STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR-0003 (REV 04/2024)

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA26-4159	N/A	N/A

4. TITLE AND SUBTITLE Caltrans Field Trials of the Intelligent Truck-Mounted Attenuator (ITMA)	5. REPORT DATE January 30, 2026
	6. PERFORMING ORGANIZATION CODE AHMCT Research Center, UC Davis
7. AUTHOR Dave Torick, Dinesh Kumar, Anh Duong, & Shima Nazari	8. PERFORMING ORGANIZATION REPORT NO. UCD-ARR-26-01-30-01
9. PERFORMING ORGANIZATION NAME AND ADDRESS AHMCT Research Center UCD Dept. of Mechanical & Aerospace Engineering Davis, California 95616-5294	10. WORK UNIT NUMBER N/A
	11. CONTRACT OR GRANT NUMBER 65A0749 Task 4159
12. SPONSORING AGENCY AND ADDRESS California Department of Transportation P.O. Box 942873, MS #83 Sacramento, CA 94273-0001	13. TYPE OF REPORT AND PERIOD COVERED Final Report January 2023 – October 2025
	14. SPONSORING AGENCY CODE Caltrans

15. SUPPLEMENTARY NOTES

N/A

16. ABSTRACT

Truck-mounted attenuator (TMA) operators are exposed to traffic-related hazards during Caltrans maintenance operations. To help reduce this exposure, the Advanced Highway Maintenance and Construction Technology Research Center (AHMCT), in partnership with Caltrans, conducted controlled public-road field trials of the Intelligent Truck-Mounted Attenuator (ITMA). The ITMA is a two-vehicle system in which a leader vehicle guides a semi- or fully intelligent follower vehicle equipped with a TMA. Building on prior closed-course evaluations, this project prepared the system for field evaluation through hardware upgrades, communications improvements, interface enhancements, and operator training. The ITMA was evaluated during striping, sweeping, and raised pavement marker operations in both semi-intelligent and fully intelligent modes. Field trials demonstrated consistent following behavior, predictable emergency stopping, and stable performance in varied roadway and GPS-challenged environments. Operator feedback indicated positive acceptance and increasing familiarity with system operation. The results support the continued evaluation of the ITMA and inform future decisions regarding its potential operational use.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Intelligent Truck-Mounted Attenuator (ITMA); Autonomous Truck-Mounted Attenuator (ATMA); Truck-Mounted Attenuator (TMA); work zone safety; highway maintenance operations; autonomous maintenance vehicles; leader–follower vehicle systems; public-road field trials; GPS-denied navigation;	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Unclassified	45	N/A

DISCLAIMER

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Caltrans Field Trials of the Intelligent Truck-Mounted Attenuator (ITMA)

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Report Number: CA26-4159
AHMCT Research Report: UCD-ARR-26-01-30-01
Final Report of Contract: 65A0749 Task 4159

DATE: January 30, 2026

California Department of Transportation

Division of Research, Innovation and System Information

Executive Summary

The California Department of Transportation (Caltrans) is moving to reduce worker exposure to high-speed traffic in maintenance zones. Truck-mounted attenuator (TMAs) offer protection, but errant vehicles still create risks. To enhance safety, researchers at the Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) partnered with Caltrans to advance the intelligent truck-mounted attenuator (ITMA), a two-vehicle system in which a leader vehicle (LV) guides a semi- or fully intelligent follower vehicle (FV). The long-term goal is to remove the FV operator entirely.

Expanding on earlier closed-course tests, this project conducted controlled field trials on public roads. AHMCT personnel upgraded hardware, improved communications and interfaces, trained crews, and supported deployments in striping, sweeping, and raised-pavement-marker operations. Testing included both semi-intelligent mode and fully intelligent mode with the operator moved to the LV. The ITMA demonstrated reliable lane tracking, stable following, effective emergency stops, and strong operator acceptance. Improvements to cameras, diagnostics, radios, LiDAR, and GPS resolved early issues. The system performed well across open highways and areas with limited GPS, and operator confidence increased. The findings confirm the ITMA is technically viable for operational use with continued refinement and training.

Problem, Need, and Purpose of Research

Caltrans maintenance crews face ongoing risks from inattentive or speeding motorists who enter work zones or strike TMA vehicles. Earlier research showed an intelligent follower system could remove operators from this danger, but real-world validation was still needed. The key challenge was in determining how to integrate the ITMA safely into active operations while ensuring work-zone safety, usability, and system reliability. Caltrans required controlled field trials to verify system behavior, measure operator acceptance, evaluate performance in real world traffic and terrain, and identify needed improvements for statewide use of the ITMA.

Project goals were to prepare the ITMA for public-road testing through hardware updates, train staff to operate it safely, conduct semi- and fully intelligent field trials within real maintenance workflows, and document performance, operator experiences, challenges, and corrective actions. The results may be used to inform Caltrans' decisions on broader ITMA deployment and support its goals of improving safety, efficiency, and reducing worker exposure to high-risk conditions.

Overview of the Work and Methodology

AHMCT prepared and validated the ITMA system for controlled public-road use by updating both vehicles with improved communications, visibility, diagnostics, and key mechanical and electrical repairs. Training materials were revised to match Caltrans procedures, and multi-day sessions were hosted to provide maintenance crews with classroom and hands-on instruction. The training ended with supervised public-road exercises.

The system was first deployed in semi-intelligent mode during striping, sweeping, and raised pavement marker (RPM) operations, allowing documentation of lane-tracking accuracy, system alerts, obstacle responses, and operator feedback. After multi-agency approval, testing progressed to fully intelligent mode with the safety operator moved to the LV. AHMCT supported these deployments and conducted focused tests to refine LiDAR, dead-reckoning, and GPS-denied performance, confirming reliable operation across varied roadway conditions.

Major Results and Recommendations

The ITMA system demonstrated strong potential for operational deployment, validated through a full lifecycle of vehicle updates, operator training, semi-intelligent operation, and fully intelligent field operations in support of typical maintenance operations that occur during Caltrans moving closures.

The following is a summary of the major results:

- Integrated smoothly into striping, sweeping, and RPM operations.
- Improved operator visibility and awareness with the upgraded display and cameras.
- Provided reliable following across varied terrain and roadway types.
- A-Stops behaved predictably and were recoverable from the LV.
- Mechanical, GPS, and communication repairs restored stable system performance.
- Detected most overhead structures accurately after tuning.
- Operators reported high acceptance and growing confidence.

The following is a summary of recommendations:

- Expand statewide training and crew resource management.
- Conduct additional testing in complex environments with unreliable GPS.
- Develop hybrid perception/navigation methods to reduce GPS dependence.
- Increase maintenance and repair support across districts
- Continue ergonomic and interface improvements based on operator feedback.

- Move toward broader deployment to support Caltrans' goal of removing FV operators.
- Require vendors to enable remote TMA deployment/stowing from the LV.

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Acronyms and Abbreviations

Acronym	Definition
AHMCT	Advanced Highway Maintenance and Construction Technology Research Center
BIT	Basic Inspection of Terminals
CalSTA	California State Transportation Agency
Caltrans	California Department of Transportation
DR	Dead Reckoning
DOT	Department of Transportation
DRISI	Caltrans Division of Research, Innovation and System Information
DVR	Digital Video Recorder
FV	Follower Vehicle
GUI	Graphical User Interface
ITMA	Intelligent Truck-Mounted Attenuator
LiDAR	Light Detection and Ranging
LV	Leader Vehicle
META	Maintenance Equipment Training Academy
PIO	Public Information Officer
RPM	Raised Pavement Marker
TMA	Truck-Mounted Attenuator

Acknowledgments

The authors would like to thank the California Department of Transportation (Caltrans) for their support, especially the District 11 East Region Maintenance team. Al Herrera, Jimmie Smith, Mario Escobar, and Ruben Ayala helped throughout the field trials, often sharing practical advice, suggestions, and on-site support that made a real difference.

Throughout this project maintenance workers and operators provided feedback, assisted in troubleshooting, and worked tirelessly to become familiar and competent with the technology. These Caltrans employees have provided a great benefit to the project, and we cherish our time and discussions with them.

