleration, and maintaining a certain speed), in a similar way as adaptive cruise control (ACC), but also for lateral control of the vehicle so that it stays in the middle of a lane. Actuators, software, electronics, and vehicle-to-vehicle (V2V) communication equipment are installed on the leader truck and the follower truck so that, together, connectivity is enabled (mainly vehicle to vehicle, or V2V communication) and autonomous driving capabilities are possible in a leader-follower style. Ultimately, the goal of this ATMA system design is to remove DOT employees from the FT and to eliminate injuries while they are performing slow moving operations.

(a) (b) (c)

Figure 1. ATMA Vehicle System: (a) system overview; (b) view from above; and (c) view from the rear.

The objective of this report is to summarize the state-of-the-art, as well as the state-of-the-practice, of the autonomous maintenance technology development. This report is structured around the following three particular topics of interest. A brief review of mobile and slow-moving operation technology, from the academic research side, is provided in Section 2. In Section 3, we focus on reviewing the Federal and State regulations for autonomous vehicles, and on analyzing how the ATMA vehicle system aligns with these regulations. Section 4 summarizes progress from the AMT Pool Fund, with emphasis on the DOT deployment status and the sponsored projects status. The purpose of this report is to work with key stakeholders from the public and private sectors who are working on autonomous maintenance technology, and to summarize and document knowledge for the purpose of autonomous maintenance technology promotion and deployment.

2. Academic Research Review of Mobile and Slow-Moving Operation

Due to its importance, the safety of mobile operations in work zones has received significant attention during the last few decades, and many technologies have already been developed. For example, a speed trailer was evaluated in Texas, using speed profiles of passenger cars and trucks as they approached and traversed rural high-speed work zones. The results showed that speed trailers and radar drones were effective in reducing the mean speed and percentage of speeders in work zones (Carlson et al. 2000). Ullman et al. documented the development of a field guide for portable changeable message signs, which have played an important role in traffic control in work zones (Ullman et al. 2005). Different Visual Enhancement Systems (VES) were used in conjunction with the TMAs to attract the attention of approaching drivers and direct them into an adjacent lane. The experimental results showed a significant difference in the performances of different visual enhancement systems (Costello and Goluchowski 2006). The best performer was then compared with a new VES, that incorporated a mobile advance warning system (Costello and Goluchowski 2007). The results showed that the mobile advance warning system had a significant influence on performance and reduced the number of vehicles entering a critical zone. The traffic calming effect of a set of Variable Message Signs (VMS), mounted on a slow-moving caravan of road marking vehicles, was evaluated (Friberg et al. 2007). The results showed that, both the average and top speeds were very high, without activating the VMS, but that the average speed was reduced by 22 km/h (or 13.7mph) when the VMS was activated. Mobile work zone alarm systems, including an alarm device and a directional audio system, were tested to estimate sound levels, merging distances and speeds, and driving behavior (Brown et al. 2015). The results illustrated that this alarm system had the potential to improve safety in work zones. Tests to evaluate the influence of truck-mounted radar speed signs (RSSs) on vehicle speeds were conducted for mobile maintenance operations in two multilane maintenance work zones in Oregon (Jafarnejad et al. 2017). The results indicated that vehicle speeds were typically lower and that variations in speeds between adjacent vehicles was less when the RSS was turned on, indicating that the RSS is a promising device for making work zones safer.

Truck mounted attenuators are energy-absorbing devices that are attached to the rear of trucks to protect the motorist and to protect the vehicle's driver upon impact (MoDOT 2020). The TMA has been in use by transportation agencies for many years, and has usually been installed on a relatively heavy vehicle. For example, Missouri DOT requires the host vehicle to be at least 16,000 lbs (MoDOT 2020), Texas DOT requires 20,000 lbs (Theiss and Bligh 2013), and in Sweden, this number is 9,000 kg (or 19,842lbs) (Wenäll 2010). While most transportation agencies are very familiar with truck-mounted attenuators, trailer-mounted attenuators are increasing in popularity. TTI performed a systematic comparison between truck-mounted attenuators and trailer-mounted attenuators, from the perspectives of structural adequacy, occupant risk for the impacting vehicle, and post-impact vehicular response. Researchers found that the concern for trailer-mounted attenuators swinging around may not be justified, given that post-impact trajectories of the impacting vehicles were similar to those reported during truck-mounted attenuator impact testing (Theiss and Bligh 2013). Additionally, three tests were performed and compared, including a TMA on a tractor, a TMA on an articulated front-end loader, and a TMA on a trailer (Wenäll 2010). The research outcome recommended that certain types of alternative TMA carrier vehicles be allowed, under the condition that the vehicle weight limits were still met. A review of the TMA application in work zones can be found, in which five states were visited to solicit information regarding support for the extent of use of TMAs. The results were summarized as guidelines for the use of a TMA in work zones (Humphreys and Sullivan 1991).

Mobile robots, or autonomous vehicles, are being widely used in the military and civilian sectors. These include unmanned air vehicles (UAV), unmanned ground vehicles (UGV), unmanned spacecraft, and unmanned underwater vehicles (UUV). Most of the existing systems are only semi-autonomous and rely on regular human intervention. To go beyond this capability will require sophisticated, yet flexible, software systems (Long et al. 2007). In particular, the consolidation of autonomous vehicles (AVs) as a technical area within the domain of intelligent transport systems extends the applicability of this technology to other fields, far away, in some cases, from civil applications. This technology and its applications have attracted the interest of the military sector to apply autonomous vehicle technology in carrying out land missions in operative scenarios. Civil autonomous vehicle technology also has been applied to carry out missions on the ground. For example, Naranjo et al. (2016) presented the application of a civil autonomous vehicle technology to develop a demonstrator of UGV for the Spanish Army, including background, architecture, and first field tests. The results showed that the developed system is possible for automatically tracking off-road routes. Although autonomy has the potential to help military drivers travel safely, while performing other tasks, many drivers refuse to rely on the technology. The joint US-UK Coalition Assured Autonomous Resupply (CAAR) was demonstrated in Michigan in 2017. This ground-breaking line-haul convoy involved a truck leading two follower trucks, using integrated on-board robotics to make autonomous decisions regarding speed and steering. It proved revolutionary and demonstrated the potential for taking humans out of the equation in supply delivery. The CAAR project successfully combined a convoy of autonomous heavy trucks with smaller robotic ground vehicles that provided last-mile delivery to troops in the field (O'Dell 2019). The Army conducted the test at the U.S. National Guard's sprawling Camp Grayling in northern Michigan. It used four Army trucks, and two from the U.K., digitally tethered into a "semi-autonomous" platoon. All trucks were equipped with the Army's drive-by-wire robotic kits, called the Autonomous Mobility Applique System. The lead truck had a human safety driver who did not take control of the vehicle, and followed a route programmed into its GPS. In real life, the cargo convoy would move bulk material from a receiving point to a central supply cache near the field of operations, where the supplies would be broken down into unit-sized shipments and loaded onto small robotic vehicles.

An Autonomous Truck Mounted Attenuator can be viewed as a combination of a Truck Mounted Attenuator and a Connected and Autonomous vehicle, with a goal of leveraging the latest technologies and reducing work zone fatalities. Such technology, since its debut, has been receiving much attention from many State DOTs, and is currently being tested and deployed in multiple States. For example, the Colorado DOT is leading an autonomous maintenance technology pool fund with DOT members in 14 states (CDOT 2018). Several member States, including Colorado, California, Minnesota, and North Dakota have developed or purchased ATMA vehicles, whereas the other member states in the pooled fund are all along the spectrum of deployment, with those that have not procured or deployed an ATMA in the ideation/planning phase of how they can bring a program to their state. Other States, that have deployed, purchased, or tested ATMA vehicle technology include at least Missouri (MoDOT 2018), in which Missouri DOT worked with researchers from Missouri University of Science and Technology and industry vendors to test and deploy ATMA vehicles for roadway striping and other roadway maintenance work; Tennessee (Inc. 2019), in which a pilot demonstration to test and evaluate the potential for an autonomous system to improve work zone safety is performed by the University of Tennessee Center for Transportation Research; as well as Florida, in which the University of Florida is supporting the Florida DOT in these initiatives. The details of the pool fund, and the State deployment status, will be discussed in later sections.

In general, ATMA is still a relatively new technology, and has not been well studied in academic research. The limited research mostly focuses on the practical side, especially on the system testing and driver operation. Tang et al. (2020) documented the evaluation methodology of a developed ATMA system and the outcomes of field-tests performed in April 2019 in Sedalia MO. The ATMA system was reviewed first, and then followed by an introduction to field-testing procedures, which included defined test cases, data that were collected, and their format. The purpose of the testing was to evaluate whether the system elements (including hardware and software components) could meet pre-defined accuracy and functional requirements for a minimum of 32 consecutive hours of operation over several days, without the need for a MoDOT operator to take control due to poor performance by the leader-follower system. Analysis methodology was proposed to quantitatively evaluate the system's performance. Statistical models and hypothesis tests were developed, and the results suggested that the ATMA system was able to function, as expected, and its performance was acceptable when compared with predefined criteria. The hypothesis test results suggested that the system was able to function consistently when the testing was repeated, indicating that the system's performance was stable and repeatable.

In another research report (Hu and Tang 2020), rules and instructions are modeled and analyzed for ATMA drivers who operate an ATMA vehicle system, particularly in critical locations where correct decision making is needed. The argument was that an ATMA vehicle system is different from general vehicles and consists of a FT and a LT, with some distance between them. The operators are, thus, required to make driving decisions, not only from the LT's perspective, but they must also consider the potential implications of their decisions on the FT. Specifically, three technical requirements are investigated, including those for car-following distance, critical lane-changing gap distance, and intersection clearance time. The results suggested a minimum car-following distance of 75 ft for a LT and 30 ft for a FT. In terms of a lane-changing critical gap, when the gap distance between the LT and the FT is set to be 100 ft, the system requires a minimum time headway of 20 seconds to perform a safe change of lanes. This number increases to 26 seconds, if the FT-LT distance increases to 200 ft. In regard to the intersection clearance time, when the gap distance between the LT and the FT is set to be 100 ft, the system requires 15 seconds to cross an intersection, or to safely make a right turn, and this number increases to 25 seconds if the FT-LT distance increases to 200 ft. When compared with a common passenger vehicle, these numbers are significantly higher, which highlights the importance of using the modeling outcomes to train ATMA system operators, as well as to provide supplemental work zone traffic management actions to work with the operation of ATMA vehicles to ensure a safe and smooth operation.

3. Federal Regulation and National Standards

In this section, we review the relevant Federal regulations and National standards and compare how the ATMA technology aligns with them. Specifically, we focus on four relevant Federal regulations, including, Automated Driving Systems: A Vision for Safety 2.0; Preparing for the Future of Transportation: Automated Vehicles 3.0; Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0; as well as Manual on Uniform Traffic Control Devices (MUTCD). It should be noted that the first three are designed to be voluntary guidance instead of mandatory regulations.

3.1 Automated Driving Systems: A Vision for Safety 2.0

Automated Driving Systems 2.0 was released by the National Highway Traffic Safety Administration (NHTSA) and the United States Department of Transportation (USDOT) in 2017, with the goal of promoting improvements in safety, mobility, and efficiency through Automated Driving Systems (ADSs). This policy, replacing the previous Federal Automated Vehicle Policy released in 2016, is entirely *voluntary*, with no compliance requirement or enforcement mechanism. A Vision for Safety contains 12 priority safety design elements: system safety; operational design domain; object and event detection and response (OEDR); fallback (minimal risk condition); validation methods; human machine interface (HMI); vehicle cybersecurity;

crashworthiness; post-crash ADS behavior; data recording; consumer education and training; Federal, State, and local laws, which we will briefly summarize below.

The design element of *system safety* requires entities to follow a robust design and validation process, based on a systems-engineering approach, with the goal of designing ADSs free of unreasonable safety risks. Entities are encouraged to define and document the *Operational Design Domain (ODD)* for each ADS available on their vehicle(s), as tested or deployed for use on public roadways, as well as to document the process and procedure for assessment, testing, and validation of ADS functionality with the prescribed ODD. The design element of OEDR requires entities to have a documented process for assessment, testing, and validation of their ADS's OEDR capabilities, which include the ability to address a wide variety of foreseeable encounters that may impact the safety operation of an ADS. The element of *fallback* asks entities to have a documented process for transitioning to a minimal risk condition when a problem is encountered, or the ADS cannot operate safely. Entities are encouraged to develop *validation methods* to appropriately mitigate the safety risks associated with their ADS approach. The design element of *HMI* encourages entities to consider whether it is reasonable and appropriate to incorporate driver engagement monitoring, in cases where drivers could be involved in the driving task, in order to assess the driver's awareness and readiness to perform the full driving task. Also, to consider and document a process for the assessment, testing, and validation of that monitoring**.** Entities are encouraged to follow a robust product development process, based on a system engineering approach to minimize risks to safety, including those due to *cybersecurity* threats and vulnerabilities. The design element of *crashworthiness* requires entities to consider the possible scenario of another vehicle crashing into an ADS-equipped vehicle and how to best protect vehicle occupants in that situation. Unoccupied vehicles, equipped with ADSs, should provide geometric and energy absorption crash compatibility with existing vehicles on the road. If a crash inevitably happens, entities should consider methods of immediately returning ADSs to a safe place, based on the design element of *post-crash behavior*. Additionally, entities are encouraged to have documentation available that facilitates the maintenance and repair of ADSs before they can be put back in service. Entities are required to establish a documented process for testing, validating, and collecting necessary data. *Consumer education and training programs* are required to address the anticipated differences in the use and operation of ADSs from those of conventional vehicles that the public owns and operates today. Entities are also encouraged to document how they intend to account for all applicable *Federal, State, and local laws* in the design of their vehicles and ADSs.

