Truck Platoon Testing Allowed Under Assembly Bill 669

Caltrans

Report to the Legislature
2019

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Executive Summary

This is the California Department of Transportation's (Caltrans') second report, as required by Assembly Bill 669 (Berman, Chapter 472, Statutes of 2017), which covers the results of testing cooperative adaptive cruise control systems to perform truck platooning operations on the State Highway System. This report covers testing from April 2017 through March 2019. The first report required by Senate Bill 719 (Hernandez, Chapter 163, Statutes of 2015) was submitted to the Legislature June 2017 and covered the time period from January 2016 through March 2017.

Testing of the heavy truck cooperative adaptive cruise control system has advanced the maturity of cooperative adaptive cruise control technology. These tests have validated that operation of vehicles at gaps shorter than the statutory 100 feet minimum, normally prohibited for caravans of vehicles traveling together, confers benefits when under close coordination. These closely coordinated vehicles have been demonstrated to:

- Reduce fuel consumption at a range of 10 to 15 percent, depending on a variety of factors,
- Enhance safety, through coordinated braking with minimal delay,
- Improve traffic flow stability, reducing stop-and-go effects,
- Increase the effective capacity of highway lanes, which reduces the adverse effects of congestion, and
- Permit free movement of other vehicles.

Authorization for carefully controlled testing at shorter gaps was provided by Senate Bill 719, which was extended by Assembly Bill 1671 (Berman, Chapter 322, Statutes of 2019) to January 1, 2024, and will require a third report to the Legislature by April 1, 2023. Additional testing is required to refine cooperative adaptive cruise control technology, specifically to:

- Collect and analyze enough data for assurance that adequate safety, operations, and environmental testing has been performed.
- Understand lane changing behavior and how other vehicles interact with platooning trucks.
- Determine the implications of cut-ins at various gap settings.
- Incorporate input from commercial vehicle drivers and fleets into the cooperative adaptive cruise control design.

Since the last report, the three-truck platoons have driven an additional 6,000 miles on the State Highway System at 55 miles per hour without incident. The platoons drove an additional 6,500 miles on a test track for fuel consumption experiments. The platoons drove a combined total of 20,500 incident-free miles since 2014 with cooperative adaptive cruise control assistance.

Background

Cooperative adaptive cruise control is the next step in the development of vehicle cruise control systems, progressing from cruise control (speed control), to adaptive cruise control (speed and vehicle distance control), then to cooperative adaptive cruise control.

Cooperative adaptive cruise control is created by integrating high-speed communications into heavy trucks equipped with commercially available adaptive cruise control, thus allowing the trucks to communicate with one another. Communication between the trucks enables cooperative and coordinated truck movements. The high-speed communications and coordinated maneuvers reduce the reaction time for braking. This not only improves safety, but also allows the adjacent trucks to travel with shorter gaps between them.

These types of driver-assist technologies allow the driver to remain in control at all times and maintains responsiblity for the operation of the vehicle. The California Highway Patrol played a key role in this pilot and worked with Caltrans' lead team to ensure testing was performed under appropriate conditions.

Statutory Reference & Purpose

- Assembly Bill 669 (Berman, Chapter 472, Statutes of 2017)
- Senate Bill 719 (Hernandez, Chapter 163, Statutes of 2015)
- Assembly Bill 1671 (Berman, Chapter 322, Statutes of 2019)
- California Government Code section 14107
- California Vehicle Code section 21705
- Report findings of the testing to the Legislature on or before July 1, 2019

Program Background

Caltrans, in partnership with the University of California at Berkeley, Volvo Group, Cambridge Systematics, Los Angeles County Metropolitan Transportation Authority, Gateway Cities Council of Governments, and Peloton Technologies, applied for and received a Federal Highway Administration grant in 2014 to fund research to develop and test a cooperative adaptive cruise control system for heavy trucks. This grant required testing in live traffic with short spacing between the trucks and was the basis for Senate Bill 719 (Hernandez, Chapter 163, Statutes of 2015), which created an exemption from the California Vehicle Code provisions that require a minimum 100-foot spacing between vehicles in a platoon. Assembly Bill 1671 (Berman, Chapter 322, Statutes of 2019) extended the sunset date of the exemption to January 1, 2024.

Caltrans and the University of California, Berkeley, California Partners for Advanced Transportation Technology Program recently published the March 2018 Cooperative Adaptive Cruise Control (CACC) for Partially Automated Truck Platooning: Final Report, which summarizes the technical findings from this grant project.

The rapid development of new technologies under the broad category known as "Intelligent Transportation Systems" has brought opportunities to improve the performance of California's transportation system. Intelligent Transportation Systems technologies include sensors that can detect the locations and motions of vehicles and other road users (pedestrians, bicyclists, and even animals), wireless communication systems that enable the exchange of data among vehicles and between vehicles and the roadway infrastructure, computer systems and software that can analyze the data, and actuators that can automatically control vehicle motions (steering, acceleration, and braking).