We also appreciate the help from Larry Schwartz, Paul Featherstone, and Bobby Cooper with the Division of Maintenance. Their feedback, logistical support, and general guidance were important in getting the field trials completed safely and successfully. Their focus on worker safety is clear and has been a great benefit to the project.

Thanks as well to Tawney Brennfleck and Charina Guarino from DRISI, who helped smooth out project management issues and kept things moving. We also want to acknowledge Joe Horton, Chief of the Office of Safety Innovation and Cooperative Research, for his long-term vision and continued support as this technology moves closer to full deployment.

We are grateful for the hard work of the AHMCT team, whose day-to-day efforts made this project possible.

Finally, we want to recognize former project panel members who have since retired or moved on to other roles: Teresa Drum, Spencer Jennings, Juan Araya, Hamid Ikram, Ty Lasky, and Duann Bennett. Their early contributions helped set the foundation for this work.

Chapter 1: Introduction

Problem

The California Department of Transportation (Caltrans) would like to remove the operator of the truck-mounted attenuator (TMA) from the vehicle, which would lead to significant reductions in operator injuries due to public vehicle impacts with TMA vehicles. An intelligent TMA (ITMA), shown in Figure 1.1, that achieves this objective was successfully evaluated on closed test sites in previous research, including testing on a closed segment of State Route 905 (SR905).[1] To proceed towards deployment of the ITMA for regular Caltrans operations, controlled field trials on public roads with and without an ITMA safety operator in the follower vehicle are essential.

Figure 1.1: Vehicles in the ITMA system

[1] D.A. Bennett and T.A. Lasky, "Evaluation of Autonomous TMA Trucks for Use in Caltrans' Operations," AHMCT Research Center, UCD-ARR-21-12-31-03, December 2021.

Objectives

This project expanded the ITMA testing trials from closed test facilities to controlled field trials on public roadways. The Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) team collaborated with Caltrans to develop testing scenarios, updated relevant training materials, provided staff training, and supported onsite field trials and training activities. In addition, the team observed and documented system performance during the field trials and is reporting all test results to Caltrans in this document.

Scope

AHMCT worked with Caltrans to advance the implementation and evaluation of the ITMA system. Building on knowledge gained from prior ITMA research, the project refined both the leader vehicle (LV) and follower vehicle (FV) platforms to enhance system performance and operational reliability. AHMCT updated existing training materials and provided instruction to the designated Caltrans trainer to support integration of the ITMA system into maintenance crew operations. The research team also assisted in training personnel from the Maintenance Equipment Training Academy (META) and district maintenance crews in preparation for ITMA field testing.

Figure 1.2: ITMA system defining the leader and follower vehicles

In addition to training activities, AHMCT developed an initial test plan for road-crew training and supported district crews throughout field trials by addressing maintenance needs and resolving technical issues as they arose. To assess user experience and the effectiveness of ITMA training, the researchers created and administered an operator survey designed to gather feedback on system operation and adoption. The project further supported Caltrans in the review and approval process for transitioning the safety operator to the LV.

Finally, AHMCT participated in and evaluated a final series of field trials to ensure the ITMA system was thoroughly tested under representative operational conditions.

Background

AHMCT conducted this project to determine whether limited, monitored field trials on remote public roadways could be safely performed using the ITMA system. The low traffic volumes typical of rural roadways provided a reduced-risk environment for assessing the system's performance under real-world conditions.

Since the safety and performance behaviors of the ITMA system had already been demonstrated at closed test sites, the next phase of feasibility testing shifted to California's public roads. The AHMCT team anticipated that a substantial portion of the field trials would occur on remote public roadways with a safety operator positioned in the ITMA FV. Once Caltrans received the necessary authorization, final field trials proceeded with the safety operator relocated to the LV under closely monitored conditions.

The field trials occurred at remote, Caltrans-operated locations in the East Region of District 11 in Imperial County. In support of these activities, AHMCT provided train-the-trainer instruction, operator training, on-site and remote field support during trials, site visits, post-trial operator surveys, and a final evaluation of system performance and suitability, including operator acceptance and identification of any operational concerns.

Literature

The AHMCT team conducted the field trials based on the methods and findings established in the previous phase of the research and made necessary changes.

Research Methodology

The AHMCT team approached the research by performing the following tasks:

- Improve both LV and FV based on work and knowledge from previous ITMA project.
- Update training materials and trained the Caltrans trainer for ITMA adoption by a Caltrans maintenance crew.
- Provided training of Maintenance Equipment Training Academy (META) and district personnel for ITMA field tests.
- Develop training scenarios for road crew training.

- Support district road crews with maintenance and technical issues during field trials.
- Develop and administer a survey for the operators to understand their opinions and thoughts for the training and adoption process.
- Support Caltrans in the successful approval process of moving the safety operator to the LV.
- Develop and participate in a final set of field trials.

Overview of Research Results and Benefits

The key deliverables of this project included:

- Updated vehicles to meet Caltrans operational needs.
- Developed training scenarios and updated training materials.
- Supported final field trials and training by traveling to the field trial district.
- Performed maintenance and repair as necessary to keep the vehicles and system operational.
- Observed and recorded performance of final field trials and reported results.

Chapter 2: Field Trials Preparation

The ITMA was previously used in Task 3265 when the two-truck system was evaluated on closed-to-the-public roadways and improvements were made to the system to allow it to better integrate with Caltrans maintenance operations. At the conclusion of the previous research task, there were several suggested items that needed to be addressed prior to field trials. This chapter summarizes those efforts as well as additional efforts that prepared the vehicles for field trials. This chapter also highlights the enhancements made to the training materials and the training activities necessary to prepare the operators for field trials.

Vehicle Updates

The AHMCT team made modifications to improve the ITMA system as well as troubleshoot existing problems, including:

- Add radio communication,
- Improve ergonomics while increasing safety operator situational awareness by adding an additional display and wireless camera,
- Add a remote modem for updates and troubleshooting, and
- Obtain a California Highway Patrol (CHP) inspection

Radio Communications

The LV and FV of the ITMA system were not integrated with normal Caltrans operations prior to this research project. Therefore, the standard two-way radio systems were installed by the contractor for District 11 East Region. The vehicles were delivered to El Centro two weeks prior to the first training event to ensure that they were ready for training. The radios were programmed in the same manner as other two-way radios used by District 11 and CHP. Utilizing the normal contractor and installing the standard radios allowed the operators to seamlessly use the radios to communicate with the entire set of vehicles during maintenance operations.

Modify Seat Changed to Add Display and Wireless Camera

During the previous research task, the safety operator seating and visibility in the LV were identified as major concerns for full deployment. Specifically, the vehicle's seating provided poor ergonomics for the safety operator as shown in Figure 2.2.

Figure 2.1: Previous vehicle seating demonstrated poor ergonomics for the safety operator

The tablet also provided limited visibility by only providing a view from the back of the lead vehicle, which did not allow the operator to see oncoming traffic beyond the FV. The systems' graphical user interface (GUI) full screen measured 8 ¾" × 5 ½" × 10 ¼" (width × height × diagonal), while the displayed image was only 4" × 2 3/8" × 5" (width × height × diagonal). Figure 2.2 shows the original GUI and the image from the rear facing camera on the LV. Changes to increase ergonomics and increase situational awareness were required prior to the start of field trials.

Figure 2.2: GUI in the LV with original camera view of the ITMA system

To address these concerns, the AHMCT team proposed the following changes:

- **LV Seating –** Replace the stationary seat with either a swivel seat or a rear-facing seat for active work zones.
- **GUI Improvements –** Install an additional camera system and a larger display.

The AHMCT team worked with the project panel for an alternative to a swivel or rear facing seat. A swivel seat would require mounting, approval, and potentially crash tests, which would have complicated the deployment process. Instead, a 10-inch display with multiple camera views was procured and installed in LV instead of a swivel seat and mounted above the existing GUI.