Although entirely voluntary, with no compliance requirement or enforcement mechanism, AV 2.0 is still informative and provides helpful guidance for ATMA system development and deployment. For example, ATMA systems should be required to build in priority safety design elements that include system safety with redundancies for navigation, obstacle detection, emergency stopping, and software developed based on rigid industry standards. The system should provide situational awareness with front/side view obstacle detections to satisfy the design element of OEDR. Additionally, a rear looking camera is usually installed in the leader vehicle. To meet the requirement of fallback, the system features should include multiple layers of redundancy to mitigate single point failures and ensure safety that incorporates multiple Primary and Backup systems. The vendor should also routinely develop and support comprehensive test/validation plans and regularly provide classroom and hands-on system training courses. In terms of testing, State DOT should prepare a closed environment, with little or no traffic, for system component testing and, once it is passed, proceed to live environment testing. The Leader-Follower TMA System should include a UI as HMI design, consisting of a vehicle mounted touchscreen tablet computer in the LT with GUI software. Cybersecurity precautions for the system should include a combination of technologies, processes, and practices protecting the network, computers, and data from attack, damage, or unauthorized access. Data, such as velocity, location, heading, vehicle gap, actuator commands, and sensor status should be collected and stored.

In addition, the pool fund has been actively sponsoring research projects that align with the 12 priority safety design elements defined in Automated Driving Systems: A Vision for Safety 2.0. For example, project 5380-19-02 “Evaluating the Human-Automated Maintenance Vehicle Interaction for Improved Safety and Facilitating Long-Term Trust”, focused on the human machine interface (for details of this project please refer to Section 4.3.2). Project 5380-19-03 “Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts” focused on the operational design domain of ATMA, (for details of this project please refer to Section 4.3.3). Project 5380-19-04 “Autonomous Truck Mounted Attenuator Incident Tabletop Exercise Support” focused on the cybersecurity of ATMA (for details of this project please refer to Section 4.3.4). Project 5380-19-05 “ATMA Incident Tabletop Exercise - Planning and Facilitation” focused on the post-crash ADS behavior of ATMA, (for details of this project please refer to Section 4.3.5). These initiatives, strongly support the development, testing, and deployment of ATMA and ensure that developed technology aligns well with the Federal regulations.

3.2 Preparing for the Future of Transportation: Automated Vehicles 3.0

Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0) builds upon Automated Driving Systems 2.0: A Vision for Safety (ADS 2.0). AV 3.0 expands the scope to all surface on-road transportation systems and was developed through input from a diverse set of stakeholder engagements, throughout the Nation. The introduction letter touches on the potential for transportation automation, and assures the reader that active steps are being taken by the USDOT to prepare for the future of transportation. Following suit is a list of six automation principles that guide their plans, efforts, and research; these points are *integrating automation safely*, *remaining technology neutral*, *modernizing regulations*, *maintaining a consistent push for regulatory and operational environments*, *actively preparing for automation*, and *protecting and enhancing the freedoms of Americans*. Further on, these guiding principles are used to explain how the USDOT’s role in automation is to ensure the safety and mobility of the traveling public, while fostering economic growth. The USDOT's' goals are to ensure that automated vehicles can be safely and effectively integrated into the existing transportation system, to support innovations that improve safety, reduce congestion, improve mobility, and increase access to economic opportunity for all Americans. And, finally, to fuel economic growth, support job creation, and workforce development by partnering with industries in adopting market-driven, technology-neutral policies that encourage innovation in the transportation system. Then, five implementation strategies are brought to light: *Stakeholder Engagement* -- Some of their *best practices*, which provide considerations and best practices for State and local governments to support safe and effective testing and operation of automation technologies; *Voluntary Standards* -- Support the development of voluntary technical standards and approaches as an effective non-regulatory means of advancing the integration of automation technologies into the transportation system; *Targeted Research* -- Describes an illustrative framework of safety risk management stages along the path to full commercial integration of automated vehicles. This framework promotes the benefits of safe deployment, while managing risk, and provides clarity to the public regarding distinctions between various stages of testing and full deployment; and *Regulatory Modernization* -- The document outlines certain subcategories of information, such as: The USDOT's role in other facets of the transportation industry; FMCSA Authorities and Key Policy Issues; Cybersecurity; Privacy; Automated Vehicles at Rail Crossings; and plans for the future; etc.

AV 3.0 outlines its methods of implementing autonomous vehicles into society at a consistent pace during the next couple of years, which aligns explicitly with the approach of ATMA technology research and implementation. The first major point of interest is the safety factor that the USDOT outlines as one of its top principles. One of ATMA technology's goals is to make workplace environments safer. The USDOT reports an estimated 39,141 people lost their lives in all modes of our transportation system in 2017. The vast majority—37,133 deaths—were from motor vehicle crashes, and the report later mentions that its standards state "Several NHTSA safety standards for motor vehicles assume that a human occupant will be able to control the operation of a vehicle, and many standards incorporate performance requirements and test procedures geared toward ensuring safe operation by a human driver." Apart from just the safety of the workplace, the document cites standards and logistical planning that go into creating a stable infrastructure that ATMA can use as a guideline for how ATMA technology should look moving forward.

Building upon the voluntary guidance provided in Automated Driving Systems 2.0: A Vision for Safety, AV 3.0 states that automation technologies are new and rapidly evolving, and the right approach to achieving safety improvements begins with a focus on removing unnecessary barriers and issuing voluntary guidance, rather than regulations that could stifle innovation. Following such a recommendation, many Pool Fund activities, as well as many individual DOT's implementations are being initiated. For example, the Pool Fund provides a communication platform to engage the various key stakeholders from government agencies, industry, academics, and research institutes. It is also important for individual DOTs to share the best practices, as well as lessons learned, to further advance the awareness and promote the deployment of ATMA technology. The Pool Fund also supports target research, in a technological neutral position, and supports the development of voluntary, consensus-based technical standards and approaches.

3.3 Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0

Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0 (AV 4.0) builds upon Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0) by expanding the scope to relevant United States Government (USG) components which have direct or tangential equities in safe development and integration of AV technologies. AV 4.0 was published in 2020, with a goal of unifying efforts in automated vehicles across 38 Federal departments, independent agencies, commissions, and Executive Offices of The President, providing high-level guidance to Federal agencies, innovators, and all stakeholders on the U.S. Government's posture towards AVs. AV 4.0 details 10 U.S. Government principles to *protect users and communities*, *promote efficient markets*, and to *facilitate coordinated efforts to ensure a standardized Federal approach to American leadership in AVs*. It also presents ongoing Administration efforts to support AV technology growth and leadership, as well as opportunities for collaboration, including Federal investments in the AV sector and resources for AV sector innovators. The United States Government is committed to fostering surface transportation innovation to ensure that the United States leads the world in automated vehicle (AV) technology development and integration, while prioritizing safety, security, and privacy and safeguarding the freedoms enjoyed by Americans. The U.S. Government recognizes the value of industry leadership in the research, development, and integration of AV innovations. Such innovation requires appropriate oversight by the Government to ensure safety, open markets, allocation of scarce public resources, and protection of the public interest. Realizing the full potential of AVs will require collaboration and information sharing among stakeholders from industry, State, local, tribal, and territorial governments, academia, not-for-profit organizations, standards development organizations (SDO), and the Federal government. AV 4.0 presents a unifying posture to inform collaborative efforts in automated vehicles for all stakeholders and outlines past and current Federal government efforts to address these areas of concern. AV 4.0 establishes U.S. government principles that consist of three core interests, each of which is comprised of several sub-areas. *I. Protect Users and Communities*: Prioritize Safety; Emphasize Security and Cybersecurity; Ensure Privacy and Data Security; Enhance Mobility and Accessibility. *II. Promote Efficient Markets*: Remain Technology Neutral; Protect American Innovation and Creativity; Modernize Regulations. *III. Facilitate Coordinated Efforts*: Promote Consistent Standards and Policies; Ensure a Consistent Federal Approach; Improve Transportation System-Level Effects. While AV 4.0 cannot practically address all areas related to AVs, the intent is to facilitate and guide future efforts in a safe and consistent manner to embolden AV innovators and entrepreneurs and enable the public.

A key point noted in AV 4.0 is how, unlike AV 3.0, the document focuses more on being considered a resource for innovation for ATMA or other transportation related endeavors. “The U.S. Government will be proactive about AVs and will provide guidance, best practices, conduct research and pilot programs, and other assistance to help stakeholders plan and make the investments needed for a dynamic and flexible future for all Americans.” This is useful for ATMA technology due to the sheer amounts of added resources the U.S. government can bring to the industry. Because of the willingness of sponsorship, leadership roles and educational opportunities will bring more participants to the transportation industry, which will lead to new ideas, competition, and kickstart of new technologies. Support from the government will also bring more ATMA research that will lead to the implementation of better and safer technologies.

3.4 Manual on Uniform Traffic Control Devices (MUTCD)

In this section, we review the relevant Sections from MUTCD that might be applicable to ATMA design and deployment. The relevant contents are focused on Part 5 Traffic Control Devices for Low-Volume Roads, as well as on Part 6 Temporary Traffic Control.

The goal of Part 5 is to create a collection of standards, tips for implementation and maintenance, and safety methods primarily for low-volume roads. This section is relevant to ATMA deployment as, in practice, DOTs tend to first deploy ATMA on low-volume roads. This is due to the slow-moving nature of ATMA vehicles. As leader-follower trucks are moving at a speed of 5~15mph on a road, the capacity will inevitably be reduced, and cause vehicles to queue and delay traffic. Part 5 of MUTCD first defines low-volume roads in three parts: 1. A low-volume road shall be a facility lying outside built-up areas of cities, towns, and communities, with a traffic volume of less than 400 AADT. 2. A low-volume road shall not be a freeway, an expressway, an interchange ramp, a freeway service road, a road on a designated State highway system, or a residential street in a neighborhood. In terms of highway classification, it shall be a variation of a conventional road or a special purpose road, as defined in Section 1A.13. 3. A low-volume road shall be classified as either paved, or unpaved. After defining the term, the chapter covers several standards and supports for these types of roads. “At some locations on low-volume roads, the use of traffic control devices might be needed to provide the road user limited, but essential, information regarding regulation, guidance, and warning. Other Parts of this Manual contain provisions applicable to all low-volume roads; however, Part 5 specifically supplements and references the provisions for traffic control devices commonly used on low-volume roads.” This section then notes, through the different subsections within the chapter, the application, design, placement, and specifications of the different signs or hazard markers that are to be placed on low-volume roads. This chapter specifically talks about different types of *signs* (Regulatory, STOP & YIELD, Speed Limit, Traffic Movement and Prohibition, Parking, etc.) and *markings* (Center Line, Edge Line, Delineators, etc.) primarily on low-volume roads. Near the last part of the chapter (section 5G), the dialogue switches to Temporary Traffic Control Zones. This last section presents procedures and guidelines to create a safe control zone; it also describes methods to control traffic near a work zone to keep casualties caused by car accidents to a minimum.

Part 6 Temporary Traffic Control, of the MUTCD, focuses on temporary traffic control (TTC) and how TTC devices are applied in a variety of situations. This section is relevant to ATMA deployment, as when an ATMA is deployed in work zone locations, a slow-moving bottleneck is present which temporarily closes one or multiple lanes of the roadway. Thus, general vehicles are forced to decelerate and switch lanes to pass this moving bottleneck. Because traffic crashes are likely to happen in this process, the ATMA operation should be supplemented with additional temporary traffic control measures.

