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Supplemental Chapter B: Heavy-Duty On-Board Diagnostic Data Collection Demonstration and Repair Data Collection Study

Agreement No. 18MSC001

Final Report

Prepared for:

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Heavy-Duty On-Board Diagnostic Data Collection Demonstration and Repair Data Collection Study

Agreement No. 18MSC001

FINAL REPORT

Submitted to:

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Executive Summary

This study, which was performed under California Air Resources Board (CARB) agreement number 18MSC001, was initiated in 2019. This study consisted of the following activities:

- **Heavy-Duty (HD) Onboard Diagnostic (OBD) Test System Demonstration**: Conduct an OBD-based HD inspection and maintenance (I/M) data collection pilot program in order to evaluate the feasibility of such a future program
- **Fleet and Industry Surveys**: Conduct fleet and industry surveys to gather information related to HD I/M program preferences, the current usage of telematics and logistic services, and HD vehicle repair and maintenance practices in an effort to help inform program development
- **Fraud and Security Evaluation**: Perform an evaluation of potential security risks and opportunities for fraud in an OBD-based HD I/M program
- **Per-Vehicle Testing Cost Analysis**: Perform a per-vehicle cost analysis for the various I/M program test methods evaluated in the program, and
- **Repair Characterization and Cost Analysis**: Collect OBD fault code, diagnostic and repair information from HD vehicle repair facilities in order to predict the types of repairs and repair costs that could be expected under a future HD I/M program.

Overviews of each of these activities are provided in the following subsections.

HD OBD Test System Demonstration

Trucks equipped with OBD systems compliant with both Society of Automotive Engineers (SAE) J1939 and SAE J1979 communication protocols were of interest in this program, as both systems are in use in the on-road HD fleet. Eastern Research Group (ERG) supported CARB's development of SAE J1939 and SAE J1979 data parameters to be collected during this study. Drew Technologies' DrewLinQ scan tools, along with SAE J1939 and SAE J1979 programming interfaces developed by Opus, were used for primary study data collection, and two HEM Data Corporation devices, the OBD Mini Logger and the DAWN Mini Streamer, were also evaluated during this pilot study.

The original data collection plan called for recruitment of fleets and repair facilities to participate in this study. A list of approximately 50 potential fleets and repair facilities was developed by CARB and ERG, with the target fleets consisting of those with OBD-equipped on-road HD vehicles with engine model year 2013 or newer. ERG and CARB initiated calls to the fleets to describe the program and inquire about each fleet's willingness to participate in program data collection efforts and on-site fleet and driver interviews regarding topics such as the use of handheld scanners, telematics services, test dongles, test kiosks, repair costs, industry preferences for the program and other issues. However, COVID-19 pandemic travel restrictions implemented in the Spring of 2020 prevented our team from performing in-person data collection and fleet interviews. Therefore, in consultation with CARB, ERG pursued other approaches to collect the necessary data for this pilot. This included gathering OBD data from the following entities:

- Personnel from the Colorado Department of Public Health and Environment (CDPHE) collected OBD data in support of this pilot using the pilot study's test equipment from fleets with whom they have an existing relationship.
- California Environmental Solutions, a California-based truck emissions testing and service company, collected OBD data using the pilot study's test equipment as part of their test operations.
- As part of their portable emissions acquisition system (PEAQS) testing at the California Department of Food and Agriculture, Mountain Pass test site, CARB personnel used HEM Data Mini Loggers provided by the Environmental Protection Agency and configured for this program by ERG.
- ERG and Opus personnel performed local testing in Austin, Texas and Tucson, Arizona, respectively

The above testing yielded data from approximately 350 trucks. Both SAE J939 and J1979 data were collected. A summary of vehicles tested during this program is provided in Table ES-1. Although trucks with engine model year 2013 or newer were the focus of this study, some older trucks were also tested, as shown in the table. In general, the intent of sampling was to verify test equipment functionality across a wide variety of vehicle types, so sampling was not performed in a way that would represent the on-road fleet fail rate (some testing was performed on vehicles at repair shops awaiting repairs). Because of this sampling approach, and also because some older trucks were included, the fail rate shown in Table ES-1 is not likely representative of that of the on-road fleet of trucks with model year 2013 or newer engines.

Table ES-1 Summary of Vehicles Tested During Pilot Program

Truck Model Year	J1939 Tests	J1939 Fail Rate	J1979 Tests	J1979 Fail Rate	Total Tests
2005	1	0.0%	0	N/A	1
2007	1	0.0%	0	N/A	1
2008	5	20.0%	0	N/A	5
2009	3	0.0%	0	N/A	3
2010	4	0.0%	0	N/A	4
2011	3	33.3%	0	N/A	3
2012	10	10.0%	0	N/A	10
2013	18	16.7%	0	N/A	18
2014	26	19.2%	2	100.0%	28
2015	27	25.9%	2	0.0%	29
2016	33	33.3%	9	33.3%	42
2017	17	29.4%	7	42.9%	24
2018	41	14.6%	4	0.0%	45
2019	27	14.8%	3	33.3%	30
2020	60	11.7%	8	12.5%	68
2021	19	5.3%	2	50.0%	21
2022	0	N/A	1	0.0%	1
Unknown	19	15.8%	0	N/A	19
Total / Average	314	17.5%	38	28.9%	352

Equipment development and testing performed during this pilot study demonstrated the feasibility of the use of OBD test kiosks, handheld devices, and telematics devices for HD vehicles in the upcoming heavy-duty I/M program.

Fleet and Industry Surveys

Driver and fleet surveys were conducted to gather program relevant information regarding fleets, preferences for the future I/M program, and other information. Two fleet surveys were conducted, one via telephone and/or e-mail, and one as an online survey distributed by CARB. A total of 37 respondents participated in these surveys. Respondents were permitted to skip survey questions, so fewer than 37 responses were received for some of the questions. Fleet size and gross vehicle weight rating (GVWR) ranges reported for responding fleets are presented in Figure ES-1.

Figure ES-1 Survey Fleet Size and GVWR Distributions Among Fleets

FLEET SIZE DISTRIBUTION (TRUCKS > 14,000 LBS. GVWR)
- Fleets with >50 Trucks; 13%
- Fleets with 21 to 50 Trucks; 10%
- Fleets with 4 to 20 Trucks; 27%
- Fleets with 1 Truck; 30%
- Fleets with 2 to 3 Trucks; 20%

GVWR RANGES (LBS.)
- Other; 10%
- >33,000 (Class 8); 27%
- 14,000 - 19,500 (Classes 4 & 5); 30%
- 19,501 - 33,000 (Classes 6 & 7); 33%
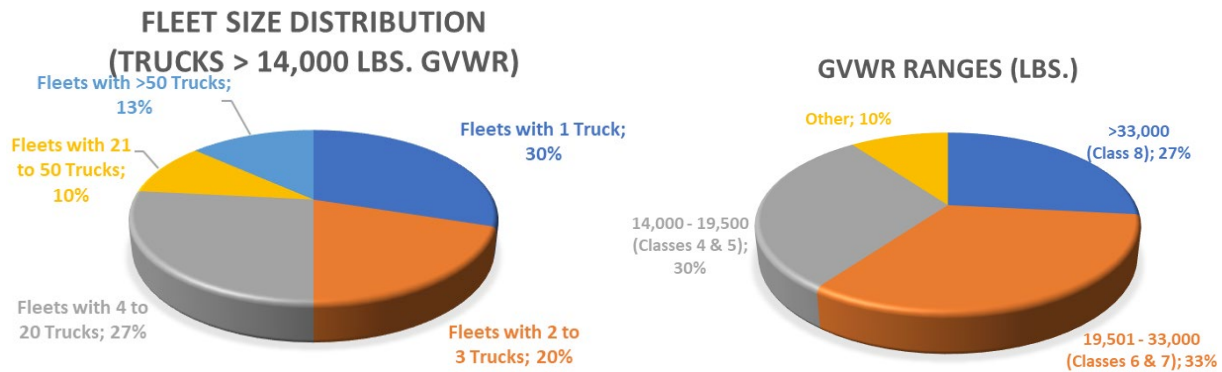
Fleet service type responses indicated 63% of the fleets operate in-state covering less than 100-mile radius, 14% of the fleets operate in-state over a 100-mile radius, 14% of the fleets are interstate, and 9% of the fleets were government or mechanic.

Figure ES-2 shows the reported types of operation (in-state < 100 miles, in-state > 100 miles, interstate, multiple selections possible) and "average age" of heavy-duty vehicles in each of the fleets.

Figure ES-2 Survey Fleet Types of Operation and Average Age of Fleet Vehicles

FLEET SERVICE TYPES

- Other (gvmnt, mechanic); 9%
- Interstate; 14%
- In-state>100 miles; 14%
- In-state <100 miles; 63%

AVERAGE TRUCK AGE DISTRIBUTION
(TRUCKS > 14,000 LBS. GVWR)

- 1 to 5 Years; 10%
- >15 Years; 27%
- 6 to 10 Years; 30%
- 11 to 15 Years; 33%
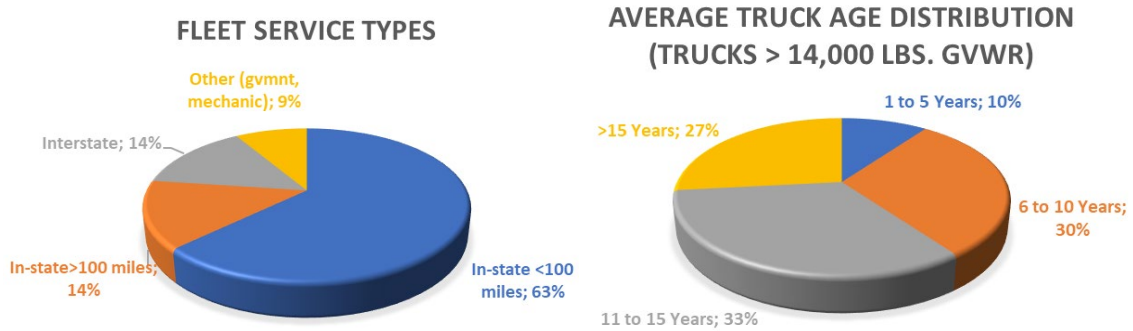
Figure ES-3 shows reported cost ranges for fleets subject to opacity testing under the Periodic Smoke Inspection Program (PSIP) test program.

Figure ES-3 Survey Fleet Reported PSIP Opactity Cost Ranges

CURRENT OPACITY COST RANGES

- Less than $50; 14%
- Internal Testing; 29%
- $150 to $200; 7%
- $50 to $100; 36%
- $100 to $150; 14%
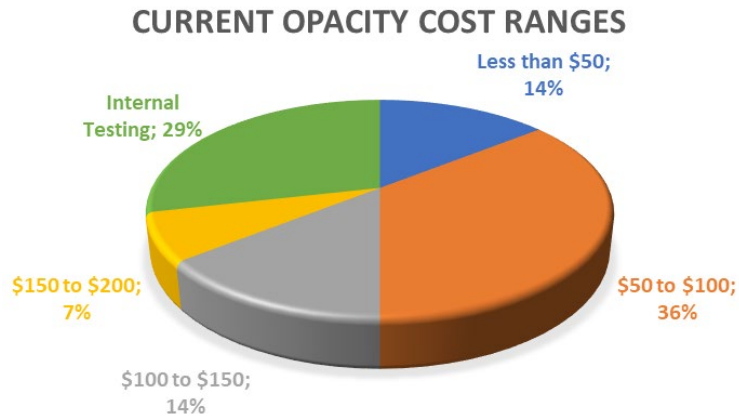
Nearly half of the respondents (43%) reported using some form of telematics and/or fleet management service. There was a strong relationship between the number of vehicles in a fleet and the use of telematics (larger fleets were more likely to utilize telematics), and a positive relationship was also seen between the average distance typically travelled by a fleet and their likelihood of using telematics (fleets with operation greater than 100 miles from domiciled base were more likely to utilize telematics than local fleets with travel distances less than 100 miles from their base). For those fleets that did report utilizing some type of telematics service, Figure ES-4 presents the reported types of services used, including:

- FM: Fleet management / logistics management support,
- OBD: On-board diagnostics used for vehicle diagnostics and preventative maintenance,
- ELD: Electronic Logging Device, including driver vehicle inspection report (DVIR) compliance,

Multiple selections were possible for this question, depending on the services provided.

Figure ES-4 Survey Fleet Reported Existing Telematics Support

TELEMATICS SERVICE TYPE
(MULTIPLE SELECTIONS POSSIBLE)
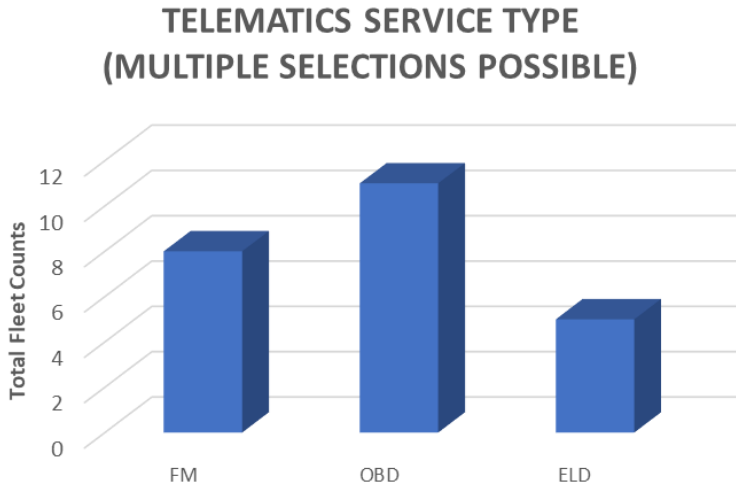
The surveys also queried respondents about the type of program compliance choice they might elect in the upcoming inspection and maintenance program for model year 2013 and newer trucks subject to OBD testing. Figure ES-5 presents respondent selections for a program that requires testing on an annual basis, and revised selections if inspections were required on a 90-day (quarterly) basis. Testing options selected included the following:

- Fleet self-testing by kiosk: Visiting a physical testing location to self-perform required vehicle testing
- Fleet onsite testing by self or 3rd party: Have a CARB-approved tester to perform required testing at a fleet yard or other convenient location, similar to trained testers for California's PSIP. (Note: Tester would be required to successfully complete the CARB-required training in order to be a CARB-approved tester),
- Telematics: Using a telematics service provider to submit required compliance testing information.

As can be seen in Figure ES-5, anticipated telematics use increases as inspection frequency requirements increase. No statistically significant trends were seen between fleet size or service type and test preference options shown in Figure ES-5.

Figure ES-5 Anticipated Program Test Preferences for Annual and Quarterly Test Frequencies

PROGRAM PREFERENCE FOR ANNUAL PROGRAM

Telematics; 27%

Fleet self-testing (kiosk) ; 23%

Fleet onsite testing (self or 3rd party) ; 50%

PROGRAM PREFERENCE FOR QUARTERLY PROGRAM

Telematics; 37%

Fleet self-testing (kiosk) ; 20%

Fleet onsite testing (self or 3rd party) ; 43%
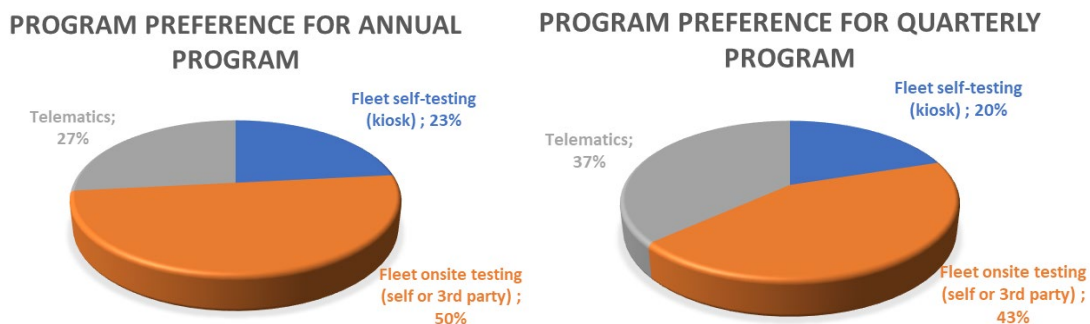
Fraud and Security Evaluation

A review of potential security risks and fraud concerns in an OBD-based HD I/M program was also developed as part of this pilot. This work was based on past experience and successful strategies developed and used in light-duty I/M testing over the past 20 years. Different types of fraud are presented, including test-related fraud in which various methods are used to obtain a passing result for a vehicle that would otherwise fail the inspection, and non-test related fraud in which non-compliant vehicles are operated without detection. Repair-related fraud is also discussed, although this is likely to be less of a program compliance issue as the future HD I/M program is currently envisioned since repair facility licensing and monitoring are not expected to be a component of the program. Methods to help identify and prevent or eliminate fraud are also presented, including a broad assortment of data analysis triggers (which are data mining techniques to identify the use of defeat devices), program reports, and ad-hoc queries that can be used to investigate data trends that reveal potential fraud. Strategies to enforce program compliance are also presented based on activities in other states and programs, with a broad variety of options and suggestions tailored for California's upcoming HD I/M program as it is currently envisioned, as there are unique elements to this HD OBD I/M testing that will present new challenges to address. These include fleet self-testing and new levels of cybersecurity threats that until recently were not considered to be of any major concern. These new threats include distributed denial of service, phishing, malware or spyware attacks, or even vehicle hacking. Section 3 of this report discusses these topics in some detail and provides recommendations for current best practices to address these situations and risks.

Per-Vehicle Testing Cost Analysis

Per-vehicle annual testing cost estimates were made using various program assumptions and scenarios including vehicle throughput, fleet growth and scrappage over time, in-state vs. out-of-state vehicle participation, vehicle exemptions, test frequencies, program duration, and many other factors. The I/M inspection methods evaluated included the following:

- Continuously connected remote OBD (CC-ROBD), such as a telematics device;

- Non-continuously connected remote OBD (NCC-ROBD), such as a handheld test device, that may be used on multiple VINs (vehicles) by a tester that could either be a fleet employee or a third-party tester available for hire.

- Physical testing location - self-testing at a specified location with a certified stand-alone or kiosk-based NCC-ROBD device operated and managed by the state or an I/M contractor. Facilities such as highway truck stops (e.g., Pilot, Flying J, other CMV outlets) could serve as candidate facilities to host kiosk testing.

Program costs were based on the following general assumptions:

- A contract period of 7 years for an I/M support contractor
- 900,000 vehicles will be subject to the OBD inspection in 2023
- Overall annual HD OBD fleet growth rate of 6% over the assumed 7-year program/contract period
- Quarterly program inspection period
- 20% average initial failure rate and an overall per-vehicle average retest rate of 25%
- 20,000 referee inspections per year

In addition to the above assumptions, program costs were also based on projected responsibilities of the program contractor and the following fleet rates for the various test methods:

- Fleet self-testing = 58%,
- Telematics data reporting = 20%,
- Third-party testing = 15%, and
- Kiosk self-testing = 7%

The bases for these assumptions are outlined in Section 3.4 of this report, along with other supporting program and test-specific information. Costing was based on the program information available at the time the analysis was performed, which could change as program plans evolve.

Based on the various program implementation and test equipment assumptions, the following cost estimates were developed:

- Per-vehicle annual cost range of $420-515 for commercial motor vehicle (CMV) and recreational vehicle (RV) owners that choose to submit their required HD I/M OBD data using CC-ROBD, i.e., telematics services. Most of this cost is due to an assumed monthly subscription fee of $30. Some CMVs and RVs already pay fees such as these for existing telematics services, so for these fleets, additional I/M services could affect existing costs rather that create new cost categories.
- For fleet self-testing, estimated cost range of $400 - $700 for an HD NCC-ROBD device, and hence an annual per-vehicle cost range of $9 to $17, based on the assumptions listed in Section 3.4.2.4.

- For third-party testing costs, an estimated per-vehicle annual cost range of $129 - $137, the majority of this cost being due to third-party labor costs.

Repair Characterization and Cost Analysis

As previously noted, in addition to the OBD data collection effort and fleet surveys, ERG was also tasked with collecting historical and on-going data from repair shops to help characterize emission-related repair costs that could be anticipated to result from the upcoming heavy-duty vehicle I/M program. The ERG team's original approach for collection of repair data was to recruit heavy-duty repair shops and/or dealers throughout California to participate in the repair data collection component of this program. However, as with other field efforts, pandemic-related travel restrictions prevented field deployment of staff, so the ERG team's approach was modified accordingly. ERG instead compiled a list of common diagnostic trouble codes (in the form of suspect parameter numbers, or SPNs) that were gathered during a previous large data gathering effort and then enlisted independent organizations to serve as sources for cost estimates for those repairs. ERG used results from a prior heavy-duty emissions deterioration study[1] that ERG supported for CARB in which diagnostic information in the form of J1939 SPNs were compiled for a sample of approximately 180,000 model year 2013 and newer heavy-duty on-road trucks. These truck records contained approximately 56,000 emissions-related SPNs that were grouped into 12 tampering, malfunction and mal-maintenance (TM&M) categories. ERG also used ECM scan data collected by a participant in the data collection task of this project to supplement the SPN listing. Using these lists of SPNs and their counts, ERG developed a list of 42 common emission-related SPNs across 8 of the most common TM&M categories, and using step-by-step repair information guidance from truckfaultcodes.com, ERG then developed a list of 51 unique repairs that were associated with the selected SPNs. Each SPN could require one of multiple potential repairs, and each repair could be associated with one or more SPNs. In general, each failure had a single associated repair, but some failures had multiple potential repairs. As an example, Table ES-2 presents five commonly occurring SPNs, their respective TM&M categories, and typical repairs identified for each SPN.

Table ES-2 Five of the Most Commonly Observed In-Use SPNs and Associated Repairs

SAE J1939 SPN and Name	TM&M Category	Common Related Repairs
3226 - Aftertreatment 1 Outlet NOx 1	NOx Sensor	-Replace SCR outlet NOx sensor
4364 - Aftertreatment 1 SCR Conversion Efficiency	SCR Catalyst	-Replace SCR outlet NOx sensor -Replace SCR catalyst
157 - Engine Fuel 1 Injector Metering Rail 1 Pressure	Fuel System Monitoring	-Replace fuel injector(s) or seals -Replace fuel rail -Replace fuel control valve -Replace fuel rail pressure sensor -Replace low-pressure fuel pump -Replace high-pressure fuel pump or actuator

SAE J1939 SPN and Name	TM&M Category	Common Related Repairs
3216 - Engine Exhaust 1 NOx 1	NOx Sensor	-Replace EGR or EGR gaskets -Replace EGR valve assembly -Replace SCR Inlet NOx sensor
102 – Engine Intake Manifold #1 Pressure	Boost Control	-Replace ambient pressure sensor -Replace EGR or EGR gaskets -Replace intake manifold pressure sensor Replace intake or turbo temperature sensor

ERG presented the list of most common and representative emission related repairs to two independent sources (one repair facility and one fleet support company) to review our list of repairs to ensure they accurately represented repairs that would be required for the most common in-field failures and to provide repair cost estimates for the various repairs. These sources estimated the costs for each repair for common engine manufacturers including Cummins, Detroit Diesel, and International/Maxxforce. One source provided two sets of costs; one for dealership pricing using original equipment (OE) parts, and one for aftermarket parts installed at an independent repair shop. Given that many emission-related repairs cannot be legally performed in California with aftermarket parts, the dealer/OE price estimates were selected as the most representative. Repair costs were averaged within each TM&M category and category-level repair costs were weighted using the prevalence of each TM&M category in the overall SPN data to reach a single repair cost of $1,977. This cost represents an estimate of the average cost (before sales tax) of repairing a 2013+ model year truck with an emission-related malfunction indicator light (MIL) on condition.

1.0   Introduction

This report documents a program conducted by ERG under contract to CARB to conduct a pilot study to inform the development of a future HD I/M program. Even though HD vehicles make up only a small portion of California's total on-road fleet, they contribute a disproportionately large portion of pollution. Trucks are the largest single source of air pollution from vehicles in the state, responsible for 70 percent of the smog-causing pollution and 80 percent of carcinogenic diesel soot[2] emitted in the state. Hence there is a strong need to control emissions from these vehicles, especially as emission control systems deteriorate and emissions increase with age.