For the GUI improvements, the existing TMA cameras (Kohltech) were used with added wireless transmission capabilities. Figure **2.3** is an image of the additional 10-inch monitor that was installed in the LV while maintaining the current mobile digital video recorder (DVR) and 4G functionality of the existing camera system. Three camera views are now available to the safety operator: left rear view, right rear view, rear view from behind the truck.

Figure 2.3: **GUI in the LV with original camera view of the ITMA system**

Install Remote Modem

The previous research task occurred primarily at AHMCT's test track. Remote troubleshooting was performed by Kratos utilizing the Wi-Fi network that AHMCT owns. Since this current research task was primarily performed in District 11, AHMCT and Kratos worked together to install a cellular modem that both parties could utilize. This system allowed remote access without utilizing any Caltrans network, which proved beneficial throughout the project. The modem is only operational when the ignition switch is in the ON position and when the switch is closed as shown by the illuminated red switch in Figure 2.4.

Figure 2.4: Cellular modem installed in the back of the LV for remote communication with the ITMA system

CHP Inspection

In line with California Vehicle Code §34505.5 requirements, the regulated vehicle was subject to standard 90-day inspections to ensure continued safe operation throughout the project period. These inspections focused on key safety-critical components, including brake adjustment, brake system condition and potential leaks, steering and suspension systems, tires and wheels, and vehicle connecting devices such as fifth wheels and towing mechanisms. Motor carriers are required to document each inspection with positive identification of the vehicle, the date and nature of the inspection and any repairs performed, and a signature from an authorized representative certifying completion of all required work. All inspection records will be electronically retained for a minimum of two years. The 90-day inspections served as an essential element of the preventive maintenance program, ensuring that regulated vehicles remained mechanically sound and compliant. The FV received its first inspection in March of 2023 prior to its shipment to El Centro. The FV received subsequent inspections every 90 days at a vendor in El Centro for the duration of the research task.

Training Development and Delivery

The AHMCT team updated the training materials provided by Kratos with Caltrans acronyms and images that depicted Caltrans vehicles to ensure the operators would have training materials that matched the physical vehicles they would be using. In addition, the AHMCT team added a section on troubleshooting to the training materials. AHMCT also developed an agenda and hands-on training scenarios. These additions to training and the Kratos materials are summarized in this section.

Training Material Updates

The original training materials supplied to Caltrans and AHMCT were updated to reflect the latest GUI, hardware, and Caltrans vehicles. AHMCT and the project panel wanted to reduce any confusion by having the PowerPoint slides and user manual match the current system used by Caltrans. Caltrans also chose to change the abbreviation of the system to “ITMA” from “AIPV”, which was originally used in the manuals. These training materials have been shared with other states, such as the Pennsylvania Department of Transportation, who are beginning evaluation of this system.

AHMCT modified and added a troubleshooting manual to the training materials that were delivered to the training participants. During the training, a binder with the presentation, user manual, and trouble-shooting guide were given to each participant. An additional binder was placed into the LV and FV to act as a reference for the operators to refresh their knowledge and perform troubleshooting while operating the ITMA system.

Training Agenda

The original training delivered by Kratos on the previous research task involved two days of training. The first day was primarily classroom training, and the second day was primarily driving the vehicle in autonomous mode. AHMCT also modified the training to a four- to-five-day experience depending on the number of participants.

AHMCT and the project panel utilized think-pair-share activities from education research to create an active learning training experience. The training days were also split between in-class and hands-on training to allow the students to hear and see the technology: they would learn objectives in the classroom and then immediately go out to the vehicles to experience, use, and touch the technology. Figure 2.5 is the agenda for the first day of training, showing the balance between classroom and hands-on learning materials.

Training Agenda:

C- Classroom

TCE- Truck on closed to public roads (El Centro Maintenance facility)

TCC- Truck on closed to public roads (CHP Facility Calexico)

TO- Truck on open to public roads

Tuesday

6:00 – 7:00	Demo, ITMA Benefits, ITMA system overview (TC,C)
7:00 – 8:00	Leader Vehicle System Components (C, TCE)
8:00 – 9:00	User Interface (C,TCE)
9:00 – 10:00	Follower Vehicle System Components (C,TCE)
10:00 – 10:30	Lunch
10:30 – 11:30	Checklist and Rollout (TCE)
11:30 – 12:30	Key Operating Parameters (C)
12:30 – 1:30	Pre- shift Checklist & ITMA Safety Information (C,TCE)
1:30 – 1:45	Debrief, big questions?(C)

Figure 2.5: One day sample of ITMA training agenda

Training Scenarios

AHMCT and the project panel determined that realistic training experiences that involved real-world scenarios and skills for the operator should be incorporated into the training program. Appendix A shows the schedule for the five-day workshop that was conducted in May of 2023, and Appendix B shows the schedule for the four-day workshop that was conducted in June of 2025.

During the first day of training, conducted at the El Centro Maintenance Yard, hands-on activities focused on familiarizing the trainees with system components and the pre-shift checklist, start-up, roll-out, and shut-down procedures. These four activities are critical to the daily operations of the ITMA. The instructors emphasized the importance of following the checklists and gently reminded the operators to rely on the checklists no matter how experienced they are.

During the second day of training, which was also conducted at the El Centro Maintenance Yard, the operators began to utilize the vehicle beyond straight driving. They practiced the roll-out procedure, making left turns, making right turns, and recovering from A-Stops and E-Stops. A-Stops are automated, or manually initiated, by pressing a yellow button, while E-Stops are manually initiated by pressing a red button located on both vehicles. A-Stops only stop the vehicle, and then normal operations can resume using the GUI to clear the A-Stop. E-Stops stop the vehicle and shutdown the engine; three procedures (shutdown, startup, and rollout) are required to resume normal operations.

As the day progressed and the operators became more comfortable with the ITMA, a set of cones were set up to challenge the operators to get the FV as close to the cone without hitting it. This activity presented a competition, but it also allowed the operators to understand the inherent offset between the vehicles due to their sizes. Although the activity appeared to be a game to the operators, it allowed them to better understand the interrelationships between the two vehicles and how to adjust their driving in the LV.

During the third and/or fourth days of training, the trainees utilized the system in more challenging scenarios. Hands-on time was given to learning the pause/catch-up feature, holding the FV at an intersection while the LV cleared the intersection, and lane taking with the FV being the first vehicle to enter the highway lane from the shoulder. The trainees also learned to utilize the offset command to clear an obstacle that is on the side of the road that may be creating an A-Stop, such as overgrown brush.

On the last day of training, the trainees, with support from AHMCT, performed operations on open-to-the-public roads as they supported sweeping operations. The CHP was also present to provide support through the Maintenance Zone Enhanced Enforcement Program (MAZEEP). The project panel determined that, throughout this research project, the ITMA would also be operated with MAZEEP support. These training activities took place on State Route 7 between Heber and McCabe Road due to its lower vehicle traffic, wide shoulders, and four lanes of traffic. This location allowed the trainees to gain real-world experience with the ITMA in a location with minimized risk.

AHMCT provided support and guidance to each trainee as they gained system and troubleshooting experience with using the ITMA system for sweeping operations. This activity allowed the trainees to experience the following tasks in a real-world setting:

- Start-up,
- Roll-out,
- Entering the main line of traffic,
- Utilizing offset to avoid obstacles on the side of the road,
- Performing U-turns,
- Exiting the main line of traffic, and
- Shutdown.

Chapter 3: Semi-Intelligent Field Trials

The semi-intelligent field trial phase represented the first sustained deployment of the ITMA system in Caltrans District 11 maintenance operations. During this phase, the FV operated in semi-intelligent mode, maintaining position behind the LV while a human safety operator provided supervisory control in the FV. A safety operator was present in both the leader and follower vehicles at all times; this safety protocol will remain in place until the system is approved by the California State Transportation Agency (CalSTA).

This chapter summarizes the results of these field trials, including integration of the ITMA with paint striping crews, sweeping operations, and raised pavement marker (RPM) teams. Key maintenance events, system repairs, false obstacle detections, and operational observations are also documented.