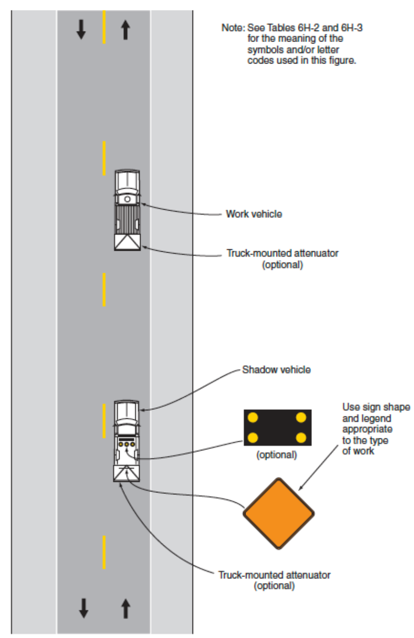


Figure 6H-17. Mobile Operations on a Two-Lane Road (TA-17)

Part 6 of the MUTCD starts with a general overlying standard, that consideration must be given to the management of traffic incidents and the needs and control of all road users (motorists, bicyclists, and pedestrians) on a highway, or on a private road open to public travel, through a Temporary Traffic Control Zone, that is an essential part of highway construction, utility work, and maintenance operations. This Chapter outlines the fundamentals of a TTC, the elements of a TTC Zone, TTC Zone devices, typical TTC Zone activities, incident management of a TTC Zone, etc. This chapter breaks down each of the above points in detail, and explains the guidelines and procedures for a variety of situations and environments related to TTC Zones. Furthermore, Part 6 of the MUTCD explores the elements and areas of TTC, pedestrian and worker safety, flagger control, TTC Zone devices and signs, types of TTC Zone activities, and the control of traffic. For the sake of simplicity, details of Part 6 are not copy pasted here.

The contents of Parts 5 and 6 of MUTCD are valuable to ATMA technologies due to the number of standards and procedures outlined. Part 5 details signs related to Autonomous Vehicles that should be used in work zones, or in highly sensitive areas. Part 6 is more flexible for the needs of ATMA technology because of the many different situations it accounts for. Part 6 would be used for high population/volume road fixtures or restorations, while Part 5 would be utilized for smaller road fixtures in underdeveloped areas of the country.

However, although the general principles are informative, MUTCD does not explicitly address the ATMA type of mobile and slow operation. As such. any practical and implementable guidance for its deployment is consistently missing in MUTCD. For example, the question of when and where to deploy an ATMA is not well studied. Due to the nature of their mobile and slow-moving operations, ATMA vehicles are usually driven slowly (e.g., 5~15mph) and, as such, the argument is to avoid slowing traffic on a busy corridor during peak hours, and to only deploy the technology on roads with low volume. However, the definition of a low-volume road that is appropriate for ATMA deployment is not clear. Another example is how to supplement ATMD deployment with additional temporary traffic control measures, such as signs and lights, to alert general vehicles of an upcoming moving work zone operation, and to avoid vehicle cutting-ins between the ATMA leader vehicle and the following vehicle.

4. AMT Pool Fund Progress

In this section, we review the overall progress of the Autonomous Maintenance Technology (AMT) Pool fund, TPF 5(380), which represents a forum for collaborative research, development, and deployment with governmental organizations, scientists, and industry. We will start by briefly introducing this pool fund and describing its mission statement. This will be followed by a list of participating State DOTs and their deployment status, the projects that have been sponsored so far, and summaries from annual peer exchange meetings, and finally, a path into the future.

4.1 Pool fund introduction and mission statement

The AMT Pool Fund is a place for sharing technology and experiences, gained from Autonomous maintenance initiatives by each participating partner. The AMT Pool Fund is currently administered by the Colorado Department of Transportation (CDOT) under the DOT Pool Funding umbrella. The Federal Highway Administration (FHWA) serves as a monitoring body, providing strategic and technical input to the Pool Fund. Both national and regional FHWA personnel participate in the AMT Research Pool.

The mission of the AMT Pool Fund is to develop and deploy ATMA or AIPVs to protect the lives of highway workers by enhancing cooperative inter-agency research that improves the safety and effectiveness of ATMA or AIPV operations, and to facilitate communication between transportation agencies that encounter challenges with implementation. The areas of potential benefit pursued by the group are defined by the goals of AMT, and AMT's specific objectives directly address activities that support progress toward realization of these goals. The Pool Fund goals below are defined for evaluating the usefulness of research projects. In addition to meeting one or more of these goals, proposed projects, to be considered for funding opportunities, should also provide specific projected outcomes and should produce results that can be implemented in practice. AMT's goals and subsequent objectives are:

(1) Drive enhancements in ATMA/AIPV to improve system performance, including gap distance, turn/pause mode, offset, GPS signal under bridges or low GPS environment, remote starting, human machine interaction, data collection, specifications, and more.
(2) Foster collaboration in ATMA operations by identifying common research and deployment needs and disseminating resulting information/technologies/methods and specifications.
(3) Provide a means of sharing research results and methods with the public and between group members by exploring and evaluating currently available and emerging technologies.
(4) Improve the safety of ATMA operations for both highway workers and the public.

For detailed information on AMT pool fund vision, mission and operations, please refer to Appendix A. For the operating rules of AMT pool fund, please refer to Appendix B, at the end of this document.

4.2 Participating DOTs and their deployment status

The Pool Fund currently has 14 State DOT members, including Alabama, California, Colorado, Illinois, Indiana, Kansas, Minnesota, Nevada, North Dakota, Ohio, Oklahoma, Texas, Virginia, and Washington DOT. The Pool Fund members meet every month. We summarize their deployment status below, as of May 2021. More details of the Annual Peer Exchange meeting minutes will be discussed in Section 4.3.

The Colorado DOT (CDOT) is the earliest to test, deploy and promote ATMA technology. As early as Oct 2017, CDOT submitted a request for the ATMA and, then, in summer 2017, CDOT completed validation testing and operator training. The Autonomous Mobility Task Force approved CDOT's request on roads with AADT of 2,500, in May 2018, which was then increased to 5,000 in January 2020. The technology system was upgraded in Oct 2019, which included cybersecurity, side view sensors, improved cameras, improved user interface and vehicle to vehicle communication, data storage, external human-machine interface (E-HMI), A-stop, backup navigation, and operation in GPS denied mode. In January 2020, the task force approved a program expansion to purchase the second ATMA truck. The second ATMA was officially authorized by the Task Force April 2021, which is currently being shipped back to CDOT from Florida. CDOT has preparations underway to train the new crew that will be receiving the vehicle and is preparing to install the leader kit and then, do validation testing.

Missouri DOT (MoDOT) initiated an RFP to purchase an ATMA vehicle in May 2017, and issued the contract to Kratos Defense in March 2018. The system functionalities include follow at various distances, up to 1500'; pause and catch up function in short duration GPS denied environments; arrow board and turn signals are synced; and so on. The performance specs include frontal collision avoidance, E-stop and failsafe systems, follow distance adjustment required, pause and catch-up function, arrow board and turn signal coordination, vehicle take over functionality, and operator friendly user interface. A 32-hour test in a control environment was completed in 2019. The control environment has little or no traffic, and the purpose of this testing was to make sure each system component works as expected. The 250-hour testing will be performed in live work zones on divided highways.

The California DOT (Caltrans) has purchased ATMA vehicles through an interagency agreement with Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) at UC Davis and is in the process of evaluating the technology. The Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) has completed all testing that was scheduled in the proposal and will resume testing after hardware vendor, Kratos, updates the ATMA system to address swerving issues. The testing is anticipated to be completed by 12/31/2021. Caltrans is also developing a classroom and hands-on training program for their operators.

In Virginia, through VTTI, a Consortia was formed in 2018 that focused on development of ATMA. The initial design goals include freeway operations, HMI, GPS-denied operation, and robust safety features. It is designed to be a multi-phase program. Phase 1 focuses on the design, building, and demo Leader- Follower ATMA System; Phase 2 will focus on Performance Evaluation and Technology Assessment; and Phase 3: will focus on Testing on Public Roadways in Real Operations. The targeted outcome is an IP package suitable for commercialization. The team has just completed Phase 1.

Significant ATMA deployment progress is also reported from the Minnesota DOT (MnDOT) and the North Dakota DOT (NDDOT). The Minnesota DOT is scheduling ATMA testing and Training in summer 2021. A 2-week closed road test and a 2-week live road test are planned. Leadership decided to move to a shouldering crew, rather than striping. The MnDOT recommends identifying procurement needs and delivery considerations, such as transport, insurance, schedule, and determining inspection requirements on AMT components upon delivery and integration. The North Dakota DOT is working with hardware vendors to reinstall equipment and ship it back to North Dakota. The NDDOT is also interested in hiring a consultant to demo the autonomous mowers. Besides these States that have procured or deployed an ATMA, the other member states in the pooled fund are all along the spectrum of deployment, in the ideation or planning phase of how they can bring a program to their state.

4.3 Sponsored projects

The AMT Pool Fund has funded a total of six research projects. In this section, we provide a brief review on each one, including the problem being addressed and the progress being made.

4.3.1 5380-18-01 ATM Coordination CSU

Topic: Autonomous Maintenance Technology Pool Fund Management

Status: This project is complete

Colorado State University (CSU) proposed to provide management of the Pool Fund to ensure that it can meet the research and project level objectives of CDOT (as the Pool Fund lead agency) and other stakeholders. This project period is 6/01/2018-5/31/2019.

In accomplish these objectives, seven tasks were designed, and have been completed.

(1) Develop and publish public-facing marketing that includes a website, events, social media.
(2) Perform Transportation Pool Fund Program Quarterly Progress Reporting, including determination of what type of reporting will be required, adherence to Pool Fund rules, maintenance of an organizational charter.
(3) Coordination of the Pool Fund, including scheduling research proposals and reviews, and invoicing.
(4) Coordination of the research projects, including management of research contractors, deliverables, publications, and reporting.

(5) Travel coordination, including planning and management of the annual meeting, hotel, travel agent, management, billing to the Pool Fund. Direct coordination of stakeholder travel with concomitant conference, planning and management of the annual meeting, hotel booking and management, travel agent management, accounting of costs and billing to the Pool Fund.
(6) Teleconference meeting organization, including planning, coordination, minutes, documenting votes.
(7) Invoicing the Pool Fund and reconciling reimbursements.

4.3.2 5380-19-02 - Human - AMV Interaction-Erika Miller – CSU

Topic: Evaluating the Human-Automated Maintenance Vehicle Interaction for Improved Safety and Facilitating Long-Term Trust

Status: This project is complete

This project has two main goals. First, *learning human response to interactions with ATMA and AIPV*: Develop a suite of Data-Driven and Statistical Learning tools that can effectively learn the complex interaction that operators have with ATMA and AIPV from heterogeneous measurements and data. In particular, the project aims to: (i) identify interactions that may be unsafe or that may rapidly become unsafe; (ii) effectively learn the trust function related to the operator as well as a comfort function; and (iii) learn how the trust function changes over time, based on dynamic weather, traffic, and operating conditions. Second, *maximize trust and safety*: Leverage the learning tools to synthesize real-time actuation and recommendation systems for ATMA and AIPV that learn to maximize the trust and comfort of the operator, while successfully performing maintenance tasks and maintaining a safe operation.

The project is complete and the repost was submitted in February 2021. The objective of this study was to evaluate how a work zone worker at the DOT perceives the usefulness of and the capabilities of automation in Truck-Mounted Attenuators. A survey study was collected from workers with experience with ATMAs from the DOT in Colorado and California. In total, 13 DOT workers responded to the survey. The survey collected information on the worker's job specifications, their experience with the ATMA, the training they received, their trust in the ATMA, their perceived usability of the human-machine interfaces (HMI, e.g., display screens), and their understanding of operating capabilities of the automation. Each of the DOT workers in this study had some previous experience with the ATMA, either in real-world applications and/or formal training. Based on responses from the survey, there were seven study participants considered as being in the "High Experience" group and six as being in the "Low Experience" group in relation to their experience with the ATMA. Overall, workers reported a positive acceptance of the ATMA technology. Generally, workers also had a positive regard towards safety and reliability of the ATMA technology, as supported by their expectations that it would reduce crash severity; and that it was an overall improvement, as compared to having a human driving the TMA. There was also a high trust in the capabilities of the automated truck in low traffic volumes.

However, workers expressed that they did not think the automation would reduce crash frequency, nor would it reduce project duration. Workers were also less confident in the automation's ability to safely change lanes and drive without assistance from a human operator. They also noted concerns regarding their trust in the automation under various contexts, such as in conditions of poor visibility, adverse weather, horizontal and vertical road curvatures, and denser traffic volumes. For many of the survey questions, individuals in the High Experience Group reported greater trust in the technology. Workers in the High Experience Group were also more likely to report the gap distance between the lead vehicle and the ATMA follow could be shorter while automated, as compared to when a human is driving, as opposed to the Low Experience Group workers being more likely to report that the gap distance should be longer in automated operations.

Overall, the AMTA technology was regarded positively by the workers surveyed in this study. However, it was noted that better calibrated trust and confidence in automation appeared to increase with more experience and training. These findings suggest that investments in ATMAs will likely be accepted and adopted by workers, and that training in these systems offers improved utility.