Future Intelligent Transportation Systems technologies will provide vehicles and their drivers with additional and enhanced information and assistive technologies. This will enable future drivers to drive more safely, smoothly, and efficiently than today. One important class of Intelligent Transportation Systems that is already available for use on many passenger cars and commercial vehicles is adaptive cruise control, which automatically controls the acceleration and braking of a vehicle so that it maintains a set following distance behind the preceding vehicle in its lane. Adaptive cruise control systems use forward-looking sensors (RADAR, LIDAR, and/or video cameras) to measure the distance to the preceding vehicle and the difference in speed between vehicles. This information is used by the adaptive cruise control system software to determine the acceleration or braking commands that should be implemented to maintain the desired spacing. Approximately 100,000 adaptive cruise control equipped heavy trucks are now on the road in the United States.

Commercially available adaptive cruise control systems for passenger cars are typically designed with a minimum time gap of 0.8 to 1.0 second between vehicles, while adaptive cruise control systems for heavy trucks typically provide a minimum time gap of 1.5 or 1.6 seconds. Defining these gaps in terms of time means that the distance between the vehicles will vary with vehicle speed. For example, at a speed of 55 miles per hour, the 0.8 second gap represents a distance of 64.5 Feet and the gap of 1.6 seconds represents a distance of 129 feet. The gap gets shorter at lower speeds, but if the speed drops below a minimum threshold value (typically in the range of 20 to 30 miles per hour), the gap stops decreasing and remains at a fixed minimum distance.

In recent years a number of adaptive cruise control systems that can operate in stop-and-go traffic or perform emergency braking have become available on many models of automobiles and trucks.

Existing adaptive cruise control systems have some limitations that can be overcome with the addition of vehicle to vehicle wireless communications of key vehicle data. Existing adaptive cruise control systems only detect changes in the motion of the vehicle immediately in front of them, not the actions of vehicles further ahead. They are relatively slow to respond to changes in the motion of vehicles ahead, and their minimum gap settings are large enough that drivers of other vehicles freely change lanes into those gaps in dense urban traffic.

With the addition of vehicle to vehicle communication of data, these systems become cooperative adaptive cruise control, which provides several performance improvements:

- Receive information from vehicles further ahead than their sensors can detect and can respond earlier and more smoothly to changes in traffic speed.
- Operate safely at shorter time gap settings (0.6 seconds, corresponding to a clearance gap of 48 feet at 5 miles per hour) enabling aerodynamic drafting of the vehicles driving closer together.
- Respond more quickly and predictably to braking actions by preceding vehicles, increasing driver comfort and confidence in the systems.
- Smooth out traffic flow disturbances, improving the stability of freeway traffic flow (dampening stop-and-go behavior).

Prior safety analyses and experiments with passenger car drivers have indicated that time gaps in the range of 0.6 seconds (clearance distance of 48 feet at 55 miles per hour) should be considered, and assessment of platoon performance and acceptability by commercial drivers require testing at these shorter gaps on public roads.

Cooperative adaptive cruise control systems can increase safety by reducing reaction time. The cooperative adaptive cruise control system in the middle and trailing truck in a three-truck platoon will begin responding within 0.2 second when the lead truck brakes or accelerates. Human reaction time is more complex, highly variable, and can range from a few tenths of a second for an attentive experienced younger driver to more than a two seconds for the average driver, a driver that is fatigued, or not focused on the driving task.

Cooperative adaptive cruise control systems currently exist only as research prototypes. The first commercially available cooperative adaptive cruise control systems are likely to be implemented on long-haul heavy trucks because of the opportunity to obtain a return on investment through the fuel savings associated with "drafting" of heavy trucks in a coordinated platoon. However, additional refinement to system designs and technical standards to govern vehicle-to-vehicle data exchanges would assist with making such systems commercially viable.

Truck Platoon Testing Status

Caltrans, in partnership with the California Highway Patrol, the University of California, Volvo Group North America, and other organizations, began collaborating on a Federal Highway Administration sponsored Exploratory Advanced Research Project to develop and test a cooperative adaptive cruise control system for heavy trucks in 2014. The primary objectives of the project were to develop and test the cooperative adaptive cruise control system on a three-truck platoon, determine driver acceptance of the system, and estimate the potential benefits of cooperative adaptive cruise control systems when deployed. The potential benefits include reduced fuel use resulting in reduced emissions, as well as improvements to freight operations and throughput.

The cooperative adaptive cruise control system was implemented on three Volvo Class-8 heavy trucks. The modified trucks were then tested on a closed test track followed by testing on California public roads, first at low speeds on local streets and then at freeway speeds. The next step in the testing and development of the cooperative adaptive cruise control system was to test the trucks on public roads at less than 100 feet spacing between adjacent trucks, which is prohibited by California Vehicle Code section 21705.