Field Trial Integration

Integration with Paint Striping Operations:

The first milestone of semi-intelligent field integration after training occurred with a paint striping crew from May through July of 2023. Across this period, the ITMA accumulated 85 miles and 13.5 hours of semi-intelligent follower operations. Table 3.1 summarizes various activities held during the integration period. These sessions exposed the system to varied roadway types, including high-speed freeways, rolling terrain, and complex vertical profiles. The table also summarizes the annual average daily traffic (AADT) in three broad categories for the region as highest, medium, and lowest.

Table 3.1: Initial operational field trials – Paint Striping

Dates	Roadway	Description
5/24/2023	I 8	4 Lane Highway, Highest AADT
6/4/2023	SR 86	4 Lane Highway, Medium AADT
6/5/2023	SR 86	4 Lane Highway, Medium AADT
6/6/2023	SR 86	4 Lane Highway, Medium AADT
6/7/2023	SR 86	4 Lane Highway, Medium AADT
7/10/2023	I 8	4 Lane Highway, Highest AADT
7/11/2023	SR 86	4 Lane Highway, Medium AADT

Dates	Roadway	Description
7/12/2023	I 8	4 Lane Highway, Highest AADT
7/13/2023	I 8	4 Lane Highway, Highest AADT

Integration with Sweeping Operations

Sweeping operations were integrated into the semi-intelligent testing framework in August 2023, following coordinated planning with District 11 staff and MAZEEP. Over two days of field activity, the ITMA completed 46 miles and 209 minutes of semi-intelligent operation, including successful performance while passing through a six-lane underpass with sidewalks, demonstrating stable following behavior in constrained environments. Several intermittent A-Stops occurred during these trials and are under investigation; however, all events were fully recoverable without incident and did not disrupt sweeping operations. Table 3.2 summarizes the different activities and routes for sweeping operations.

Table 3.2: Initial operational field trials – Sweeping

Dates	Roadway	Description
8/15/2023	SR 7	4 Lane Highway, Low AADT
8/16/2023	I 8	4 Lane Highway, Highest AADT

On August 14, 2023, a pre-meeting was held to review the sweeping workflow under semi-intelligent control and clarified that TMAs are not typically used for entrance and exit ramp sweeping, meaning the ITMA would be limited to mainline sweeping. The discussion then focused on strategies for moving closure trains and planning both middle- and right-shoulder sweeping sequences. The session concluded with operator questions and a review of potential operational challenges.

Field trials were conducted on August 15 and 16, 2023, during which the ITMA operated as the semi-intelligent FV. On August 16, several A-Stops occurred on westbound I-8 due to front obstacle detections likely caused by dust produced during sweeping, wind conditions, and partial contamination of the front LiDAR lens. All A-Stops were fully recoverable from the LV and did not disrupt sweeping activities. After the midday break, the LiDAR lens was cleaned, and no further A-Stops were observed during eastbound operations. Support for sweeping operations occurred on March 7 and March 8, 2025. The operators controlled the FV as if the safety operator was not in the vehicle; however, there was a safety operator in both the LV and the FV. A safety operator will remain in the FV until after the Public Information Officer (PIO) events and CalSTA approval.

Integration with Raised Pavement Marker (RPM) Operations

The ITMA was integrated into District 11's RPM operations beginning in October 2023 (see Table 3.3). Prior to field deployment, AHMCT met with Francisco Saaverdra, the District 11 RPM Crew Supervisor, to review ITMA capabilities, summarize progress from earlier field trials, discuss the crew's standard RPM workflow, and identify points where the ITMA could be incorporated. The session also included a general question-and-answer period to ensure the crew understood how the system would function alongside their established procedures.

Table 3.3: Initial operational field trials – RPM

Dates	**Roadway**	**Description**
10/9/2023	SR 111	4 Lane Highway, Medium AADT
10/10/2023	SR 111	4 Lane Highway, Medium AADT
10/11/2023	SR 111	4 Lane Highway, Medium AADT
10/12/2023	SR 111	4 Lane Highway, Medium AADT
10/13/2023	SR 111	4 Lane Highway, Medium AADT
11/13/2023	SR 86	4 Lane Highway, Medium AADT
11/14/2023	SR 86	4 Lane Highway, Medium AADT
11/15/2023	SR 86	4 Lane Highway, Medium AADT
11/16/2023	SR 86	4 Lane Highway, Medium AADT
11/17/2023	SR 86	4 Lane Highway, Medium AADT

AHMCT provided on-site support on October 10 and 11, 2023, assisting the crew through initial integration and validating that the ITMA could operate effectively within RPM traffic control and work sequences. After the initial deployment, AHMCT continued to support remaining operational days remotely, responding to operator questions and system behavior reports as needed.

A notable remote-support event occurred on November 16, 2023, when the ITMA applied its brake and shut down during the startup procedure. The behavior was suspected of being caused by an unreleased E-stop, and Kratos confirmed this diagnosis within 15 minutes. AHMCT virtually guided the operator through the correct reset sequence, after which the ITMA returned to normal operation for the remainder of the day. This incident demonstrated that routine system faults could be resolved quickly and effectively through remote communication, reducing downtime and eliminating the need for on-site technical staff during later stages of the RPM trials.

Underpasses

The ITMA demonstrated strong performance in underpass environments across multiple operations. During paint striping activities, the system successfully completed more than 15 passes beneath roadway structures and overpasses, maintaining lane alignment and stable following behavior despite GPS shadowing and abrupt lighting transitions and without requiring manual overrides. Similar performance was observed during sweeping operations where the ITMA navigated a six-lane underpass with sidewalks without issue. Together, these results show that the system can reliably handle constrained or GPS-challenged underpass conditions during semi-intelligent operation.

However, the system did need to be stopped in one situation that involved an overpass on a curved, slightly sloping strip of the freeway. The FV deviated from its path more than expected, so the safety operator performed an A-Stop. The vehicle was then manually driven by the safety operator who was in the FV until the FV was no longer under the overpass. This section of road was no longer utilized in future field trials to reduce risk to the crew and the public.

Faults and Repairs

Front LiDAR False Obstacle Detection (Highway A-Stop Event)

During the week of August 15, 2023, the ITMA experienced repeated front-obstacle detections and intermittent A-Stops while operating on a four-lane highway with drainage swells running perpendicular to the direction of travel.

Conditions Leading to A-Stop

The false detections occurred on roadway segments with a slight depression and perpendicular drainage, which created geometric conditions that the front LiDAR misinterpreted as obstacles. As a result, an A-Stop was triggered and continued even after the vehicle cleared the affected area. The system repeatedly detected a non-existent obstacle and was unable to resume forward motion, preventing normal semi-intelligent operation along that segment.

Corrective Measures

On September 6, 2023, the AHMCT team, with the guidance of Kratos, adjusted the LiDAR sensor slightly upward to reduce ground-strike returns and prevent misclassification of roadway dips (see Figure 3.1). In Figure 3.1, ground-strike returns appear as clusters of blue points near 0 degrees and along the right side of the figure. Due to the high density of returns within the vehicle path (the yellow rectangle) that were not associated with the LV, the system incorrectly classified the area as an obstacle and initiated an A-Stop.