While the current program involves performing annual SAE J1667 smoke opacity tests on HD diesel vehicles over 6,000 pounds (lbs.) GVWR with engines over four years old[3], the new program as required by Senate Bill 210[4] would involve conducting electronic scans (SAE J1939 or SAE J1979) on non-gasoline HD trucks with engine model year 2013 or newer, while older non-gasoline HD trucks would still be subject to the SAE J1667 smoke opacity test. The test frequency for scans and opacity tests has not yet been determined. Performing electronic scans of newer trucks would allow more effective monitoring of modern emission-control systems used on 2013 and newer trucks, such as selective catalytic reduction (SCR) and diesel particulate filter (DPF) systems. In this way, the lower NOx and PM emissions levels to which these trucks were certified can be maintained by ensuring these emission control systems are functioning properly.

The focus of this pilot study was to conduct an OBD-based HD I/M demonstration program and a repair data collection and analysis program under CARB agreement number 18MSC001. Specifically, the program was designed to assess the feasibility of drivers submitting OBD data from their own vehicles or fleets using various methods (self-testing at various locations, outside testing services, or through some form of telematics-integrated solution). This study was performed to evaluate methods and issues associated with the various data collection and transmission options and to obtain vehicle driver feedback on program preferences and their data collection experience. In addition to assessing methods and equipment most suitable for collecting program data, another objective of this pilot was to collect OBD fault code and diagnostic and repair information from HD vehicle repair facilities that could be used to develop estimates of types of repairs and costs that would be associated with truck repairs required under a HD I/M program. To conduct this pilot, ERG teamed with Gordon-Darby, a subsidiary of Opus Inspections, who provided our team with extensive I/M program and OBD (SAE J1939 and J1979) data collection experience and equipment.

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[2] https://ww2.arb.ca.gov/news/california-takes-bold-step-reduce-truck-pollution
[3] https://ww3.arb.ca.gov/msprog/truckstop/azregs/opacityfaq.htm
4 https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB210

2.0 Materials and Methods

This section provides a description of the work performed to accomplish this study. As noted previously, the focus of this study was to collect HD vehicle OBD and repair data and gather information regarding industry preferences for the upcoming HD I/M program required under SB210. This study was initiated in 2019, and the original study plan entailed extensive onsite OBD and repair data collection activities to conduct the various project tasks. However, COVID pandemic travel restrictions implemented in the Spring of 2020 prevented travel and field efforts as originally envisioned from occurring, so alternate approaches were used in order to achieve the objectives of the pilot study. The original and alternate approaches ultimately employed for the project tasks are described in the following subsections.

2.1 Task 1: OBD-Based HD I/M Demonstration Program

2.1.1 Study Plan

To initiate this program, ERG developed a study plan for performing the two primary tasks necessary for accomplishing this work. Our approach was developed to capture the necessary information to assess multiple OBD data collection methods for trucks utilizing both SAE J1939 and SAE J1979 (ISO 15765 with a SAE J1962 connector) communication protocols. All of this data is referred to as "OBD data" throughout this report. The study plan included proposed data collection methods and hardware; techniques for conducting driver and fleet personnel surveys; approaches to collecting information regarding perceptions and feedback; and a description of evaluations to be performed. In addition to using Drew Technologies' DrewLinQ handheld scanners and tablets (described later in this report) to collect OBD data from trucks, we also included steps for testing equipment from other providers in order to gather performance information and feedback on various types of test systems and procedures. Questionnaires were developed to guide our team members when surveying drivers and fleets regarding preferences for test options such as type of equipment and test program that would best align with current options, including self-testing, self-serve kiosks, telematics devices, and other inspection solutions and program preferences.

The study plan also included approaches to identify repair shops from which we could collect the required repair data for the project. As described later, our planned approach was to collect historical repair information and also to work with larger repair facilities over a period of several weeks or months in order to collect ongoing fault and repair information relevant to the objectives of this pilot program. A list of candidate fleets developed using existing CARB and ERG contacts was compiled and included in the study plan, along with a list of the most valuable repair information to be obtained from the repair facilities.

The study plan also included methods and procedures to collect OBD and repair data using methods that were minimally disruptive to drivers, fleets and fleet managers and also repair facilities. We developed approaches that protected a facility's confidential business information and also made it convenient for the repair facilities to participate in the study.

2.1.2 HD OBD Test System Demonstration

ERG and CARB initiated this task by identifying fleets that might be willing to participate in the pilot study. A list of candidate fleets and repair facilities was developed based on fleets with whom ERG had a previous relationship through other programs, attendees that had participated in CARB's HD I/M workgroup meetings and workshops, and existing fleet / facility contacts known by CARB personnel. Target fleets were those with OBD-equipped on-road diesel (or non-gasoline)-powered HD vehicles with engine model year 2013 or newer, GVWR greater than 14,000 lbs. In this way, a preliminary list of approximately 55 fleets / facilities was developed. ERG and CARB contacted as many of these organizations as possible to describe the program, collect general information about the fleet vehicles, fleet operations and repair infrastructure and repair approaches, and to determine willingness to participate in the pilot study, either by way of the OBD data collection effort, repair data collection effort, or both. These initial calls were held as joint conference calls with each organization, ERG, and CARB personnel.

All fleet participation was voluntary, and the fleets were not compensated or provided any monetary incentives to participate in this study. However, vehicles that did participate and pass the OBD scan were eligible to receive annual credit for the PSIP for the year in accordance with the PSIP provision that allows fleets to submit OBD data in lieu of performing annual smoke opacity testing if smoke opacity testing has not already been performed for that vehicle and test cycle.

For those fleets and repair facilities agreeable to some level of participation, tentative agreements were made for future fleet manager and driver interviews, truck OBD testing, and repair data collection efforts, depending on each fleet and agreement. Tentative agreements were made with approximately 20 organizations that included fleets, repair facilities, or fleets with associated repair facilities.

While the initial fleet and repair facility calls were underway, the ERG team worked with CARB to finalize the list of OBD data parameters to be collected in the program and to develop test equipment suitable for use in this pilot. We anticipated most vehicles to be tested in the program would have powertrains compliant with the SAE J1939 protocol (i.e., those with powertrains manufactured by Cummins, Detroit Diesel, Navistar, and Paccar), although some candidate trucks would likely be equipped with powertrains compliant with the SAE J1979 protocol, such as late-model Volvo, Ford, General Motors (GM), Isuzu, Hino, and other vehicles that broadcast the requisite parameters on the SAE J1962 network. A list of both J1939 and J1979 parameters targeted during this pilot is provided in Appendix A. Note that in this appendix, all J1939 SPNs within each listed parameter group number (PGN) will be collected from every reporting controller. The specific J1939 and J1979 parameters required for meeting the PSIP provision for submitting OBD data in lieu of performing annual smoke opacity testing are shown with bold font. The final list of parameters to be collected in the future program could vary from this list.

Drew Technologies, a subsidiary of Opus Inspection, Inc., programmed and provided the DrewLinQ device for use in the program, a heavy-duty scanning tool with J1939, J1708/J1587,

ISO 15765, and OBD communication capabilities[5]. This equipment was programmed to collect all necessary diagnostic data from both J1939 and J1979 trucks according to CARB's data requirements, with functionality similar to that which could be expected for a program-based handheld test device or a testing kiosk. The Drew Technologies' DrewLinQ device that was used in this program is shown in Figure 2-1.

Figure 2-1 DrewLinQ Heavy-Duty Truck Data Collection Device

The DrewLinQ requires use of a personal computer (PC) or tablet computer, and on-line activation of the device is necessary prior to usage. Once activated, the DrewLinQ may be used to test specific vehicles according to guidelines provided in the Section 10 of the DrewLinQ User Manual. This manual provides details for connecting to and collecting data from the various connectors and communication protocols expected to be encountered in this program. Opus provided six DrewLinQ devices and associated hardware for use in this program, and ERG provided and installed software on six laptop computers for use with the DrewLinQ devices. Figure 2-2 is a screen image of the software display on a laptop captured while the device is scanning a vehicle.

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5 Drew Technologies DrewLinQ User Manual, Document Revisions: 12/07/2016, available at www.drewtech.com > downloads > drewlinq > DrewLinQ_User_Manual

Figure 2-2 DrewLinQ Heavy-Duty Truck Data Collection Device
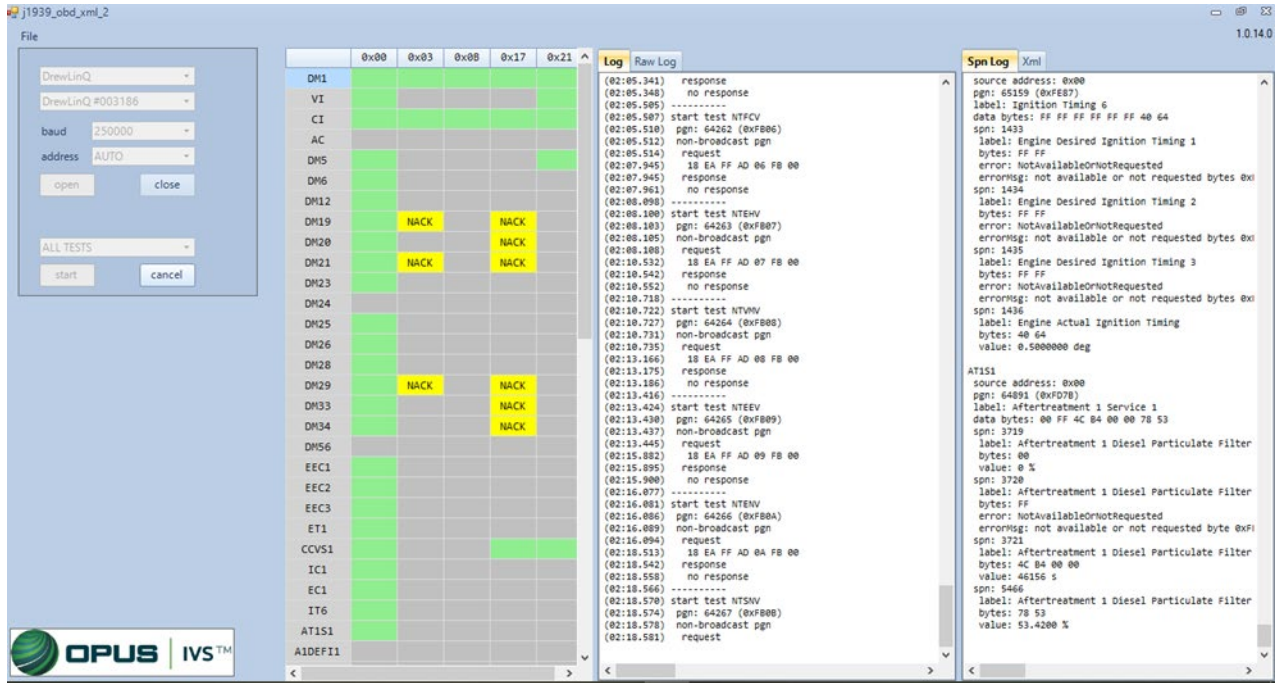
The horizontal rows in the datagrid shown above represent the various SAE J1939 PGNs being requested from the truck, while the datagrid's columns represent the responding controller. The scanning process is automated and creates a log file listing data requests and responses in hexadecimal format, a SPN Log file which lists hexadecimal and decoded results, by PGN, and an extended mark-up language (XML) file which contains data from the SPN Log file in XML format. Similar files are also generated for SAE J1979 files, except a parameter identification (PID) Log is generated instead of an SPN Log, following SAE convention.

HEM Data Corporation[6] also provided two acquisition devices for use in the program, the OBD Mini Logger and the DAWN Mini Streamer, shown in Figure 2-3 below. While the OBD Mini Logger is a configurable datalogger capable of collecting and logging data from both J1939 and J1979 data streams, and can also serve as a telematics device, the Mini Streamer provides real-time streaming of J1939 and J1979 data to a PC, Android device or iOS-based tablet (iPad) (as shown in Figure 2-3) for collection of "snapshot" vehicle service and performance data, such as that collected during a vehicle inspection. ERG developed J1939 and J1979 configuration files tailored to collect the program parameters listed in Appendix A for the Mini Logger and acquired and installed the necessary application on an iPad for use with the Mini Streamer.

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[6] http://hemdata.com

Figure 2-3 HEM Data OBD Mini Logger and DAWN Mini Streamer

The Drew Technologies DrewLinQ was the primary data acquisition device used for this program, although testing with HEM Data was performed for device evaluation and quality assurance and quality control (QA/QC) purposes, and it was also used by CARB personnel for a special data collection program described later in this report. All data collected in this program was compiled, reviewed, and summarized and transferred to CARB. Data review consisted of comparison of data with CARB's specifications and reasonable processing and conversion of the OBD hex data, although for the full-scale program, it is envisioned that hex data will be transferred to CARB prior to engineering conversion, and converted by CARB on their vehicle information database. For data collected from individual trucks with multiple devices, comparison between results from the various devices was performed to ensure consistent results were obtained with the different equipment.

The original approach for this project was to staff the OBD data collection phase of the study with two technicians who would be responsible for downloading the HD vehicle's OBD data, collecting truck metadata, documenting any data collection issues for each tested OBD tool, and conducting the driver or fleet manager surveys when possible. These tests and fleet interviews would be scheduled and performed with the fleets that had been contacted by ERG

and CARB, as previously described. A list of on-site interview questions was developed which would be conducted with drivers and fleet managers, and field team members would also gather information regarding industry test preferences and seek input regarding testing procedures. Vehicle metadata, such as truck and engine make, model, model year, engine family and other vehicle attributes, would be simultaneously collected with the OBD scans. Our goal was to collect scans on a minimum of 200 and up to 500 OBD-equipped HD vehicles with engine model year 2013 and newer.

As test equipment preparation and verification was concluding in the Spring of 2020, pandemic-related travel restrictions related to the COVID-19 pandemic were implemented which prevented field deployment of staff. Some limited testing was performed by both Opus personnel locally at their Tucson, Arizona test facility and by ERG staff locally at truck rental facilities in Austin, Texas. Along with testing with the DrewLinQ equipment, limited testing of the HEM Data OBD Mini Logger and the DAWN Mini Streamer was performed during the Austin-based testing. However, the Tucson and Austin-based testing was insufficient to collect adequate program OBD data or to conduct fleet and driver interviews; therefore, in consultation with CARB, ERG pursued other approaches to collect in-use scan data and information regarding industry preferences, as described below.

Through initial contacts with CARB, a California-based truck maintenance and repair facility was identified that maintained a large database of engine scan data from trucks that were brought to the facility for repairs. This facility provided ERG online access to this database, from which multiple years of ECM scan data from model year 2013 and newer trucks that were scanned prior to servicing was downloaded. These data were compiled and used in the repair cost analysis described for Task 2.

As another data collection effort, personnel from the CDPHE agreed to conduct data collection with HD fleets with whom they have existing relationships. These tests were initiated with DrewLinQ equipment that captured both J1939 and J1979 data. In agreement with CARB, testing of out-of-state trucks was acceptable for purposes of test equipment verification.

A California-based truck emissions testing and service organization also agreed to perform testing with the DrewLinQ equipment. This equipment was provided to this organization for in-house testing as well, an arrangement was made with CARB for the facility to grant a PSIP credit for eligible vehicles that passed the OBD scan with no DM12 or DM28 (diagnostic message) codes for SAE J1939-compliant trucks, and no MIL or diagnostic trouble codes (DTCs) for SAE J1979-compliant trucks. However, no PSIP exemptions were required or granted under this program.

As part of CARB's preparation for various program test components, CARB personnel performed testing at Mountain Pass with various remote sensing device (RSD) systems, including their PEAQS and also various optical RSD systems. To support this effort and to acquire additional ECM scan data, the Environmental Protection Agency (EPA) agreed to a loan of EPA-owned HEM Data Mini Loggers to CARB for this two-week test program conducted in November 2020. ERG created configuration files to capture the pilot program's J1939 and J1979 parameters and also some additional live parameters. These configuration files and operating instructions were provided to CARB personnel for use in this study.

The devices used for both SAE J1939 and SAE J1979 HD data collection during this program represented functional proofs of concept for hand-held devices and kiosks. As described in this section, pandemic-related travel restrictions prevented staff travel, so direct (face-to-face) feedback from drivers was not possible. Instead, feedback regarding these types of devices was sought from fleets and drivers during the fleet surveys, and feedback regarding use and functionality of the equipment was also provided by CDPHE staff and the California-based truck emissions testing and service organization, both who performed program testing in support of this program. Additionally, ERG and Opus staff evaluated the equipment performance relative to program requirements based on local testing performed in Austin, Texas and Tucson, Arizona. Results of testing and functionality evaluations are provided in Sections 3 and 4 of this report, and additional kiosk requirements and considerations for the full-scale program are provided in Section 3.3. A list of all trucks for which ECM data was collected during this program is provided in Appendix B.

2.1.3   Fleet and Industry Surveys and Test System Demonstration

Fleet Surveys

As part of the pilot program, the ERG team was tasked with obtaining fleet and driver feedback on test options, including handheld scanners, telematics devices, test "dongles" (small devices that connect to the OBD port and broadcast results to a base or through a mobile phone or other device) and also testing "kiosks". A survey was developed to question program participants about their test preferences. Since ERG was unable to deploy and perform in-person interviews, we contacted fleets that had originally agreed to participate in the program in an effort to conduct "remote" fleet interviews via telephone or e-mail. ERG had limited success with these remote interviews as we were able to conduct interviews with approximately 40% of the roughly 20 fleets that originally agreed to participate in the program. Results of these interviews are presented in Section 3 and included in Appendix C of this report.

Based on the low number of responses, ERG and CARB then drafted a revised survey for online distribution by CARB and to various drivers, fleets, and trucking organizations. This survey was distributed by CARB to workgroup members and posted on their online diesel truck information portal (the Truckstop[7]). Due to CARB's revisions to the online survey, questions differ from the remote (telephone/email) survey previously developed by ERG. Detailed tabular and statistical survey results were presented directly to CARB, and a summary of the online responses are presented in Appendix D of this report.

I/M Personnel Interviews

ERG also contacted I/M program personnel in several other states involved in HD vehicle test programs to discuss their program experiences and observations and seek input for CARB's upcoming HD I/M test program. Concepts and recommendations applicable for this program are provided in Section 4 of this report.

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[7] https://ww3.arb.ca.gov/msprog/truckstop/truckstop.htm

Telematics Provider Surveys

Also as part of this pilot program effort, ERG identified and contacted telematics providers to inform them of the CARB HD IM initiative and explain how a key component of the CARB program will allow for broad use of telematics to demonstrate program compliance. In addition to providing information on the upcoming HD IM program, ERG also sought to assess the interest of these telematics providers and learn more about the any challenges of using remote OBD data collection in an IM program, specifically with regard to data security, data transmission, fraud prevention and integration with the CARB vehicle inspection database (VID). We also wanted to gauge telematics providers opinions on our assumption that the primary cost of such a system would likely be the device purchase cost and provider subscription fees, and the possibility of integrating electronic logging device (ELD), telematics and fleet services with program compliance, and the extent of hardware upgrades necessary for program support, i.e., whether this would entail an entire newly-developed system or if modification of the existing telematics solution would suffice.

ERG attempted contacting telematics providers by e-mail and telephone, if possible. Our initial contact focused on introducing ourselves as providing CARB contract support and explaining the nature of our pilot study and the upcoming CARB HD I/M program. Through the course of the pilot program, our team identified 28 potential companies, although 15 of those initially identified did not appear to be well suited for program support, i.e., these vendors provided fleet-management support but did not collect OBD data. ERG attempted to contact the remaining 13 companies and discussed our pilot and the upcoming heavy-duty I/M program with seven of them. After the initial dialog with ERG, some telematics companies coordinated directly with CARB regarding possible future program support. Our project partner for this pilot, Opus Inspections, also provided telematics expertise based on their prior remote OBD program support and prior remote OBD guidance development.

2.1.4 Evaluation of Potential Security Risks and Opportunities for Fraud

ERG worked with our partner on this project, Opus Inspections, to perform an evaluation of potential data security risks and opportunities for fraud, based upon both the design of the planned upcoming program and past industry experience. This analysis was based largely on data analysis methods designed to identify outliers revealing efforts to bypass the inspection system and requirements, including the use of triggers (i.e., automated algorithms that flag suspicious data), which are powerful data mining tools that are designed to identify program fraud and suspicious testing activity. These have been used routinely in light-duty I/M programs, and similar algorithms were tailored for the design of this HD I/M program. As opposed to conventional decentralized programs, this future program will have an even greater degree of "decentralization", in that it will not employ private state-certified inspection stations, but only certified inspection devices (and certified inspectors). Our approach incorporated our team's experience in building triggers tailored for the anticipated design of this upcoming program. This approach can reveal inconsistencies and mismatches that could be used for detecting potential program fraud. This evaluation also included an evaluation of fraud / security concerns in a remote OBD / telematics program. Some examples of existing programs and systems are provided for reference, along with recommendations for program design to minimize program fraud as much as possible.

2.1.5 Per-Vehicle OBD Testing Cost Analysis

Based on their program experience, ERG's partner Opus Inspection developed estimates of per-vehicle program costs as the program is expanded from a pilot into a full-scale program. Costs were developed using different program assumptions and scenarios, such as throughput, in-state and out-of-state vehicles, exemptions, test frequencies, etc., based on information provided by CARB during the pilot program. This information was collected through CARB-sponsored workshops and workgroups, and also as defined in CARB's SB210 Heavy Duty Inspection & Maintenance Request for Information released November 18, 2020[8]. Costs were developed for the broad variety of program implementation options, including kiosk operation, i.e., self-testing, independent contractor fleet testing, internal fleet testing, and various telematics solutions. The ERG team also worked with CARB to ensure our costs were developed according to planned program criteria and objectives. Results of this cost analysis are provided in Section 3.

2.2 Task 2: OBD/Repair Data Collection

In addition to the OBD data collection effort described for Task 1, our team was also tasked with collecting historical and ongoing data from repair shops to help characterize emission-related repair costs that could be anticipated to result from the upcoming heavy-duty vehicle I/M program. As previously described, COVID-19 pandemic-related travel restrictions were implemented which prevented field deployment of staff, so the ERG Team's approach was modified during the fieldwork planning stage to accomplish program goals under these new travel restrictions. The following subsections describe our original and revised approaches for data collection, analysis, and reporting activities under this task.

2.2.1 Overall Approach

As described in our study plan, the ERG team's original approach for collection of repair data was to recruit heavy-duty repair shops and/or dealers throughout California to participate in the repair data collection component of this program. ERG and CARB identified and contacted repair shops and dealerships to find out more about their operations and to evaluate willingness to participate in the program. These initial contacts included organizations that had participated in prior CARB HD I/M workshops as well as CARB contacts from prior projects. We sought to recruit shops throughout California that supported a diversity of vocations and fleet types, from small shops to large repair facilities.

The original objectives were to collect pre- and post-repair OBD scan data, either using our team's scan tools or via the scan tools utilized by each shop in their day-to-day operations. We also sought to collect truck metadata, such as engine and truck make / model / model year information, and the shop's diagnostic and repair information. Our objective was to gather the aforementioned historical information as well as current, ongoing diagnostic and repair information for several weeks or longer at each shop. Using this information, ERG would attempt to associate repair information (including procedures, parts, and costs) with OBD fault codes for at least 300 (or more) OBD-equipped diesel-powered heavy-duty trucks (GVWR >

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8 REQUEST FOR INFORMATION, Event Number: 18002, RFI_CARB_SB210_Heavy_Duty_Inspection_and_ Maintenance_2020522 For SB210 Heavy Duty Inspection & Maintenance (HD I/M)

14,000 pounds, with 2013 or newer engines) that have illuminated MILs from participating repair shops.

As our team was unable to visit repair facilities to begin repair data collection, we initially attempted to acquire historical repair data from agreeable shops remotely. However, due to a very limited response and lack of emission-related diagnostic and repair information available in the records that *were* received, our team sought another approach for developing ranges of representative repair costs for heavy-duty truck emission-related repairs.

ERG performed the estimate of repair costs primarily on the basis of determining the most frequent emissions-related repairs that occur in-use and their respective TM&M category, the cost associated with each, and the relative prevalence of failures within each TM&M category to determine an estimate of the average repair cost for a heavy-duty truck with a MIL on. The following subsections describe the data sources and steps followed by ERG to determine estimated I/M program related repair costs on a per-truck basis with a focus on the initial year of the program. The following figure gives a broad overview of the approach taken by ERG to develop the cost estimates.