4.3.3 5380-19-03 - ATMA Dev Guide - XB-Missouri S&T

Topic: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
Status: This project is ongoing

The objective of this project is to identify the Operational Design Domain (ODD) of ATMA. Specifically, what is a good AADT threshold for the consideration of ATMA deployment? The motivation of this project is that, despite the fact that ATMA technology is being rapidly developed and deployed, the practicable and implementable guidance for its deployment is largely missing in the Manual on Uniform Traffic Control Devices (MUTCD) and other Federal regulations and National standards. Without such guidance, State DOTs have been making their own criteria to answer the question of when and where to deploy ATMA. For example, the Colorado DOT is using an annual average daily traffic (AADT) of less than 6,000 as the criteria to identify low-volume roads for ATMA deployment. This is because of the nature of mobile and slow-moving operations, since ATMA vehicles are usually driving slowly (such as 5~15mph) and, as such, the argument is to avoid slowing traffic on a busy corridor during peak hours. A problem with this criterion is that AADT on multilane highways varies for different DOTs. Roads with an AADT lower than 6,000 might be common in Colorado, but in other States, such as California and New York, most roads are much busier than that. So, the question is whether this AADT threshold is reasonable, and how should we develop a sound method to scientifically determine this threshold?

To bridge this important gap, this project aims to develop microscopic traffic flow models to identify the Operational Design Domain of ATMA, on a typical multilane highway, as well as a typical two-lane highway, respectively. Learning from the Highway Capacity Manual (HCM), the

Level of Service (LOS) of a multilane highway is mainly determined by six measures, including speed, delay, throughput, density, environmental, and the ratio of demand/capacity, whereas the LOS of a two-lane highway is mainly determined by the Percent of Time Spent Following (PTSF). As such, this proposal will build the linkage between AADT, and a highway Level of Service, in order to determine the maximum AADT that allows AMTA deployment, and to make sure that the highway Level of Service remains within some desirable range.

This project includes a total of six tasks, namely Task 1 Literature review, Task 2 Traffic flow modeling, Task 3 Data collection and model calibration, Task 4 Optimal deployment strategy development, Task 5 Open-source software tools development, and Task 6 Reporting. Tasks 1 and 2 are finished, and Task 3 data collection and model calibration is delayed due to COVID-19. The team is currently exploring another dataset for model validation purposes. It is also envisioned that, as State DOTs are resuming ATMA operation, the data collection process will resume in Summer 2021. This project team has presented two ATMA research papers, titled "Field Testing and Evaluation of Leader-Follower Autonomous Truck Mounted Attenuator Vehicle System for Work Zone Maintenance" and "Quantification of Traffic Impact by Leader-Follower Autonomous Truck Mounted Attenuator Vehicle System for Work Zone Maintenance", at the TRB 2020 Annual Meeting. In addition, the former paper has been accepted for publication at the Journal of Transportation Research Record. On 7/9/2020, the team also presented an invited webinar, titled "Work Zone Safety and How to Use New Technologies to Mitigate Work Zone Intrusion", which was by the TRB Standing Committee on Maintenance and Operations Management AKR10. The webinar attracted 600+ registrants with $95 paid tickets. The Satisfactory rate was 93%.

4.3.4 5380-19-04 ATMA Tabletop-Cybersecurity-CSU

Topic: Autonomous Truck Mounted Attenuator (ATMA) Incident Tabletop Exercise Support

Status: This project was kicked off on 3/12/21, and is ongoing

The objective of this project is to assess the cybersecurity of the ATMA system, explore the threats and potential attack vectors, and address any discovered vulnerabilities. This project is allocated to last 12 months, but an 18-month period of performance is noted on the internal CSU proposal documents to allocate additional time for unforeseen overruns in time. The motivation of this project is the potential effect of a cybersecurity attack on the AMT barrier that would lead to a traffic crash. In fact, this scenario may be an inevitability, in which the barrier technology should mitigate the potential tragic abrupt dissipation of energy. However, when crashes happen, the sequence of determining crash causation starts with traffic crash reconstruction. This process gathers physical and digital evidence, associated with the crash, and reconstructs the events that lead to the crash. This process is not well understood with AMT since the technology is new and an actual traffic crash has not happened yet.

The task-oriented approach, with associated deliverables, is detailed below.

Task 1: Project Management and Tabletop Approach Outline **-** Support the work plan to facilitate the 'table-top' exercise, including an outline of the 'table-top' activities, witnesses/individuals to be involved, etc., including the drafting of possible crash scenarios to be finalized in Task 4. Four deliverables include:

1) Literature Review – Conduct a review of literature on published research that addresses the topic being researched. This review will be discussed at the project kick-off meeting. One person we would like to contact is Weston Brown of the Scottsdale Police Department in Arizona. He investigated a fatal crash involving a Tesla car with a high degree of automation.
2) Kick-off Meeting – Support a detailed plan and schedule of activities to be followed in completing the research work. This plan and schedule will be presented at the kick-off meeting to the Research Oversight Team. This plan will include the different stakeholders and interests, the types of data, and a list of possible experts to interview.
3) Quarterly Progress Reports (QPR) – The QPRs document the progress made on each task and highlights significant events. These reports will be prepared in accordance with the format required and provided at www.PooledFund.org. They will be submitted on the 15th of the month following the quarter end (April, July, October, and January).
4) Draft outline of ATMA Tabletop Mock Activity

Task 2: Collection of ATMA Documentation **-**The required documentation of the operation and maintenance of ATMA units for legal defense, including the data and cybersecurity elements to be considered in the event of a traffic incident involving the ATMA. This activity will require site visits and inspection of the ATMA. The proposers will also need access to maintenance systems, wiring diagrams, and diagnostic processes for the ATMA. Two deliverables will include:

1) Assist in updates to the draft outline of ATMA Tabletop Mock Activity with necessary documentation and assignments to stakeholders in preparation for the event.
2) Final outline and running of the ATMA Tabletop Mock Activity

Task 3: Tabletop Mock Event **-** Support and participate in the investigation of three crash scenarios (specified on the following page), with incident response, post incident actions, data access/type simulations, and expected legal actions from those involved, including but not limited to the adverse driver, ATMA owner employees, ATMA manufacturer, and ATMA owner financing and bonding entities. Photos representing example scenarios that illustrate potential situations, along with captions, are shown on the following page. These examples will be used for inspiration. ATMA Tabletop Mock Event will be deliverable.

Task 4: Final Report **–** A Final Report detailing the major findings, pre- and post-table top, including the recommended actions and documentation after an incident. Final presentation and final research report will be deliverable at the end of this project.

4.3.5 5380-19-05 ATMA Tabletop-Planning and Facilitation

Topic: ATMA Incident Tabletop Exercise - Planning and Facilitation

Status: This project has been kicked off, and is ongoing

The objective of this project is to develop guidelines for proper documentation of operation and maintenance of ATMA units and to provide guidance for appropriate post incident actions. The motivation of this project is that ATMA owners require guidance as to how to document the operation and maintenance of these devices, and to require guidance as to proper actions and documentation after an impact event or other incident. A method, proposed by this project, to prepare for an impact event is to complete a "tabletop exercise", where a team of ATMA owners, operators, crash reconstructionists, cyber security professionals and experts, and legal claims professionals evaluate several crash scenarios.

The task-oriented approach, with associated deliverables, is detailed below.

Task 1: Project Management and Tabletop Approach Outline **-** Develop the work plan to facilitate the 'table-top' exercise, including outline of the 'table-top' activities, witnesses/individuals to be involved, etc., including the drafting of possible crash scenarios to be finalized in Task 4. Four deliverables are included:

1) Literature Review – Conduct literature review of published research addressing the topic being researched. This review will be discussed at the project kick-off meeting.
2) Kick-off Meeting – Develop a detailed plan and schedule of activities to be followed in completing the research work. This plan and schedule are to be presented at the kick-off meeting to the Research Oversight Team for approval before performing the work.
3) Quarterly Progress Reports (QPR) – The QPRs document progress made on each task and highlights significant events.
4) Draft outline of ATMA Tabletop Mock Activity.

Task 2: Collection of ATMA Documentation **-**The required documentation of the operation and maintenance of ATMA units for legal defense, including the data and cyber security elements to be considered in the event of a traffic incident involving the ATMA. Two deliverables are included:

1) Updated draft outline of ATMA Tabletop Mock Activity with necessary documentation and assignments to stakeholders in preparation of the event.
2) Final outline and run of show of the ATMA Tabletop Mock Activity.

Task 3: Tabletop Mock Event **-** Lead and participate in the mock enactment/trial of three crash scenario 'table-top' exercises, with incident response, post incident actions, data access/type simulations, and expected legal actions from those involved including, but not limited to, the adverse driver, ATMA owner employees, ATMA manufacturer, and ATMA owner financing and bonding entities. The 'table-top' exercise will include members of the Autonomous Maintenance Technology Pool Fund in a virtual and/or live environment.

Task 4: Final Report **-** Final Report detailing the major findings pre- and post-table-top, including the recommended actions and documentation after an incident. Final presentation and final research report will be submitted at the end of this project.

4.3.6 5380-20-06 - ATMA Documentation - XB-Missouri S&T

Topic: Systematic Documentation for Autonomous Maintenance Technology Promotion and Deployment

Status: This project has been kicked off, and is ongoing

This project aims to produce a set of documents to provide systematic technical support for State DOT or other agencies that are interested in deploying ATMA. The scope of work of this project is to conduct a literature review of Federal and State regulations on autonomous vehicle testing and deployment, work with key stakeholders from public and private sectors that are working on autonomous maintenance technology, and to summarize and document knowledge of the purpose for autonomous maintenance technology promotion and deployment. The following documents, outlined in the task approach, will be developed to support agencies at various stages of working with ATMA.

A 26-month frame is proposed to finish three tasks, with a total of ten deliverables.

Task 1: Project Management, including three deliverables.

1) Literature Review – Conduct a literature review of published research addressing the AMT-related study. This review will be discussed at the project kick-off meeting.
2) Kick-off Meeting – Develop a detailed plan and schedule of activities to be followed in completing the research work. This plan and schedule are to be presented at the kick-off meeting to the Research Oversight Team for approval before performing the work.
3) Quarterly Progress Reports (QPR) – The QPRs document progress made on each task and highlight significant events. These reports will be prepared in accordance with the format required and provided at www.PooledFund.org and are due on the 15th of the month (April, July, October, and January) following the end of each calendar quarter. These reports will be delivered with any invoice and should be correlated with each other.

Task 2: Systematic Documentation, including five deliverables.

1) System Description Document, to help DOTs that are in the early stage of exploring the technology.
2) System Test Manual, to support DOT engineers in testing the capabilities of the system.
3) Concept of Operation (ConOps), to document how the ATMA system is intended to be used, and the external conditions expected during use of the system.
4) Development Needs Document, to keep track of all future development needs.
5) ATMA User Manual Updates (at no cost), to include a detailed description of the system components, functions, capabilities, contingencies, and step-by-step procedures for DOT engineers to access and use the system.

Task 3: Final Report: Final Report detailing the major findings of this project. Final presentation and final research report will be submitted at the end of this project.

4.4 AMT Annual Peer Exchange Meetings

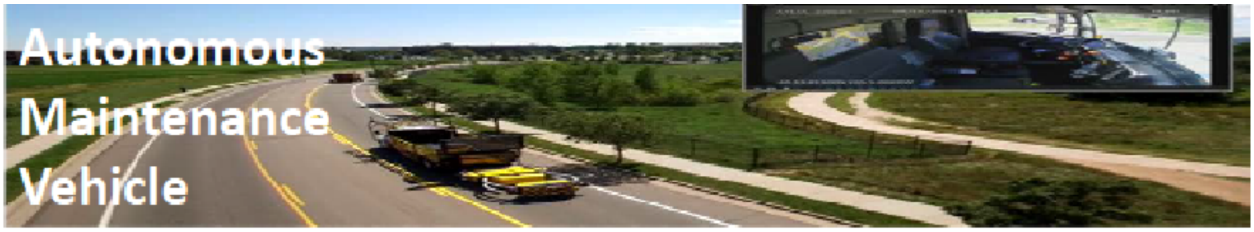
The Pool Fund has been organizing the annual peer exchange meetings for the fall of each year. Below, we are summarizing the main takeaways of the meetings.

4.4.1 AMT Peer Exchange Meeting in 2019

The October 22-23, 2019 Peer Exchange, hosted in Colorado, presented a 2-day information exchange and demonstration of Colorado's AMT. Some of the participants of this successful demonstration are depicted in Figure 4. The purpose of this Peer Exchange meeting was the sharing of technology and experiences gained from autonomous maintenance initiatives from each participating state. The AMT Pool Fund was administered by the CDOT under the DOT Pool Funding umbrella. The FHWA serves as a monitoring body, providing strategic and technical input to the Pool Fund.

Figure 2. AMT Pool Fund 2019 Peer Exchange Demonstration Attendees.