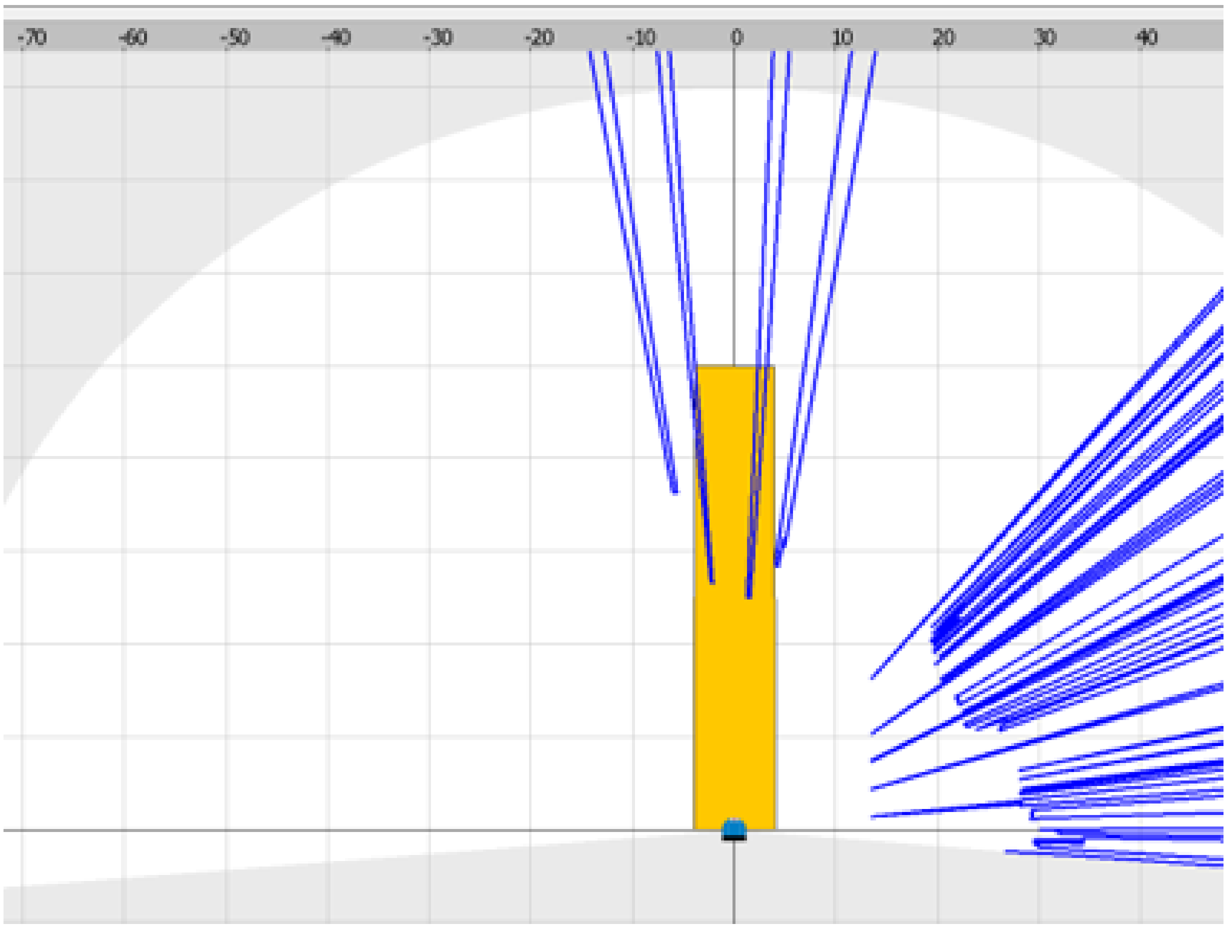

Figure 3.1: Ground reflections before adjustment causing A-Stops. (Each square represents 20 feet vertically and 10 degrees horizontally, the front of the truck is located at the small blue rectangle.)

Following the adjustment, system performance was validated by confirming that the LiDAR could detect an average adult at 100 feet and by traversing the same highway section three times without further false detections. As shown in Figure 3.2, the only return within the planned travel path after adjustment was the LV, demonstrating that the correction successfully eliminated false obstacle readings. These results highlight the importance of proper sensor alignment, particularly on highways with non-level vertical profiles.

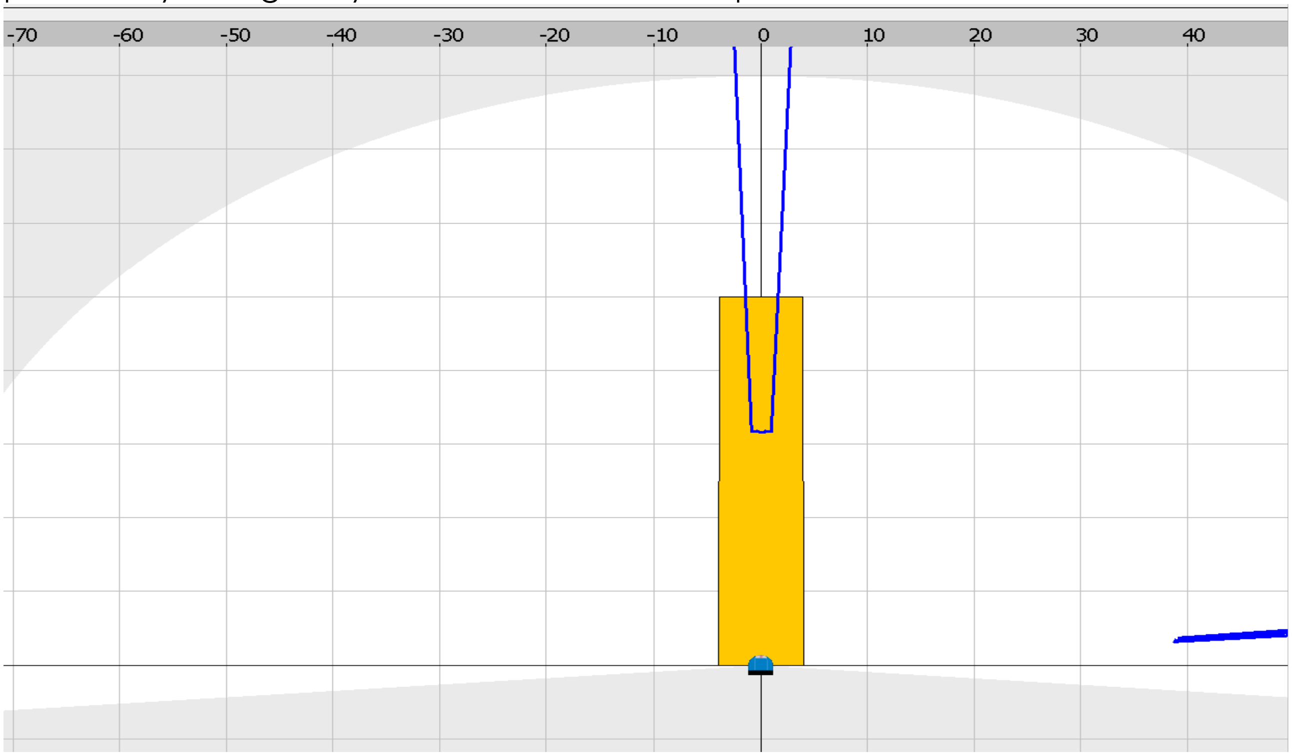

Figure 3.2: Ground reflections after adjusting LiDAR. (Each square represents 20 feet vertically and 10 degrees horizontally, the front of the truck is located at the small blue rectangle.)

Brake Light Failure

A brake light and turn-signal malfunction were first identified during a routine pre-shift inspection in mid-2023, prompting an extended troubleshooting effort that continued into early 2024. AHMCT performed detailed wiring checks and diagnostic testing but was unable to isolate the source of the failure. A local diesel mechanic shop and a Hino dealership also evaluated the issue and confirmed that it did not originate from the base vehicle's electrical system. Kratos later determined that the fault was caused by components they had installed and implemented a temporary workaround to restore brake-light functionality while developing a permanent fix. The temporary workaround was implemented at the end of May 2023 to allow training and the initial field trials to continue. The final correction was completed on January 22, 2024, restoring proper brake-light and turn-signal behavior prior to fully intelligent operations. The multi-stage troubleshooting process delayed several early field activities and postponed the conclusion of the initial training event for several weeks.

GPS Card Failure

In December 2023, the ITMA experienced a GPS card failure that required supplier replacement. A repair visit was scheduled for the week of January 22, 2024, and AHMCT and Kratos provided on-site support during the service period from January 22 to 24, after which the supplier installed a new GPS card and restored system functionality. Additional system changes were later validated on March 4, 2024, but these updates introduced new operational errors that became apparent during training on March 5, 2024. Working closely with AHMCT, the supplier quickly identified the root cause, developed a corrective action, and implemented a fix by March 6, 2024, which returned the system to stable operation.