Common Repairs and their TM&M Categories → Average Cost of Repairs in Each TM&M Category → Frequency of Each TM&M Category when a MIL Set → Average by-truck repair cost if MIL On

2.2.2 Common Emission Related SPNs Causing MIL On and TM&M Categories

The initial determination for this approach was to identify the most common or representative repairs that could be necessary to address MIL-on conditions. This would later allow for determining the costs associated with those repairs. To do this, we utilized results from a recent heavy-duty vehicle emission deterioration study[9] that ERG supported for CARB in which diagnostic information (in terms of J1939 SPNs) was compiled for a sample of approximately 180,000 model year 2013 and newer heavy-duty on-road trucks. These truck records contained approximately 56,000 emissions-related SPNs which were grouped into the following 12 TM&M categories:

- Boost Control
- EGR
- Fuel System Monitoring
- NOx Sensor
- PM Filter
- PM Filter Frequent Regen
- Reductant Delivery

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[9] "Updates to Heavy-Duty Emission Deterioration in EMFAC", Report, Version 3, submitted to the California Air Resources Board July 21, 2020, Agreement No. 17AQP006.

- SCR Catalyst
- Cold Start Strategies
- Exhaust Gas Sensor Monitoring – Oxygen,
- Misfire Monitoring
- NMHC Catalyst

Because of the large amount of available SAE J1939 data (relative to SAE J1979 data) which included all emissions-related categories, our analysis relied solely on SAE J1939 data results. Since general emission control technologies are common across all trucks, our analysis was based on the assumption that individual system and component failure rates would be relatively independent of the OBD protocol (SAE J1939 or SAE J1979), so the repair cost estimates developed for this program would apply to both SAE J1939 and J1979-protocol trucks, although adjustments were made to account for differences in costs among manufacturers.

It should be noted that many trucks had more than one SPN recorded per malfunction, so the SPN rate does not directly represent the MIL illumination or truck failure rate. Because of the complexity of characterizing J1939 "emissions" vs. "non-emissions" codes, in that previous study ERG and CARB developed a process to classify each SPN as "emissions-related" or not, based on MIL illumination, inclusion in DM12 and 28, and other factors, and to assign TM&M categories to each emissions-related SPN. Those processes are described in that earlier report and the same conventions were applied in this work as well. Notably, Appendix N of Version 3 of that report was used to correlate each SPN to its respective TM&M category.

The most common SPNs from the earlier report were brought together with the most common SPNs identified during the data collection portion of Task 1 of this pilot, in which the participating repair shop also provided historical SPN counts from scans of trucks in for repair. Using these two lists of SPN counts, ERG selected 42 of the most commonly occurring emissions-related SPNs, which encompassed emission-related failures in the following eight of the twelve TM&M categories:

- Boost Control
- EGR
- Fuel System Monitoring
- NOx Sensor
- PM Filter
- PM Filter Frequent Regen
- Reductant Delivery
- SCR Catalyst

Our objective was not to create a census of all the TM&M categories in our repair cost development, but instead develop a fairly broad distribution of repair types that would accurately reflect the most common I/M related repairs. For this reason, the four least common TM&M categories are not represented, which are cold start strategies, exhaust gas sensor monitoring – oxygen, misfire monitoring, and NMHC catalyst. SPNs related to these types of faults were far less common than the faults we characterized. We believe these would most accurately represent the range of common I/M related repair costs with a reasonable amount of effort. This provided

our initial estimate of the range of some of the more common failures that could be seen in the first year of a heavy-duty truck I/M program. Table 2-1 presents the list of the most common SPNs that were selected, along with their associated TM&M category and the number of observed counts as noted in the previous report.

Table 2-1 Selection of Most Common SPNs and their relative counts

SPN	SAE J1939 SPN Name	TM&M Category	SPN Counts
3226	Aftertreatment 1 Outlet NOx 1	NOx Sensor	2506
4364	Aftertreatment 1 SCR Conversion Efficiency	SCR Catalyst	2375
157	Engine Fuel 1 Injector Metering Rail 1 Pressure	Fuel System Monitoring	2154
1761	Aftertreatment 1 Diesel Exhaust Fluid Tank Volume	Reductant Delivery	2088
3216	Engine Exhaust 1 NOx 1	NOx Sensor	2031
102	Engine Intake Manifold #1 Pressure	Boost Control	1550
3364	Aftertreatment 1 Diesel Exhaust Fluid Tank Quality	Reductant Delivery	1468
3610	Aftertreatment 1 Diesel Particulate Filter Outlet Pressure	PM Filter	1381
3031	Aftertreatment 1 Diesel Exhaust Fluid Tank Temperature 1	Reductant Delivery	1366
3058	Engine Exhaust Gas Recirculation System Monitor	EGR	1303
3361	Aftertreatment 1 Diesel Exhaust Fluid Dosing Unit 1	Reductant Delivery	1283
3251	Aftertreatment 1 Diesel Particulate Filter Differential Pressure	PM Filter	1242
641	Engine Variable Geometry Turbocharger Actuator #1	Boost Control	1221
5743	Aftertreatment 1 SCR Temperature Sensor Module	SCR Catalyst	1198
3556	Aftertreatment 1 Hydrocarbon Doser 1	Not Assigned	1114
411	Engine Exhaust Gas Recirculation 1 Differential Pressure	EGR	998
2659	Engine Exhaust Gas Recirculation 1 Mass Flow Rate	EGR	989
5848	Aftertreatment 1 SCR Intermediate NH3	SCR Catalyst	922
2791	Engine Exhaust Gas Recirculation 1 Valve 1 Control 1	EGR	893
51	Engine Throttle Valve 1 Position 1	EGR	872
5397	Aftertreatment 1 Diesel Particulate Filter Regeneration Too Frequent	PM Filter Frequent Regen	862
3362	Aftertreatment 1 Diesel Exhaust Fluid Dosing Unit 1 Input Lines	Reductant Delivery	791
4334	Aftertreatment 1 Diesel Exhaust Fluid Doser 1 Absolute Pressure	Reductant Delivery	785
5835	Aftertreatment 1 Particulate Sensor	PM Filter	772
27	Engine Exhaust Gas Recirculation 1 Valve Position	EGR	743
3936	Aftertreatment Diesel Particulate Filter System	PM Filter	716
5585	Engine Fuel 1 Injector Metering Rail 1 Cranking Pressure	Fuel System Monitoring	703
5394	Aftertreatment 1 Diesel Exhaust Fluid Doser Valve 1	Reductant Delivery	654
94	Engine Fuel Delivery Pressure	Fuel System Monitoring	537
5357	Engine Fuel Injection Quantity Error for Multiple Cylinders	Fuel System Monitoring	505
96	Fuel Level 1	Fuel System Monitoring	495
5298	Aftertreatment 1 Diesel Oxidation Catalyst Conversion Efficiency	NMHC Catalyst	454
4094	NOx limits exceeded due to Insufficient Diesel Exhaust Fluid Quality	Reductant Delivery	439
1172	Engine Turbocharger 1 Compressor Intake Temperature	Boost Control	409
3521	Aftertreatment 1 Diesel Exhaust Fluid Property	Reductant Delivery	398
95	Engine Fuel Filter Differential Pressure	Fuel System Monitoring	380
3061	Engine Cold Start Emission Reduction Strategy System Monitor	Cold Start Strategies	360
3064	Aftertreatment Diesel Particulate Filter System Monitor	PM Filter	337
164	Engine Fuel Injection Control Pressure	Fuel System Monitoring	334
4339	Aftertreatment 1 SCR Feedback Control Status	SCR Catalyst	323
4363	Aftertreatment 1 SCR Outlet Temperature	SCR Catalyst	323
6713	Engine Variable Geometry Turbocharger Actuator Software Identification	Boost Control	311
105	Engine Intake Manifold 1 Temperature	Fuel System Monitoring	225

It should be noted that, due to the complex and interrelated nature of the emissions-control systems involved, the SPN/FMI diagnostic is not always a direct indicator of the specific problem, but rather can be a general indication of the malfunction. Because of this, the actual system that requires attention may differ from the TM&M category. For example, SPN 3610, FMI 2 (Aftertreatment 1 DPF Outlet Pressure fault) could reasonably be expected to be a DPF fault, and the TM&M category is PM filter, but the related diagnostic information (as described in the next section) indicates one possible cause is excessive DEF deposits in the aftertreatment decomposition tube (i.e. the SCR). This is the reason why some SCR-related repairs are associated with a PM Filter TM&M category. Other apparent discrepancies may exist; in our repair classification in the next section some repairs are associated with SPNs that may seem unrelated to upon initial review.

2.2.3   Repair Costs Associated with Each TM&M Category

ERG investigated various approaches for estimating repairs and repair costs for the most likely repairs associated with failures that could result in each of the 42 most common SPNs. To initiate the process, ERG used commercially available repair resources to cross reference SPNs to repairs. One such resource was a subscription that we acquired to "truckfaultcodes.com", and we also used SPN-based lookups from "Diesel Laptop Repair Tree" data available from an independent subscription (these Repair Tree references appear to be a subset of information available with ERG's "truckfaultcodes.com" subscription). These sources include pdfs that describe diagnosis procedures for each of the various manufacturers' engines for many SPN and FMI code combinations. ERG reviewed a representative sample for each SPN and determined the most likely and/or common failures and repairs. Where necessary, ERG also performed internet searches for clarification or to identify any other potential repairs. Obviously, not all possible failures and repairs were identified in this manner, but the goal was to capture those most prevalent or likely.

ERG associated each SPN with one or more potential failures. In general, each failure had a single associated repair, but some failures had multiple potential repairs (for example, a nonfunctioning component could potentially be cleaned or completely replaced). Because each SPN could have multiple potential failures, each with multiple repairs, and a given repair could be necessary for multiple SPNs, our list included 119 combinations of SPNs, failures, and repairs. However, for the estimation of associated repair costs, there were 51 unique combinations of failure and repair. The list of unique repairs is presented in Table 2-2.

Table 2-2 Unique List of Failures and Repairs Associated with Common SPNs

Failure or Failed Component	Repair
Aftertreatment pressure buildup/clog	Perform a stationary regen
Ambient pressure sensor	Replace sensor
Clogged DPF (i.e. non-"regenable")	Replace DPF
Collapsed or obstructed fuel pickup lines	Replace fuel sending unit/fuel lines/clear obstruction
DEF doser unit/valve or wiring	Replace doser injector
DEF doser unit/valve or wiring	Replace Doser Pump
DEF filter	Replace DEF filter
DEF heater failure	Replace DEF heater
DEF plumbing problem or leak	Repair or replace DEF lines
DEF quality sensor	Replace sensor
DEF temperature sensor	Replace sensor
DPF cracked or broken	Replace DPF
DPF inlet pressure sensor	Replace sensor
DPF outlet pressure sensor	Replace sensor
ECM	Reflash or replace
EGR actuator motor	Replace EGR valve / actuator
EGR differential pressure sensor	Replace sensor
EGR leak	Replace gaskets (Gasket, Engine Head Set)
EGR leak	Replace Entire EGR
EGR position sensor	Replace sensor
EGR valve failure	Replace EGR Valves (each)
EGR valve failure	Replace EGR valve assembly KIT
Engine fuel injector internal leakage (i.e. into cylinder)	Clean or replace fuel injector(s)
Engine fuel injector(s) or fuel rail external leak	Replace injector seals
Engine fuel injector(s) or fuel rail external leak	Replace injectors
Engine Oil Separator	Replace or clean separator
Excessive DEF deposits in decomposition tube	Clean decomposition tube
Excessive DEF deposits in decomposition tube	Replace entire SCR
Exhaust fuel injector failure	Replace exhaust fuel plumbing
Exhaust fuel injector failure	Replace exhaust fuel injector
Fuel filter replacement (all if multiple)	Replace fuel filter(s)
Fuel pump or fuel pump actuator failure	Replace fuel pump
Fuel pump or fuel pump actuator failure	Replace actuator (pump)
Fuel rail pressure relief valve	Replace fuel valve (relief valve)
Fuel rail pressure relief valve	Replace fuel rail
Fuel rail pressure sensor	Replace sensor
High Pressure/Injection pump	Replace HP injector pump
Intake manifold pressure sensor	Replace sensor
Intake or turbo temperature sensor	Replace sensor
Intake throttle valve assembly	Replace intake throttle valve
Intake throttle valve position sensor	Replace sensor
LP side fuel lift pump	Replace lift pump
NH3 sensor or wiring	Replace sensor
PM sensor	Replace sensor
SCR Inlet NOx sensor	Replace sensor
SCR Inlet Temperature Sensor	Replace Exhaust Gas Temp Sensor
SCR outlet NOx Sensor	Replace NOx sensor
SCR outlet temperature sensor	Replace sensor
SCR poisoning/failure	Replace SCR catalyst
Turbo VGT actuator	Replace actuator
Turbocharger Failure	Replace turbo

Next, ERG acquired trial subscriptions to two commercially available repair cost estimation services in order to evaluate the suitability of using these resources to estimate repair costs for the various repairs previously identified. However, for several reasons, including use of original equipment manufacturer (OEM) flash codes, lack of labor hour estimate resources for repairs of some OEMs and also a lack of consolidated information in parts costs, ERG instead chose to seek repair cost information for our list of repairs from organizations with direct experience in performing and estimating costs for these types of repairs. ERG developed agreements with two organizations to acquire repair and parts costs for our list of repairs. One organization was a California-based truck maintenance and repair facility that performs aftermarket repairs on heavy-duty vehicles (this was the same facility that provided engine scan results as part of Task 1 of this study). The other organization was a US-based (but not located in California) independent owner/operator (IOO) and fleet support organization that provides warranty and repair services. ERG tasked each of these organizations with reviewing our list of repairs to ensure they accurately represented repairs that would be required for the most common in-field failures and with providing repair cost estimates for the final program repair list.

ERG requested that the two participating sources provide a review of the repair list for representativeness of repairs that would be seen in the industry, as well as repair cost information for parts and labor for each of the identified common emission-related repairs for various engine manufacturers in the 2013+ model year ranges. The participants provided estimates of the costs associated with each individual repair for various engine manufacturers. Neither organization suggested any changes to the repair lists by either suggesting the addition of any other repairs or the removal of repairs they thought unnecessary for our work. The repair costs provided by each of the two participating organizations were not formatted or organized the same way, however. As a result, ERG needed to take additional steps to get the data on the same basis.

The first respondent provided specific individual cost estimates for each repair for OEM and aftermarket parts for Cummins, Detroit Diesel, and International for the model year range of interest. The source did not separate the costs out between parts, diagnostic, and labor; a single total cost estimate was given for each manufacturer for OEM/dealer parts and service as well as aftermarket/independent shop parts and service. ERG reviewed these costs with CARB, and based on this review, ERG worked with the respondent to obtain clarification of some of the costs that seemed to be outside of an expected range. Upon this revisit, the source either provided the justification for the cost in question, or did adjust those costs deemed unreasonable. Using this supplemental data, ERG adjusted the overall costing accordingly and in coordination with CARB.

The other source provided only labor hour estimates for most of the given repairs for Cummins, Detroit Diesel, International, and Volvo. In many cases, the second source provided a high and low range for each engine make. They instructed ERG to use an estimate of $145/hr labor rate to calculate the associated labor cost and that, because they did not have access to parts costs estimates, their recommended way to estimate these would be to double the labor cost to estimate the total repair cost including parts. The second source did not discern between OEM and aftermarket costs. ERG performed the calculations as instructed to develop ranges of costs for each make based on the second source's input. To put the basis as similar as possible to the first source, ERG split the costs by engine manufacturer into three groups, Cummins, Detroit Diesel, and Other (comprised of International and Volvo).

By following these steps, ERG was able to generate independent estimates of emission related repair costs. No repair costs in this analysis were based on warranty information, which could bias the estimates toward manufacturer defects rather than TM&M-related causes. Because most SPNs could be linked to multiple possible repairs and many individual repairs actions could fix problems across more than one TM&M category, it was not possible to directly estimate overall repair costs associated with the I/M program by directly weighting the costs by SPN counts. Instead, costs were used to estimate an average TM&M-category-level repair cost as described in the next section.

2.2.4   Frequency of TM&M Categories Causing MIL Set

In Section 2.2.2, we presented the assignment of each SPN into respective TM&M categories based on previous work. Because multiple repairs could be necessary for any given SPN, this cost analysis is weighted on a TM&M category basis, not on the basis of the counts of individual SPNs occurring in actual use. This analysis uses the same SPN counts from ERG's previous Emission Deterioration Report (Version 3, Appendix N) as were used to determine the most common SPNs but uses the counts from each TM&M category from *all* SPNs. In this way, we can use all available information to support the cost estimates to help alleviate the lack of knowledge of the prevalence of individual repairs and their costs in the on-road fleet.

Table 2-3 presents the total SPN counts falling in each of the 8 TM&M categories for which we have repair cost estimates. The percentages have been normalized to 100% using only the counts in these categories (and excluding counts of the other categories). These values will be used to weight the respective average repair costs of repairs associated with each category.

Table 2-3 Total SPN counts in each TM&M category and percentage that will be used to weight the average cost of each category

TM&M Category	Sum of SPN Counts	Percentage
Boost Control	5,905	10.85%
EGR	6,353	11.68%
Fuel System Monitoring	8,678	15.95%
NOx Sensor	8,085	14.86%
PM Filter	6,395	11.75%
PM Filter Frequent Regen	862	1.58%
Reductant Delivery	10,583	19.45%
SCR Catalyst	7,552	13.88%
Total	**54,413**	**100%**

2.2.5   Cost Calculations

To estimate the overall repair-related costs of the I/M program, ERG took the following steps:

1. Average the repair costs within each TM&M category. Only one instance of each malfunction and repair combination is included in each category. However, the cost for any individual repair can appear in multiple categories if applicable.

2. The overall estimated average cost of repairing a MIL-On condition is calculated by taking the weighted average (at the category level) of the average cost of repairs in each TM&M category.

The necessary assumptions and steps to execute these calculations have been presented and discussed in previous sections. The completed cost calculations are described in Section 3.5.

3.0   Results

This section presents results and findings from the following tasks and subtasks performed as described in Section 2.

- Task 1: OBD-Based HD I/M Program Demonstration
  - HD OBD Test System Demonstration
  - Fleet and Industry Surveys
  - Evaluation of Potential Security Risks and Opportunities for Fraud
  - Per-Vehicle OBD Testing Cost Analysis
- Task 2: OBD/Repair Data Collection
  - Per-Vehicle I/M Program Repair Cost Estimates

Task 1: OBD-Based HD I/M Program Demonstration

3.1   HD OBD Test System Demonstration

As described in Section 2, pandemic-based travel restrictions prevented our team from performing field testing as originally envisioned, so limited local testing was performed by the project team, as well as local testing by other organizations. Field data was collected from a total of 352 trucks, as listed below:

- CDPHE personnel conducted 178 tests between November 2020 and March 2021.
- ERG and Opus collected data from 26 trucks locally (in Austin, Texas and Tucson, Arizona, respectively)
- Results from 25 trucks were collected from a California-based truck emissions testing and service organization
- ECM scan data for 123 trucks were captured by CARB in the Mountain Pass evaluation program (95 SAE J1939 format and 28 SAE J1979 format).

In addition to the above scans, pre-repair ECM scan data from 114 trucks was downloaded from a repair database maintained by a California-based truck maintenance and repair facility. These records were selected based on presence of DM01 trouble codes and an illuminated MIL, and these results were used in the repair cost analysis described for Task 2.

Overall results and truck characteristic data are shown for all truck field scans in Appendix B. A summary of pass/fail results of this testing (excluding data collected from the maintenance and repair facility database) is shown below in Figure 3-1. Since engine model year frequently lags truck model year by 1, Figure 3-1 only shows model year 2014 and newer trucks (so no results from trucks with model year 2012 or older engines are shown). With the exception of CARB's Mountain Pass program, these vehicles were not sampled in a way to represent the on-road fleet, but instead selection was a convenience sample based on existing relationships between testing organizations and the truck facilities or fleets. For most of the testing, rather than fleet characterization, the intent was to verify test equipment operation across a wide sample of vehicle types. Because of the sampling approach, some of these vehicles could have been available for testing since they were awaiting repairs. Accordingly, this fail rate may be higher

than that of the on-road fleet. Since some vehicles for which program data was collected were model year 2013 or older, the total count of vehicles shown in Figure 3-1 is less than the total number of trucks tested in the program.

Figure 3-1 OBD "Fail" Rate by Truck Model Year for Pilot Sample
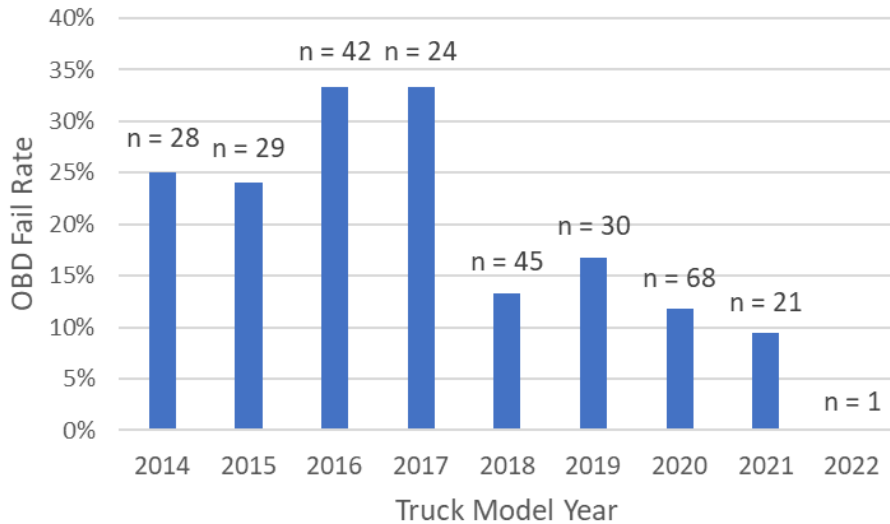
"Fail" criteria: J1939 DM1 MIL or DM12 / DM28 MIL or SPN, or J1979 MIL on or $0A DTCs, fleet does not necessarily represent on-road fleet due to convenience sampling methodology

Figure 3-2 shows the count of trucks, by make, for all field testing that was conducted during this pilot (including CARB's Mountain Pass program).

Figure 3-2 Truck Makes Tested During Pilot
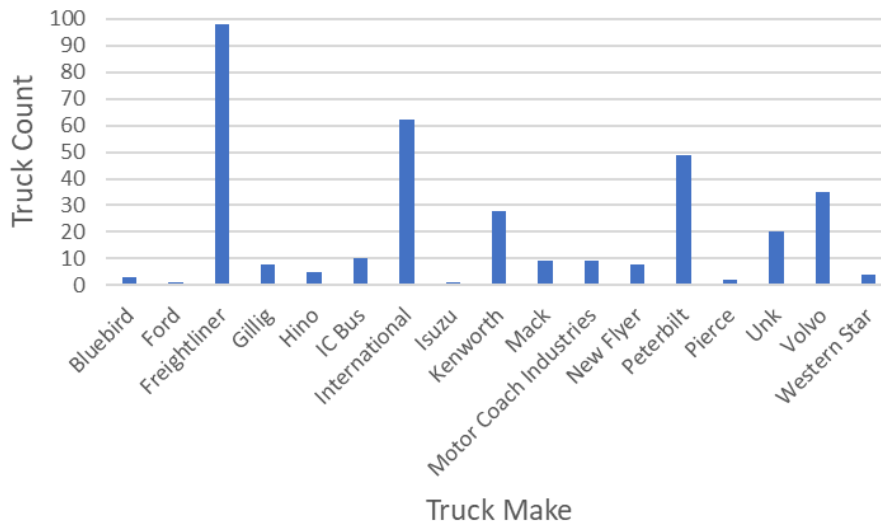
Table 3-1 lists the truck protocols, by truck make, for those tested as part of this pilot study. Some truck makes (such as Volvo and Mack) do utilize both SAE J1939 and J1979

protocols. Occasionally, both protocols can be utilized on the same truck (CAN1 and CAN2 networks). Although both protocols were identified on one Volvo tested during this program, overall test dispositions aligned with one another. For purposes of this reporting, this vehicle was categorized as a J1939-compliant vehicle.

Table 3-1 Communication Protocols by Truck Make

Truck Make	SAE J1939	SAE J1979	Total
Bluebird	3		3
Ford	1		1
Freightliner	98		98
Gillig	8		8
Hino		5	5
IC Bus	10		10
International	62		62
Isuzu		1	1
Kenworth	28		28
Mack	4	5	9
Motor Coach Industries	9		9
New Flyer	8		8
Peterbilt	49		49
Pierce	2		2
Unknown	20		20
Volvo	8	27	35
Western Star	4		4
Total	314	38	352

Vehicles compliant with SAE J1939 were considered to have an emissions-related fault if they had an active DM1 (PGN 65226, active DTCs) MIL (SPN 1213) commanded on or a DM12 (PGN 65236, emission-related active DTCs) or DM28 (PGN 64896, emission-related permanent DTCs)) MIL on or SPN. Other MIL or flash SPN dispositions or an active disposition of other lamps (SPN 987 Protect Lamp, SPN 624 Amber Warning Lamp, and SPN 623 Red Stop Lamp) were not considered emission-related faults for the purposes of this program. No monitor readiness (DMs 5, 21, or 26) were considered in our results compilation. Vehicles compliant with SAE J1962/J1979 were considered to have an emissions-related fault if they MIL commanded on (Service $01) or permanent DTCs (Service $03).