The agenda of the 2019 annual meeting is shown below

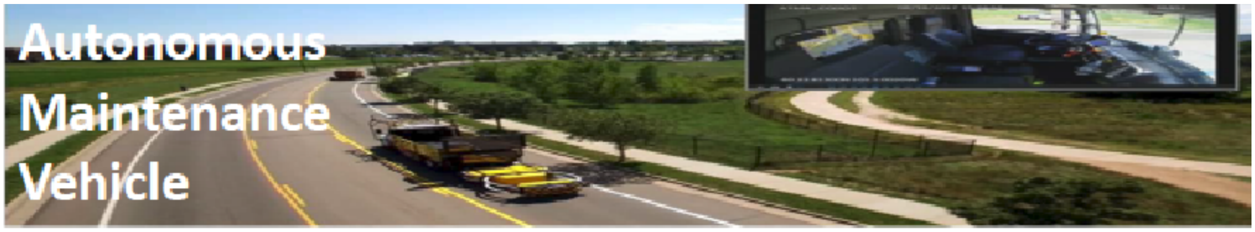


Annual Autonomous Maintenance Technology (AMT) Peer Exchange

Colorado State University Powerhouse Energy Campus
430 North College Avenue
Fort Collins, Colorado 80524
October 22 - 23 2019
8:30 am – 4:30pm

Tuesday, October 22 Morning Session	
	CSU Van Pick up at Hilton at 8am, at Best Western on College 8:15
8:30 – 9:00	***Welcome/Participant Introductions – Colorado Department of Transportation -***
9:00 – 10:30	***Overview of Current Deployments – States and Use Cases*** Missouri – Chris Redline (via Zoom) California – Theresa Drum Colorado – Tyler Weldon
10:30- 10:45	***Break***
10:45- 12:00 **10:45 – 11:15** **11:15 – 11:30** **11:30 – 11:45** **11:45 – 12:00**	***Research Highlights*** *Work Zone Data Exchange* - Todd Peterson, US DOT *Using AMT Vehicle Data to Improve AV Integration* – Dr. Steve Simske, Colorado State University, Systems Engineering Department *Evaluating the Human Automated Maintenance Vehicle Interaction for Improved Safety and Long-Term Trust* – Dr. Erika Miller, Colorado State University, Systems Engineering Department *Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts Missouri S&T* – Dr. Xianbiao (XB) Hu, Missouri Science and Technology
12:00	***Break for Lunch***
	Tour of Powerhouse -Optional
1:30 – 2:15	***Highways England* – Maynard Factor, Kratos**
Afternoon Session: CSU Chrisman Field	
2:30 – 4:30	***Vehicle Demonstration – CSU Christman Field***
6:00	***Pick up at Hilton; 6:15 Pick up at Best Westerns College*** ***Dinner at Austin's 6:30 reservations***

Autonomous Maintenance Technology Pool Fund



Annual Autonomous Maintenance Technology (AMT) Peer Exchange Colorado
State University Powerhouse Energy Campus
430 College Avenue
Fort Collins, Colorado 80524
October 22 - 23 2019
8:30 am – 2:30pm

Wednesday, October 23 Morning Session	
	CSU Van Pick up at Hilton at 8am, at Best Western on College 8:15
8:30 – 9:45	*Current Deployment Lessons Learned Panel* How to Procure Daily Operation Integration Training program & materials Moderated by Ashley Nylen, Project Manager, CDOT California – Theresa Drum Colorado – Tyler Weldon Minnesota – Rashmi Brewer Missouri – James Shannon (via Zoom)
9:45 – 10:00	*Break*
10:00 – 10:45	*Continuation*
10:45 – 12:00	*Future Research Needs and Focus Areas* General Discussion
12:00	Break for Lunch
Afternoon Session	
12:30 – 1:45	AMT Monthly Meeting Minutes adopted Review of Mission Statement New Business
1:45	Adjourn

Autonomous Maintenance Technology Pool Fund

A high-level summary of the major findings and discussion of the AMT Pool Fund Annual Meeting 2019 are noted below:

- Immense productive value in meeting in person to discuss various deployment efforts and challenges among the various states
- Substantive discussion around where each ATMA program lived in the various state DOTs. Some featured the ATMA program "homed" in the maintenance and operations division, others included in the intelligent transportation systems divisions, while some also featured the program as part of their research branch.
- Extensive discussion about working toward building a comprehensive toolkit that can be utilized by various states for all elements from initial planning, messaging to leadership, procurement, regulation and legislation challenges, pre-deployment, deployment, testing, validation, operational procedures, etc.
- Identifying metrics for success of each state's program and how that's messaged
- Group discussed the workgroups and agreed to update them over the coming year so they are more relevant to the main needs of the pool fund members. Group agreed that things have changed significantly since the original pool fund was formed and the pool fund should work to update the workgroups to create meaningful knowledge and tools that can be used by the members.

For more detailed information on the 2019 AMT peer exchange meeting, please refer to Appendix C.

4.4.2 AMT Peer Exchange Meeting in 2020

Annual AMT virtual Peer Exchange was held on October 26, 2020. In-person meeting was planned originally, however, due to COVID-19, the meeting was eventually online. Detailed contents, including current deployment, Research Projects Update, Group Updates, financial status, and discussion, were discussed. The meeting of the 2020 annual meeting is shown below. For more detailed information on the 2020 AMT peer exchange meeting, please refer to Appendix D.

Annual Autonomous Maintenance Technology (AMT) Virtual Peer Exchange
Monday, October 26th, 2020
9:00am – 12:00pm (MST)

Agenda	
9:00 – 9:20am	Welcome and Introductions
9:20 – 10:15am	Current Deployments: States that have previously deployed an ATMA will focus their presentations on challenges they have faced during deployment and how they have overcome those challenges. Other states that are earlier in their deployments will provide an overview of their program and status. ● 9:20am – 9:30pm California ● 9:30am – 9:40am Colorado ● 9:40am – 9:50am Missouri ● 9:50am – 10:05am North Dakota ● 10:05am – 10:20am Virginia
10:20am – 10:40am	FY19 Research Projects Update ● Dr. Erika Miller (Colorado State University) ● Dr. Xianbiao Hu (XB) (Missouri Science and Technology)
10:40am – 10:50am	BREAK
10:50am – 11:20am	Work Groups Update ● 10:50am – 11:00am - Deployment Toolkit Themes and Overview ● 11:00am – 11:20am – Policy and Legislative Working Group – Work Session ● Outreach and Education Working Group Update Provided in Packet
11:20am – 11:50pm	Financial Status FY20 Research Projects Status Discussion Topic: Navigating social distancing in maintenance operations – tactics/processes/procedures implemented by states, what has worked well, what has not worked well, identify current challenges/gaps, etc.
11:50am – 12:00pm	Wrap Up/Action Items Adjourn

Appendices

Appendix A – AMT Pool Fund Vision, Mission, Operations Document

1. Introduction

The Autonomous Maintenance Technology (AMT) Pool fund, TPF 5(380) represents a forum for collaborative research, development, and deployment with governmental organizations, scientist, and industry. This pool fund will the sharing of technology and experiences gained from Autonomous maintenance initiatives from each participating partner. Autonomous Maintenance Technology - AMT Pool fund currently administered by the Colorado Department of Transportation (CDOT) under the DOT Pool Funding umbrella. This document sets forth the vision and mission shared by the parties and the organization operating procedures. The Federal Highway Administration (FHWA) serves as a monitoring body, providing strategic and technical input to the pool fund. Both national and regional FHWA personnel participate in the AMT Research Pool. FHWA Sponsor - Todd Peterson

1.1. Vision and Mission

1.1.1 Vision

Autonomous Truck Mounted Attenuator, AMT or **Autonomous Impact Protection Vehicle (AIPV)** supporters share a common vision of **collaborative** autonomous traffic mobile attenuator research efforts, of **deployment** of these protection vehicles and **methods** to enhance the safety of highway workers, and of serving the traveling public through **safer** and **more efficient** autonomous technology deployment and refinement.

1.1.2 Mission

The mission of this pool study is to **develop** and **deploy ATMA or AIPVs** to protect highway workers lives by enhancing cooperative inter-agency research that improves the safety and effectiveness of ATMA or AIPV operations, and to facilitate communication between transportation agencies that encounter challenges with implementation.

1.1.3 Goals and Objectives

The goals of AMT define areas of potential benefit pursued by the group. AMT's specific objectives directly address activities that support progress toward realization of the goals. The below pool fund goals are defined for evaluating the usefulness of research projects. In addition to meeting one or more of the below goals, proposed projects should also be specific in their projected outcomes and should produce results that can be implemented in practice. AMT's goals and subsequent objectives are:

(1) **Drive enhancements** in ATMA/AIPV to improve system performance including gap distance, turn/pause mode, offset, GPS signal under bridges or low GPS environment, remote starting, human machine interaction, data collection, specifications, and more.

(2) **Foster collaboration** in ATMA operations by identifying common research and deployment needs and disseminating resulting information/technologies/methods and specifications.

(3) **Provide** a means of sharing research results and methods with the public and between group members by exploring and evaluating currently available and emerging technologies
(4) **Improve the safety** of ATMA operations, to both highway workers and the public.

1.2 Guiding Principles

The set of guiding principles for the pool fund include:

1. The individual components of the pool fund are locally organized and managed under the direction of a state-level pool fund.
2. Individual states provide for the coordination with local-level participants, both government and industry.
3. Each state-level organizational structure and pool fund may reflect individual priorities.
4. Comparison of the state-level pool funds and interest will inform the identification of joint pool fund activities.
5. The AMT Pool Fund management functions will require a minimum level of support.

1.3 Pool fund Partners

Active Pool fund Pool voting member agencies for the 2020 year are as follows:

1. Alabama Department of Transportation (ALDOT)
2. Colorado Department of Transportation (CDOT)
3. California Department of Transportation (Caltrans)
4. Illinois Department of Transportation (IDOT)
5. Kansas Department of Transportation (KDOT)
6. Minnesota Department of Transportation (MnDOT)
7. Nevada Department of Transportation
8. Ohio Department of Transportation (ODOT)
9. Oklahoma Department of Transportation (OKDOT)
10. Texas Department of Transportation (TxDOT)
11. Washington Department of Transportation (WSDOT)
12. Virginia Department of Transportation (VDOT)

Pool Fund Organization

AMT's organizational structure is constructed to meet the group's objectives, to encourage collaboration, while also effectively managing the member agencies and projects. The organizational structure is shown Figure 3.

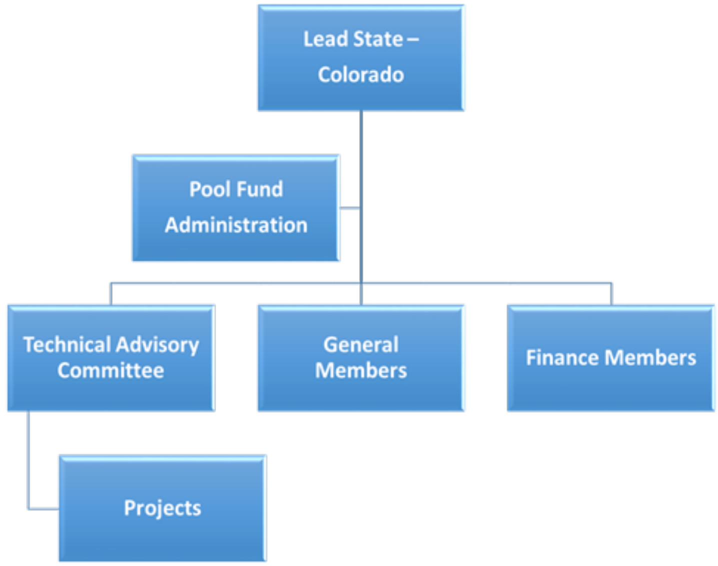


Figure 3. Outline of Organizational Structure.

1.4 Technical Advisory Committee

The Technical Advisory Committee (TAC) consists of each agency contributing a minimum of $25,000 a year for at least three years. Each contributing agency receives one (1) vote in decisions made by the TAC. The TAC jointly manages the administration of the group, and has final approval in the creation and funding of projects. TAC members or General members may propose ideas for projects. Only TAC members may decide to award projects. The TAC may invite additional voting and non-voting members through a vote of approval from the TAC.
The TAC will adopt pool fund policies and procedures as deemed appropriate, including selection of a Chair and Vice Chair if the TAC so votes.
The TAC is responsible for creating and terminating various committees or other organizational unites as required to satisfy pool fund needs. The TAC will also approve budgets and work projects for Pool studies by a majority vote.
For a designated member of the TAC to continue active membership, the participating entity must continue annual financial support of a minimum of ***$25,000***. If an entity fails to meet its annual commitment, it may, at the discretion of the TAC be assigned non-voting member status until its financial participation is continued.
On a case-by-case basis, the TAC may consider allowing an organization to become a voting member of AMT through an in-kind contribution. For continued active membership beyond the first year, this entity must contribute annual financial support of at least ***$25,000***. As with other agencies, if an entity fails to meet its annual commitment, it may, at the discretion of the TAC, be assigned non-voting member status until its financial participation is continued.
The AMT Operating Procedures, Appendix A, may be updated separately from this document.