Brake Pedal Actuator Cable Issue

An intermittent brake pedal actuator issue first appeared on March 6, 2024, when the brake pedal did not release during morning operations; the fault could be cleared, allowing activities to continue, but the supplier began investigating a long-term solution. Kratos attempted a repair from May 29–31, but the issue persisted and contributed to delays in field testing. A second repair effort took place on June 18–20, during which two Kratos engineers successfully corrected the actuator cable issue and restored proper turn-signal functionality through a corresponding software update. The system was then validated and recalibrated with two District 11 operators on June 20–21, after which the supplier confirmed the ITMA was fully functional and "100% demo ready." This multi-stage repair process was essential to ensuring reliable braking performance prior to moving toward fully intelligent operations.

SEMI-INTELLIGENT OPERATIONS SUMMARY

The semi-intelligent phase demonstrated that the ITMA could be successfully integrated into striping, sweeping, and RPM operations, showing stable performance across varied roadway environments, including underpasses and rolling terrain. The system handled A-Stops predictably and safely with all events fully recoverable, while early maintenance issues, particularly those related to brake systems and sensor calibration, highlighted the need for support from the research team or the supplier. Throughout this phase, operators became increasingly familiar with the system's capabilities and limitations, and the challenges encountered played a valuable role in shaping both the planning approach and the training materials required for fully intelligent operations.

Chapter 4: Fully Intelligent Field Trials

Efforts to Transition to Fully Intelligent Operations

Transitioning the ITMA from semi-intelligent operations to fully intelligent operations required a formal, multi-agency approval process involving Caltrans, CalSTA, and the CHP. This process was particularly important because of the larger size and weight of the ITMA vehicle and the plan to relocate the safety operator to the LV while maintaining full remote-control capability.

AHMCT and DRISI led the preparation of an issue memo for the CalSTA Secretary. This memo summarized all past and ongoing ITMA research, the results of semi-intelligent field trials, and operator feedback gathered to date. It formally requested permission to move the safety operator to the LV where they would still retain full remote-control authority over the FV at all times. The memo also provided justification for advancing to fully intelligent operations, including operator-safety benefits and the controlled nature of the proposed test environment.

As part of the approval process, AHMCT and Caltrans conducted technology demonstrations for multiple state agencies in the eastern region of District 11. These demonstrations—similar in format to earlier briefings provided to District 11 members and CHP in September 2023—included ride-along sessions and operational walkthroughs to allow agency representatives to observe the system directly.

Following this multi-agency review and successful demonstrations, CalSTA approved operation without a safety operator in the FV on March 13, 2024. This approval allowed the project to move into the fully intelligent testing phase and evaluate the ITMA under real work-zone conditions. The decision acknowledged the potential for significant safety benefits by removing the TMA operator from a high-risk position, while ensuring that agency oversight, teleoperation safeguards, and human supervision remained in place throughout the trial.

Training Refresher for Fully Intelligent

A closed-course refresher training session was conducted on the morning of August 8, 2024 for all operators. The session revisited core ITMA procedures, including system setup and shutdown, and provided a detailed briefing on what fully intelligent operations entail. AHMCT instructors emphasized safety practices, communication protocols, situational awareness, and the importance of continuous monitoring during operation. The training also reviewed known system limitations and areas that can cause GPS-denied navigation to ensure operators were fully prepared for the transition to fully intelligent field trials.

Support Final Field Trials

Sweeping Operations

Due to delays in the start of final field testing, AHMCT traveled to District 11 to support the ITMA's transition into fully intelligent sweeping operations on August 8 and 9, 2024. These dates marked the first use of the fully intelligent ITMA on open-to-the-public roads while supporting active sweeping activities. Following this initial deployment, the ITMA was scheduled to be used in fully intelligent mode one day per week from August 26 through December 31, 2024, providing routine sweeping support under monitored conditions.

Paint Striping Operations

AHMCT traveled to El Centro to support fully intelligent ITMA operations with the paint striping crew from November 12 to 14, 2024. During this deployment, the system operated as designed, and no issues were reported. AHMCT again supported the paint striping crew on February 19 and 20, 2025, during which the ITMA continued to function in fully intelligent mode.

Raised Pavement Marker Operations

AHMCT provided on-site support in El Centro from October 6 to 8, 2024, for the RPM crew's first fully intelligent operations using the ITMA. During this period, the system performed as intended with no reported issues.

Six-Month Survey Results

Operator experience with TMA vehicles varied widely, ranging from two years to nearly two decades, and this diversity of backgrounds shaped the feedback on fully intelligent ITMA operations. Despite the differing experience levels, operators were consistent in their use of ITMA documentation: all participants reported relying on the instructions or checklists regularly, either "often", "all the time", or with strong comfort. These similarities indicate that the support materials were accessible, practical, and integral to daily operation.

A common theme across responses was that the ITMA requires more time to set up on the roadside compared to a standard backup vehicle. Most operators estimated an additional 10 to 15 minutes, primarily due to the need for the GPS signal to stabilize and allow the system to latch onto the lead vehicle. Although this extended setup was acknowledged, operators generally did not report that ITMA accessories made preparing for a moving lane closure more difficult; nearly all selected “neutral”, suggesting that while slower, the process was not perceived as burdensome or unsafe.

Safety perceptions varied but remained generally positive. Most operators either disagreed or were neutral regarding the statement that the system negatively impacted their ability to operate the TMA safely. When asked about challenges, the few concerns raised included the computer pad interface and delays in GPS acquisition. Several operators reported no issues at all. Operators also adapted quickly to the system with most reporting comfort after only a handful of uses, between four and ten times, and in one case after a single session.

Overall confidence in the ITMA’s value was strong. Operators explicitly supported further Caltrans investment in the system, citing benefits for striping and RPM operations in particular. The positive feedback, combined with the willingness of operators to continue using checklists and follow procedures, suggests strong acceptance of the ITMA and its potential to improve maintenance safety and operational efficiency on California highways.

Faults, Inspections and Repairs

Radio Failure

Abnormal performance occurred during sweeper operations in September 2024. The operators were able to still support operations, and there were no incidents. The problem was reported to AHMCT by the operators on September 9. AHMCT personnel traveled to El Centro on September 17 and worked with Kratos to determine the cause of abnormal performance. One of the vehicle-to-vehicle radios was determined to have failed. AHMCT returned to El Centro once the new radio arrived on September 23 and repaired the system with virtual guidance from Kratos. AHMCT confirmed that the system was performing normally on September 24, and the ITMA was put back into service.

Inspections

A CHP Basic Inspection of Terminals (BIT) inspection was completed for the FV in accordance with the required 90-day inspection interval for commercial vehicles over 10,001 pounds during the entire research project. Additional compliance activities, including smog testing for both the leader and follower vehicles, were also conducted to meet state emissions requirements. These inspections ensured ongoing compliance with state-mandated inspection requirements.

Overhead Passes

During a sensor upgrade in early June 2025, Kratos applied refinements to the ITMA LiDAR system intended to improve overhead-pass detection. However, the updated configuration initially produced a higher rate of false positives, leading to larger drifts during dead reckoning (DR) mode, which required a systematic review and adjustment of the system's qualifying parameters, the set of tunable thresholds and filters used by the ITMA, to classify overhead objects.

Field Testing and Parameter Tuning (June 16 to 17, 2025)

Two days of structured field testing were conducted on I-8 between Dogwood, Forrester, and Vanderlinden with additional testing along Route 7 and Highway 111. The team performed repeated manual and ITMA-guided passes under a variety of overhead conditions, including bridges, overhead signs, complex cloverleaf structures, tree canopies, and light poles. Parameter adjustments were made iteratively based on LiDAR logs collected during each run.