For the 211 SAE J1939-compliant scans performed in the main study with the DrewLinQ device, most scan durations ranged between 3 and 4 minutes. Ten of the 211 tests were four minutes or longer, five were five minutes or longer, and three were seven minutes or longer. Additional details on scan durations are provided in Table 3-2. The maximum test duration listed in the table was 10 minutes and 13 seconds, which as a 2021 Freightliner with 21 responding controllers, and the shortest test was 2 minutes and 56 seconds, which was a 2018 Peterbilt with 1 responding controller.

Fewer SAE J1979-compliant trucks were tested during this pilot than SAE J1939-compliant trucks, but out of the nine SAE J1979-compliant trucks that were tested with the DrewLinQ scanner during the main study (excluding Mountain Pass tests), these tests were much shorter in time duration. Details regarding the DrewLinQ scan durations for SAE J1979-compliant trucks are provided in Table 3-2. All 9 SAE J1979 trucks listed in Table 3-2 were Volvos, and all had two responding controllers.

Table 3-2 Length of Scan Time by Protocol

	SAE J1939 Duration	SAE J1979 Duration
Average Scan Duration	3 minutes, 28 seconds	1 minute, 15 seconds
Standard Deviation	47 seconds	3 seconds
Maximum Scan Duration	10 minutes, 13 seconds	1 minute, 22 seconds
Minimum Scan Duration	2 minutes, 56 seconds	1 minute, 12 seconds

The DrewLinQ device created three file outputs for each scan:

- A file that ends in "_log.txt" is the basic application log showing queries of the PGNs
- A file that ends in "_spnlog.txt" (or "_pidlog.txt" for SAE J1979) shows the parameter bytes decoded into SPNs (or PIDs).
- A *.xml file is also created which is the representation of the data in xml based on CARB's data schema that was available when the application was developed.

ERG's review of DrewLinQ scan files showed all SAE J1939 CARB parameters are requested and captured except DM30 (PGN 41984), which was not included in the program as it was not in the CARB data schema in use as the time. However, this could be implemented in a full-scale program.

For J1979, review of the data showed successful request (and collection, when available) of all SAE J1979 parameters excluding Freeze Frame Data (Service $02), although this could be implemented in a full-scale program.

Also, both J1939 and J1979 systems requested the NOx and greenhouse gas Real Emissions Assessment Logging (REAL) tracking data (PGNs 64252, 64253, 64254 and 64258 through 64279 for the SAE J1939 protocol and Service $01 ITIDs 41 through 46 and ITIDs 61 through 76 for the SAE J1979 protocol), but since REAL data are not mandatory prior to model year 2022 engines, these parameters were not collected during the field study.

A sample of the DrewLinQ's SAE J1939 output files (log, spn log, and xml from a J1939 vehicle) are provided in Appendix F, and a sample of the DrewLinQ's SAE J1979 output files (log, pid log and xml from a J1979 vehicle are provided in Appendix G. The ultimate format of data to be required for a CARB-compliant device will be specified in CARB's latest data specification[10]. The data format is currently defined in Section 5.5 of the data specification, and the current format is the data header and the controller area network (CAN) Bus data in hexadecimal format. Accordingly, data outputs from CARB-compliant equipment will differ

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[10] https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdim/meetings/20201116_hdim_obd_device_specs.pdf

from those shown in Appendices E and F, and test disposition determinations will be made on the CARB HD I/M database.

As stated in Section 2.1.2, the HEM Data Mini Logger and DAWN Mini Streamer were also evaluated in this study. These devices were used to collect data from several trucks by ERG at rental facilities in Austin. As described previously, the OBD Mini Logger is a configurable datalogger capable of collecting and logging live data with a user-defined acquisition rate, while the Mini Streamer provides real-time streaming of J1939 and J1979 data to a PC, Android device or iPad for collection of "snapshot" vehicle service and performance data, such as that collected during a vehicle inspection. HEM Data staff worked directly with CARB to evaluate each unit's capability relative to the data requirements, and based on that effort, they report either unit has the capability of acquiring all SAE J1939 and J1979 parameters required by the CARB program, excluding the DM30 for the Mini Logger, since the multi-step process of acquiring this parameter is a challenge with the Mini Logger. However, HEM Data reports DM30 can currently be acquired with the Mini Streamer.

Future Program Test System Options

ERG demonstrated test systems through internal testing, testing with partners, and through solicitation of feedback from fleets and drivers during our fleet surveys. Some such systems, such as test systems located in truck stops, could look similar to those shown below in Figures 3-3 and 3-4. These are functional light-duty OBD kiosks from the District of Columbia (DC) and Ohio I/M programs. For a HD OBD Kiosk the basic structure of the kiosk would remain the same, but a much greater space would be required to accommodate a Class 8 tractor with a trailer. Also, the OBD connector, software and OBD scan tool would be redesigned to meet the requirements of the HD OBD application. These units would also require some form of HD dongle, described in Section 3.3, to transfer results to the unit shown in these images, either wirelessly, such as via Bluetooth, or through direct contact when the dongle was cradled back into the test system at the conclusion of the test. Since raw hexadecimal data would be transmitted from the unit to the CARB I/M database, a conventional vehicle inspection report (VIR) would not be necessary, but a confirmation of successful test completion could be printed and submission and/or the confirmation could be e-mailed to the owner.

Figure 3-3 DC I/M Kiosk

Figure 3-4 Ohio I/M Kiosks

Examples of existing HD OBD test system hardware are provided in Figures 3-5 through 3-8. As with the fixed place kiosks described above, these mobile units would also require some form of dongle to transfer results to the unit shown in these mobile units wirelessly or via a direct link. Again, since raw hexadecimal data would be transmitted from the unit to the CARB I/M database, a conventional VIR would not be needed, but confirmation of test completion could be printed or sent by email to the owner.

Figure 3-5 Example Mobile Test System Entry Screen

Figure 3-6 Example Mobile Test System Menu Selection

Figure 3-7 Example Mobile Test System Side View

Figure 3-8 Example Mobile Test System Profile View

It is envisioned test systems such as these could provide the basis for the approximately 20 kiosks that could be provided by the CARB program contractor as part of the upcoming HD I/M program (this approach and these quantities are subject to change). As described later in this report, these units would require minimal user input to operate and would essentially conduct the

test automatically after entry of the necessary driver and truck information. Results would be automatically transferred to CARB in the required format upon completion of the test.

3.2 Fleet and Industry Surveys

Fleet and Industry Survey Results

ERG conducted two fleet surveys, one consisting of telephone and e-mail surveys of fleets with whom ERG and CARB had previous interactions, and a subsequent online survey that was based on the original survey but modified by CARB, and then electronically distributed by CARB to workgroup members and posted on their online diesel truck information portal, the Truckstop[11]. Aggregated results from the telephone/e-mail and online fleet surveys are provided in Appendices C and D, respectively, with some summary highlights presented here. These highlights are based on responses received from both the telephone and online surveys combined when the questions aligned suitably for consolidation, or from just the online survey when those questions differed significantly from the telephone survey. The number of respondents varies from question to question, since responses were not mandatory for proceeding in either survey and blank responses were allowed.

Figure 3-9 shows the fleet size distributions for trucks of 14,000 lbs. or greater GVWR in each fleet and an estimate of the "typical" GVWR of vehicles in each of the fleets.

Figure 3-9 Survey Fleet Size and GVWR Distributions Among Fleets
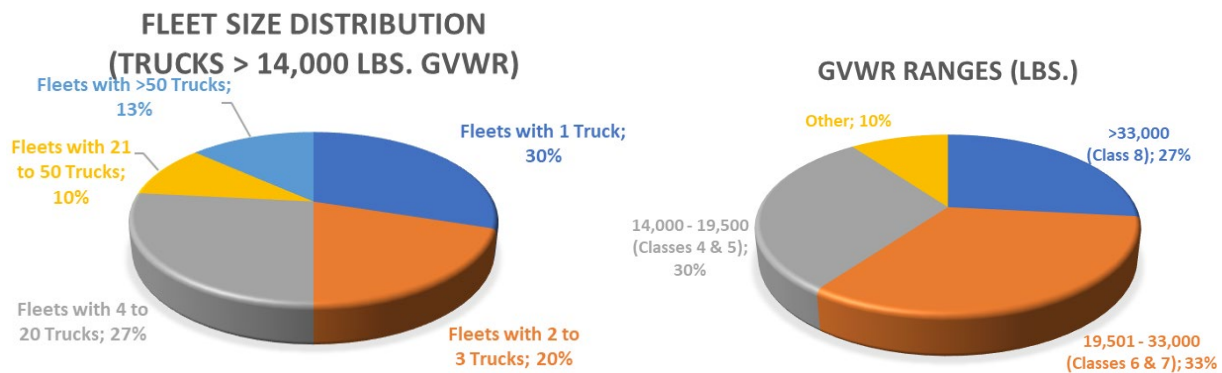
Figure 3-10 shows the reported types of operation (in-state < 100 miles, in-state > 100 miles, interstate, multiple selections possible) and "average age" of heavy-duty vehicles in each of the fleets.

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[11] https://ww3.arb.ca.gov/msprog/truckstop/truckstop.htm

Figure 3-10 Survey Fleet Types of Operation and Average Age of Fleet Vehicles

FLEET SERVICE TYPES

Other (gvmnt, mechanic); 9%

Interstate; 14%

In-state>100 miles; 14%

In-state <100 miles; 63%

AVERAGE TRUCK AGE DISTRIBUTION (TRUCKS > 14,000 LBS. GVWR)

1 to 5 Years; 10%

>15 Years; 27%

6 to 10 Years; 30%

11 to 15 Years; 33%
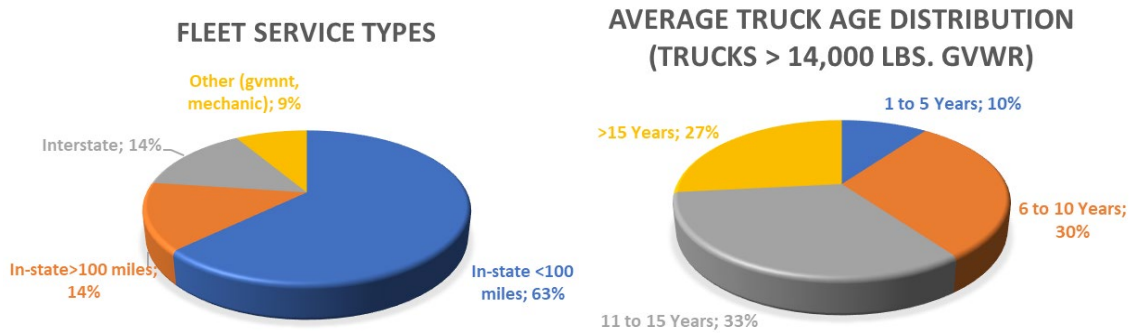
Of 35 respondents, 30 (86%) reported being subject opacity testing under the PSIP test program. Eleven of those thirty respondents indicated they performed their own opacity tests. Figure 3-11 presents the reported cost ranges for those who responded. As can be seen in this figure, some of the respondents who performed their own testing did not estimate their internal operational costs.

Figure 3-11 Survey Fleet Reported PSIP Opacity Cost Ranges

CURRENT OPACITY COST RANGES

Less than $50; 14%

Internal Testing; 29%

$150 to $200; 7%

$50 to $100; 36%

$100 to $150; 14%
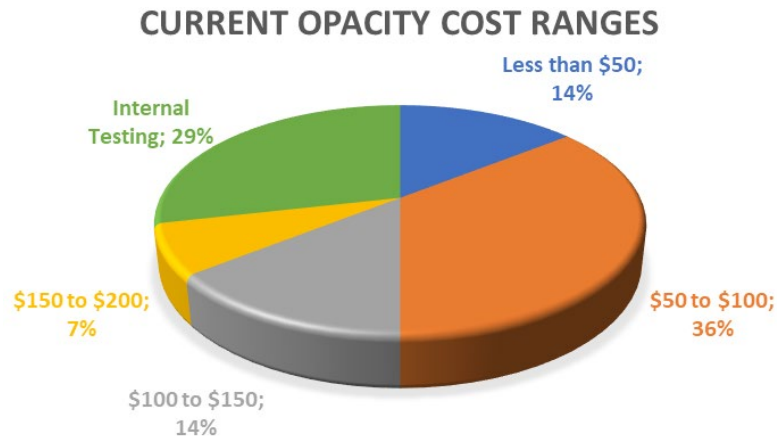
Of 37 respondents, 16 (43%) reported using some form of telematics and/or fleet management service. There was a strong relationship between the number of vehicles in a fleet and the use of telematics (larger fleets were more likely to utilize telematics), and a positive relationship was also seen between the average distance typically travelled by a fleet and their likelihood of using telematics (fleets with operation greater than 100 miles from domiciled base were more likely to utilize telematics than local fleets with travel distances less than 100 miles from their base). For those that did report utilizing some type of telematics service, Figure 3-12 presents the reported types of services used, including:

- FM: Fleet management / logistics management support,
- OBD: On-board diagnostics used for vehicle diagnostics and preventative maintenance,
- ELD: Electronic Logging Device, including driver vehicle inspection report (DVIR) compliance,

Multiple selections were possible for this question, depending on the services provided.

Figure 3-12 Survey Fleet Reported Existing Telematics Support

TELEMATICS SERVICE TYPE
(MULTIPLE SELECTIONS POSSIBLE)
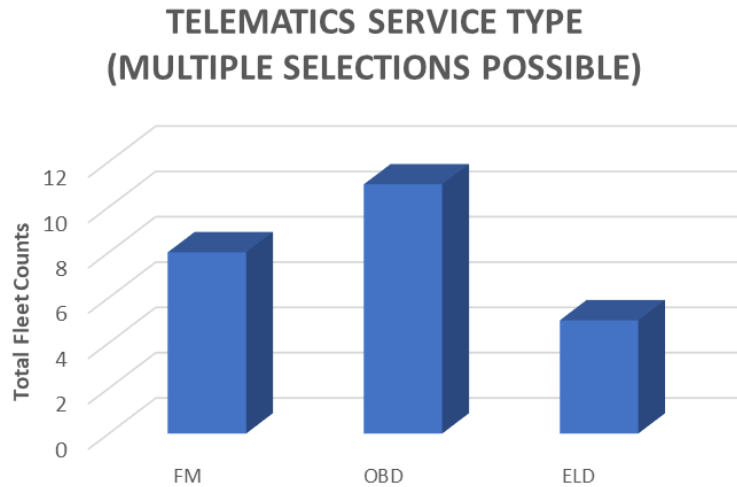
Reported prices for telematics services varied based on the type of services / support and how hardware and other costs were included in the plan. Monthly subscription rates ranged from under $50 to over $200 per truck (including hardware costs for some trucks). About half the respondents reported separate hardware costs, ranging from $50 up to $800 one-time costs. It is important to note that these telematics subscription costs included items and services beyond what would be required for the upcoming HD I/M program, including electronic logging device (ELD), fleet logistics, and other services. These would not necessarily be the costs associated with a system that offered support for CARB's upcoming program.

The surveys also queried respondents about what type of program compliance choice they might elect in the upcoming inspection and maintenance program for model year 2013 and newer trucks subject to OBD testing. Figure 3-13 presents respondent selections for a program that requires testing on an annual basis, and revised selections if inspections were required on a 90-day (quarterly) basis. Testing options selected included the following:

- Fleet self-testing by kiosk: Visiting a physical testing location to self-perform required vehicle testing
- Fleet onsite testing by self or 3rd party: Have a CARB-approved tester to perform required testing at a fleet yard or other convenient location, similar to trained testers for California's PSIP. (Note: Tester would be required to successfully complete the CARB-required training in order to be a CARB-approved tester),
- Telematics: Using a telematics service provider to submit required compliance testing information.

As can be seen in Figure 3-13, anticipated telematics use increases as inspection frequency requirements increase. No statistically significant trends were seen between fleet size or service type and test preference options shown in Figure 3-13.

Figure 3-13 Anticipated Program Test Preferences for Annual and Quarterly Test Frequencies

PROGRAM PREFERENCE FOR ANNUAL PROGRAM

- Telematics; 27%
- Fleet self-testing (kiosk) ; 23%
- Fleet onsite testing (self or 3rd party) ; 50%

PROGRAM PREFERENCE FOR QUARTERLY PROGRAM

- Telematics; 37%
- Fleet self-testing (kiosk) ; 20%
- Fleet onsite testing (self or 3rd party) ; 43%
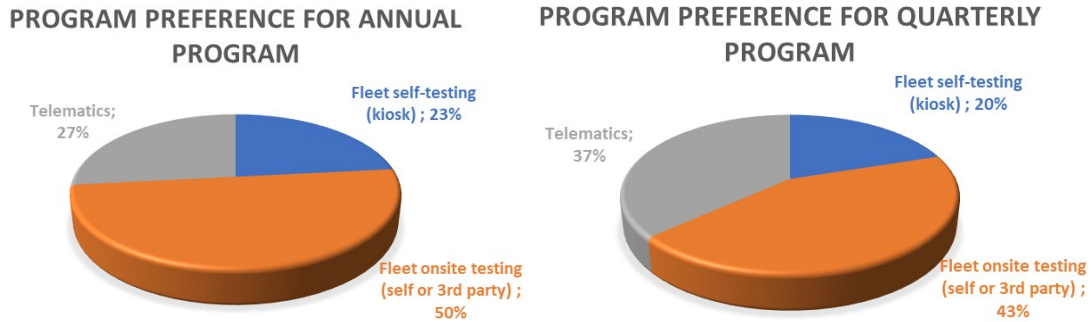
Survey respondents were also queried about any negative issues experienced when connecting the vehicle's electronic control unit (ECU) to an external device such as an ELD, telematics devices, diagnostic scan tool, or other device. Of the 28 respondents to this question, four (14%) reported having some type of issue while 16 (57%) reported no issues. Eight respondents (29%) were unsure if any issues were encountered. Of those that did report issues, the following were reported:

- Issue with power take-off (PTO) energy management along with telematic device, possibly from too many devices on diagnostic link,
- Phantom codes, body module malfunctions, dead batteries (post-operation communication),
- Unable to communicate on trucks with a 500k baud communication rate,
- Truck to logger communication failures and driver logs frozen.

The surveys also queried respondents about average annualized repair costs, excluding typical O&M service, and also about the estimated average downtime required for such repairs. Figures 3-14 and 3-15 present these results reported by respondents.

Figure 3-14 Reported Average Repair Costs

ANNUALIZED PER-VEHICLE REAPIR COSTS (EXLUDING O&M)

Normalized Fleet Percentage

Category	Approx. %
Less than $1,500	32%
$1,500 to $3,999	27%
$4,000 to $7,999	23%
$8,000 to $10,999	2%
$11,000 to $14,999	14%
$15,000 to $20,000	5%
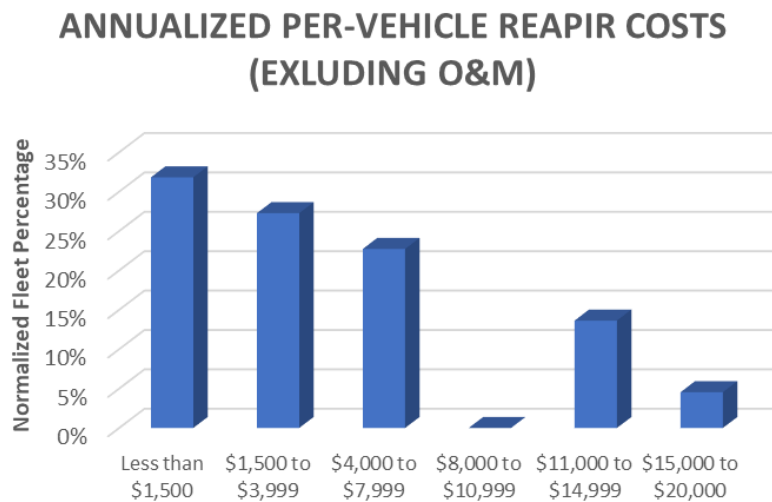
Figure 3-15 Reported Average Repair Downtime

ESTIMATED AVERAGE REPAIR DOWNTIME
(EXCLUDING O&M)

[Bar chart: Normalized Fleet Percentage vs downtime categories. < 1 day ≈ 14%, 1 to 2 days ≈ 35%, 3 to 6 days ≈ 38%, 1 to 2 weeks ≈ 11%, 3 to 4 weeks ≈ 1%, > 1 month ≈ 3%]
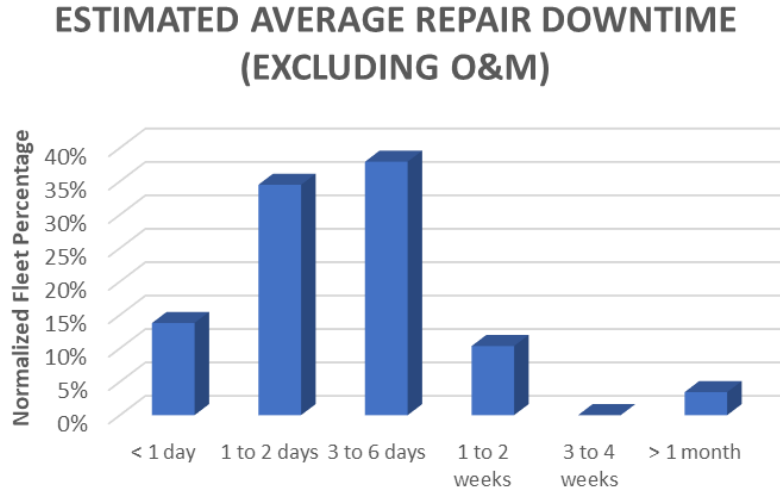
The online survey also included the question pertaining to residual emissions warranties: "*Consider two used Class 8 tractors. Assuming both vehicles have an equivalent age, mileage, and planned future use, how much would you value a residual emissions warranty of 200,000 miles on a used vehicle when you make the vehicle purchase decision?*" Figure 3-16 shows the ranges of value of a residual emissions warranty reported by respondents. Respondents were also asked if they had ever previously purchased an extended emissions warranty for a Class 8 truck, and three of the 26 respondents (12%) indicated they had.

Figure 3-16 Reported Resale Residual Emissions Warranty Worth

ESTIMATED RESIDUAL EMISSIONS
WARRANTY WORTH ON RESALE

[Bar chart: Normalized Fleet Percentage vs value categories. No additional value ≈ 52%, $0-$249 ≈ 5%, $250-$999 ≈ 6%, $1,000-$2,500 ≈ 20%, $2,501-$5,000 ≈ 7%, More than $5,000 ≈ 10%]
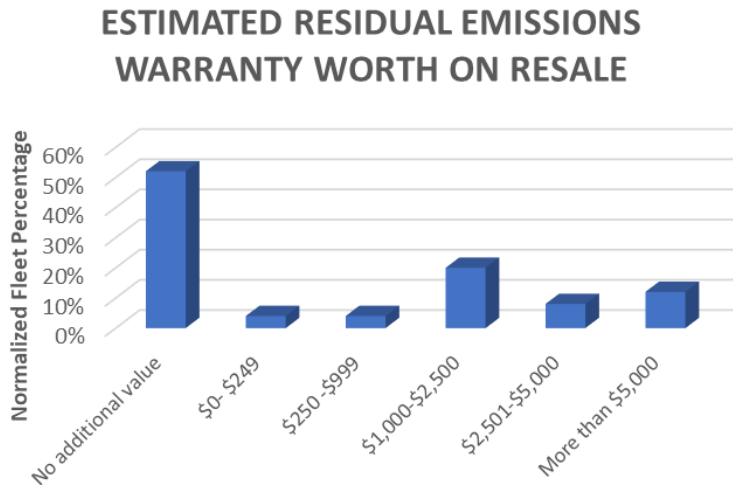
Finally, the following is a summary of the various types of feedback that was received in response to each survey's request for program recommendations, preferences, or other thoughts or input related to the development of a HD I/M program. The highlights below are paraphrased and summarized. Verbatim responses are provided in Appendices C and D.