1.5 Lead State

The Lead State (Colorado) administers the activities of TAC and coordinates the awarded projects. The Lead State responsibilities include 1) membership in the TAC, 2) coordinating the efforts of the TAC, and 3) taking the lead on approving projects and overseeing project progress. The lead state supplies the pool fund administration. The Administration as directed by the lead state will assist in drafting RFPs, developing a proposal ranking and consultant selection process for the TAC's approval, presentation of lists of consultants and RFP response materials to Committees of the TAC.

The Administration is responsible for distributing RFPs, preparing contract documents and performing other functions related to contracts administration and management. The Administration will assure that contracts, schedules, work plans, and project descriptions are followed. It is also responsible for quality control and evaluation, recommendations regarding preparation of contract documents, change order requests, and authorizing progress payment, and providing contract progress reports to the TAC.
The AMT Lead State will administer all contracts unless the Lead state designates another agency to administer a specific contract. The Lead-State may designate another agency as administrator with TAC approval. If a quorum is not present, the entire membership must be polled. All contracts will follow the guidelines of the agency administering the contract.

1.5.1 Pool fund Administration

Funding
Pooled funding is derived from contributions received from participating entities. For U.S. states utilizing pooled SP&R funds, uniform treatment of funding is assured under existing FHWA mechanisms for such pooled funding projects.
Administration
Pool fund administration handles the group's budget and group travel, provides funding on approved projects, and organizes and budgets for annual group meetings, and is responsible for preparing Quarterly Reports to catalogue how the group budget and project status each quarter. Per Diem and travel will be administered for each entity consistently with the policies of the Administration and that entity's prevailing per diem and travel policies.

1.6 Finance Members

Finance members from each state may participate in pool fund meetings but have no vote. This participation is to further communication and collaboration among the states.

1.7 General Members

General Members may attend annual meetings and participate in discussion of group proceedings at the request of the TAC. Representatives of private sector members are also General Members. General Members do not have voting rights. Additional Universities are also general members that may participate in discussion and provide technical input or support. Universities are non-voting members and may respond to TAC-issued RFPs. All general members must recuse themselves from attendance at voting project meetings to prevent conflict of interest issues.

1.8 Member Meetings

To encourage collaboration, the TAC meets regularly to discuss the group's progress and future steps. The TAC and General Members will meet annually, and member agencies can choose to send multiple representatives to the meeting, but will still receive only one TAC vote. These meetings allow the group an opportunity to propose new projects, discuss current progress and future intentions, and, ultimately, ensure that the group is moving towards its stated goals.

1.9 Future Organizational Structure

Upon reaching the number of 15 participating states, the organizational procedures and organization structure may require changes to improve the effectiveness of administration. Currently, this would tentatively consist of a board of three Lead States that would oversee the TAC and the rest of the group. Addition of an Information Officer may become useful as group communications and project information and data start to increase. Decisions to change the structure is a responsibility of the TAC, based upon current group administration and organizational performance and efficiency.

2 RFP Development and Project Management

2.1 RFP Development

AMT defines and develops technical projects using multiple, complementary approaches, as follows.

1. Review of member agency plans. The TAC will continually review the current research, implementation, and interests in AMT technologies and methods of the member agencies. This can present common themes among members to us as a basis for a RFP for a project.
2. Proposals by AMT members. Member agencies may propose projects developed independently. These may reflect the interests of the proposing agency, and should benefit the group objectives or makes progress towards achieving group goals. Collaboration in the development of projects is encouraged, and results will be made available to the entire group.
3. Indirect Costs. Indirect costs for an AMT project are limited to 20% of the project costs.

Approval of RFP's/Selection Processes
If external resources are required, committees of the TAC will organize, review, and approve RFPs to assure their consistency with the work program and budget. Committees will recommend the selection of consultants, after consideration of a list of qualified consultants prepared by the Pool Fund Administration. Committee consultant selection will assure consistent treatment of consultants and that the qualified list is consistent with the approved consultant selection process.
Review Products/Recommend Alternatives
Committees will be responsible for establishing a degree of expertise in their given areas of research. This expertise will facilitate in-depth analysis and detailed presentations before the TAC. The Committees will review the products of their respective consultant teams and make recommendations to the TAC.

2.2 Project Cycle

Projects managed and funded by AMT are expected to follow an annual cycle of progress shown in Table 1. This will allow a common project schedule to simplify management.

Table 1 Proposal and Project Cycle	
Task	**Date**
1. Problem Statements due for RFPs **Problem Statements define what the project seeks to address**	**December**
2. Problem Statement Review **TAC reviews problem statements to decide on project approval**	**February**
3. RFPs are prepared	**March**
4 Advertise Proposal (RFPs) **Approved problem statements are advertised for research proposals**	**March**
5. Review Proposals/Budgets **Proposals are reviewed by the TAC members to allocate funding and determine project budgets**	**April**
6. Contracts Approved **Final approval of research contracts by the TAC**	**May**
7. Contracts Issued by Lead State	**June**
5. Research **Research efforts will continue as snow levels permit throughout the winter**	**Summer**
6. Project status reports	**Quarterly**
7. Project Report **Final report of project results**	**End of contract; report at annual Peer to Peer Exchange**

Projects requiring multiple years of research are reviewed each year, consistent with this cycle, to re-evaluate scope, results, and budget based on the previous work.

<u>Product Acceptance</u>

The TAC is responsible for approval and acceptance of final products from project teams.

2.3 Project Areas of Interest

During the introduction of the AMT Pool, multiple initial topics were discussed. These set out to further the goals of the group, and are as follows.

- Begin Documenting the Evolution of the AMT
- System Developments
    - Improvements to adjustable gap distance

    - System-level Challenges
    - Human-machine interfaces
    - Regulatory Help and Guidance
- Technological improvement
    - Low GPS Environments
    - Electronic package reports for trip logs (pre & post)
    - Peer Support
    - Control System checks
    - Pause and Turn Mode
    - Radar Verification
    - Various Operations in addition to striping
    - Training
    - Career Development

Appendix B – AMT Pool Fund Operating Rules

Original 9.18.2018, revised 11.27.18 to include working groups, revised 12.20.18 to include scopes for each working group. Working groups revised and updated 1.16.20.

1 Quorum

To serve as a quorum of the TAC, any committee or subcommittee shall consist of more than one-half of the voting membership. Voting members and non-voting members carrying written proxies in actual attendance at any meeting shall count toward a quorum.

2 Proxy Votes

All proxy votes shall be in writing and dated as to effective date and date of cancellation. Voting members may identify, in writing or via e-mail, an individual to serve as proxy for a one-time event, or for all events at which the voting member is not present. The proxies may cover all issues subject to vote or may be limited to specific issues, as stated in writing. One-time proxy votes shall be delivered to the TAC or appropriate committee chair at the start of each meeting and recorded in the meeting minutes.

3 Voting Procedures

All votes may be cast by voice or by a show of hands. Any voting member may request a roll call vote. For decision making between meetings, voting by telephone, email, or facsimile polling may be undertaken when deemed suitable by the appropriate committee chair. All voting members will be polled, with a quorum required for approval.

4 Committee Size and Structure

A committee shall have a minimum of three voting members. There shall be no limit on non-voting members. Each AMT member organization shall have no more than one voting representative on a committee. The committee chair shall be selected by the TAC, and shall be responsible for determining committee membership and reporting to the TAC on committee activities.

5 Contracting Procedures

The AMT lead state will administer all contracts unless the TAC designates another agency to administer a specific contract. The TAC may designate another agency as administrator by a majority vote of the voting membership. If a quorum is not present, the entire membership will be polled. All contracts will follow the guidelines of the agency administering the contract.

6 Lists of Qualified Consultants/proposers

Mailing lists of qualified consultants or proposers shall be maintained by the Pool Fund Administration and submitted to each committee for suggested additions or changes.

7 Newsletter

At the discretion of the TAC, an AMT newsletter or electronic newsletter will be developed with the objective of a wide yet targeted circulation. The TAC will determine the appropriate body to be charged with preparing this newsletter.

8 Reports of Technical Consultants

Technical consultants and leads of projects will make presentations to committees of the TAC and will be responsible for presenting committee approved final products to the TAC for acceptance.

9 Travel Support

The TAC member or designated representative of each active member agency will be eligible for reimbursement of reasonable costs for travel, including registration fees, accommodation, and sustenance, to attend approved AMT meetings. Travel costs of attendance at AMT meetings by others may also be reimbursable in special cases approved in advance by the AMT Pool Fund Administration or the TAC.

Travel costs are to be kept to a minimum. The Pool Fund Administration and management consultant are charged with coordinating events requiring travel as appropriate to minimize travel costs. If approved by the TAC, reasonable travel costs for attendance by TAC members or designated representatives at other events germane to the AMT program may be reimbursed. The procedure to obtain travel reimbursement in these cases is as follows:

- Those desiring to use AMT funds to travel will submit an email request to the AMT chairman and the Pool Fund Administration stating the 1) purpose of the trip, 2) start and end dates of the trip, and 3) estimated cost of the trip.
- Approval of the request will be based on 1) the person or purpose of the trip that has been approved by the AMT TAC and 2) funding exists within the AMT program to cover the anticipated travel costs.
- Approval by both the TAC and the Pool Fund Administration will be authorization for the person to travel and obtain reimbursement from AMT.
- The TAC and Pool Fund Administration are responsible for notifying the management consultant of action they take.
- Reimbursement will follow the same procedure and dollar limits currently used to reimburse qualifying members who attend AMT meetings.

At the discretion of the Pool Fund Administration, or if approved by the TAC, reasonable travel costs for attendance of invited guests at AMT meetings or other related events may be reimbursed.

10 Meetings and Registration Fees

From time to time, AMT will hold general meetings open to members and nonmembers alike. The fee for attendance at these meetings may be charged by vote of the TAC or waived by the TAC or the Pool Fund Administration. Fees may be lowered or waived differently for TAC members or their representatives, invited guests or speakers, or other general meeting attendees. Friends of AMT (FOA) will pay reduced registration fees as determined by the Pool Fund Administration.

Other AMT meetings, including business meetings, committee meetings and working sessions, will generally be restricted to TAC or committee members, their designated representatives, and other invited guests. At the discretion of the TAC or appropriate committee chair, however, these meetings may be opened to broader participation. The TAC, Pool Fund Administration or committee chair will set the registration fees for such meetings, as appropriate. Registration fees collected by the host state in excess of the meeting facilities costs are the property of AMT and are to be used to defray the cost of other AMT expenses. Host states, or the management consultant, shall provide a meeting expense summary to the Pool Fund Administration after each meeting.

11 Internet Web Site

The AMT pool fund will maintain an internet web site for use by members and non-members. The public portion of the web site will be used to disseminate information deemed important by the TAC to non-member agencies, and will include general information concerning the AMT Pool Fund, information on member agencies, and any information relating to completed projects. In addition, a portion of the web site will be restricted to AMT members only. This section will include meeting and conference call minutes and project status reports.

12 Mailing Lists

The Pool Fund Administration will maintain a mailing list of all organizations and individuals eligible to receive approved AMT materials. This will be used as the basis for distribution of minutes of general meetings, meeting announcements, approved technical reports, press releases and newsletters (if available). All active member entities will be included on this mailing list. Organizations or individuals which are not on the mailing list, but which attend or pay the registration fee for a general AMT meeting, may receive minutes and other materials associated with that meeting.

13 Technical Committees

AMT technical committees study those areas of interest identified by the TAC. These committees established are listed below:

13.1 The Membership Outreach Committee

The Membership Outreach Committee is responsible for keeping up on potential new membership opportunities by assisting in the development of outreach materials. Committee members are the key points of contact for potential new members. The Membership Outreach Committee will meet as necessary, as instructed by the TAC to address issues that arise concerning membership. The TAC will assign participation in the Membership Committee.

13.2 The Web Site Review Committee

The Website Review Committee is responsible for monitoring web site items and reviewing potential new changes to the site, including proposed links to RWIS-related Internet sites. The Web Site Review Committee consists of the TAC members selected or volunteered.

14 Working Groups and Resource Sharing

AMT working groups are those identified by the TAC. The working groups may incorporate subject matter experts from member organizations and do not have to be voting members. However, it is expected that each member or their delegate will belong to one of the working committees. The working groups have been re-structured for each working group to compile various tools in their individual operations that can be rolled up into a large Autonomous Maintenance Technology Toolkit that others can leverage as they roll out deployments in their DOTs.

Expectations of each Working Group meetings include:

1. Regularly scheduled meetings (rather than adhoc): every quarter at a minimum scheduled in calendar year (CY) 1Q
2. Membership of WG confirmed 1Q, including lead of WG
3. Anticipated yearly goals: 1-3 goals per year to be shared in CY1Q
4. Update with TAC at end of every quarter

These working groups include:

- Pre-Deployment fundamentals

Early discussions in the DOTs, program planning, specifications, procurement

- Deployment: Systems Engineering and Integration
    - Operations plan
    - Training
    - Program assessment
- Outreach: presentations, off site meetings, website etc.
    - DOT operations outreach regarding program
    - AMT Pool Fund Outreach
- Legislative and Regulatory

The purpose of the working groups is to provide technical expertise, direction, and consensus to the pool fund.