To address this issue, Senate Bill 719 added Government Code section 14107 to provide an exemption to section 21705 of the Vehicle Code allowing Caltrans, in coordination with the California Highway Patrol, to perform testing of technologies that enable drivers to safely operate motor vehicles with less than 100 feet between adjacent vehicles. The change to this law enable close-spaced public road testing. In 2017, Assembly Bill 669 modified Government Code section 14107 by extending the sunset date from January 1, 2018 (established in Senate Bill 719) to January 1, 2020. Assembly Bill 1671 (Berman, Chapter 322, Statutes of 2019) further extends the sunset date to allow testing to continue through January 1, 2024.

Caltrans and the California Highway Patrol began collaborating on the truck platooning project soon after Caltrans received the grant award from the Federal Highway Administration and prior to enactment of Senate Bill 719. After the passage of Senate Bill 719, Caltrans worked with the California Highway Patrol to establish a process for the testing organization to provide a testing or demonstration plan to the California Highway Patrol for review and input on the proposed locations, times, and other factors. The plans were then revised to everyone’s satisfaction before any testing took place.

For all project activities thus far, the trucks have traveled 20,500 miles in platoon operation without incident. A total of 11,500 miles were driven on California public roads for cooperative adaptive cruise control development and testing with 9,000 miles driven on a test track during the fuel consumption experiments.

Previous Report

Pursuant to Senate Bill 719, Caltrans provided the Legislature a report titled "Truck Platooning Testing Allowed Under Senate Bill 719" in June 2017. The report covered testing and project activities from 2015 through March 2017. This included the testing required to develop the prototype cooperative adaptive cruise control system, fuel consumption experiments performed on a test track, and two public demonstrations in California.

Since that report, the following additional testing activities were conducted between April 2017 and March 2019:

- Continued cooperative adaptive cruise control development testing on San Francisco Bay Area highways
- An experiment of truck drivers experience and preferences using the cooperative adaptive cruise control system on highways in Northern California
- A second round of fuel consumption experiments at Canada's Department of Transportation test track near Montreal, Canada
- A public demonstration for federal decision-makers on Interstate 66 in Virginia.

Program Status/Program Accomplishments

System Development

A cooperative adaptive cruise control system was designed, implemented, and tested on three Volvo Class-8 heavy truck tractors (Figure 1) during the summer and fall of 2015. These trucks have already been equipped with Volvo's production adaptive cruise control system, so only relatively modest modifications were required to the equipment on these trucks. The additional equipment includes:

- A 5.9 Gigahertz Dedicated Short-Range Communication radio transceiver, which broadcasts information about the truck's behavior ten times per second and receives similar information from the other trucks' radios. This is similar to a Wi-Fi system, but designed specifically for use in safety critical applications.
- Two antennas for the Dedicated Short-Range Communication radio, mounted on the side mirrors of the truck.
- A 5 hertz global positioning system receiver and antenna to provide accurate positioning information.
- A small PC-104 computer to operate the cooperative adaptive cruise control software and collect data about system performance during experiments.
- A tablet computer to provide a supplementary display to the driver about the operation of their truck and the other trucks that it is clustered with under the cooperative adaptive cruise control coordination and control.
- An emergency disengage button to deactivate the prototype cooperative adaptive cruise control system if it is not working correctly.

The truck modifications are shown schematically in Figure 1 below:

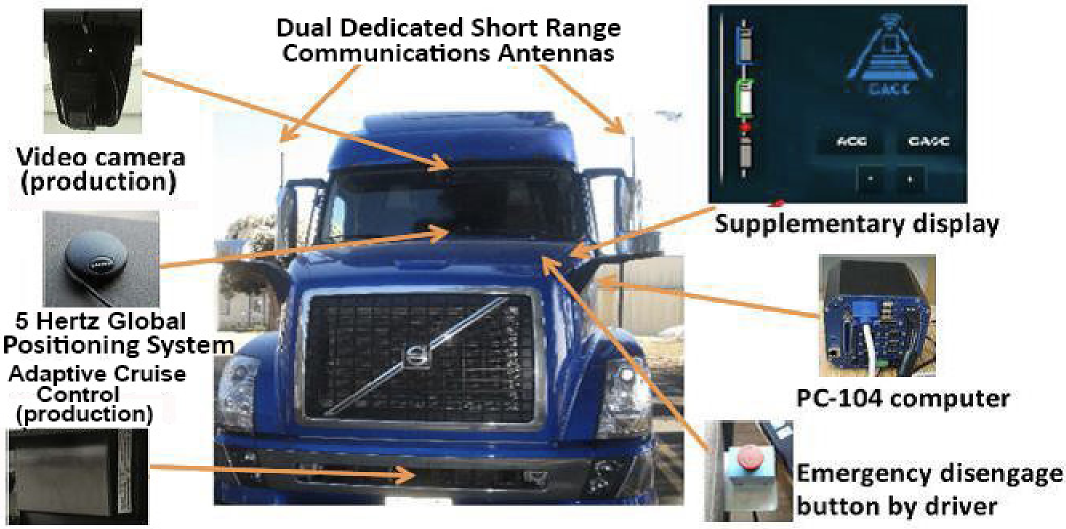

Figure 1. Additions to the Volvo Class-8 Truck Tractor to Implement cooperative adaptive cruise control