- Quarterly testing is too frequent and burdensome and quarterly testing costs are going to be prohibitive, including operators in NOx-exempt counties that require an opacity-based test,
- Low mileage pre-2013 trucks under Ag exemption should continue to be exempt,
- Recommendations for survey changes and improvements,
- Suggestions for program implementation, including not rushing program development, recommendations for implementation of the test program (i.e., align with the 90-day BIT), consistent and aligned enforcement, equipment and test system certification, grace periods for repairs, state-provided training for test equipment, allowing internal fleet testing to occur and appropriate application of lessor vs. lessee responsibilities,
- Test equipment recommendations, feedback regarding causes of fault codes and program diagnostics, percentage, and prevalence of derates.

3.3   Potential Security Risks and Opportunities for Fraud

3.3.1   Fraud in a Traditional I/M Program

Inspection fraud is a well-known problem in traditional light-duty (LD) vehicle I/M programs involving testing performed at either decentralized private test or test and repair shops or centralized inspection facilities operated by the program contractor. The I/M industry has spent considerable effort combatting and minimizing such fraud, and these efforts continue to evolve as program offenders find new and innovative ways to avoid program requirements. Electronic OBD data collection for I/M compliance purposes in a less controlled environment, i.e., outside of the traditional inspection station environment, presents further unique challenges in this regard. In this section, we discuss fraud (Section 3.3.1) and fraud prevention techniques (Section 3.3.2) as they pertain to traditional I/M programs, since many of the opportunities for traditional I/M program fraud apply equally well to a decentralized HD OBD program in California. Section 3.3.3 then follows with some possible scenarios for the upcoming HD OBD I/M program, along with inherent fraud risks associated with various program test scenarios and approaches to combat those types of fraud. The various fraud risk mitigation strategies are then summarized in Section 3.3.4.

OBD Inspection Fraud

Currently, OBD inspection fraud can involve a variety of possible methods, which are summarized in the following bullets:

- Disconnecting a vehicle's battery or using some other means to clear OBD DTCs, also called fault codes, prior to the inspection.
- Entry of improper vehicle characteristics into the test system in order to cause the automated system to subject the vehicle to a less stringent type of emissions test. For example, entry of an improperly high GVWR causes the system/inspector to perform a lesser test than an OBD scan in some state inspection programs.
- Testing a known clean vehicle in place of the vehicle subject to the inspection, a fraudulent technique known as "clean scanning" or "clean plugging."

- Use of so-called "defeat devices" and OBD simulators on vehicles, which act to hide OBD fault codes and provide "clean" inspection data.

Application of OBD readiness criteria and consideration of permanent trouble codes in I/M compliance test pass/fail determinations will help prevent the first type of inspection fraud (code clearing) listed above. Additionally, more rigid test system programming that prevents inspectors from modifying identification information sent from the program's central vehicle information database (VID) can help prevent fraud, and requiring OBD-only testing for specified vehicle types also prevents test systems from selecting a less stringent test for these vehicles.

Clean scanning and defeat devices continue to be challenges for the I/M industry, and programs continue to develop new approaches to address these issues. As inspection fraud schemes grow increasingly sophisticated and adapt to existing fraud detection/prevention methods, detection and prevention techniques and procedures have in turn evolved to handle these new fraudulent inspection threats. In addition, analysis of the OBD data stream to identify and prevent test fraud can be effective in maintaining inspection integrity and preventing fraud.

Non-Test Related Fraud

Another area of fraud in existing I/M programs occurs outside the inspection process, instead involving the various program enforcement methods. This type of fraud is typically described as either sticker-based (programs in which a passing vehicle receives a windshield sticker that must be displayed), or registration-based (programs in which a failing vehicle cannot be re-registered with the state Department of Motor Vehicles (DMV) until the vehicle passes the I/M inspection). Of the 30 states plus the District of Columbia with a current LD I/M program, 23 (including California) have registration-based enforcement and 6 have sticker-based enforcement.[12] One state, New York, does both, and Rhode Island combines registration denial with roadside enforcement checks. States likely do not typically use multiple enforcement methods due to the cost and program burden, and the possible redundancy of inspection and registration stickers.

The above program counts reflect the I/M industry view that registration-based enforcement is a more effective approach to maximizing motorist compliance with I/M program requirements than a sticker-based/on-road enforcement approach. Maximizing compliance is critical to maintaining an I/M program that is effective in delivering projected air quality benefits. Even if test fraud is reduced to zero, a program in which motorists can find other ways to circumvent compliance requirements could experience a significant loss in projected benefits.

In a registration-based program, compliance certificates are essentially electronic, and initial enforcement against noncomplying vehicles occurs automatically in cyberspace with denial, suspension or revocation of the vehicle registration occurring in the DMV vehicle database. Secondary on-road enforcement occurs if someone continues to drive an unregistered vehicle. Most non-complying vehicles are brought into compliance with I/M requirements during the initial enforcement process, when they cannot re-register their vehicle without a passing an

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12 "I/M Jurisdiction Report," National OBD Clearinghouse/I/M Solutions Group, September 23, 2020, https://www.obdclearinghouse.com/Jurisdiction/jurisdictionPDFs.

I/M test. This means a much smaller fraction of non-complying vehicles must be dealt with in the on-road environment.

In a sticker-based program, enforcement typically only occurs in the on-road environment and—unlike a registration-based system, this enforcement effort must be aimed at all vehicles, to find those that are not in compliance. Therefore, a larger enforcement effort is required, relying on law enforcement officers (LEOs) to identify these non-compliant vehicles on-road as described below. Other disadvantages of sticker-based enforcement include:

- **Certificate Fraud** – Counterfeit stickers are a known problem in sticker-based programs, although existing programs have implemented various measures to reduce the potential for such fraud. Stickers are treated as a control document, with special stock, encrypted security codings, controlled issuance protocols, and other measures used to minimize a potential violator's ability to create fraudulent stickers that would pass inspection by law enforcement personnel.

- **On-Road Enforcement Efforts** – Sticker enforcement is somewhat of a low priority with on-road LEOs, given other, much more significant criminal enforcement issues they deal with on a daily basis.

   On the other hand, LEOs are trained to run the registration when they pull any vehicle over, meaning that noncompliant, that is uninspected or unregistered vehicles, will be caught during all roadside stops under a registration-based system. In fact, out-of-date registration tags are often used to justify stopping a vehicle, providing due cause, if they suspect the driver might be involved in other illegal activities. Therefore, the LEOs are more likely to identify unregistered vehicles than instances of expired stickers.

The above issues should be considered in deciding on the specific enforcement compliance methods that will be used in the HD OBD program, particularly for heavy-duty out-of-state vehicles operating in but registered outside of the state of California.

Repair-Related Fraud

Another area of historical fraud in LD I/M programs is repair related. Most programs have a repair cost limit; vehicle repairs above this limit trigger the issuance of a repair cost waiver for that inspection cycle. For example, if at least $650 is spent on emissions-related repair and diagnostic costs, not including the cost of the compliance inspection, at a licensed repair station in the California Smog Check program and the vehicle still fails, it may qualify for a repair cost waiver.[13] Other programs have similar limits, which are usually subject to cost of living adjustments.

While less widespread than inspection fraud, repair-related fraud involves the falsifying of repair cost invoices and other information to enable a vehicle to illegally qualify for a repair cost waiver. We are currently unaware of any contemplated repair cost waivers for the HD OBD

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[13] "Repair Cost Waivers," Bureau of Automotive Repair Smog Check Program Referee Program, https://asktheref.org/Services/Repair-Cost-Waivers.

program; however, if they are considered for implementation in the program, such fraud concerns would need to be addressed.

3.3.2 Fraud Prevention Techniques in a Traditional I/M Program

3.3.2.1 I/M Enforcement Triggers

A primary tool in preventing inspection fraud is the use of automated data mining queries known in the I/M industry as enforcement triggers. These business intelligence/artificial intelligence (BI/AI) tools are designed to identify program fraud and suspicious testing activity, thus "triggering" subsequent enforcement actions against suspected program offenders. One set of the most sophisticated types of existing triggers is based on the approach documented in the 2001 report to the US EPA by the consulting firm Sierra Research.[14] EPA contracted with Sierra to develop a comprehensive approach to this issue, which could then be distributed as technical guidance to states interested in implementing automated triggers in their I/M programs. This approach incorporates several important features:

- The performance of each end-user (inspection station or inspector) is compared not to a set standard but to the performance of their peers across the entire network. This type of peer-to-peer comparison minimizes anomalies due to variabilities inherent in the underlying data and makes it much easier to identify individuals that are exhibiting questionable performance. These data outliers stand out not because of data variance, but instead because their behavior is fundamentally different from other stations and inspectors.

- Individual triggers focus on various sets of program inspection data to identify problem stations or inspectors based on the particular performance metrics incorporated into that trigger. Individual station and inspector trigger scores are computed based on a standard 0-100 scale, with 100 equaling the worst performance and 0 equaling the best performance. Use of this standard scale in turn enables the weighting of individual triggers into an overall weighted trigger score for each station and inspector.

- Quantification and identification of the worst performing stations and inspectors makes it easy to focus follow-up enforcement efforts on those performers, maximizing the efficacy of available enforcement resources. Particularly if such resources are limited, these types of trigger results provide the "biggest bang for the buck" in minimizing inspection fraud and improving I/M program effectiveness.

- As the worst performers are identified, and either removed from the program or forced to eliminate non-compliant behavior, the calculated performance of all end users automatically readjusts, thereby identifying the next set of the worst performers.

For example, an initial trigger analysis may identify a station that is doing nothing but clean scan OBD inspections, which would earn it a rating of 100 for the worst performance in a

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[14] "QA/QC Procedures Based on Program Data and Statistical Process Control Methods for I/M Programs," prepared for U.S. Environmental Protection Agency, Certification and Compliance Division, by Sierra Research, Inc., Report No. SR01-10-02, October 2001.

program. But if this station is identified and removed from the program, the next worst station, say it is performing 80% clean scans, would then earn the 100 rating and pop to the top of the list for follow-up enforcement action.

Over time, this can cause inspection fraud across the entire program to drop. Stations and inspectors are still identified in the top tier of bad performers, but when fraud detection is enforced, the absolute level of their performance is better relative to the initial worst performers. In practice, this effect can be diluted somewhat due to new program offenders entering I/M programs that replace ones that have been identified and addressed, but over time, the effective use of triggers for enforcement action will result in fewer vehicles being able to bypass the test requirements through fraud.

Although the above approach assumes a station-based model, the same strategies could be applied using a vehicle-to-vehicle analysis (or device-to-device, fleet-to-fleet, or other comparative metrics) in the upcoming California HD I/M program.

Example Inspection Triggers

The description of the Sierra/EPA triggers approach would benefit from some real-world examples to illustrate how they work and have been actually implemented in existing I/M programs. Sample reporting screens from an I/M program that has integrated this approach into its data analysis/reporting software are provided, along with accompanying descriptions. We note that these examples reflect just one method of I/M enforcement data mining and presentation approaches implemented by the various states. There may be others that offer strong benefits as well. For example, the California Bureau of Automotive Repair (BAR) has its own substantial suite of triggers that are being used to identify Smog Check non-compliance.

eVIN Trigger– Sample screens for one example trigger, eVIN Mismatch, are provided below. This trigger evaluates mismatches between VINs entered by the inspector and what is recorded from the electronic data stream collected from test vehicles' OBD systems. Such mismatches are symptomatic of clean scanning, where a clean vehicle is fraudulently substituted for the vehicle that is supposed to be tested. Use of this type of trigger would only be applicable for the program if user entry of the VIN is required for an NCC-ROBD inspection (rather than solely relying on eVIN downloaded from the ECM). As described in Section 3.3.5, the possibility of invalid eVINs being downloaded from the ECM may necessitate user VIN entry for NCC-ROBD inspections.

The first screen shows the results that are initially returned. Figure 3-17 provides a quick glimpse of a network-wide performance decile chart. Based on how the trigger results are calculated and displayed, good performers (those with fewer mismatches) are grouped toward the left side of the chart and poor performers (those with more mismatches) toward the right, so the chart on the screen below generally reflects good performance across the network on this trigger. More than 4,900 stations are shown in the 0 decile, with only 76 stations spread across deciles 1-9. These results are not surprising, given that this state's law enforcement agencies have been using this trigger for 13 years to identify suspected clean scanners. A much greater number of non-0 decile stations were identified upon initial rollout of this trigger in the state's vehicle inspection program.

The decile chart enables the user to quickly identify possible problem performers, which is much more obvious in this type of analysis and graphical presentation than if a standard text report was simply displayed or available to the user.

Figure 3-17 eVIN Trigger Mismatch
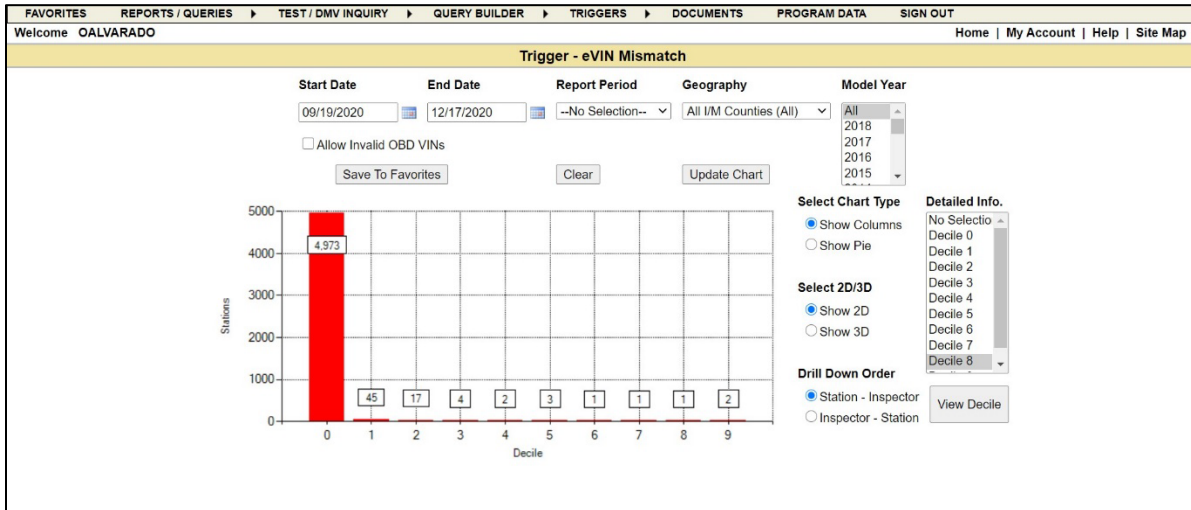
This graphic report is run nightly as part of the program's reporting suite. It has several additional features worth mentioning:

- While it defaults to data collected over the past three months, the report can be run for other reporting periods, making it easy to compare performance over time.

- A geography dimension allows the report to be run for different areas. While it defaults to all I/M counties, individual enforcement regions or other available geographic identifiers can also be selected, increasing its usefulness. An enforcement user in one region of the state is likely to only be interested in stations and inspectors performing inspections in that region. This allows them to easily customize the report for their use.

- Vehicle model year specific reports can also be run, if that is of interest to the user. The analysis also defaults to only looking at inspection results with valid eVINs, i.e., ones that pass a check digit check. But a user can check a box to also include invalid eVINs (eVINs that do not pass a check digit verification) to identify program violators that may be using a vehicle with an invalid VIN for clean scan purposes.

- The trigger defaults to looking at stations first, with drilldown to inspector results, but the order of this drilldown can be reversed if desired.

- The Detailed Info. section enables the user to view and extract detailed information for each decile populated with one or more stations (or inspectors). Clicking on one of the deciles, in this case Decile 8 shown in Figure 3-17, returns the decile details screen

shown below. Only one station record is shown, reflecting that only this station is included in this "next to worst performing" decile.

Figure 3-18 eVIN Trigger Detailed Decile Information

The above screen shows 30 mismatches between eVIN and entered VIN in the 47 inspections performed by the station (ID: 1P54267, personal identifying information is blacked out) during the specified reporting period where eVIN was recorded. The user can click on the Station ID hotlink to return results for individual inspectors who are recorded as having performed these inspections, as shown in the sample screen.

Clicking on the Trigger IQ Details link for station 1P54267 returns the Detailed Information screen shown in Figure 3-19 below. Mismatches between entered VIN and eVIN are highlighted by red and green shading. Red shading reflects a "bad" entered VIN for the vehicle that was supposed to be tested and green the "good" (correct) electronic VIN for the vehicle that was actually tested. This makes it very easy for program administrators and law enforcement personnel to identify the suspected problem tests.

Figure 3-19 eVIN Trigger Detailed Station Information

Limited data from each vehicle test record are displayed to make it easy to review the records. Test date and time are also included as data elements in the table since tests performed very close together are another indicator of questionable behavior.

Check boxes enable retrieval of additional data fields for each displayed test, plus another check box culls out the good tests and only shows suspect tests, i.e., those with eVIN versus entered VIN mismatches. Another important element is the hotlink for each eVIN; this is linked to DMV vehicle registration data maintained in the VID and can be clicked to quickly return vehicle identification, owner, registration county and registration expiration date information on the vehicle used for the suspected clean scanning.

Total time required to run this trigger and review the results, including the detailed analysis of the underlying data, was less than 5 minutes. In that 5 minutes, a user can identify the worst "potential" clean scanning performers during the specified analysis period in the entire statewide inspection network, look at the underlying data to see why they were identified and determine their particular pattern of problem behavior, and find additional supporting information, such as test date and time, that provides further evidence of suspect behavior.

This example demonstrates the power and effectiveness of this trigger approach in quickly and easily identifying the "low hanging fruit" in terms of problem stations and inspectors. It is a potent tool for identifying such non-compliant behavior, particularly in an environment where there may be limited enforcement resources. By starting with the worst

offenders and working toward the left of the triggers bar chart, an agency can maximize the positive impact of available enforcement resources on program benefits and improve public confidence in the integrity of the program. Other significant positive elements and potential uses of this triggers approach include:

- The same trigger(s) can be run before and after follow-up enforcement visits to a station/inspector to see if the visit had a positive impact in changing questionable behavior.

- Multiple triggers can be combined, with user selectable weightings, to see if some stations or inspectors are performing badly in multiple ways.

The above screens allow users to identify and investigate the suspected worst performers; in addition, a separate trigger tool, shown below in Figure 3-20, allows users to enter a station or inspector they suspect may be performing fraudulent tests. Returned results are identical in format to the more detailed trigger result screens shown above; this is just a different way of drilling down to station or inspector-specific results.

Figure 3-20 eVIN Trigger Station or Inspector Search

Trigger Truth Tables – Building on the Sierra/EPA report, states and I/M contractors have developed various triggers that compare OBD data recorded for an individual inspection to a dataset of known good values. Comparing inspection records to such a dataset enables the identification of problem or potentially fraudulent tests. The program we are using for an example incorporates two of these types of triggers - OBD Readiness and OBD Communications Mismatch:

- The OBD Readiness Trigger is based on a comparison of the supported or unsupported status of individual readiness monitors for a test vehicle versus those contained in a "truth table" of readiness monitor status by VIN "stem" (a VIN stem is comprised of the first 10 digits of the VIN, not including the 9th check digit character). These "truth tables" are based on statistical analyses of large datasets of historical OBD data collected in vehicle inspection programs using verified scan equipment. These analyses of millions of inspection records identify supported or unsupported status for individual VIN stems where 80% or more of the records show the same status. Mismatches between recorded and truth table readiness "fingerprints" are an indicator of possible clean scanning

behavior. In the HD I/M program, engine family name or some other downloaded parameter might be used instead of VIN stem.

- The OBD Communications Mismatch Trigger is based on a comparison of recorded communications protocols for vehicles that fail OBD initially and then pass on retest. This is primarily utilized for LD vehicles in I/M programs that also collect pre-CAN (legacy protocols). Any passing retest that has a different OBD communications protocol from that recorded for the vehicle's initial fail is flagged as a problem test and used in generating these trigger results. The communications protocol recorded for each test is also compared to the protocol contained in a truth table of protocols by VIN stem. Mismatches between recorded and truth table communications protocols are another indicator of possible clean scanning behavior. This may be of less benefit in the upcoming HD I/M program due to the limited number of communication protocols in vehicles subject to the program, so other criteria, such as changes between engine family names or other downloaded criteria, could instead be used.

These and other truth table-based triggers are used as part of various programs' OBD data mining/enforcement efforts. They require a known good dataset, which is produced by analyzing recorded OBD data and applying various constraints, e.g., 90+% of the data has to agree for a truth table record to be created. Other truth tables utilizing parameters and data collected in the program under consideration, including communication response times, module identifiers, responding modules by vehicle type and other parameters can be used for development of truth tables to be used in program enforcement.

Defeat Device Detection – OBD data can also be mined to identify suspected use of these fraudulent devices. This includes OBD simulators that can be programmed to produce data that appears to come from the test vehicle, but with "clean" test results, allowing the vehicle to pass its inspection regardless of its true failure status. This could also include detection of devices that mimic signals from OBD sensors to conceal disabled or removed emission-control components, for example, pre and post-SCR NOx sensors or pre and post-DPF pressure sensors. The approach to and effectiveness of identifying various devices can depend on the device's strategy and sophistication. A device that alters real OBD data, such as a system that modifies all associated DMs and freeze frame data, but leaves other fields and call/response times unaffected, can be more difficult to identify than an OBD simulator that exhibits certain patterns.

Various states utilize OBD simulator triggers to address this issue. These triggers search the inspection data for fingerprints of known OBD simulators and continue to add more simulators as they are found. One aspect of such a fingerprint involves the OBD 12 volt pin voltage reported during the OBD inspection. As with the existing triggers, the performance of individual stations and inspectors would be compared to their peers, allowing quick identification of likely offenders. For detection of devices that mimic the signal of OBD sensors, review of reported data for appropriate ranges, comparison with known mimic set-points or review of dynamic data over several seconds of operation could help reveal these devices.

3.3.2.2   Additional OBD Fraud Detection and Enforcement Tools

In addition to the trigger methods described above, fraud detection tools used by various I/M programs include other data analysis/reporting approaches. One example program incorporates the following clean scan related reports and queries:

- Clean scan query,
- Clean scan report,
- Probable vehicle query, including optional clean scan information,
- Legal query,
- History inquiry with optional clean scan information.

This program's triggers, reports and queries incorporate design features and content specifically requested by law enforcement and legal personnel, which help ensure that the processes and results are legally defensible and can be used in a court of law. This is important to ensure that resulting enforcement cases are not dismissed due to legal technicalities or other reasons not associated with the merits of a case.

Clean Scan Query – The next screen shown below in Figure 3-21 is an example of one of these tools, the predefined clean scan query. This tool includes the standard dimensioning tools incorporated in the program's reporting suite at the top of the screen, plus the user can enter one or multiple query criteria: station identification, inspector identification, OBD VIN or eVIN, vehicle license and entered VIN. For the upcoming HD I/M program, a query such as this could be used to compare entered vs. downloaded VINs, VIN to vehicle mismatches, VIN decode errors, or comparison of VIN with that of prior tests.

Figure 3-21 Station Clean Scan Query

Probable Vehicle Query– The probable vehicle query was developed to help law enforcement agencies identify the potential vehicles being used to conduct clean scans at an inspection station. Since most 1996-2004 model year vehicles do not report the eVIN in the OBD data stream, a comparison of other (non e-VIN) OBD parameters was implemented and automated to generate a list of potential vehicles that match the electronic signature of a suspected clean scan vehicle.

The screens provided below show how the user can search by station and date to return a list of OBD emissions inspection records for that station/date. The first is Figure 3-22. The user then clicks on the Entered VIN hyperlink for a record of interest to obtain the probable vehicle list for that test vehicle. Both test vehicle and the list of probable vehicles can be filtered by vehicle make, model and model year. A Top 10 or Top 20 list is returned, based on the number of different vehicles with unique entered VINs identified as having a matching electronic OBD signature among multiple data fields recorded in the I/M inspection record. A sample Top 10 list is provided in Figure 3-23.

Figure 3-22 Probable Clean Scan Vehicle Query

Figure 3-23 Probable Clean Scan Vehicle Top 10

Make	Model	Model Year	VIN	Total
LEXS	RX 330	2004		273
TOYT	SIENNA	2005		259
LEXS	ES 330	2005		257
TOYT	SIENNA	2004		221
LEXS	RX 330	2005		219
TOYT	4RUNNER	2004		215
LEXS	ES 330	2004		180
TOYT	HIGHLANDER	2005		164
LEXS	ES 300	2003		140
TOYT	4RUNNER	2003		135

3.3.2.3   Ending the Cycle of Inspection Fraud

One lesson the I/M industry has learned over the past 40 years is that inspection fraud can be very difficult to fully eliminate, possibly since mandatory inspection and repair programs are not largely favored by motorists. Although the large majority of motorists subject to an I/M program are law abiding individuals who will comply with the program, only a small percentage of non-compliance can result in a great number of fraudulent (or evaded inspections) due to the sheer number of overall vehicles subject to the program.