- Pre-Deployment Working Group: Compile background information from each state's pre-deployment activities. Tools include: early background/visioning discussions/points with leadership, program vision or framework, procurement specifications, challenges to consider and plan for, etc.
- Deployment: Systems Engineering and Integration: Deployment logistics in a state's operation including: general operation planning for integration, concept of operations, or general operations plans, training plans and programming, and program assessment/success criteria for each state.
- Outreach and Education: Provide presentations and information on the pool fund at off site meetings, conferences, and other gatherings of transportation maintenance professionals. This group will review and propose various marketing materials when needed. This group will compile various presentations made available by each individual state for others to utilize the various material.
- Legislative and Regulatory: Recognizing that the various states have different regulatory and legislative environments, this working group will compile the legislative and regulatory environment in each state that has deployed an ATMA and summarize the challenges, lessons learned, and items to consider.

Appendix C – 2019 AMT Peer Exchange Meeting Minutes

Introduction

The October 22-23, 2019 Peer Exchange, hosted in Colorado, presented a 2-day information exchange and demonstration of Colorado's AMT. Some of the participants of this successful demonstration are depicted in Figure 4. The purpose of this Peer Exchange meeting is the sharing of technology and experiences gained from autonomous maintenance initiatives from each participating state. The AMT Pool Fund is currently administered by the CDOT under the DOT Pool Funding umbrella. The FHWA serves as a monitoring body, providing strategic and technical input to the Pool Fund.

Figure 4. AMT Pool Fund 2019 Peer Exchange Demonstration Attendees.

Overview of Current Deployments

1) The **Missouri Department of Transportation (MODOT)** (Chris Redline), while not a member, has been an advisor group to the Pool Fund. They have worked through several stages of AMT deployment and were willing to share their experiences with the participants. With approximately 30 injuries per year, the desire to eliminate injury in the rear protective vehicle during highway maintenance, Missouri initiated their development in 2017 as well. They also contracted with Kratos for the AMTA technology outfitting dump trucks. Their May 2019 testing included verification and 32 hours of testing with the intent of 250 live work hours of work zone testing. Issues corrected to pass initial testing are captured in The MODOT system required functionalities consisting of leader-follower system – rear truck mounted attenuator (TMA) unmanned; ability to follow at various distances up to 1,500 feet; capability for pause and catch up; can function in short durations in environments where GPS is denied; arrow boards and turn signals must be synced.

Challenges their system cannot overcome are 1) platooning the trucks to be at highway speeds, 2) following through traffic signals and intersections, and 3) driving laterally offset from the lead vehicle. MODOT's system can use GPS or inertial systems for navigation. Several issues identified during the initial testing were solved to finish the 32-hour testing. Kratos upgrades included upgrades of the GPS card to garner 2.5x the number of satellites contacted, the GPS antenna upgrade to amplify the GPS, and a roof-mounted warning LIDAR. Missouri University Science & Technology (S&T) is their academic partner. Initial deployment is expected in 2020-2021.

2) **<u>California's Caltrans Division of Maintenance (Caltrans)</u>** (Theresa Drum) presented the status of California's AMT adoption. Most crashes of concern involve its striping operations which typically have no fatalities. In 2017, after seeing Colorado's AMT efforts, Caltrans started their own program using test Level 2 attenuators. California currently is not allowed to have an autonomous vehicle on its roads. The University of California - Davis is its academic partner. Caltrans is also developing a classroom and hands-on training program for their operators.

Figure 5. Caltrans AMT Vehicle.

3) **<u>Colorado's Department of Transportation (CDOT)</u>** (Tyler Weldon, David Reeves, Ashley Nylen) presented an update on their program showing an overview of technology development, AMTA task force creation, Pool Fund request, and project vision. As many obstacles exist in getting this technology on the highways, a clear vision has been valuable. Approximately 110 highway test miles of striping operations, through June 2019, were logged. After testing the first generation of the Kratos system, Colorado has the second generation (August 2019), a major upgrade of the AMTA under test now with a new paint truck. System upgrades include cybersecurity, side view sensors, improved cameras, improved user interface and vehicle to vehicle communication, data storage, external human-machine interface (E-HMI), A-stop, backup navigation, and operation in GPS denied mode. An anomaly in this testing

was that the truck radio had to be turned down from 30 watts to 5 watts. CDOT continues to integrate its experiences and feedback into the Pool Fund and the AMT working groups.

Figure 6. CDOT's Paint Truck with AMTA Vehicle.

4) **<u>Minnesota's Department of Transportation (MnDot)</u>** (Rashmi Brewer) briefed regarding their goals and status with procurement and delivery for summer maintenance efforts. Kratos is also the industrial supplier for this system that is being retrofitted to an existing MnDOT truck. Project goals are to 1) improve worker safety with automation, 2) demonstrate technology to support policy and educate the public on worker safety technology, 3) learn from user feedback to improve technology and work zone safety, 4) identify how technology can be used to improve operations, and 5) learn how DOTs can use technology and share best practices with other users. MnDOT recommends identifying procurement needs and delivery considerations, such as transport, insurance, schedule, and determining inspection requirements on AMT components upon delivery and integration.

Figure 7. MnDOT AMT Project.

Research Highlights

1) **<u>Work Zone Management Program: Work Zone Data Initiative (WZDI)</u>**

Todd Peterson, US DOT FHWA, presented WZDI, a project within the Work Zone Management Program. The purpose of the WZDI was to create consistent language for communication work zone activity data (WZAD) across organizational boundaries and through project lifecycles. Looking at a work zone from a data management standpoint can contribute to more data-driven decisions, workflows, integration of consistent reliable information on work zone activities. This becomes more critical as emerging technology and associated potential risk can occur. Trying to manage the transition of this information into a functional data base will be challenging. Work zone data has historically been static. With this new initiative, dynamic ephemeral data will be collected from work zone planning, construction and maintenance functions, real time system management and traveler information, safety and mobility, law enforcement and emergency service providers, and CAV hardware. Challenges to adoption include resource constraints, commitment to broader standards, difficulty in developing scalable applications and supporting hardware. The Work Zone Data System (WZDS) draft architecture showed data flows between numerous systems components. Components of the WZDI include understanding the state of practice now, compiling a framework and data dictionary, and using pilots to refine the practice. The Work Zone Data Exchange will be used to collect and manage this data. For the AMT applications, WZDI would like to build out use case for data generation for mobile WZ operations, have a WZDI Pilot state generate WZDx feed from AMT-derived data, and leverage an AMT application for a case study. Demonstration grants of approximately $200,000 for 12 awards has been made available. See slides in Appendix B.

2) **<u>Using AMT Vehicle Data to Improve AV Integration</u>**

Dr. Steve Simske, Colorado State University (CSU) Systems Engineering Department, explained ways that CDOT's data program could be used to identify missing persons, for human trafficking search, suggested alternate routes for ongoing traffic, to assess the impact of CDOT repair, replacement and congestion pricing processes on retail traffic, and to identify efficient route times for non-time critical shipments. He stated that coordinating data-in-motion from drones or autonomous vehicles could assist first responders, enhance safety, and mobility. The information from AMTAs could also be used to improve AV integration into the transportation system. A foundation for utilizing AMT data can be used to solve future AV rerouting suggestions, real-time transportation efficiency services, and best practices for roadside communication to alert human operators of likely automation reliability issues in work zones.

3) **<u>Evaluating Human Automated Maintenance Vehicle Interaction for Improved Safety and Long-Term Trust</u>**

Dr. Erika Miller, CSU Engineering Department, presented planned work on a Pool Funded project with work zone safety as a critical concern. From a human standpoint, it is "literally someone's job to drive a track that exists to get collided with...". In operating condition, 100 feet is the recommended shadow vehicle spacing when operating below 45 mph. At 10 mph, this equates to a 6.8 second gap and, at 20 mph, it equates to a 3.4 second gap. Dr. Miller's project is to explore human automated vehicle interaction and human trust in the system in adoption and adaption. The study will identify gaps in knowledge aimed at training needs and best practices.

4) **<u>Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts at Missouri S&T</u>**

Dr. Xianbiao (XB) Hu, Missouri University of Science and Technology, discussed his research highlights at Missouri University S&T with MoDOT's Leader-follower AMTA system. His work technically supports the Kratos and MoDOT project and includes an AMT Pool Fund project on statistical analysis of AMTA system testing and quantification of AMTA impact on traffic operations. A system test on a controlled roadway included a test plan with 32 test cases, including parameters of follow distance accuracy, lane accuracy, obstacle detection, and communication loss. In conjunction with this work, a grant to AMTA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts has been funded by the USDOT.

Figure 8. MoDOT and Missouri S&T AMT Vehicles.

5) **<u>Highways England – Maynard Factor</u>**

The Kratos Unmanned Systems Division presented the Highways England Deployment of the Autonomous Impact Protection Vehicle (AIPV) that was analogous to the AMTA program. England's program encompassed three phases: operation at Goodword, deployment on M4 highway, and unmanned operation. The deployment occurred with a baseline configuration in 2017. Initial deployment on M3 highways included an operation on 1,000+ miles. Necessary improvements from the baseline were a robust user interface, V2V Hardening for radio frequency (RF) interference, and robust obstacle detection to support cone lanes. Resolution of issues during testing resulted in GPS card upgrade, antenna upgrade, configuration setting adjustment, resolving RF interference with datalink configuration modification, and antenna placement. The program moved into Phase 2 in November 2019. All issues identified during testing have been retrofitted into an existing system by CDOT, MoDOT, Caltrans, and MnDOT.

Figure 9. Kratos Highways England AMT.

6) **<u>Vehicle Demonstration – CSU Christman Field</u>**

CDOT demonstrated the new paint striping vehicle, with its AMT following vehicle, at CSU's Christman Field, a former aircraft landing area. The interaction between the vehicles was successfully demonstrated for participants. Opportunities for experience in both the leader and follower vehicles provided participants with real time experience in an operations environment.

Key Takeaways

A panel on Current Deployment Lessons Learned was moderated by Ashley Nylen (CDOT), with Panel members: Theresa Drum (Caltrans), Tyler Weldon (CDOT), Rashmi Brewer (MnDOT), and via Zoom James Shannon (MoDOT). The group brought together lessons learned from all parties regarding the things that worked well, and those that did not work so well, as key insights. The topics included: How to Procure, Daily Operation Integration, and Training Program and Materials.

1) How to Procurement
   - Determine which organization in your state is funding the AMT – Who will purchase the technology – fleet vs Research? Better buy-in if through the fleet.
   - Make sure you understand your State Purchasing Process.
   - Set up a service agreement even if you do not use it.
   - The choice of a leader vehicle is very important.
   - Involve users early in the process to promote buy in.
   - Make sure you have buy in from the Division of Equipment early by their participation in leader vehicle selection.
   - Know who your fleet manager is early and garner his/her participation in creating specifications.
   - Make an ATMA leader kit. Include how to do incoming inspection and how to package for storage.
2) Daily Operation Integration
   - Do you have a standard configuration maintenance truck?
   - Know the Standard Operations Plan for your state (following distance, etc.).
   - Determine turning radius of truck as an input on where to test AMT technology.
   - Look for a university partner in your state to help.
   - Identify needs from all stakeholders, particularly existing ones, if retrofitting a vehicle.
   - In certain states, autonomous vehicles may currently be illegal. Determine if you will need legislative changes.
   - Don not remove radios to insert a Kratos system. Find another way. Operators want their radios.
   - When the AMTA Leader Kit or Follower Kit is received, know who will inspect it and store it.
   - Learn what external hardware needs protection – cameras, external antennas.
   - Keep a risk and mitigation register and update it at least every 2 months.
3) Testing
   - Keep the Kratos user manual in the vehicle.

- Understand what you want to share as data.
- Test in scenarios.
- Target summer conditions for testing.
- Make sure maintenance people are on site to fix trucks when they break down during training and testing.
- Elaborate on a field application! Who is covering staging? Who rolls out standard CONOPS? Lay out operational domains; think of it as a long trailer.
- Have a verification procedure for recalibration. Make certain how often a system needs re-calibration and what cues are needed for recalibration.
- Lessons learned from the initial testing are to ensure that dependable lead vehicles are used in your testing.
- Allow adequate time for the calibration of the Kratos NextGen system.
- Operation improvements are much more user friendly with “pause mode”.
- Hose out vehicle periodically.

4) Training
   - Familiarize crews with the operation of AMT. Answer all questions. Reduce skeptical thinking with information from other users and operators.
   - Train operators kinesthetically – add slides for reference.
   - Make it a multidisciplinary effort, including Maintenance and Computer (CAV).

Future Research

The meeting concluded with a discussion of future research areas that the members wish to explore and the revamping of our Pool Fund working groups to promote participation and preparation of Pool Fund deliverables. Suggested future research areas that were discussed included:

- How often in operation does calibration need to occur?
- A common verification procedure
- Common validation with users and equipment vendors
- Standard CONOPS
- Cybersecurity
- Crash reenactment
- Crash protocol
- Tandem plowing
- Remotely controlled start for follower
- Keeping the gap technology

Conclusion

A high-level summary of the major findings and discussion of the AMT Pool Fund Annual Meeting 2019 are noted below:

- Immense productive value of meeting in person to discuss various deployment efforts and challenges within various states.