This cooperative adaptive cruise control system has been designed to give the driver the choice of five different time gap settings, depending on driver preferences, current local traffic, and weather conditions. These settings represent time gaps of 0.6, 0.9, 1.2, 1.5, and 1.8 seconds (corresponding to clearance gaps between the trucks of 48, 73, 96, 121, and 146 feet when driving at the California highway truck speed limit of 55 miles per hour). A view of the tablet computer screen that displays the status of the system and allows the driver to change the gap setting is shown in Figure 2 below:

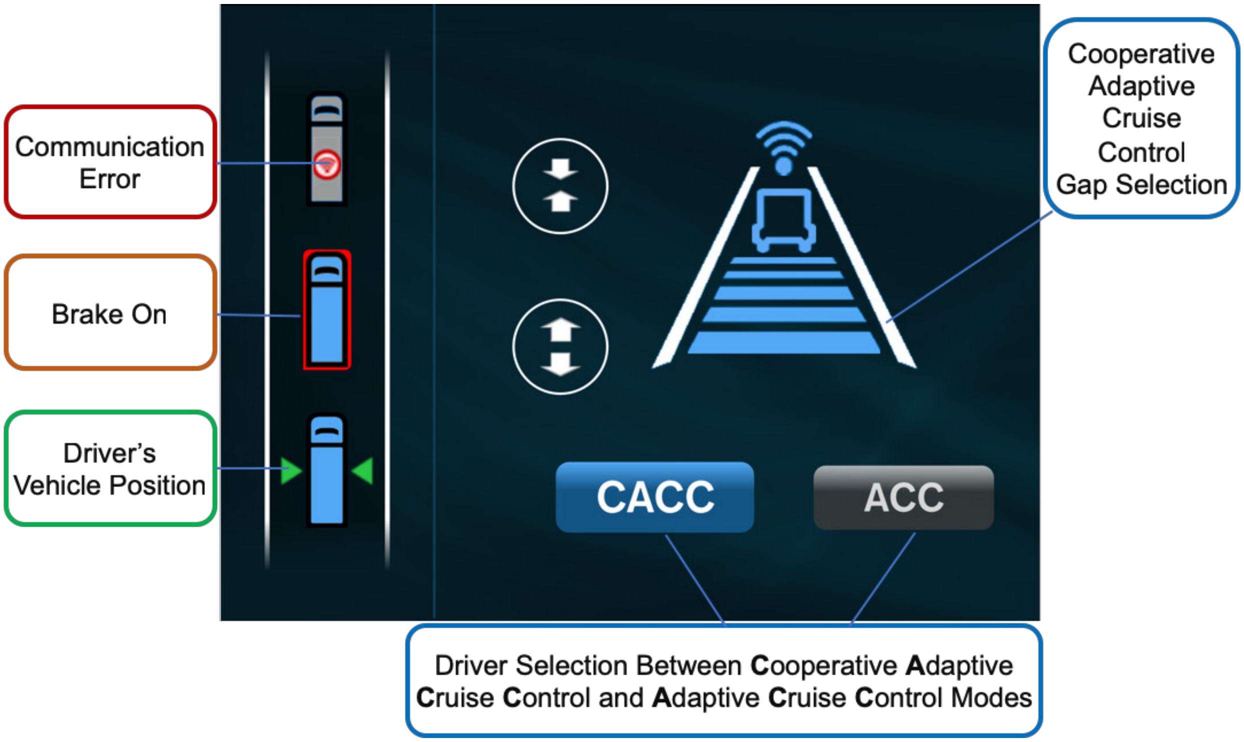

Figure 2. The display of the driver-vehicle interface inside the truck.

The number of bars below the vehicle icon on the right side of Figure 2 indicates the length of the time gap setting that is currently active. The buttons with arrows are used to increase or decrease the gap setting. The graphics on the left of the display indicates the position of this truck (green arrowheads) relative to its peers, and the red boundary on the icon of the middle truck indicates that its service brakes are active. Other symbols can be displayed to show a loss of communication with another truck or to indicate a malfunction on another truck.

The performance of the heavy truck cooperative adaptive cruise control system went through multiple cycles of development and testing to verify that the system was capable of:

- Accurately maintaining the desired gap setting at freeway driving speeds between 30 miles per hour and the legal freeway truck speed limit.
- Smoothly responding when other vehicles cut into the gap between the trucks, gradually increasing the gap to maintain a safe distance behind the cut-in vehicle (this gap needs to be longer than the cooperative adaptive cruise control gap behind the preceding truck because the cut-in vehicle is not part of the cooperative platoon and cannot communicate its actions and condition).

- Smoothly closing the gap to the preceding truck in the platoon after a cut-in vehicle has vacated the lane (cut-out), leaving the preceding truck as the next vehicle ahead in the lane.
- Tightly coordinating automatic braking, so that whenever any of the trucks in the platoon applies its service brakes, the braking command is sent to the trucks behind it, and they apply their brakes within the next 0.1 second communication update interval (much faster than human drivers are able to perceive brake light activation).
- Displaying information about faults on the other equipped trucks to the drivers of all the trucks in the platoon.