The level of inspection fraud in decentralized versus centralized programs has been heavily debated over the years. But it is obvious that decentralized repair shops have a significant chore in performing mandatory vehicle inspections while also looking after their often long-time customers' interests because shop owners' and inspectors' natural inclination is to try to keep their customers happy. This is how they keep existing customers, attract new ones, and stay in business and thrive. Telling a vehicle owner that their vehicle failed its inspection, and they have to spend hundreds of dollars to get it fixed is not a very good way to keep customers happy or even keep them at all. This issue will likely be less applicable to this program, since neither inspection facilities nor repair shops will be certified, and testing services will likely be disassociated from repair services.

Failed vehicle inspections in decentralized programs sometimes lead to the owners of these vehicles shopping around for an inspection shop that can provide them with a passing

inspection. And too often, they find one. It is typically very hard to close down a shop that is fraudulently passing vehicles and word about such shops gets around fast.

The above discussions about tools to identify fraud are necessary, but an inspection program also needs to be efficient in stopping the fraud that is identified in order to be effective. We have been told by multiple programs how difficult it is to get their court systems to levy significant legal penalties against stations and inspectors found guilty of inspection fraud. It appears particularly hard to actually shut any stations down. The due process clause of the Fourteenth Amendment guarantees due process of law before the government may deprive someone of "life, liberty, or property." In the past, many courts have interpreted this to protect the right of an inspection station owner or inspector to continue to earn their livelihood by inspecting vehicles, except in the most egregious cases.

Taking legal action against stations and inspectors also requires significant time and resources. Months of activity are often involved in performing follow-up enforcement activities against program violators identified by triggers analysis and other methods, building a solid legal case, and proceeding through the applicable adjudication and legal processes. In the meantime, the station or inspector that is the target of the case typically continues to perform hundreds of tests, taking in money in bribes and further reducing the program's air quality benefits.

In addition, opening another station under a new name can be relatively quick and easy. As a result, there are a number of anecdotes in the industry of how a state worked diligently to close down a non-compliant repair shop found to be performing fraudulent tests, only to have it reopen very quickly under the name of a relative or friend of the prior owner. This shop then starts committing renewed inspection fraud, perpetuating this cycle of fraud, with little overall benefit achieved by closing the first station.

The courts' position on inspection fraud has changed somewhat over the past 10-15 years, and there have been some high-profile cases in Texas, New Jersey and other states involving significant judgements against noncomplying stations and inspectors. However, it still remains difficult to shut stations and inspectors down in most states. One lesson learned over the last 40 years in the LD I/M industry is that it is much easier to identity non-compliant stations and inspectors, largely through the types of enforcement triggers and other tools described in Sections 3.3.1 and 3.3.2, than it is to shut these stations down. As with any type of legal fraud, it would therefore be better to prevent inspection cheating altogether rather than identifying it and pursuing enforcement actions after-the-fact.

Trigger Lockouts

For conventional I/M testing, the automated nature of vehicle inspection systems and the OBD inspection process now makes it possible to prevent inspection fraud before it happens. Inspection and/or data analysis software can be used to evaluate OBD test results and make yes/no decisions on whether a station or inspector can continue to perform inspections.

This could conceivably be done on a real time basis for individual inspections. For example, it would be relatively easy to terminate an inspection, and possibly lock out the inspector's access to the test system, if an entered VIN does not match the eVIN downloaded from a test vehicle. However, testing instances in which other types of triggers detect potential

inspection fraud are less clear cut; hence the term "potential" fraud. Making this decision on an individual inspection basis can be difficult and may be subject to successful legal challenges.

These concerns are addressable, however, through careful selection of the specific type of advanced triggers, such as those described previously, to be used in terminating inspections. In fact, BAR is currently doing this in their OBD Inspection System (BAR-OIS) software; tests which trigger certain criteria are terminated and the vehicle is directed to a referee station for completion of testing.[15]

A second approach to preventing inspection fraud would be to use the advanced type of triggers described previously to identify stations and inspectors in which the preponderance of collected inspection data supports a finding that they are committing inspection fraud. The stations/inspectors would then be automatically locked out from performing future inspections until the case is adjudicated or otherwise resolved. Such lockouts would prevent questionable performers from conducting more potentially fraudulent inspections. Any legal processes would still take their typical time to be completed, but during this period, the program would not suffer further loss in air quality benefits due to continued test fraud.

There are two sets of issues, legal and technical, with this approach. First, the program would need to have the legal authority for such lockouts. Perhaps this could be accomplished through station signoff on this approach in the station agreement/contract that each station signs in order to participate in a program. We are not offering any legal opinion on this issue, particularly given that the legal merits of the issue may be different in different states. If a state wishes to pursue such an approach, additional investigation with legal counsel would be warranted.

The second set of issues is technical, in terms of how to incorporate such lockouts into the deployed testing systems, but these are ones that are very solvable. BAR is also doing this, locking out stations that are identified through triggers built into the BAR-OIS network.[16] Our example I/M program has similarly incorporated a set of trigger lockouts into their inspection network. Thresholds can be set by state oversight staff for when a lockout would automatically be set on an inspector, if the inspector exceeds the entered mismatch or "error" percentage for any one of the four listed triggers: eVIN, OBD readiness, OBD communication protocol mismatch and GVWR change. For example, if the OBD readiness threshold is set to 80%, a lockout would be set on any inspectors with a readiness mismatch rate > 80% for their most recent "X" number of OBD tests, where "X" is equal to the number 30 on the screen shown below in Figure 3-24, entered into the Trigger Lockout Threshold field.

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[15] Private communication with Garrett Torgerson, Supervising Air Quality Engineer, Engineering & Research Branch, California Bureau of Automotive Repair, September 23, 2020.

[16] Ibid.

Figure 3-24 Trigger Lockout Settings

The trigger lockout setting screen is straightforward and user-friendly; the user just needs to enter the specified thresholds. Threshold = NONE for a trigger threshold percentage causes the trigger to not be included by the system in deciding whether to set an automatic lockout for an inspector, e.g., these lockouts are currently not being set for any inspectors since all four trigger threshold percentages are set to NONE.

While this state's Department of Public Safety, who has lead oversight for inspection fraud enforcement in the I/M program, supported the initial development of this automated trigger lockout, they have not chosen to implement the lockout process to date. We are uncertain whether this is because they received an unfavorable legal opinion about this program element or if there are other administrative reasons involved.

Given that BAR has incorporated both inspection terminations and inspector lockouts in the Smog Check program, it appears these should be legally acceptable in the California HD OBD program as well. It could certainly be considered for implementation as part of an overall inspection fraud deterrence/prevention program.

The inspection terminations and inspector lockouts described above are fraud detection and reduction tools that require minimal human intervention. However, as test determinations will not be immediately made by the NCC-ROBD device, but rather the test determinations will be made at the VID after upload and conversion of hex test data, approaches for implementation of inspection terminations and inspector lockouts would differ from those in the BAR Smog

Check program. However, some of the general concepts presented here could be implemented to prevent the accumulation of fraudulent test results after potential fraud is identified.

Possible Negative Consequences – One argument that has been raised against implementing automatic lockouts of questionable vehicle inspections is that it does not allow an oversight agency to covertly identify and eliminate program fraud. If an inspection is locked out, the perpetrators become immediately aware that their fraudulent approach did not work, possibly without the agency being aware of the attempted fraud. This could lead to program scofflaws "shopping around" with different schemes to get around the inspection process.

To partially address this issue, any system of automatic lockouts should record and report the inspection and vehicle identification information in any instance where an inspection is terminated and/or a tester is locked out. The bigger policy issue is whether it is better to identify inspection fraud covertly and thus allow follow-up enforcement or overtly and thus prevent fraud from occurring.

Enforcement Penalties and Public Disclosure

The existence of strong negative consequences, with a history of these being imposed on convicted program violators, can have substantial deterrence value against crime. If significant monetary penalties, and perhaps jail time, could be imposed for fraudulent testing convictions, and disclosed both publicly and specifically within the industry, this is likely to cause a significant decrease in such illegal acts.

As described previously, getting the courts to take strong actions against stations and inspectors found guilty of committing inspection fraud has often proven elusive in the past. However, this has been changing, at least in some states.

Criminal Charges/Convictions – Some states have successfully prosecuted criminal cases against vehicle repair shop owners and inspectors for performing fraudulent inspections. In 2014, the New Jersey Division of Criminal Justice charged three individuals with second-degree conspiracy, second-degree computer crimes and third-degree tampering with public records or information. All three were sentenced to 364 days in jail.[17,18] Additional criminal cases have also occurred in New Jersey.[19] Texas has successfully prosecuted such cases, with felony charges

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[17] "Owner and Employees of Auto Inspection Business in Paterson Charged With Using Electronic Devices to Falsify Emission Inspection Results," New Jersey Office of the Attorney General, January 15, 2014, https://nj.gov/oag/newsreleases14/pr20140115a.html.

[18] "Paterson auto shop owner and two employees sentenced to one-year jail term for falsifying emission reports," *Paterson Times*, June 5, 2015, https://patersontimes.com/2015/06/05/paterson-auto-shop-owner-and-two-employees-sentenced-to-one-year-jail-term-for-falsifying-emission-reports/.

[19] "Dirty business: N.J. motor vehicle inspectors charged in emissions scam," *NJ.com*, January 16, 2019, https://www.nj.com/news/2016/12/dirty_business_nj_motor_vehicle_inspectors_charged.html.

being applied in some cases.[20] At least one of the Texas cases, prosecuted with the aid of the U.S. EPA, resulted in the convicted parties being sentenced to 15 months in federal prison.[21]

New York has also successfully pursued criminal felony convictions against inspection fraud.[22] Pennsylvania has levied criminal felony charges against inspection stations engaging in fraudulent activities.[23] And in the last of our examples, EPA obtained convictions in federal court in a case in which a Los Angeles-area repair shop owner and inspectors were charged with Clean Air Act violations. [24,25] Charges of conspiracy in this case carried a statutory maximum penalty of five years in federal prison, and a charge of making false statements in a record carried a statutory maximum penalty of two years.

We are providing these examples to demonstrate that it is possible to successfully prosecute inspection fraud-related criminal activities. Courts in at least the above states have found these convictions to justify significant monetary and incarceration penalties. The examples are also provided to show that government prosecutors have been successful in getting convictions on charges that contain significant weight, including:

- Conspiracy
- Computer crimes
- Forgery
- Fraud
- Violating federal environmental regulations
- Conspiracy to violate the Clean Air Act
- Tampering with public or government records
- Criminal possession of a forged instrument
- Making false statements in a record
- Misapplication of entrusted property and property of government or financial institutions

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[20] "Texas DPS arrests 7 in motor vehicle inspection fraud investigation in El Paso," *El Paso Time*, June 7, 2019, https://www.elpasotimes.com/story/news/crime/2019/06/07/texas-dps-vehicle-inspection-fraud-case-nets-7-arrests-el-paso/1369734001/.

[21] "Emissions Inspectors At Vehicle Inspection Stations In Arlington, Texas, Sentenced For Falsifying Texas State Emissions Test Results," U.S. Attorney's Office, Northern District of Texas, March 19, 2013, https://www.justice.gov/usao-ndtx/pr/emissions-inspectors-vehicle-inspection-stations-arlington-texas-sentenced-falsifying.

[22] "A.G. Schneiderman Announces Felony Convictions of NYC Motor Vehicle Inspectors for Issuing Over 13,000 Fake Inspection Certificates," New York Office of the Attorney General, April 13, 2016, https://ag.ny.gov/press-release/2016/ag-schneiderman-announces-felony-convictions-nyc-motor-vehicle-inspectors-issuing.

[23] "Mount Holly Springs police: Auto shop gave new inspection stickers to unsafe vehicles," *The Sentinel*, November 24, 2019, https://cumberlink.com/news/local/crime-and-courts/mount-holly-springs-police-auto-shop-gave-new-inspection-stickers-to-unsafe-vehicles/article_05edc9ed-55d6-5a06-8cbd-fa038645af2b.html.

[24] "9 Charged in Federal Court with Circumventing Smog Check Program by 'Clean Piping' over 1,300 Vehicles that Were Never Tested," U.S. Attorney's Office, Central District of California, February 2, 2016, https://www.justice.gov/usao-cdca/pr/9-charged-federal-court-circumventing-smog-check-program-clean-piping-over-1300.

[25] Bell Gardens Man Sentenced To Prison For Circumventing Smog Check Program, *Patch Media*, June 20, 2017, https://patch.com/california/cerritos/bell-gardens-man-sentenced-prison-circumventing-smog-check-program.

- Obstructing the administration of law enforcement
- Failure to make required disposition of funds
- Tampering with or fabricating physical evidence
- Recklessly endangering another person

Prosecutors typically file as many charges as possible in criminal cases, and we do not know exactly which of the above charges may have been successful in the example cases. However, we do know that several of the cases resulted in felony convictions. We have not conducted an exhaustive search, so do not know just how widespread in the I/M industry such cases and convictions might be. But they are demonstrative of the potential for pursuing significant legal charges against non-compliant stations and inspectors. We suggest CARB follow a similar strategy in the HD OBD program. We believe such a strategy will act as a substantial negative deterrent and aid in significantly limiting inspection fraud in the HD OBD program.

California Monetary Penalties – Other than the EPA criminal case referenced previously, our limited research did not identify any imposition of criminal penalties in California for other Smog Check inspection fraud convictions. We did, however, find cases that resulted in significant monetary penalties for reimbursement of applicable enforcement costs.[26,27]

Vehicle Owner Penalties – While we did not find any Internet articles regarding the imposition of penalties on the owners of vehicles involved in inspection fraud, this is another area where we believe the maximum possible penalties should be applied. Fraudulently passing a vehicle inspection almost always involves conspiracy between two willing parties, the inspector, and the vehicle owner. Both parties should be subject to the maximum extent of the law, in order to achieve the maximum deterrence effect. This would be particularly true in the HD OBD program, given its focus on commercial vehicles and businesses.

Public Disclosure of Convictions – We also recommend that inspection fraud convictions be publicized, both inside and outside of the HD OBD program. CMV operators that are subject to the program should be notified of convictions, reinforcing the twin messages that inspection fraud will not be tolerated and that severe penalties will be imposed on anyone found guilty of such violations.

Testers and facilities participating in the program, such as truck stop locations, certified third-party testers, certified fleet testers, telematics service providers, or other program providers should be similarly notified. News releases would also alert the public. Public dissemination of this information will likely further serve as a deterrent to program fraud.

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[26] "BAR Precedential Decision No. 2018-01," OAH No. 2016120680, California Bureau of Automotive Repair, November 21, 2018, https://www.bar.ca.gov/pdf/2018-01.pdf.

[27] "Proposed Decision of the Administrative Law Judge," OAH No. 2014040815, California Bureau of Automotive Repair, May 15, 2015, https://www.bar.ca.gov/pdf/accusations/ea-633765_2015_05_15_dec.pdf.

3.3.3 Preventing Fraud in California's OBD-Based Heavy Duty I/M Program

Although the design of California's upcoming HD I/M program is still under development, the various types of OBD testing and data reporting being considered in the HD OBD program are described below, along with discussions of data security risks and the potential avenues of inspection fraud associated with each test type. Some HD I/M inspection methods currently under consideration for this program include the following[28]:

- Continuously connected remote OBD (CC-ROBD), such as a telematics device;

- Non-continuously connected remote OBD (NCC-ROBD), such as a handheld test device, that may be used on multiple VINs (vehicles) by an HD I/M approved tester that could be either one of the following:

  o A CARB-certified tester that would be an employee of the fleet who would conduct onsite testing of their fleet vehicles, or

  o A third-party tester, who would be an outside testing contractor (also certified by CARB), who would provide fleet test services for a fee, likely onsite at the fleet's facility

- Truck stop / physical test locations testing - self-testing at a specified location with a certified stand-alone or kiosk-based NCC-ROBD device operated and managed by the state or an I/M contractor. Facilities such as highway truck stops (e.g., Pilot, Flying J, other CMV outlets) could serve as candidate facilities to host kiosk testing. Systems such as those shown in Section 3.1 (under "Future Program Test System Options") could be used for this purpose.

The following factors could increase the potential for fraud in the upcoming HD I/M program to be greater than that in a traditional I/M program:

- **Less control/oversight over the testing process**. The multiple OBD data reporting options being evaluated for this program have a common theme, and that is testing will not occur in a controlled inspection station environment. To varying degrees, these options involve the fleet or owner-operator having direct responsibility for the testing process. As with private vehicle owners, some percentage of CMV operators can be expected to attempt inspection fraud. Significant controls need to be incorporated into each OBD data reporting option to minimize the potential for successful fraud.

- **Battle in cyberspace**. The clash between motorists who are attempting to fraudulently pass their vehicle inspections, and program administrators blocking or identifying those attempts, is an ongoing battle. The continued penetration of OBD testing into the I/M

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[28] Draft Proposed Regulation Order, Heavy-Duty Vehicle Inspection and Maintenance Program presented at the March 24, 2021 HD I/M Workgroup, Appendix A, Section 2196.3, HD I/M Inspection Methods, https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdim/meetings/20210329_draft_proposed_hdim_reg_text.pdf

fleet means that this conflict is being increasingly waged in a virtual environment involving electronic data collection.

The OBD data reporting options being considered for California's HD OBD program, particularly the telematics option, would shift this effort even further into cyberspace, potentially exposing the program to a pool of talented hackers. The everyday news continues to contain new reports of successful hacks into very complex and well-protected governmental and private networks and systems.

While to our knowledge, until recently[29], the LD I/M industry has not previously attracted this level of hacking expertise, it is something that should be of concern in implementing this HD I/M program.

- **High cost of repairs**. Some might think that the level of cheating in the HD OBD program would be less, due to an elevated concern about the potential impact among the fleets and independent owner-operators on their business if they were to be caught. However, this conclusion is not supported by actual experiences in heavy duty vehicle inspection programs in Europe. During a conversation with California BAR staff,[30] they indicated that Dutch law enforcement authorities have told BAR that test fraud among heavy-duty vehicles is significantly higher in the Netherlands vehicle roadworthiness inspection program. Driven by very high repair costs for HD vehicles, vehicle owners in that program are choosing to pay monetary fines for failing the test rather than get their vehicles repaired.

  While American and European experiences and trends do not always track well with one another, we suspect that in this case the European experience would be relatively representative of what could be expected in American HD I/M programs. If so, penalties for non-compliance with the California HD OBD program need to be very significant, involving large monetary fines as well as jail time, if possible, to act as a sufficient deterrent to fraud in the program. Fines and other financial penalties should be levied in such a way as to withstand bankruptcy filings.

- **HD OBD data collection and analysis are currently in their infancy**. This sharply contrasts with the existing state of LD OBD data collection/analysis, which has been expanded and refined over the last 25 years. As a result, fraud detection in the LD OBD I/M industry has a massive head start in identifying fingerprints of fraud and building truth tables of known good values. It will take time and effort for HD OBD I/M to catch up in this regard, during which some level of ongoing fraud may go undetected until tools capable of finding this fraud can be identified and developed.

- **Out-of-state vehicle compliance requirements**. Requiring compliance of out-of-state vehicles increases complexity and the opportunity for non-compliance, since

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[29] https://www.bostonglobe.com/2021/04/07/metro/contractor-dispatches-potential-software-fix-vehicle-inspection-stations-mass-7-other-states-system-still-out/

[30] Private communication with Garrett Torgerson, Supervising Air Quality Engineer, Engineering & Research Branch, California Bureau of Automotive Repair, September 23, 2020.

conventional registration denial techniques cannot be applied here. Compliance will be based on on-road enforcement strategies described in this section.

In this section, we provide a brief overview of the fraud risks associated with the program testing approaches under consideration, and also non-test related fraud risks. Each fraud risk section includes information regarding strategies for preventing such fraud. Since this program is still in development, it is possible other program implementation scenarios may be utilized for the future program. However, many of the thoughts and strategies presented here will be applicable to other I/M program approaches as well.

3.3.3.1 General Fraud Risks and Prevention Techniques

As previously stated, most of the security risks and opportunities for fraud in a statewide OBD-based HD I/M program in California are common to multiple components of the program, including the OBD test options that are currently under consideration, VID and information technology (IT) threats, and non-test related threats. These general threats, and solutions and strategies for addressing these mutual concerns are presented below, followed by individual sections that describe threats and offer prevention solutions for specific components of the test program.

Risk 1: OBD Code Clearing: This is the practice of eliminating trouble codes (i.e., by a system reset) in order to extinguish the MIL, delete the trouble codes, and pass the inspection. This has been addressed in light and medium-duty vehicle OBD inspection programs through the required setting of readiness monitors before the vehicle is eligible for inspection, and also through the program inclusion of permanent trouble codes that cannot be reset through a battery disconnect or a scanner reset comment in the pass/fail determination. Similar logic implemented in the upcoming HD I/M program, using appropriate HDV criteria for different readiness monitors and permanent trouble codes that apply to heavy-duty diesel vehicles, is expected to curtail this risk.

Risk 2: OBD Clean Scanning/Plugging – This is the substitution of a vehicle with no faults in place of a vehicle with faults in order to pass the inspection. We recommend implementation of the enforcement triggers and other reports/queries described previously to prevent this risk. This would include evaluation of the e-VIN and use of truth table comparisons as part of the triggers data mining strategy. We also suggest that additional HD OBD-specific triggers be developed and used, including:

- **ESN Trigger**. Engine Serial Number is a field contained in the HD data stream. Although we do not believe ESN is included in the DMV registration record for HD vehicles, and therefore the downloaded ESN cannot be compared with the ESN in the registration record, once captured and recorded, an ESN could be linked to a particular VIN for corroboration of later inspection data.

- **Other Triggers**. Other strategies currently under consideration by CARB may also be used to identify clean scanning / plugging. These involve developing and reviewing "fingerprints" of ECM data for comparison against "truth tables" or

subsequent tests, for similar trucks. Some parameters for consideration include responding control units, monitor supported profiles, parameters broadcast by responding control unit, calibration identifier (CAL-ID), calibration verification number (CVN), controller-specific test results, and call/response timing, along with other strategies currently under consideration by CARB. Further research during ongoing processes will likely identify additional triggers that can be added.

In addition, implementing test terminations, trigger lockouts, and the enforcement penalties/disclosures described previously (as allowed under California law), could further reduce this type of fraud.

Risk 3, Improper Vehicle Characteristics Identification – One potential source of fraud is application of a less stringent test (such as an opacity test for pre-OBD vehicles). While having the ability to "fall back" to this less stringent test will not likely be an issue in the upcoming HD I/M program, monitoring opacity and OBD test results to ensure OBD equipped HD vehicles are receiving the proper inspection will prevent the use of incorrect test methodologies.

Risk 4, Use of Defeat Devices/OBD Simulators – OBD simulators can be used to perform fraudulent inspections by simulating a vehicle in cyberspace, producing a complete and clean data stream in lieu of the actual OBD data stream from the test vehicle. These devices can be detected because each type of such a device has its own individual electronic fingerprint. Data mining can therefore be used to identify inspection records containing such fingerprints. Evaluation of call/response timing during data collection may also be performed to detect use of such a device. We recommend the use of simulator fingerprinting and trigger identification to identify suspected instances of simulator use.

Risk 5, Cybersecurity / Enterprise System Threats – Just like existing I/M VIDs and networks, the HD VID and network will likely face the full range of cybersecurity issues that continue to threaten web-based enterprises. These include:

- Distributed denial of service (DDoS) attacks, including Botnets, Smurf attacks and TCP SYN (transmission control protocol synchronize) flood attacks.

- Man-in-the-Middle (MitM) attacks, including Session hijacking, internet protocol (IP) spoofing, Replay attacks, and Eavesdropping attacks

- Social engineering attacks, including Phishing, Spear phishing and Homograph attacks

- Malware and Spyware attacks, including Trojan viruses, Ransomware, Malvertising, Wiper malware, Drive-by downloads and Rogue security software.

- Passwords attacks, including Brute-force password guessing and Dictionary attacks

- Advanced persistent threats (APTs)

Explanations of the above issues is beyond the scope of this report, so under the assumption that CARB staff have general knowledge about such security threats, these explanations are being omitted here.

A number of these threats, in particular APTs, require sophisticated attackers and involve major efforts, so they are typically launched against nation states, large corporations or other highly valuable targets. Although the likelihood that the HD VID and network would be a target of such attacks is relatively low, the enterprise still needs to be well-protected from such cyberthreats.