Key Results

- **Reliable Detection of Overpasses and Signs:** After refinement, the qualifying parameters successfully detected 26 of 27 overhead structures with early and stable transitions into DR Mode. One anomaly at South La Brucherie Road was not repeatable and considered an outlier.
- **Performance in High-Density Environments:** The cloverleaf interchange at Highway 111 proved challenging due to a rapid succession of signs and underpasses, occasionally preventing timely recovery from DR Mode. This scenario does not reflect typical maintenance operations, which would not traverse two clovers consecutively.
- **Tree Canopies and Light Poles:** Large overhead tree canopies were consistently detected and handled with quick recovery. Light poles did *not* trigger DR Mode at any point, indicating the parameters successfully filter narrow vertical objects.
- **Successive Overpass Sequences:** Multiple passes between Dogwood and South La Brucherie demonstrated that the ITMA can transition between DR Mode and GPS Mode with minimal drift, even under rapid sequences of overhead structures.
- **Additional Observations:** Increased E-crumb errors were noted during transitions between Idle and Go OCU modes; although, these scenarios fall outside normal SOP. GPS firmware was found to be outdated (v3.85 vs. latest 4.15), and Kratos updated the firmware. Operators also requested a more flexible Toughpad mount for improved ergonomics inside the cab.

Conclusion

The June testing campaign confirmed that the refined qualifying parameters provide robust detection of overpasses, overhead signs, and natural overhead features with minimal lateral drift and reliable GPS-denied navigation transitions. Apart from one non-repeatable outlier, the system performed consistently across a diverse set of roadway environments.

Chapter 5: Conclusion and Future Works

This project aimed to address a central Caltrans safety goal: removing the human operator from the TMA follower vehicle to reduce injuries and fatalities caused by work-zone strikes. Previous research demonstrated that the ITMA performs safely and reliably at closed test sites, including SR-905. The next step toward operational deployment was to conduct controlled and well-monitored field trials on public roadways to evaluate real-world feasibility, operational suitability, and crew acceptance.

To achieve these objectives, the project expanded testing from closed-course environments to remote, low-traffic public roads. The work involved updating ITMA system components, refreshing training materials, preparing Caltrans trainers and district staff, supporting live field trials, and documenting observed performance. These activities were essential precursors to full deployment and allowed Caltrans to evaluate ITMA behavior under authentic operating conditions while maintaining layered safety controls, including phased relocation of the safety operator.

Efforts also focused on preparing the ITMA system and Caltrans personnel for field deployment by completing vehicle updates and delivering structured operator training. Several hardware improvements were implemented to improve safety, ergonomics, and system reliability. The team coordinated with District 11 to complete radio communication upgrades, installed and commissioned the onboard modem, and verified connectivity for remote log downloads. A 10-inch, multi-view display was installed in the LV, paired with wireless transmission of existing cameras, providing operators with expanded situational awareness without requiring major vehicle modifications.

Training materials were refined to align with Caltrans terminology, incorporate system updates, and include clearer troubleshooting steps. Pre-operation checklists were added to strengthen operator readiness. AHMCT worked closely with META staff and district crews to deliver both classroom and hands-on instruction, guiding operators through system components, safety functions, A-Stop and E-Stop operations, communications procedures, and known limitations of the ITMA technology. Multiple crews were successfully trained, competency exams completed, and field exercises conducted, including managing A-Stop/E-Stop events and operating the ITMA in active work zones. These updates and training efforts ensured that both the vehicles and operating personnel were adequately prepared for safe, controlled field trials.

The semi-intelligent field trial phase kicked off deployment of the ITMA system within active District 11 maintenance operations. In this mode, the FV maintained position behind the lead vehicle while safety operators remained present in both vehicles. Across this phase, the ITMA was successfully integrated into paint striping, sweeping, and RPM workflows, demonstrating stable following behavior in a range of roadway environments, including high-speed freeways, rolling terrain, and constrained underpasses. Operators reported that the vehicle behaved predictably in semi-intelligent mode, and all A-Stop events triggered during operations were fully recoverable without disrupting maintenance activities.

The integration with multiple crews provided valuable insight into how the ITMA performs under different operational workflows. Striping and sweeping operations exposed the system to dust, debris, and GPS-challenged zones, while RPM operations validated that the ITMA could be incorporated into more stop-and-go work. Operators across all crews gained familiarity with system behavior, and AHMCT provided both on-site and remote technical support to ensure continuity of operations.

Several system challenges emerged during this phase, including false obstacle detections from the front LiDAR, brake-light and actuator issues, and isolated GPS component failures. While these issues did not compromise safety, they highlighted the importance of continued system refinement and robust sensor calibration in preparation for fully intelligent operation. Each issue was resolved through collaborative work between AHMCT, Kratos, and District 11 staff.

Overall, the semi-intelligent research phase demonstrated that the ITMA can be effectively integrated into real maintenance operations, provided critical operational learning, and laid the groundwork for the transition toward fully intelligent field trials. The system operated as a semi- or fully- intelligent system for over 650 miles and 110 hours without a non-recoverable incident.

The fully intelligent phase marked the transition to the ITMA system being utilized as designed with the safety operator relocated to the LV. Moving to this stage required a formal, multi-agency approval process involving Caltrans, CalSTA, and the CHP, due to the size of the ITMA and the need to ensure that remote oversight remained safe and compliant with state requirements. AHMCT and DRISI prepared the necessary technical documentation and issued memos summarizing past research results, operator feedback, and system safety characteristics. These materials supported technology demonstrations for state agencies and ultimately resulted in CalSTA approval for conducting fully intelligent operations.

Before entering public-road deployment, operators completed refresher training that revisited system procedures, safety responsibilities, dead-reckoning limitations, and communication protocols essential for fully intelligent operation.

Re-training ensured that personnel were prepared to supervise the ITMA remotely and manage its behavior confidently in live work-zone environments.

During fully intelligent trials, the ITMA was integrated into sweeping, striping, and RPM operations, demonstrating reliable performance across all workflows. Operators continued to depend on checklists and documentation, and survey feedback reflected increasing comfort, strong acceptance, and confidence in the system's safety benefits. Although a few routine issues—such as communication or component faults—emerged, each one was resolved without incident and did not significantly interrupt field operations.

An earlier sensor upgrade introduced initial false positives in overhead-obstacle detection, resulting in increased drift during DR Mode. Two days of structured field testing were conducted to refine the LiDAR thresholds and filters, after which the system achieved consistent detection of overpasses, signs, and tree canopies with stable DR transitions. While cloverleaf interchanges revealed edge cases, these conditions do not reflect typical maintenance routes. Overall, the updated parameters produced reliable performance once again.

Parallel to operational testing, the ITMA vehicles continued to undergo required inspections, including CHP BIT checks and state-mandated smog tests, ensuring that both vehicles remained compliant with all regulatory and safety requirements throughout testing.

Collectively, the fully intelligent phase demonstrated that the ITMA can safely operate without a FV safety operator while supporting Caltrans maintenance activities.

Key Contributions of the Research:

- Advanced ITMA toward Caltrans' safety goal by transitioning from closed-course testing to controlled public-road trials, moving closer to removing the TMA operator from the FV.
- Prepared the ITMA system and vehicles for field deployment, completing major hardware updates including radio upgrades, onboard modem installation, wireless camera integration, and improved operator displays.
- Developed and delivered comprehensive training, updating materials with Caltrans terminology and guidelines, adding troubleshooting guidance, creating checklists, and training META staff and District 11 crews through both classroom and hands-on sessions.
- Integrated the ITMA into active maintenance workflows, progressing from stable semi-intelligent operation to reliable, fully intelligent performance in striping, sweeping, and RPM activities with operators expressing strong confidence in system safety.

- Built a consistent regulatory and maintenance compliance process through regular CHP BIT inspections, smog tests, and system checks, supporting safe and reliable operation on public roadways.
- Established a strong foundation for statewide deployment, providing technical findings, training improvements, and operational insights needed for the next phase of corporate implementation.

Full Implementation Challenges

Moving the ITMA system from a research-supported field pilot into full operational deployment will require a structured transition process aligned with Levels 4 and 5 of Caltrans' implementation framework. As the system moves beyond supervised trials, several operational, technical, and organizational considerations are expected to influence full-scale adoption.

A primary requirement will be expanded operator training, not only on system procedures but also on Crew Resource Management principles, specifically communication, coordination, error-management, and shared situational awareness. As the ITMA enters broader use, additional training cycles will be needed to accommodate new crews, reinforce best practices, and ensure consistent understanding of system behaviors and limitations. Continued engagement with current maintenance teams will be essential to identify pain points, refine training materials, and evolve documentation based on real-world operator feedback.