Los Angeles Interstate 710 Simulation
Performance data collected during the platoon tests were used to calibrate a computer simulation model that predicts the traffic impacts when a high percentage of heavy trucks are equipped with cooperative adaptive cruise control. A computer simulation was developed for the Interstate 710 corridor from the Port of Long Beach to downtown Los Angeles, where there is a very high volume of heavy truck traffic. The initial simulation results indicate that if all of the heavy trucks on this freeway were using the cooperative adaptive cruise control system, there is a potential to relieve some of the most serious bottlenecks along that corridor with increases of vehicle throughput of 7 to 11 percent, and increases of travel speed of up to 48 percent, depending on the location along the corridor. These improvements are possible because the cooperative adaptive cruise control system allows the trucks to operate at shorter gaps than normal.

Driver Experience Research

In May 2017, the first study of its kind, human factors research was performed to better understand truck drivers on the road experience and usage of cooperative adaptive cruise control. Nine commercial fleet drivers were recruited to operate two following trucks in a three-truck platoon. Drivers could engage and disengage the cooperative adaptive cruise control system on each of the two following trucks using the adaptive cruise control stalk, brake pedal, and safety button shown in Figure 3 on the next page.

Drivers could also select the cooperative adaptive cruise control or adaptive cruise control time gap via the driver-vehicle interface, which is a tablet display mounted on the instrument panel (see Figures 2 and 3). There were five-time gaps available to the drivers: 0.6 seconds/49 Feet; 0.9 seconds/73 feet; 1.2 seconds/97 feet; 1.5 seconds/121 feet; and 1.8 seconds/145 feet.

The 160-mile test route began at University of California, Berkeley Richmond Field Station, traveled over several highway sections, turned around at Westley on

Interstate 5 and returned to Richmond Field Station. Once past Walnut Creek on Interstate 680, drivers had the freedom to select the cooperative adaptive cruise control time gap they preferred for truck platooning. Drivers were responsible for steering during the whole experiment. A background questionnaire and a post-experiment debriefing questionnaire were used before and after the on-the-road driving respectively to document each driver's background information and experiences from multiple perspectives. Driver behavior data were recorded throughout the experiment.

Figure 3. The cooperative adaptive cruise control stalk (left) and truck cockpit interior (right) with driver-vehicle interface and safety button (right).

The results showed test drivers on average did not prefer using cooperative adaptive cruise control to drive too close (< 0.9 seconds/73 feet) or too far (1.8 seconds/145 feet) behind the lead truck and seemed to prefer using time gap settings of 1.2 seconds (97 feet) and 1.5 seconds (121 feet). The shorter gaps limited their forward driving view because they were so close to the trailer in front. The largest time gap seemed to encourage more frequent vehicle cut-ins. However, test drivers spent on average 30 percent of their cooperative adaptive cruise control driving time at the shortest time gap (0.6 seconds). The "conservative" drivers (five drivers in group 1), who kept more of a distance between their truck and the truck ahead of them, spent 48 percent of their cooperative adaptive cruise control usage at time gap 1.2 seconds and 26 percent at time gap 1.8 seconds, which strongly correlates with their preferences for the moderate-to-long time gaps. But it is interesting to notice that the "aggressive" group (four drivers in group 2), who were comfortable with a closer following space (tailgating), spent more than 60 percent of their cooperative adaptive cruise control usage at the shortest time gap, which did not reflect their relatively weak post-experiment preference for this time gap, showing a discrepancy between actual usage and subjective preference. Their concerns about road safety may have lowered the aggressive drivers' preference for the shortest time gap, which they experienced the most during the test.

Fuel Consumption Experiments

The primary motivation for heavy truck owners and operators to purchase and use cooperative adaptive cruise control technology is expected to be its potential for significant fuel savings. These savings are attributable to two factors: smoother acceleration and deceleration profiles under automatic speed control, based on improved truck platoon operational stability, and reduced aerodynamic drag based on the ability to drive the trucks significantly closer together than they would be driven otherwise. One of the major efforts under the current project has been a series of carefully controlled test track experiments to measure fuel consumption savings due to the reduced aerodynamic drag that can be achieved in steady cruising at highway speeds and various gaps between adjacent trucks. These tests were performed in October 2016 and August 2017 at a test track in Montreal, Canada, in cooperation with Transport Canada and the National Research Council of Canada, which provided extensive experimental support for the tests.

Energy consumption experiments were conducted in October 2016. A second round of tests were conducted in August 2017 under a United States Department of Energy grant. In both experiments, rigorous industry standard test protocols were followed to ensure the accuracy of the results. Each test condition was repeated at least three times, representing constant speed driving for at least 172 miles. The trucks were pulling 53-foot dry goods van trailers, the most common configuration for long-haul trucking, and were either empty or loaded at a typical weight of 65,000 pounds for the complete tractor-trailer combination. Most of the tests were done at 65 miles per hour, a typical long-haul truck operating speed, with additional cases at 50 miles per hour or 55 miles per hour. The baseline case for comparison of energy savings was for each truck to drive independently, separated from the others by one mile along the track, and pulling a loaded standard trailer.