Development and use of comprehensive security plans are an important tool in protecting against the broad range of threats facing web-connected enterprise systems, and these plans are standard requirements for VIDs and networks in existing I/M programs. Key features of such a plan include:

- **Administrative Controls** focus on the management of the information system and the management of risk for a system. They include techniques and concerns that are addressed by the enterprise management team.
- **Operational Controls** address security methods focusing on mechanisms primarily implemented and executed by people, as opposed to systems. They require technical or specialized expertise and rely upon management activities as well as technical controls.
- **Technical Controls** focus on security controls that the computer system executes. These controls provide automated protection for unauthorized access or misuse, facilitate detection of security violations, and support security requirements for applications and data.

Table 3-3 summarizes the controls that are available to address enterprise risks in a comprehensive security plan.

Table 3-3 Enterprise Security Plan Contents

Control Group	Control Description
Administrative Controls	
Policy, standards, and guidelines	1. Information Security Policy 2. Information security standards and guidelines 3. Computer use and software licensing policy 4. Computer use and software licensing agreement 5. Password guidelines
Information system security documentation	1. Security plan
Information system security documentation maintenance	1. Security plan update
Operational Controls	
Configuration management	1. Baseline configuration and inventory 2. Change control 3. Monitoring configuration changes

Control Group	Control Description
Disaster recovery planning	1. Disaster recovery plan
	2. Disaster recovery plan update
Incident response	1. Incident handling
Media protection	1. Media access
	2. Media storage
	3. Media transport
Physical protection	1. Physical access control
	2. Transmission medium access control
	3. Display access controls
Environmental protection	1. Emergency lighting and power
	2. Fire protection
	3. Temperature and humidity controls
	4. Water damage protection
Personnel security	1. User categorization and restriction
	2. Personnel transfer or termination
System and Information Integrity	1. Flaw remediation
	2. Malicious code protection
Technical Controls	
Access control	1. User account management
	2. Access enforcement
	3. Information flow enforcement
	4. Separation of duties
	5. Least privilege
	6. Unsuccessful login attempts
	7 System use notification
Audit and accountability	1. Auditable events
	2. Audit monitoring
	3. Protection of audit information
Identification and authentication	1. User identification and authentication
System and communications protection	1. Information remnants
	2. Denial of service protection
	3. Boundary protection
	4. Transmission integrity
	5. Transmission confidentiality

Risk 6, Vehicle Hacking/IoT Threats – The amount of data contained in a modern vehicle is huge. Even non-autonomous vehicles are loaded with a variety of smart sensors which include global positioning system (GPS) devices, built-in communications platforms, cameras, and artificial intelligence (AI) controllers. Communications links, some offered through built-in vehicle OEM hardware and others through installation of aftermarket devices, can be through a large variety of external platforms, including:

- Vehicle OEM and third-party provider services, including entertainment services, e.g., SiriusXM radio and video, vehicle navigation/location services, emergency services, e.g., GM OnStar, insurance companies, remote vehicle diagnostics, fleet management, personal assistant, e.g., Amazon Alexa services, vehicle start/stop and lock/unlock services, and much more.

- Internet connectivity via Apple Carplay or Android Auto.

- In-vehicle Wi-Fi services, offered by most phone carriers, using the built-in Wi-Fi hotspots that are now pre-installed in newer vehicles by all the major OEMs. Even if it is not pre-installed, Wi-Fi equipment can be added to most vehicles manufactured after 1996. Some car Wi-Fi devices plug into the OBD port. But wireless routers are also being installed now in vehicles.

- Federal ELDs on commercial vehicles.

The above is just a small snapshot of what modern vehicles, which are now considered mobile data platforms linked to an ever-increased array of connected services, are becoming. Connected vehicles are equipped with internet connectivity and, in most cases, a wireless local area network (WLAN). This enables the vehicle to access data, send data, download software and patches, communicate with other IoT (internet-of-things)devices, and provide Wi-Fi for onboard passengers.

Connected vehicle services are a big part of the projected revenues for the Internet of Things. IoT is evolving many different markets, and as these markets grow, they are going to inter-connect. There are substantial investments being made in this space with things like mobility-as-a-service (MaaS), insurance, fleet management, fleet telematics and IoT infrastructure, not to mention the investments going into autonomous vehicles.

Vehicle connectivity is two-way. In-vehicle infotainment systems and telematics units have become top priority for over-the-air (OTA) software updates. The OEMs plan to add new applications and services, ranging from car-sharing to detecting fuel levels. A flood of audio and video streaming media—via Wi-Fi, 4G and 5G—is washing over vehicles. All these new applications and cybersecurity demands OTA. When a hack occurs, it is critical for OEMs to quickly broadcast software patches. Because there is no such thing as bug-free software, vehicles must be prepared to correct software errors.

The next frontier of OTA updates is happening in the whole vehicle. The OEMs need to be able to target not just TCUs (telematics control units) but also the various ECUs, developed by different chip vendors, installed in each vehicle. These ECUs are tasked with controlling various systems of a vehicle, ranging from engine control to air bags and seat adjustments.

A major IoT issue is the lack of a standard protocol, which lends itself to not only marketplace opportunities, but also to multiple pathways for hackers seeking sensitive data on IoT devices. This information includes private conversations, sensitive images, tracking information, and access to any accounts used with devices. These devices can be easily leveraged by attackers for blackmail or personal gain.

With vehicles in particular, the threat of personal harm is also very real. When vehicles are partially or entirely controlled by computers, attackers have the opportunity to hack vehicles just like any other device. This could enable them to use vehicles as weapons against others or as a means to harm the driver or passengers.

How does all of the above pertain to HD OBD connections? First, it means that connected vehicles represent a huge target for hackers. Second, all the inter-connectivity centered on these vehicles plus intra-connections in the vehicle itself provide possible pathways for interested hackers. Anything coming into the vehicle in cyberspace—infotainment and telematics data, software updates, etc.—provides a possible avenue for hacker entry. Once in the vehicle, one potential threat is that the hack could somehow spread to the vehicle OBD system. While the probability of this occurring may be low, the damage that could be done if such a hacking attempt were to be successful is very high. Therefore, it is a threat that needs to be considered.

While these are significant, there may be little that CARB or an HD I/M program oversight contractor can specifically do to protect against such threats. Protection against these threats is dependent on actions the OEMs and the connected services providers take in maintaining adequate protection against a data breech or other cyber-intrusion into the CMVs taking part in the HD OBD I/M program.

One recommendation, however, is to educate the CMV operators on the issue to ensure they are aware of the need to avoid introducing questionable applications into their vehicles' virtual environments. An additional possible protection might be to have each operator sign some sort of agreement with the program that commits them to exercising reasonable care in regard to such applications.

Risk 7, Packet Sniffing/Editing – A sophisticated form of potential fraud would be to somehow intercept and alter the OBD test results, or raw data, as they are being transmitted from the dongle to the kiosk/docking device or from the kiosk/device to the VID. The first part of this, capturing such data as it is being transmitted, is common enough in cyberspace to have earned its own label—packet sniffing. Packet sniffing is done using specialized hardware or software that has been installed somewhere on a network, either wired or wireless. This can be used to catch data in mid-transmission long enough to sniff or inspect it and, if it is interesting, capture it, copy it, and then send it along to its destination, without anyone knowing about it.

This technique is used by hackers and online thieves, as well as security experts and network administrators. For example, companies use packet sniffing to monitor their networks to ensure that their employees are not visiting restricted websites or malicious websites which could load malware. Packet-sniffing software may also be used to breach company networks and steal data. Once inside, hackers can virtually eavesdrop on any unencrypted information being exchanged between computers and traveling on a network.

Packet editing refers to the second part of what would need to be done to intercept and alter the OBD inspection results, which is possible using existing applications. For example, Charles Proxy inserts itself as a man-in-the-middle hypertext transfer protocol (HTTP) proxy and

can perform scripted modifications. A competent hacker could potentially build and sell such an application for use in the upcoming HD I/M program.

When possible, use of physical direct connections can help prevent this risk. For example, docking of dongles in docking stations at truck stop or kiosk test facilities is preferable to using Bluetooth or Wi-Fi communications between the dongles and the docks.

Use of HTTPS encryption is advised for HD OBD communications, and possible use of Virtual Private Networks (VPNs) should be considered. With HTTPS communications, all transmissions are encrypted and cannot be read by a hacker. Even if a hacker could sniff out the data, it would be unreadable. A VPN provides additional protection by routing all Internet activity through an encrypted network that a hacker cannot invade, and snoopers cannot trace. A VPN also hides an actual IP address from anyone who might try to track it and trace it back to another computer.

Risk 8, OBD Editor – This type of device could take advantage of a key data security vulnerability of the OBD inspection process. Specifically, because these inspections require access to the vehicle diagnostic link connector (DLC), this port is physically available. An OBD editor could be developed that plugs into the DLC, with the dongle then plugging into the OBD editor. This device would not attempt to simulate a full OBD data stream, but instead would allow the vehicle's actual data stream to flow through the device, only modifying those data bits that would cause the vehicle to fail the inspection. Because of this, there would be no device-specific electronic fingerprint, hampering detection via any post-inspection data mining techniques.

A quick Internet search revealed mention of such devices on industry insider forums, although the information appeared to generally be second-hand, and we did not identify anyone reporting having actually seen one. For example, one post[31] by a California Smog Check technician, who heard this in 2015 from another technician, described such a device, with a reported asking price of $12,000. While we are unaware of any such device actually being available, this type of test fraud is theoretically possible and could possibly currently exist. In our opinion, this is a difficult potential inspection fraud threat to identify and prevent in the HD OBD I/M program. An active enforcement program, including reviewing posts on industry insider forums, may be used to help identify the use and prevalence of such devices. Strong enforcement penalties and public disclosure of all successful enforcement cases would be particularly important here, to order to provide a strong negative deterrent to the use of OBD editors.

3.3.3.2   CC-ROBD Fraud Risks and Prevention Techniques

CC-ROBD devices are reporting devices attached to a vehicle on a consistent basis. These could include OBD telematics solutions, such as those already in use by fleets under contract with the OEM or third-party telematics provider solutions, such as those currently used

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[31] "The #2 Smog Producing Shop in California Got Popped for Clean Plugging," Stop the Star Program Blog, blog post by locopoco, November 8, 2017, http://stop-the-star-program.3084.x6.nabble.com/The-2-Smog-Producing-Shop-in-California-Got-Popped-for-Clean-Plugging-td5061880.html.

to monitor fleet logistics, vehicle maintenance and other needs, or electronic logging devices used to maintain compliance with federal ELD requirements.

These two types of systems are part of one integrated solution in the more advanced CMV packages which already monitor the vehicle's ECM. Such systems could potentially automatically transmit OBD data to the HD VID on the specified interval, either directly or through the telematics service provider's database. CARB has been considering several options for CC-ROBD data submission, with one likely scenario being 90-day submissions. As noted previously, periodic testing requirements could potentially be met without affecting a vehicle's normal operating schedule and without the need for fleets to purchase additional equipment, although upgraded equipment and service cost increases are likely.

While the above appear to be attractive telematics-based data reporting options for the HD OBD I/M program, certain technical and logistical considerations pertain to their possible use in this program, as discussed below.

ELD Overview – ELD service providers are required to enable data transfers using two pathways—wireless Web services and email. ELDs are programmed to collect vehicle parameters related to a driver's hours of service (HOS), which are then used to create entries related to the driver's required record of duty status (RODS). Required data include date; time; location information; engine hours; vehicle miles; and identification information for the driver, authenticated user, vehicle, and motor carrier. Location data must be recorded by an ELD at 60-minute intervals when the vehicle is in motion, and when the driver powers up and shuts down the engine, changes duty status, and indicates personal use or yard moves. ELDs are programmed to transmit the required RODS data to a secure computer server managed by the Federal Motor Carrier Safety Administration (FMCSA). In addition, some currently-available ELDs also allow recording of OBD diagnostics information and fault codes. Supplementary non-RODS data that is collected can be sent to other locations, e.g., a fleet logistics/maintenance application being run on the truck. These ELDs that also provide OBD diagnostic information would be the most likely candidates to provide services for this program, although additional programming would likely be needed to collect all the required data for a HD OBD I/M data collection. The feasibility of this would be contingent upon existing ELD/telematics services providers' interest in supporting the upcoming HD I/M program, which has historically been a challenge in light-duty I/M programs.

Telematics Overview – As previously noted, a variety of existing fleet logistics and vehicle maintenance telematics-based applications are installed in CMVs. Many of these are likely to include integrated ELD functionality as well. The same issues that pertain to ELDs also apply to telematics, including the telematics service provider's (TSPs') interest in providing HD I/M services and the cost to modify the telematics systems to provide program support services, in particular for those TSPs who utilize equipment and firmware from a third-party provider.

In considering likely TSP vendor interest in the HD OBD program, it is worthwhile to look at the LD I/M inspection industry's experience with telematics OBD I/M support. Oregon,

California, and Nevada all have working LD remote OBD programs. The California[32] and Nevada[33] programs are both aimed at LD vehicle fleets, and the following four telematics companies are currently participating in the BAR's Continuous Testing Program (CTP):

- Networkfleet / Verizon Connect
- Geotab, Inc
- GPS Insight
- Forward Thinking Systems, LLC

Networkfleet/Verizon Connect: This company holds the largest market share of these existing service providers. Verizon Connect, the telematics unit of Verizon, offers multiple CMV telematics applications. Its solutions include Fleet Tracking software, Fleet Dash cam software, Driver Management and Safety software, Route Optimization software, Road Assistance software and more. It also offers an ELD application, which can be integrated with its fleet tracking software. The 360Quadrants industry rating platform rates Verizon Connect's telematics applications in the top tier of commercial vehicle telematics (CVT) providers.[34]

Geotab, Inc: Specializing in vehicle tracking and fleet management technology, Geotab provides open platform fleet management solutions. It helps fleets manage their drivers and vehicles by extracting accurate and actionable intelligence from real-time and historical trip data. The company's flagship product, MyGeotab, provides industry-specific vehicle tracking and fleet management solutions that optimize fleet performance based on industry type. Other solutions include MyGeotab Dashboard, an online interactive fleet management dashboard, GPS Fleet Management and an integrated ELD application. Its applications are rated in the next to the top tier of CVT providers.[35]

GPS Insight: This company's existing telematics solution focuses on location data and visibility into driver's daily activities. Its applications, including ELD software, are also rated in the next to the top tier of CVT providers.[36]

All three of the above companies are considered by 360Quadrants to be current Top 10 Visionary Leaders in the commercial vehicle telematics market.[37] Previous 2018 and 2019

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[32] "Continuous Testing Program (CTP) Pilot and Enrollment Application," California Bureau of Automotive Repair, https://www.bar.ca.gov/PubWebQuery/FINE/PublicLetterOfResponseForm.aspx?form=ctp.

[33] "Emissions Continuous Monitoring," Nevada Department of Motor Vehicles, https://dmvnv.com/emission_cm.htm.

[34] "Best Commercial Vehicle Telematics," 360Quadrants, March 2020, https://www.360quadrants.com/automotive/commercial-vehicle-telematics.
[35] Ibid.

[36] Ibid.

[37] Top 10 Visionary Leaders in the Commercial Vehicle Telematics Market – 2020," 360Quadrants, March 3, 2020, https://blog.360quadrants.com/2020/top-10-visionary-leaders-in-the-commercial-vehicle-telematics-market-2020/.

rankings by other research firms[38,39,40] ranked Networkfleet and Geotab at the top of CVT providers, with GPS Insight in the top 20 of these companies. In 2019, Verizon continued to take the nationwide market share lead with over 1.59 million active subscribers, followed by Geotab at 1.36 million.[41]

Forward Thinking Systems: This company is a leading provider of fleet management and asset tracking systems. Forward Thinking System's IntelliHub, FleetCam, Field Warrior, Monarch, Route Matrix, and Road Angel applications provide fleet tracking, fleet camera, GPS tracking, electronic logbooks, dispatching, navigation, fleet management, and route optimization services, including an integrated ELD application. It is not rated on the 360Quadrant platform.

According to BAR staff,[42] two additional companies are in the final stages of being added to the CTP. Fleet participation is currently limited to government fleets, although two private fleets are grandfathered into the program, with about 15,000-20,000 LD government vehicles currently participating. BAR believes an additional 20,000-30,000 government vehicles will be added over the next 12-18 months.

The participation of the above companies—which includes the top two nationwide commercial TSP providers by market share—in the CTP suggests there could be significant industry interest in participating in the California HD OBD program. However, none of the existing TSP vendors adapted their existing TSP packages; instead, all of these companies developed new OBD dongles for the collection and transmittal of the required OBD information to BAR's database[43]. This could also apply to the upcoming HD OBD I/M program, in particular since the data requirements for the upcoming HD I/M program are greater than those for BAR's LD CTP program.

Since existing ELD and telematics services may be provided at the OBD port, an integrated solution could support the HD OBD I/M program without competing data requests. However, it is possible that a HD I/M solution operating in parallel with another OBD device (i.e., via a splitter) could be problematic since both would require access to the single OBD port, and issues could arise from competing requests from the parallel systems. Some telematics vendors have indicated this would not be an issue (in particular with 90-day collection frequency) but care would need to be taken in system specifications and design to ensure conflicts did not arise from competing data requests for non-broadcast parameters.

[38] "Top 10 Companies Providing Telematics Solutions – 2018," *CIOApplications*, https://telematics.cioapplications.com/vendors/top-telematics-solution-providers.html.

[39] "The CompassIntel A-List Index in Fleet Tracking," *Compass Intelligence*, 2020, https://www.compassintelligence.com/fleet-tracking-index-a-list-index.html.

[40] "Telematics Companies Ranked by ABI Research," *Automotive Fleet Magazine*, June 5, 2019, https://www.automotive-fleet.com/333259/telematics-companies-ranked-by-abi-research.

[41] Ibid.

[42] Private communication with Garrett Torgerson, Supervising Air Quality Engineer, Engineering & Research Branch, California Bureau of Automotive Repair, September 23, 2020.
[43] Ibid.

ELD and Telematics-Related Security and Fraud Threats – Third-party telematics devices and services have the same security risks and opportunities for fraud as other data collection methodologies. These include traditional OBD inspection fraud, cybersecurity threats, vehicle hacking/IoT threats, packet sniffing/editing, and OBD editors. Opening up this enterprise to one or more ELD/CVT service providers may also increase cybersecurity threats due to:

- A larger number of systems/networks operated by individual service providers, each with potential web exposure. Each of these would need to be well protected in order to adequately protect the overall enterprise.

- Individual CVT providers would offer additional services besides HD OBD I/M telematics. Larger, more complex enterprises may offer a "bigger target" to potential hackers and thus attract more unwanted attention. These larger enterprises would also have more systems and networks to protect, giving them more exposure to attack.

In addition, generally CMV telematics service providers' clients are the fleets they serve, rather than the state agency monitoring those fleets. This can create an internal conflict of interest in telematics fleet monitoring for I/M compliance.

Preventing Inspection Fraud in a Telematics Based Environment

Risk 9, Increased Internet Exposure Due to Telematics Support – As described previously, participation of CVTs in the HD OBD I/M program could increase the exposure of the HD I/M program's network to cybersecurity threats. Requiring each of the participating CVT providers to implement comprehensive security plans, similar to the requirements for the HD OBD I/M program's oversight contractor, will help reduce this threat.

3.3.3.3 NCC-ROBD Fraud Risks and Prevention Techniques

3.3.3.3.1 Fleet and IOO Self-Testing

Self-Testing Overview

Fleet-owned vehicles currently make up the majority of the commercial motor vehicles that would be subject to the HD OBD program in California. Available information[44] from 2015 indicated that nationwide, fleet owned CMVs made up 91% of the overall HD fleet. In California, the percentage of fleet owned vehicles is currently estimated at 73%[45]. This percentage could increase as a result of the 2019 passage of Assembly Bill 5 (AB 5), which effectively makes it illegal for fleets to contract with owner-operators under their authority. Implementation of this requirement is currently on a temporary court-ordered hold,[46] with the

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[44] "Independent Owner Operator Truck Driver Statistics for the United States," Globecon Freight Systems, June 18, 2015, http://www.globeconfreight.com/blog/independent-owner-operator-truck-driver-statistics-united-states/.

[45] Estimate provided during personal communication with CARB staff

[46] "California law that blocks fleets from using owner-operators paused at least through late 2020," *Commercial Carrier Journal - Fleet Management Magazine*, June 19, 2020, https://www.ccjdigital.com/california-law-fleets-owner-operators-paused/#:~:text=California's%20A.B.,late%202020%2C%20if%20not%20longer.

federal Ninth Circuit Court of Appeals scheduled to hear oral arguments as to whether trucking should remain exempt from AB 5, while a lawsuit brought by the California Trucking Association (CTA) makes its way through court—a process that could take years to complete. Unless the current legal challenge to AB 5 is successful, owner-operators that currently contract with fleets will either have to leave the state or sell their equipment to the fleets and become company drivers.[47]

Based on the above information, it is assumed that at least 75% of the overall California HD OBD fleet will be fleet owned. For the fleets that do not opt for an HD I/M telematics solution, on-site self-testing performed by internal staff or through a third-party tester (trained and certified by CARB for program testing) may be the most likely program compliance option. In fact, it is highly likely that these test options may be elected by IOOs as well. Each of these are discussed separately in this section.

For self-testing by fleets and IOOs, the expected OBD test equipment will likely consist of a handheld test device with an OBD dongle / docking station. The device/dongle will communicate the inspection results to the docking station through a local transfer method, e.g., direct connection, Bluetooth, or Wi-Fi, and then the device will likely send those results to the VID via a wired connection. Test determinations would likely be made on the HD VID, and the user or fleet manager could log into their account to view and print test results, as necessary.

Self-Testing Security and Fraud Threats

A source of potential fraud that would be particularly applicable to IOOs and fleets involves the possibility that the IOO or one or more testers at a fleet facility would perform fraudulent tests, using one of the OBD inspection fraud methods described previously. For fleets, this is similar but not identical to what occurs with fraudulent I/M inspection stations and inspectors. In the latter case, such fraud is usually done for monetary reasons, i.e., the inspector either requests or is given a bribe to pass a motorist's vehicle.

In the case of fleet vehicle self-testing, however, a facility or tester would likely be committing such fraud under the direction of at least the level of fleet maintenance management, and possibly at the level of fleet ownership. It is highly unlikely that a vehicle maintenance technician working at a fleet facility would commit inspection fraud on their own without the buy-in and direction of some level of upper management. Additionally, IOOs who test their own vehicles may be incentivized to engage in fraud in order to avoid vehicle repair costs and associated downtime and inconvenience.

Preventing Self-Testing Inspection Fraud

Risk 10, Fraudulent Fleet and IOO Self-Testing – This potential area of inspection fraud involves a fleet tester or IOO using one or more of the OBD inspection fraud methods described previously to improperly test and pass failing vehicles. In addition to the overall use of triggers

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[47] "Landstar, Prime among fleets telling owner-operators they'll need to leave Calif. to continue as contractors," *Commercial Carrier Journal - Fleet Management Magazine*, November 21, 2019, https://www.ccjdigital.com/landstar-prime-among-fleets-telling-owner-operators-theyll-need-to-leave-calif-to-continue-as-contractors/.

to look for such test instances, LD I/M programs typically operate a covert audit program aimed at identifying and documenting this type of fraud at vehicle inspection stations. Covert audits cannot be done at fleet facilities, however, since the fleets are testing their own vehicles. Any audits performed at the facility would have to be overt, i.e., with the fleet's knowledge, rather than covert. Overt audits are generally less effective in identifying fraudulent testing.

Another possible fraud minimization method that has been implemented in some LD I/M programs is web-based video observation of vehicle inspections, in which a remote operator observes either live video or still shots of the test process. While we are listing this as a possible approach to reduce fleet self-testing fraud, we also note that it would be costly to implement and unlikely feasible at private fleets. It is also unclear how effective remote observations would be in reducing the potential for this fleet self-testing inspection fraud. Since OBD self-tests would simply involve DLC connections and OBD data downloads inside the vehicle, any video observation functionality might need to be integrated into the dongle itself in order to be effective. While not technically difficult, this would increase the complexity and cost of this test method.

A lower cost, more effective approach to reducing possible fleet fraud would be VID data review and triggers, and application of stringent legal penalties against fleets found to be guilty of such fraud. Since such fraud would likely be occurring at the direction of management, penalties for fleet self-testing fraud should therefore be imposed against not only the technicians involved in such testing, but also against the business entity and company ownership.