- Substantive discussion about each ATMA program in various state DOTs. Some featured the ATMA program "homed" in the maintenance and operations division, others included it in the intelligent transportation systems divisions, while some featured the program as part of their research branch.
- Extensive discussion focused on working toward building a comprehensive toolkit that can be utilized by various states for all elements from initial planning, messaging to leadership, procurement, regulation and legislation challenges, pre-deployment, deployment, testing, validation, operational procedures, etc.
- Identifying metrics for the success of each state's program and how that can be messaged.
- The group discussed work groups and agreed to update them over the coming year so they are more relevant to the main needs of Pool Fund members. The group agreed that things have changed significantly since the original Pool Fund was formed, and it should work to update the work groups to create meaningful knowledge and tools that can be used by the members.

Appendix D - 2020 AMT Peer Exchange Meeting Minutes

Annual AMT virtual Peer Exchange was held on October 26, 2020. Detailed contents, including current deployment, Research Projects Update, Group Updates, financial status, and discussion, are listed as below.

1) Current Deployment

<u>Caltrans 2020 ATMA Update</u>

- Overview ATMA Research Project
    - Background: California has experienced several attenuator hits during striping, sweeping, and raised pavement markers - motivation to pursue the technology. Project features a partnership with Maintenance, Equipment, Research and Innovation. Initiated an interagency agreement with AHMCT at UC Davis.
        - Key Component: Development of a solid spec
        - AHMCT worked with Royal and generated a PO; UC Davis purchased using research funds
    - Next Steps:
        - Design Review
        - Inspections
        - Designation of Leader Vehicle and Operators to train:
            - Time involved is potential challenge
            - Mutual decision to install leader kit on an AHMCT vehicle (put on a pickup truck)
        - Test Plan
        - Training schedule
    - Challenges:
        - Delivery delayed
        - Royal removed the radio to accommodate E-stop
            - If they want buy-in from field maintenance, there needs to be a radio in it
            - Colorado resolved this with an installation above the dash
        - Dead Reckoning under the UC Davis overpass ATMA transitioned back to GPS based navigation approximately 75 yards past the overpass - it would make an abrupt left or right turn off the road
        - After KRATOS made the upgrades/adjustments, the ATMA had to was tested
        - Obstacle Detection Performance
        - Operation when OCU is powered OFF while not in operation

<u>CODOT 2020 ATMA Update</u>

- Background
    - Oct 2017: CDOT submitted a request for the ATMA

    - Summer 2017: CDOT completed validation testing and operator training
    - May 2018: Autonomous Mobility Task Force Approved CDOT's request on roads with AADT of 2,500
    - Oct 2019: Technology System Upgrade
    - Jan 2020: Task Force approval program expansion
- Lessons Learned:
    - Transition to a new lead operator - importance of having a crew member at champion level
    - Technology challenges continue to arise (GPS card issue, follow up issues, etc.)
    - Procurement challenges for second ATMA purchase
        - Rates
        - Service agreement
        - Lack of comparable data - importance of compiling quotes/contracts in toolkit
    - COVID restrictions delayed start and delayed identification of technology challenges. Solution - still use the ATMA with operator behind wheel to gain trust and understanding of the system.
- Questions/Discussion:
    - (Theresa Drum, CalTrans) inquired about status of CDOT's deployment on volume of roadways. (Ashley Nylen, CDOT) we presented to our Autonomous Mobility Task Force, in January of this year, and elaborated on accomplishments to date and walked through trainings and tests and asked for higher AADT (5,000 vehicles)

<u>MODOT 2020 ATMA Update</u>

- Background:
    - TMA crashes are at an all-time high during 2020 YTD
- Goal: Eliminate operator injuries
- Timeline:
    - May 2017 RFP
    - March 2018 - Contract executed with Kratos
    - June 2019 - Began 250 Live work zone test
    - June 2019 - Suspended testing
    - Fall 2019 - Upgraded system
    - March 202 - COVID suspended project
    - August 2020 - Plan developed to resume testing
- Functionality:
    - What can it do:
        - Leader-follower system
        - Follow at various distances up to 1,500'
        - Pause and catch up
        - Function in short duration GPS denied environment

            - Arrow board and turn signals are in synce
    - Performance specs
        - Frontal collision avoidance
        - E-stop and failsafe systems
        - Require follow distance adjustment
        - Need pause and catch up unction
        - Coordinate arrow board and turn signal
        - Need vehicle take over function
        - Operator friendly user interface
    - Contract with Kratos Defense and Security Solutions
        - $550k to retrofit two MoDOT trucks
        - No payment until performs
    - 32-hour testing April/May 2019
        - State fairgrounds
        - V2V dropouts
        - Radar timeout E-stop
        - Entering DR too often
        - Veered off-course
    - 250-hour testing June 2019
        - Live work zones on divided highways
        - Location accuracy issues under bridges
        - Accuracy issues GPS degradation/DR/follow
        - Kratos Solutions
            - GPS upgrade
            - GPS antenna upgrade
            - Roof mounted warning LIDAR
    - Questions/Discussion:
        - (Ashley Nylen, CDOT) Is 32-hour testing state statute or procurement law? (Chris) The team developed the testing, no statues, wonder what the best way to procure equipment and ensure its safe, so MoDOT came up with 32- and 250-hour testing

<u>VTTI ATMA Project Overview</u>

- Automated TMA Program:
    - Background:
        - Virginia TMA Crash Experience
            - 121 crashes from 2011-2014 involving TMAs in Northern VA
            - Majority in traffic dense districts
            - Mobility operations provide less certainty, consistency, and diverse expectations
    - Current Project Overview:

        - Consortia, formed in 2018, co-funded development of ATMA prototype
        - Initial design goals:
            - Freeway operations, HMI, GPS-denied operation, robust safety features
        - Multi-phase program:
            - Phase 1: Design, build, and demo leader-follower ATMA system
            - Phase 2: Performance evaluation and tech assessment
            - Phase 3: Testing on public roadways in real operations
        - Targeted Outcome:
            - IP package suitable for commercialization
    - Leader-Follower system components
        - LV Features
            - AVRP
              HMI tablet
            - V2V communications
            - GPS with RTK
            - IMU
            - SLAM map generator
            - LIDAR (2)
        - FV Features
            - AVRP system
            - HMI tablet
            - V2B communication
            - GPS with RTK
            - IMU
            - SLAM map interpretation
            - LIDAR (3)
            - Forward radar
            - Rear radar
            - Forward camera
            - Four external e-stop plungers
            - Forward e-stop bar
            - Internal revert to factory E-stop
            - Remote wireless E-stop
            - VTTI data acquisition system
        - V2V Transmission Content
            - System and position status
            - Ter
            - GPS path information
            - SLAM map features
            - Operation modes

            - Commanded headway
            - Waypoint management (hold/release)
            - Object detection in safety zone
    - Control Features:
        - Internal human machine interface controls
            - Set following distances between 50 feet and 400 feet
            - Lt lateral offsets
            - Execute lead hold, follow hold, and release
            - Object detection temp hold and release
            - Right, center, and left tracking modes
            - Establish remote operation and terminate
        - External human machine interface
            - Lights and audio signaling intent and status
            - FMVSS compliant
    - External Communication
        - External HMI components will communicate intended status to personnel outside the vehicle
        - Various colors, motion patterns, and sounds indicate state of system
        - The external aspects of ATMA HMI offer many research questions and will be the focus of a student dissertation
    - Next Steps:
        - Develop consortia consensus, Phase 2 performance tests, Phase 3 transition plan
    - Questions:
        - Who led the development of consortiums?
            - TransUrban surveyed what was available at the time and wanted to know how to proceed
            - Spoke to VTTI and partnered with VDOT
        - Can tech be used for automated tractors and mowers?
            - The tech is probably there, if correct applications are applied, but have not looked into them as potential markets
        - Is all design and installation done in-house at VTTI?
            - Everything is done in-house - design documentation, upkeep and maintenance are all done in-house
        - Are there any cybersecurity requirements for the communication between vehicles?
            - Communication between vehicles is not fully locked down and that is a next phase activity
            - Have experience working cybersecurity issues and are working security functions through the Commonwealth Cyber Security Initiative

2) Research Projects Update

ATMA Research Progress at CSU

- Evaluating the Human Automated Maintenance Heckle Interaction for Improved Safety and Facilitating Long Term Trust
  - Evaluate how work zone workers perceive the usefulness and capability of ATMA tech
  - Automation can undermine safety and project success if not operated correctly
  - Identify the disconnect between operators and tech; and how this relates to training
- Methodology:
  - Online survey
    - Demographics relating to the job
    - Experience with the ATMA
    - Trust in the ATMA
    - Automation HMIs
    - Operating capabilities
  - 13 responses
    - 12 CDOT, 1 CalTrans
- Survey:
  - Experience Level
  - ATMA Design
    - Neutral:
      - Automation is frustrating to use
      - Display warns about too many obstacles
    - Agree:
      - E-stop buttons on lead and follow in a good location to press during an emergency
      - Information on lead HMI clear and understandable
      - Workload reasonable for startup and monitoring HMI
  - Safety and Trust
    - Disagree:
      - Automation better then own driving skills
      - Automation will reduce frequency of crashes
      - Automation will reduce duration of project
    - Agree:
      - Overall TMA improvement compared to human driving
      - Automation will reduce severity of crash
  - Importance of Operating Procedures
  - Confidence in Automation
  - Operating Limitations

- Summary
  - Workers reported a positive acceptance of the ATMA tech
    - Reduce severity of crash
    - Reasonable workload for operating
    - Overall trust in automation reliability
  - Concerns related to trust under poor visibility and dense traffic

ATMA Research Progress at Missouri S&T

- FY 20 AMT Pool Fund Research Progress
  - Motivation: MUTCD did not address ATMA/AIPV type of mobile and slow operation
  - Goal: model and identify operation domain of ATMA vehicles
  - Tasks:
    - Assess ATMAs impact on traffic operation with traffic flow modeling and analyses
    - Collect field data to analyze the key characteristics of APIV
    - Calibrate AMTA model -general traffic mixed traffic flow
    - Develop simulation models for ATMA impact analyses
    - Document methods and results
    - Reporting
  - Timeline:
    - Kickoff – 10/14/2019
    - Expires – 12/31/2022
- Other research progress
  - Development of autonomous trucks operation guidelines and driver training process
    - ATMA LT-Driver behavior differs from general traffic
    - Technical approach
      - Key decision-making point analysis
      - Traffic flow modeling
      - Data collection
      - Model calibration
      - Reporting
  - Optimization of transportation infrastructure system performance with autonomous maintenance technology in work zones
- FY21 AMT Pool Fund Research Plan
  - Systematic documentation for autonomous maintenance technology promotion and deployment
    - System Description Document
    - System Test Manual

- Concept of Operation
- Development Needs Document
- ATMA User Manual Updates

3) Group Updates

Policy and Legislative Working Group (MnDOT)

- Kristin White presented a brief overview of the efforts that the Policy and Legislative Working Group have been focusing on over the last few months. Would like to use today as a working session to better understand the current climate of legislative policy in each state and the direction in which they are headed.
- Kristin conducted an interactive MentiMeter activity with the group to understand the policies, procedures in each state, as well as the items, activities, and resources that would help states overcome or advance any policy of legislative issues they have experienced. Full mentimeter results are available here.
- Kristin's team has compiled a summary of CAV Legislation. Kristin asked the group to review the information recorded for each state and reach out to Kristin with any edits or follow up on the information noted.

4) Financial Status

- 5380-19-02: Evaluation the Human-Automated Maintenance Vehicle for Improved Safety and Facilitating Long Term Trust - nearing completion, as noted in presentation
- 5380-19-03: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts - more than 80% complete, need additional data, as noted in presentation
- ATMA Tabletop Research Projects (two proposals)
    - 5380-20-04: ATMA Tabletop Planning and Facilitation Update by Tyler Weldon (Approved by pool fund March 2020)
- 5380-20-05: ATMA ATMA Cybersecurity Complement, Dr. Jeremy Daily, CSU (Approved by Pool Fund June 2019 via survey results - noted in August 2020 minutes)

5) Discussion

Navigating social distancing in maintenance operations – tactics/processes/procedures implemented by states, what has worked well, what has not worked well, identifies current challenges/gaps, etc.

- California: has either eliminated need for certain operations or has purchased handheld battery operator cleaners for vehicles. Supplies are limited, which has been challenging.
- Minnesota: Also trying to limit the number of people in vehicles and making sure there is only one person in a vehicle, or putting someone in a back seat.

- CDOT: Looking for options for those in quarantine. Perhaps there is remote learning that can make their time more valuable, etc., while they are physically unable to be in the vehicle.

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