The cooperative adaptive cruise control test cases chosen were for four of the available cooperative adaptive cruise control gap settings 0.6, 0.9, 1.2, and 1.5 seconds, corresponding to clearance distances of 57, 86, 114, and 143 feet at 65 miles per hour. The 1.8-second gap setting was not used in the fuel consumption experiment because the researchers believed that testing with that gap setting would not provide any additional information related to fuel consumption. Using these gap settings at the California truck speed limit of 55 miles per hour produced gaps of 48, 73, 96, and 121 feet, respectively.

A primary goal of the second set of tests was to perform fuel-economy testing of the three-truck platoon for longer and shorter separation distances than were evaluated in the first set of tests in 2016. Testing gaps ranged from 13 feet to 300 feet compared to the first experiment which had gaps ranging from 48 feet to 146 feet. The first experiment ran only three truck platoons plus a single truck that acted as a control vehicle. Whereas, the second experiment included additional scenarios: two-truck and three-truck platoons following at constant speed (65 and 55 miles per hour), cut-ins between truck one and two and between truck two and three for three-truck platoons following, two-truck and three-truck platoons following a sport utility vehicle, and speed variations between 55 miles per hour and 65 miles per hour for constant cruising at 65 miles per hour and 55 miles per hour for one minute alternatively. The results were similar to the first round of tests, except that the researchers were able to collect a wider range of data, which provide a better understanding of the drafting effect at very close spacing (13 feet) and longer spacing (300 feet). That data will also be used to understand and model truck behavior which can be used in simulations and evaluations to get more accurate estimates of fuel use and air quality impacts.

The primary energy saving results from the truck tests are summarized in Figure 4 and Figure 5. Figure 4 shows that the lead truck saved from 0 to 10 percent fuel, the middle truck saved 6 to 17 percent fuel, and the trailing truck saved 9 to 13 percent fuel, as compared to the fuel consumption when driven individually. The trends on these plots show that generally shorter gaps lead to increased fuel savings. The test data from other research in the United States, Europe, and Japan confirm that the energy savings increased dramatically as the gaps get shorter (less than 50 feet in the tests performed under this project).

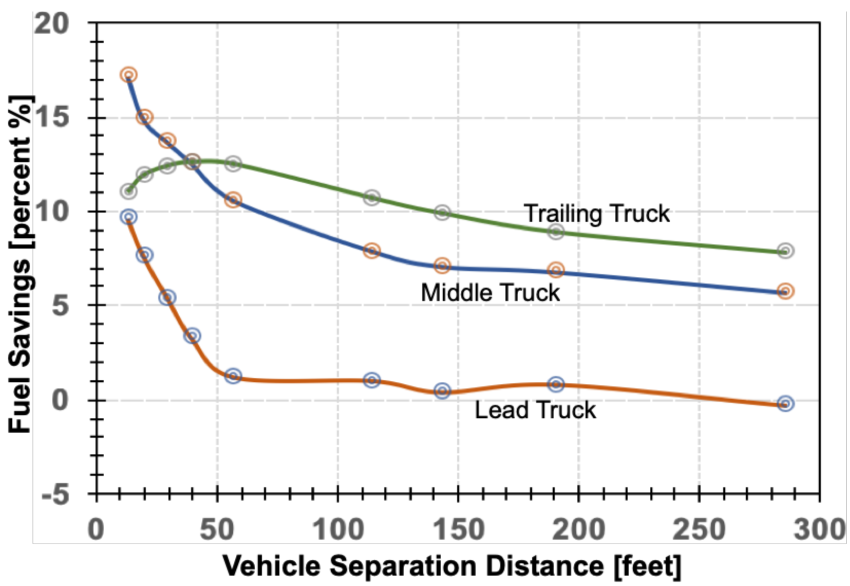

Figure 4. Individual-vehicle fuel-savings results for three-vehicle cooperative adaptive cruise control test (at 65 miles per hour and 65,000 pound vehicle mass)