Another important challenge involves deploying the ITMA into higher-traffic, more complex operating environments. Trials to date have focused on manageable roadway conditions, but statewide deployment will eventually require operation in dense urban areas, mountainous terrain, and multilane interchanges. These environments introduce added complexity, particularly for the current ITMA architecture's strong dependency on consistent, high-quality GPS. In dense corridors—such as downtown San Diego, built-up coastal districts, or narrow mountain passes—GPS shadowing and multipath interference may compromise positioning performance. Long-term solutions may involve evaluating vision-based navigation or hybrid perception systems as part of future research efforts.

Sustained deployment will also require strengthening maintenance, support, and repair structures. The current reliance on a small number of repair locations could slow response times as statewide adoption grows. Establishing additional service centers, identifying at least one statewide repair shop, or training district yards on basic troubleshooting and routine maintenance would significantly improve system uptime and reduce operational disruptions. Streamlined reporting pipelines and standardized diagnostic procedures will further support districts as they assume full ownership of technology.

Collectively, these considerations include:

- Expanding training capacity,
- Preparing crews for more complex operating conditions,
- Addressing GPS-dependency, and
- Building a broader maintenance and support network.

Overall, these items represent key challenges that must be addressed before transitioning the ITMA to full Caltrans deployment. Each will play a central role in ensuring that the system can be scaled safely, reliably, and efficiently across the state.

Future Works:

Future work will focus on expanding operator readiness and evaluating next-generation capabilities to support broader deployment. As additional districts adopt the ITMA, more comprehensive crew training covering system operation, communication practices, and routine maintenance will be necessary to ensure consistent performance statewide. Future research should investigate vision-based or hybrid navigation approaches to reduce the system's dependence on high-quality GPS, especially in dense urban corridors or mountainous regions where GPS reliability is limited. Continued refinement of operator ergonomics, display configurations, and in-cab interfaces will further improve usability and help integrate the system more seamlessly into day-to-day maintenance operations.

References

1. D.A. Bennett and T.A. Lasky, "Evaluation of Autonomous TMA Trucks for Use in Caltrans' Operations," AHMCT Research Center, UCD-ARR-21-12-31-03, December 2021.

Appendix A:
Training Agenda for 5-Day Course

C- Classroom
TC- Truck Closed to public roads
TO- Truck Open to public roads

Monday Agenda

Time	Activity
7:00 – 8:00	Demo, ITMA Benefits, system overview (TC,C)
8:00 – 9:00	Leader Vehicle System Components (C, TC)
9:00 – 10:00	Follower Vehicle System Components (C,TC)
10:00 – 11:00	User Interface (C,TC)
11:00 – 11:30	Lunch
11:30 – 12:30	Pre- shift Checklist, Safety, A&E Stops (C,TC)
12:30 – 1:30	Checklist and Rollout (TC)
1:30 – 2:30	Operating Parameters (C)
2:30 – 2:45	Debrief, big questions?(C)

Tuesday Agenda

Time	Activity
7:00 – 8:00	Pre-Shift Checklist, Checklist, Rollout (TC, C)
8:00 – 9:00	Review Monday, Procedures
9:00 – 10:00	Troubleshooting (C,TC)
10:00 – 11:00	Operating Parameters (interactive) (C)
11:00 – 11:30	Lunch
11:30 – 12:30	Hands-on Training (C)
12:30 – 1:30	Hands-on Training (C)
1:30 – 2:30	User Manual Review (C)
2:30 – 2:45	Debrief, big questions?(C)

Wednesday Agenda

Time	Activity
7:00 – 8:00	Review Tuesday, Pre-Shift Checklist, Checklist, Rollout (TC, C)
8:00 – 9:00	Hands-on Training (TC)
9:00 – 10:00	Safety, A&E Stops (interactive) (C,TC)
10:00 – 11:00	Hands-on Training
11:00 – 11:30	Lunch
11:30 – 12:30	Troubleshooting (interactive)
12:30 – 1:30	Incident form and roundtable
1:30 – 2:30	Hands-on Training
2:30 – 2:45	Debrief, big questions?

Thursday Agenda

Time	Activity
7:00 – 8:00	Review Wednesday, Pre-Shift Checklist, Checklist, Rollout (TC, C)
8:00 – 9:00	Hands-on Training (TC)
9:00 – 10:00	Exam (C)
10:00 – 11:00	Review exam, issue certificates(C)
11:00 – 11:30	Lunch
11:30 – 12:30	Open road procedures (C)
12:30 – 1:30	Open road trials(OR)
1:30 – 2:30	Open road trials(OR)
2:30 – 2:45	Debrief, big questions? (C)

Friday Agenda

Time	Activity
7:00 – 8:00	Review Thursday, Pre-Shift Checklist, open road planning(C,CR)
8:00 – 9:00	Open road trials(OR)
9:00 – 10:00	Open road trials(OR)
10:00 – 11:00	Open road trials, debrief(OR,C)
11:00 – 11:30	Lunch
11:30 – 12:30	Open road trials (OR)
12:30 – 1:30	Open road trials(OR)
1:30 – 2:30	Documentation, Data Transfer (C,CR)
2:30 – 2:45	Debrief, big questions?

Appendix B:
Training Agenda for 4-Day Course

C- Classroom
TCE- Truck on closed to public roads (El Centro Maintenance facility)
TCC- Truck on closed to public roads (CHP Facility Calexico)
TO- Truck on open to public roads

Tuesday Agenda

Time	Activity
6:00 – 7:00	Demo, ITMA Benefits, ITMA system overview (TC,C)
7:00 – 8:00	Leader Vehicle System Components (C, TCE)
8:00 – 9:00	User Interface (C,TCE)
9:00 – 10:00	Follower Vehicle System Components (C,TCE)
10:00 – 10:30	Lunch
10:30 – 11:30	Checklist and Rollout (TCE)
11:30 – 12:30	Key Operating Parameters (C)
12:30 – 1:30	Pre- shift Checklist & ITMA Safety Information (C,TCE)
1:30 – 1:45	Debrief, big questions?(C)

Wednesday Agenda

Time	Activity
6:00 – 7:00	Pre-Shift Checklist, Checklist, Rollout Review Monday (TCE, C)
7:00 – 8:00	Operating Procedure Familiarization (C)
8:00 – 9:00	Hands-on Training (TCE)
9:00 – 10:00	A&E Stops (C,TCE)
10:00 – 10:30	Lunch
10:30 – 11:30	Hands-on Training (TCE)
11:30 – 12:30	Hands-on Training (TCE)
12:30 – 1:30	User Manual Review (C)
1:30 – 1:45	Exam (C)

Thursday Agenda

Time	Activity
6:00 – 7:00	Pre-Shift Checklist, Checklist, Rollout, Review Exam (TCC, C)
7:00 – 8:00	Certificates and Hands-on Training (TCC)
8:00 – 9:00	Hands-On Training- Safety, A&E Stops (interactive) (C,TCC)
9:00 – 10:00	Hands-on Training- Operating Parameters (TCC)
10:00 – 10:30	Lunch
10:30 – 11:30	Hands-on Training- Troubleshooting (C,TCC)
11:30 – 12:30	Hands-on Training- Operations (TCC)
12:30 – 1:30	Incident form and roundtable (C)
1:30 – 1:45	Debrief, big questions?(C)

Friday Agenda

Time	Activity
6:00 – 7:00	Review Thursday, Pre-Shift Checklist, open road planning(C,CR)
7:00 – 8:00	Exam and Review of Exam(C)
8:00 – 9:00	Open road trials(TO)
9:00 – 10:00	Open road trials, debrief(TO,C)
10:00 – 10:30	Lunch
10:30 – 11:30	Open road trials (TO)
11:30 – 12:30	Open road trials(TO)
12:30 – 1:30	Documentation, Data Transfer (C,CR)
1:30 – 1:45	Debrief, big questions?(C)