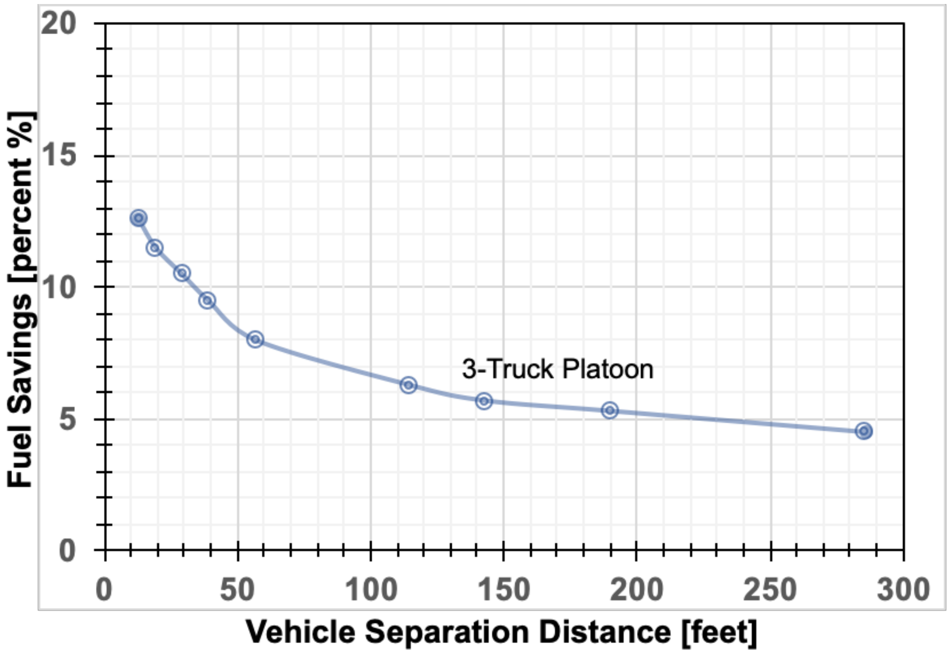

Figure 5. Total-platoon average fuel-savings results for three-vehicle cooperative adaptive cruise control tests (at 65 miles per hour and 65,000 pounds vehicle mass)

Miles Traveled

Since the last report, the three-truck platoons have driven an additional 6,000 miles on the State Highway System at 55 miles per hour without incident. The platoons drove an additional 6,500 miles on a test track for fuel consumption experiments. Since 2014, the three-truck platoons have driven approximately 11,500 miles on California highways and 9,000 miles on the test track for the fuel consumption experiment. In total, the platoons drove 20,500 miles without incident. When the heavy trucks were in platooning operation, the mileage includes cooperative adaptive cruise control development, two fuel consumption tests, a driver acceptance experiment, and three major demonstrations, as well as a number of smaller demonstrations. The three-truck cooperative adaptive cruise control platoon drove on San Francisco Bay Area freeways dozens of times over that last few years for testing and development purposes. The platoon also drove on State Route 87 from the San Jose convention center to Skyport Drive for demonstration in June 2016, at the Intelligent Transportation Systems America annual meeting; along the southern section of Interstate 110 between the Port of Los Angeles and Sepulveda Boulevard for a public demonstration in March 2017; and on Interstate 66 in Virginia in a demonstration for public officials in September 2017. In all cases, drivers of other vehicles cut in between the trucks at all separation gaps. The coordinated operations of the truck platoon at the shorter gaps did not impede the ability of other drivers to change lanes when they needed to. This indicates that the truck cooperative adaptive cruise control system was not creating the type of obstruction to traffic addressed in Vehicle Code section 21705.

Related Projects and Activities

The California Department of Transportation executed a contract with the University of California, Berkeley in March 2019 to perform additional development work on the three Volvo trucks that are equipped with the cooperative adaptive cruise control system. The development work will include improving the cooperative adaptive cruise control system to work at speeds less than 30 miles per hour, so the platoon can navigate through construction zones or congestion without having to disengage the cooperative adaptive cruise control system. In addition, University of California, Berkeley researchers are working with Volvo engineer to fix an issue where the truck's service brake sometimes causes the truck vehicle control system to shut down the cooperative adaptive cruise control system and revert to manual control. The contract duration is 12 months and will expire in March 2020. The majority of the on the road testing are scheduled to take place at the end of the project, which would requiring an extension of the existing statutory authority for testing.

Caltrans is continuing its partnership with the California Highway Patrol, the University of California, Berkeley, Volvo Group, Cambridge Systematics, Los Angeles County Metropolitan Transportation Authority, and Gateway Cities Council of Governments. The team recently received one of three Phase 1 discretionary grants awarded by the Federal Highway Administration to develop test plans for Truck Platooning Early Deployment Testing. If the team successfully completes the work in Phase 1, they may have the opportunity to apply for a Phase 2 grant to carry out the testing regime developed in the Phase 1 work. One or more Phase 2 grants could be awarded within the next year, which would require an extension of the statutory authority for testing.

Caltrans has partnered with the Arizona, New Mexico, and Texas departments of transportation to develop an Interstate 10 connected corridor. The corridor coalition charter specifically mentions truck platooning as one of its goals to improve freight movement, safety, and efficiency along the corridor. A high-level connected freight corridor concept of operations was recently completed. One priority area is the development of policy, regulatory, and infrastructure modifications needed to support connected automated vehicles including cooperative adaptive cruise control truck platooning. The Interstate 10 corridor coalition has partnered with the Caltrans lead truck platooning early deployment test team to perform operational tests on some portion of the Interstate 10 corridor starting from east of the Inland Empire in California through Texas.

In an independent effort, Peloton has developed their own truck platooning technology, and has worked with Caltrans and the California Highway Patrol for approval to test their technology on California highways. They began testing their system in California under the authority of Senate Bill 719 and continued it under Assembly Bill 669. Peloton refers to their cooperative adaptive cruise control system as PlatoonPro. PlatoonPro is similar to the testing conducted by Caltrans, the California Highway Patrol, Volvo, and the University of California Berkeley.

Before testing upgrades of their driver-assistive platooning system on public roadways, Peloton Technology rigorously tests the system in the laboratory via simulation and on closed-courses to ensure proper functionality. They performed much of their initial testing at the closed course facility at Crows Landing near Patterson, California.

Types of tests Platoon conducts include:

- Vehicle-to-vehicle communications
- Braking capacity of different configurations and weights of tractor trailer combinations
- Braking on wet pavement
- Extreme braking events
- Vehicle cut-ins
- System fuel consumption under various conditions

In accordance with industry best safety practices, certain types of testing are performed only on closed course tracks—extreme or wet braking, vehicle cut-ins, and loaded trailers configurations.

Since the last legislative report on truck platooning testing, Peloton reports it has continued working with trucking fleets, manufacturers, and other stakeholders to further test and develop their PlatoonPro truck platooning system. This development process has involved thousands of hours of track testing and on-road validation to meet and maintain strict standards for safety.

State laws governing automated truck platooning vary based on vehicle class, time intervals between vehicles, minuimum following distances, and safe driving standards. Many other states have enacted exemptions through legislation, similar to California, that allow for testing on public roads. However, truck platooning systems have yet to reach commercial deployment.

In addition to development work, track testing, and roadway evaluation of its system in California, Peloton has conducted tests and demonstrations in Arizona, Florida, Michigan, Nevada, Tennessee, Texas, Utah, and Washington State. In 2018, Peloton began hauling commercial freight in Texas for select fleets with its PlatoonPro system.

Conclusion and Next Steps

The tests of the heavy truck cooperative adaptive cruise control system performed under the authority of Senate Bill 719 have advanced the maturity of cooperative adaptive cruise control technology. These tests have validated that operation of vehicles at gaps shorter than the statutory 100 feet minimum, normally prohibited for caravans of vehicles traveling together, confer benefits when under close coordination. These closely coordinated vehicles have been demonstrated to:

- Reduce fuel consumption. In the case of heavy trucks, these savings can be in the range of 10 to 15 percent depending on a variety of factors.
- Enhance safety through coordinated braking with minimal delay.
- Improve traffic flow stability, reducing stop-and-go effects.
- Increase the effective capacity of highway lanes, reducing the adverse effects of congestion.
- Permit the free movement of other vehicles.

The closely coordinated cooperative adaptive cruise control heavy trucks showed that they were able to interact safely and smoothly with drivers of other vehicles. During the course of the project testing and demonstrations, other drivers did not hesitate to change lanes into the gaps between trucks that were driving under cooperative adaptive cruise control coordination. This persistence of lane changing demonstrated that close spaced cooperative adaptive cruise control trucks did not create an impediment to traffic movement and lane choice.

The authorization for carefully controlled testing at shorter gaps was provided by Senate Bill 719. Assembly Bill 1671 (Berman, Chapter 322, Statutes of 2019) further extends the sunset date to January 1, 2024, to allow continued testing. Additional testing is required to refine cooperative adaptive cruise control technology, specifically to:

- Collect and analyze enough data for assurance that adequate safety, operations, and environmental testing has been performed.
- Understand lane changing behavior and how other vehicles interact with platooning trucks
- Determine the implications of cut-ins at various gap settings.
- Incorporate input from commercial vehicle drivers and fleets into the cooperative adaptive cruise control design

Appendix A. Statutory Reporting Reference

CALIFORNIA GOVERNMENT CODE
TITLE 2. GOVERNMENT OF THE STATE OF CALIFORNIA
DIVISION 3. EXECUTIVE DEPARTMENT
PART 5. DEPARTMENT OF TRANSPORTATION
CHAPTER 2. Powers and Duties
ARTICLE 1. General

14107. (a) The department, in coordination with the Department of the California Highway Patrol, may conduct testing of technologies that enable drivers to safely operate motor vehicles with less than 100 feet between each vehicle or combination of vehicles.

(b) Notwithstanding Section 21705 of the Vehicle Code or any other provision of law, motor vehicles participating in testing of those technologies pursuant to subdivision (a) may be operated with less than 100 feet between each vehicle or combination of those vehicles.

(c) The department may only use motor vehicles and streets and highways in testing conducted pursuant to subdivision (a) that the Department of the California Highway Patrol authorizes for those uses.

(d) A person may not operate a motor vehicle participating in testing conducted pursuant to subdivision (a) unless the person holds a valid driver's license of the appropriate class for the participating vehicle.

(e) The department shall report its findings from the testing conducted pursuant to subdivision (a) to the Legislature on or before July 1, 2017, and shall submit an updated report to the Legislature on or before July 1, 2019. The reports required by this subdivision shall be submitted in compliance with Section 9795.

(f) This section shall remain in effect only until January 1, 2020, and as of that date is repealed, unless a later enacted statute, that is enacted before January 1, 2020, deletes or extends that date.