3.3.3.3.2 Third-Party Testing
Third-Party Testing Overview

This OBD data reporting option would involve the use of CARB trained/certified testers who would use CARB-certified devices to provide OBD inspection services to interested fleets and IOOs. The option would likely be modeled after the current smoke tester structure and requirements in CARB's PSIP. Test equipment would likely be similar to that used by fleets for fleet self-testing.

Third-Party Testing Security and Fraud Threats

Third-party testing would have the same security risks and opportunities for fraud as those listed above for fleet self-testing, including traditional OBD inspection fraud, cybersecurity threats, vehicle hacking/IoT threats, packet sniffing/editing, and OBD editors. In addition, third-party testing could pose similar fraud concerns to those that apply to traditional LD I/M testing. These include:

- The third-party testers would be balancing their responsibility to properly perform the HD OBD inspections while also looking after their customers' interests. Some testers might be more inclined to help the CMV operators than protect the government's and the public's interests.

- The wages earned by the testers may be relatively low. This in turn could incentivize third-party testers to attempt to earn additional income by either (1) offering to pass a

failing vehicle for a bribe or (2) accepting an offered bribe from a vehicle owner to pass the failing vehicle.

- Testers that charge less for their services are likely to get more business from potential customers. But cutting their fees might mean that the low-cost testers are more likely to consider an illegal "test-to-pass" scheme designed to recover the money they are not making on legitimate testing.

Third-party HD OBD testers would operate in a mostly autonomous/self-directed manner. Even those that perform testing at fleet facilities are unlikely to be closely supervised. This provides them with additional opportunity to potentially perform fraudulent testing. The lack of oversight might also attract a greater percentage of individuals who prefer to work without constraints or supervision, i.e., a group which could be more willing to commit test fraud.

Preventing Third-Party Testing Inspection Fraud

Risk 11, Fraudulent Third-Party Testing – This potential area of inspection fraud involves a third-party tester performing fraudulent tests, possibly for bribes. In addition to the overall use of triggers to look for such test instances, two additional strategies are available for guarding against this:

- **Web-based video observation** of the OBD test performed by the testers. As noted above for fleet self-testing, this could be difficult and costly to implement in this type of program, in particular for third-party testers who are likely mobile.
- **Standard test fee** for all testers. This recommendation is aimed at eliminating possible cost factors that could lead to third-party testers offering fraudulent tests for bribes or agreeing to offers from fleets or owner-operators to perform such tests. Testers would not be able to undercut the cost of OBD inspections offered by other testers with the expectation that they might be able to make more money through bribes. Setting a standard test fee would level the field and avoid the introduction of cut-rate testing in the HD OBD I/M program.

3.3.3.4 Physical Test Location Fraud Risks and Prevention Techniques

Physical Test Location Testing Overview

Another option for program services would be to provide testing opportunities at commercial facilities such as highway truck stops (e.g., Pilot, Flying J, other CMV outlets) or at drive-up kiosks (either stand-alone or located at commercial truck stops). This type of testing would be assumed to involve some type of driver self-testing their truck at a kiosk or at a facility staffed by a customer service agent or program / contractor staff. Depending on the prevalence and location of these facilities, these might be attractive test options for IOOs with one or few trucks to test.

Kiosks or portable/fixed test systems with dongles could be utilized at these facilities. Either of these options would actually be variations on the same approach, since both would

involve the insertion of a dongle onto the vehicle's DLC, with automatic interrogation of the OBD system and subsequent transmittal of the inspection results to the central HD VID. The primary difference is in how the dongle would be provided to a truck operator:

- Approach 1: Kiosks could be installed at the participating facilities, similar to a "Redbox machine" or commercial automated teller machine (ATM). The operator removes a dongle that is docked in the kiosk, takes it to the vehicle, performs the test, and returns the dongle to the kiosk upon completion. The kiosk would then transmit results of the test to the HD VID.

- Approach 2: Dongles are offered through the service counter at participating facilities. The operator checks out the device through the service clerk (or through a self-help checkout), performs the test and returns the dongle to the clerk or the system following the completion of the test, at which time results of the test are transmitted to the HD VID.

For either of these approaches, the operator could log into their HD I/M program's user portal at a later date/time to retrieve and print their test results, as needed. Approach 1 could be a bit more of a guided test, depending on the kiosk design. For example, written and pictorial instructions could be displayed on a video screen, and audio instructions could also be provided, to prompt the operator through the test process. However, these would add somewhat to the cost of the kiosks and may be of limited value since OBD truck inspections are likely to be performed at some distance from the kiosk.

Approach 2 could also consist of a guided test if arrangements were made with the participating facility to have the service clerk available to physically aid the operator in performing the test. There could be a cost associated with this level of service, and challenges associated with the facility staff managing their regular duties and I/M inspection support. Alternatively, printed instructions could be made available to operators to self-test their trucks.

With both options, there is the issue of how OBD inspection results will be transmitted to the HD VID. Use of inspection kiosks in LD OBD I/M programs, although limited, provides some useful lessons for the operation of HD OBD inspection kiosks. For example, kiosks in the Ohio LD inspection program initially had interlocks that required the bar code reader and the OBD scan device to be "re-docked" before the VIR would print out. However, it was found that some customers did not properly re-seat the devices inside the kiosk, causing the kiosk to be out of service until a technician made a service visit to make sure the devices were properly re-seated. However, for the upcoming HD I/M OBD program, it may be possible to implement auto-resets or other features in order to prevent such issues. Upon successful reseating, the kiosk could display a successful test transfer notification, or a warning message otherwise. The kiosk or test system could then send results via a wired connection to the VID.

With an untethered system, there would likely to be some level of dongle attrition, through either unintentional or intentional actions. Transferring inspection results after dongle redocking could minimize such attrition. Dongle docking and then sending the OBD data from the dongle to the kiosk or test system via a wired connection also would be less technically complex and costly than having the dongle connect wirelessly, although this could pose some obstacles in terms of the dongle's ability to reach the truck's DLC from the kiosk or test system.

Physical Test Location Testing Security and Fraud Threats

Given the above considerations, we are assuming that truck stop and kiosk dongle testing, under both Approaches 1 and 2, will only involve the truck operator, generally unaided, completing the testing. This type of self-testing would have the same security risks and opportunities for fraud as those listed for fleet self-testing, including traditional OBD inspection fraud, cybersecurity threats, vehicle hacking/IoT threats, packet sniffing/editing, and OBD editors.

Preventing Physical Test Location Testing Inspection Fraud

Risk 12, Fraudulent Truck Stop and Kiosk Testing – This potential area of inspection fraud involves fraudulent testing, such as vehicle substitution, occurring at kiosk / truck stop facilities, either with a dongle provided by a service clerk or dispensed from a "Redbox" style automated machine. In addition to the overall use of triggers to look for such test instances, there are two possible additional strategies for guarding against this:

- **Web-based video observation** of the OBD self-tests performed by the truck operators, and
- **A covert audit/observation program** aimed at kiosks or truck stop facilities

Both of these strategies would be relatively costly, which may reduce their feasibility as a fraud deterrent. It is also unclear how effective either type of surveillance would be in reducing the potential for this type of inspection fraud with so many individual testers / drivers. As noted previously, any video observation functionality might need to be integrated into the dongle itself, increasing the complexity and cost of this test method.

Regarding covert observations and auditing, any drivers or facilities / clerks attempting to fraudulently test trucks are likely to employ strategies to avoid detection. As with fleet-self testing, likely the most effective approach to minimizing fraud at kiosk / truck stop testing locations, in addition to the use of triggers, will be to impose stringent penalties for those found guilty of inspection fraud.

3.3.3.5 Non-Test Related Fraud Risks and Prevention Techniques

As noted previously, in addition to test fraud committed during an I/M inspection, other fraudulent activities have historically been used in LD I/M programs to circumvent program compliance requirements. Some of these types of non-test fraud, and methods for preventing such fraud in the HD OBD I/M program, are described in this section.

Non-Test Related Fraud Overview

In general, this section pertains to HDVs (CMVs and recreational vehicles or RVs) in operation in California that are not compliant with the HD OBD I/M program. For vehicles registered in California, registration-based enforcement may be utilized to minimize non-compliant operation. For these in-state vehicles, this can be applied for the test cycle for which the registration renewal is due, and perhaps enforcement of the other three test cycles could be

retroactively applied (penalty for lapsed emissions tests) and/or applied for off-cycle OBD tests by certification compliance checks during the 90-day Basic Inspection of Terminals [48](BIT) truck inspections, or possibly some other compliance enforcement approach. Even with registration-based enforcement, some fraction of non-complying vehicles will continue to be driven in non-compliance status. These vehicles will include some mix of in-state vehicles with DMV registration holds, out-of-state vehicles that have been identified and perhaps cited but are still being driven, and out-of-state vehicles not yet identified as being non-compliant. Since an estimated 50% of the CMVs in operation in California could be registered out-of-state [49], enforcement of program compliance can be a challenge for these out-of-state vehicles, as registration-based enforcement is not an option.

As discussed during numerous workshops and workgroups[50], CARB is exploring several approaches for ensuring program compliance, both for California-registered and out-of-state CMVs and RVs. These include the use of automated license plate recognition (ALPR) cameras to identify non-compliant vehicles operating in California and enforcement activities conducted by both CARB enforcement staff and the California Highway Patrol (CHP), such as roadside emissions monitoring testing and checks for valid compliance certificates during vehicle inspections. CARB is also considering temporary operating permits and exemptions for certain out-of-state vehicles[51] in order to ease compliance requirements in certain situations. The level of effort necessary to effectively identify non-compliant vehicles and to enforce HDV I/M program requirements is a concern for a large program such as this with requirements for out-of-state vehicles. The following sections presents possible strategies for addressing non test-related fraud and maximizing on-road HD I/M program compliance.

Preventing Non-Test Related Fraud

Risk 13, Out-of-State Vehicle Non-compliance – In addition to intentional non-compliance, a potential exists for out-of-state vehicle owners and CMV drivers to be surprised by and unprepared for California's HD OBD I/M program requirements. This in turn may cause some fraction of these owners and drivers to be resistant to the program and look for ways to circumvent the program requirements. The following are possible options for dealing with this:

- **Public outreach** - An outreach program aimed at notifying both non-California CMV and RV owners of the program requirements before their entry into California could increase awareness and reduce unintentional non-compliance. This could involve articles in industry and trade magazines, working with and outreach to CMV and RV industry associations, such as the American Trucking Association, California Trucking Association, and RV associations such as the ones listed on RV Links website[52], etc. Highway signage at entry points into the state could also help raise awareness of HD vehicle owners and drivers who otherwise do not know about the program and its requirements.

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48 https://www.chp.ca.gov/CommercialVehicleSectionSite/Documents/O%20chp800h.pdf
49 "Request for Information for SB210 Heavy Duty Inspection & Maintenance (HD I/M)," Event Number 18002, California Air Resources Board, November 18, 2020, page 12.
50 https://ww2.arb.ca.gov/our-work/programs/inspection-and-maintenance-program/Meetings-and-Workshops
51 https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdim/meetings/202100329_hdim_workgroup_presentation.pdf
52 RV Links Resource Site, http://www.rvlinks.com/RV_Associations_and_Clubs-USA-.html.

- **Possible out-of-state OBD testing capability**. If HD out-of-state vehicles could be tested before entry into California, this might mitigate otherwise adverse reactions when owners and drivers enter the state and learn they are subject to OBD testing and possible vehicle repairs. This out-of-state testing could consist of telematics solutions, truck stop or kiosk test options, or other solutions.

Working to ensuring owners of all subject out-of-state vehicles are aware of, and understand, the HD program requirements, including non-compliance penalties, will act to minimize program non-compliance among these vehicles. This awareness will minimize surprises when drivers enter the state, or when they receive a non-compliance notice or citation from the state which could lower program acceptance rates and lead to increases in attempted fraud.

Risk 14, License Plate Compliance Challenges– Several factors that can affect the ability of ALPR cameras to effectively capture truck license plate information for license plate-based enforcement. These include:

- **Non-standard license plate mounting locations and obscured plates:** License plate placement requirements for commercial vehicles varies by state, vehicle type and other parameters. In addition, many states allow plates to be placed within a wide range of locations on a commercial vehicle. The wide range of allowable plate locations, the possibility of multiple plates on tractor/trailer units, and obscured plates can create challenges in properly reading and processing plates on all commercial vehicles passing by the cameras.

- **Switched license plates:** While using stolen license plates to commit fraud in the HD I/M program may seem excessive, plate switching among trucks and other strategies to avoid compliance could occur due to the high cost of compliance for some vehicles, particularly if drivers believe on-road enforcement and enforcement at mandatory truck stops is minimal.

In addition, immediate enforcement of compliance (rather than just detection) can be challenging with stand-alone ALPR cameras, which can detect non-compliant trucks but not help enforce compliance. However, ALPR cameras mounted on Department of Public Safety (DPS) vehicles, at RSD/ PEAQS sites, or at weigh or border patrol stations have an integrated enforcement component in place once a non-compliant truck is identified. Depending on the ALPR camera deployment methods utilized to identify subject out-of-state vehicles and in-state noncompliant vehicles, possible approaches to deal with license plate-based enforcement could include the following:

- **ALPR evaluations and pilot testing:** CARB's continued efforts aimed at refining methods for deployed ALPR cameras to read license plates placed in a variety of locations on a range of HD vehicles will help ensure maximum fleet coverage. As CARB is planning, efforts to evaluate reading the Department of Transportation registration numbers as an additional or alternative method for identification of out-of-state CMVs will also serve to increase ALPR effectiveness.

- **Partnering with the California Border Protection Stations**. Compliance efforts in coordination with the California Department of Food and Agriculture can increase compliance coverage. Ideally, this would involve license plate inspections and/or other compliance determinations and enforcement activities at border protection stations (BPS), either by BPS inspectors or other personnel.

Risk 15, Other Non-Compliant Vehicle Operation – As noted previously, likely some fraction of non-complying vehicles will continue to be driven in non-compliance status. These vehicles could include some mix of in-state vehicles with DMV registration holds (although CARB reports this generally is not an issue), out-of-state vehicles that have been cited but are still being driven (perhaps intending to leave the state prior to receiving any repairs), and out-of-state vehicles not yet identified as being in non-compliance. Efforts to educate CHP and other personnel about the HD OBD I/M program and working with law enforcement officers and CARB enforcement staff to establish clear on-road enforcement priorities can aid in addressing this issue. This can involve elevating the priority of checking for valid compliance certificates during any vehicle inspection operation and citing non-compliant vehicles, or other strategies CARB deems effective. In addition, automatic determination of program compliance through data gathered from law enforcement vehicles equipped with on-board ALPR cameras would offer immediate compliance enforcement opportunities. The key will be whether on-road enforcement resources and activities will be sufficient to effectively identify such vehicles and compel their owners to bring the vehicles into compliance. The establishment of clear and achievable compliance goals and a dynamic enforcement program can help the program track and improve progress over time.

3.3.4   Summary of Potential Risk/Fraud Mitigation Strategies

Key findings regarding the potential security risks and possible inspection fraud in California's HD OBD I/M program are summarized below.

1. Imposition of stringent enforcement penalties, including large monetary fines and criminal charges, can serve as a strong deterrent to possible fraud.

2. Advanced enforcement triggers can be used to identify suspected fraud, terminate fraudulent inspections, and prevent non-compliant testers from performing additional testing.

3. A strong, comprehensive security plan, covering the entire testing/data reporting network, is an important tool in preventing against a variety of cybersecurity threats.

4. Despite all of the above, a potential still exists for fraudulent testing and other forms of program non-compliance. A dynamic fraud prevention and compliance enforcement program is an essential element of minimizing program non-compliance.

Table 3-4 summarizes the potential opportunities for program fraud and security risks, as well as recommended mitigation measures, as described above.

Table 3-4 Risk and Fraud Mitigation Strategies for the HD OBD Program Risks

Risk #	Risk Description	Mitigation Methods
General Fraud Risks and Prevention Techniques	
1	OBD code clearing	1. Readiness code requirements
2	OBD clean scanning/plugging	1. Enforcement triggers and other reports & queries 2. Truth table comparisons 3. Add HD OBD specific triggers 4. Trigger-based test system lockouts, if legally allowed 5. Severe enforcement penalties & disclosure
3	Improper vehicle characteristics identification	1. Required OBD testing of all subject vehicles, regardless of vehicle characteristics 2. Ensure that no OBD vehicles are instead receiving an opacity test
4	Use of defeat devices/OBD simulators	1. Simulator fingerprinting/trigger identification
5	Cybersecurity / enterprise system threats	1. Comprehensive security plan and strong cybersecurity features across the entire enterprise 2. Strong passwords 3. Keep software updated
6	Vehicle hacking/IoT threats	1. CMV operator education and possible agreements
7	Packet sniffing/editing	1. Use physical direct connections where possible 2. Use of https encrypted communications 3. Possible VPN use
8	OBD Editor	1. Severe enforcement penalties & disclosure 2. Active enforcement program
CC-ROBD: Telematics Data Reporting-Specific	
9	Increased Internet exposure due to telematics support	1. Required strong cybersecurity protection by each provider
NCC-ROBD: Fleet and IOO Self-Testing-Specific	
10	Fraudulent fleet and IOO self-testing	1. Web-based video oversight 2. Severe enforcement penalties & disclosure
NCC-ROBD: Third-Party Testing-Specific	
11	Fraudulent third-party testing	1. Web-based video oversight 2. Standard test fee for all testers
Physical Test Location Testing-Specific	
12	Fraudulent truck stop / kiosk testing	1. Web-based video oversight 2. Covert auditing of facilities 3. Severe enforcement penalties & disclosure
Non-Test Related Fraud Risks and Prevention Techniques	
13	Out-of-state vehicle non-compliance	1. Public outreach program to CMV and RV owners 2. Possible out-of-state OBD testing capability
14	License plate compliance challenges	1. ALPR evaluations and pilot testing 2. Partnering with the California Border Protection Stations

Risk #	Risk Description	Mitigation Methods
15	Other non-compliant vehicle operation	1. Establishing on-road enforcement priorities and tracking program compliance

3.3.5 Other Program Options and Thoughts

As CARB has been doing, continuing to evaluate and dynamically develop the program to address challenges will bolster efforts for an effective HD OBD I/M program. Other methods may ultimately be utilized in this program to achieve program compliance, such as referee testing, mobile testing performed by CARB staff or a program contractor, or other approaches. Many of the concepts and solutions presented in this section could apply to those strategies as well.

CARB's program implementation plan does provide an opportunity to address issues associated with test criteria development, VID data collection, integration with the DMV to enforce registration denial, vehicle registration changes, and other issues. Other test-related issues, such as invalid eVINs that may be downloaded from a truck's ECM, could require program adjustments during this period to ensure positive driver / truck identifications are made. These could include requirements for the test system to allow the user/tester to user enter data (VIN or other identifiers) required for a positive registration match. These requirements could be necessary for a positive DMV truck / owner match for all test records. In addition, additional entry, such as entry by a bar-coded VIN, can allow comparison of e-VIN with bar-code or user-entered VIN for additional fraud detection. The need for this is best balanced by the need for a relatively automated test system with minimal user interaction.

3.4 Per-vehicle OBD submission Cost Analysis

Developing cost estimates for the OBD data reporting methods associated with a California OBD heavy-duty I/M program still under development involves significant uncertainties. Since there are no other full-scale HD OBD programs at present, the features and costs of such possible programs are not available for comparison purposes. The design of the California HD OBD program is also somewhat of a moving target, as CARB continues to develop regulations implementing a heavy-duty vehicle I/M program for non-gasoline heavy-duty on-road motor vehicles, as specified by California Senate Bill 210.[53]

Advancement of CARB's rulemaking process has partially addressed some of the current uncertainties about the scope of the HD I/M program. The RFI released for the HD I/M System program[54] also focuses on many of these issues. In some ways, this makes the development of cost estimates for the HD OBD test methods easier, since certain program features, e.g.,

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[53] SB-210 Heavy-Duty Vehicle Inspection and Maintenance Program (2019-2020), Chaptered 09/20/2019, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB210.

[54] "Request for Information for SB210 Heavy Duty Inspection & Maintenance (HD I/M)," Event Number 18002, California Air Resources Board, November 18, 2020.

inspection frequency, appear to be largely finalized,[55] at least with enough certainty to accept these as agreed upon assumptions for current costing purposes.

On the other hand, we are faced with developing cost estimates that parallel those requested from private vendors as part of the HD I/M System RFI process. This leads to a question of whether our cost estimates need to be based on all the assumptions, both explicit and implicit, incorporated into the RFI. And if our assumptions differ in some ways from those in the RFI, differences will arise between costing estimates in this report and those provided by vendors that respond to the RFI.

After discussing this issue among our team, and reaching out to CARB with some relevant questions, we decided that we would use the same or similar assumptions to those contained in the RFI where we believe those assumptions are reasonable and justified. In certain instances, we have decided to use somewhat different assumptions based on our professional judgment and experience. In such cases, we have provided justification for these different assumptions.

3.4.1 Key Assumptions

There are a number of assumptions that must be made in order to develop estimated costs for a program as large and complex as the new HD OBD program. Many of these are common to all of the test methods that will be part of the program, while others apply to certain individual test methods. Both types of assumptions are listed centrally in this section, to provide a single place where they can be easily reviewed and understood.

3.4.1.1 Common Issues

Assumptions and other issues common to all HD OBD test methods are listed below, along with supporting reasons for their selection.

1. **Program/Contract Duration**. There will be significant initial capital and other startup costs associated with the HD program, including those related to test equipment purchases, VID hardware and software, etc. Sufficient time would be needed to capitalize these costs over the duration of the program oversight contract in order to avoid excessive annual costs to program participants, i.e., HD vehicle owners. In addition, starting a new vehicle inspection program will undoubtedly involve some fine tuning in terms of program requirements and operations as CARB and its oversight contractor gain experience.

   For these reasons, we strongly recommend a longer duration contract period. **A period of 7 years is assumed for this costing analysis.**

2. **Interest Rate**. Estimated initial program implementation costs must be amortized over the assumed 7-year program/contract duration. Creating the applicable annual

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[55] We understand that no decisions are fully final until the CARB rulemaking process has been completed.

amortization schedule requires entry of a projected annual percentage rate (APR). An APR of 5% is assumed for this purpose.

3. **Program size**. There will be 900,000 non-gasoline vehicles subject to OBD inspection in the initial implementation year of 2023. This is based on a total estimate of 1.2 million vehicles in 2023, with 75% of these OBD equipped.[56] Fifty percent of these HD vehicles are assumed to be California registered, with the other 50% assumed to be registered out of state.[57]

It is difficult to project how much the subject OBD HD fleet might grow over the 7-year program and oversight contract duration we have assumed for costing purposes. Available EMFAC/California DMV registration data[58] shows a growth rate of slightly less than 1% in medium-heavy-duty trucks ranging from 14,001-33,000 lbs. GVWR for the period of 2015-2019. However, this is more than offset by a 1.2% decline in heavy-heavy-duty trucks over 33,000 lbs. GVWR during the same period. Motorhomes and buses both show a 2.5% growth rate during this period. The following table shows California statewide HD vehicle counts, including CARB's 2023 estimate of 600,000.

Table 3-5 California Registered Non-Gasoline HD Vehicles *

Year	HD Vehicles	Motorhomes	All Buses	Total
2015	430,390	32,711	48,999	512,100
2016	443,451	33,046	50,211	526,708
2017	453,862	34,776	54,091	542,729
2018	456,029	36,176	53,936	546,141
2019	429,638	36,034	53,920	519,592
2023				600,000 (est.)

*HD Vehicles are > 14,000 lbs. GVWR, and motor home and bus counts include all weight categories, since the EMFAC database does not show those below and above 14,000 lbs. GVWR.

Motorhomes – All of the motorhome counts in the above table are assumed to be greater than 14,000 lbs. GVWR, based on estimates available in U.S. EPA's MOVES 201X documentation. [59] The US EPA document indicates all 1981 and newer non-gasoline motorhomes are at or above this GVWR breakpoint in the MOVES weight class 160 and above. Roughly 50% of pre-1981 motorhomes are shown as being less than 14,000 lbs. GVWR, but given their age, we have assumed the fleet fraction of these vehicles is zero

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[56] "HD I/M RFI," California Air Resources Board, November 18, 2020, pages 4, 11.

[57] Ibid, page 12.

[58] "EMFAC Fleet Database," Mobile Source Analysis Branch, Air Quality Planning and Science Division, California Air Resources Board, https://arb.ca.gov/emfac/fleet-db.

[59] "Population and Activity of On-road Vehicles in MOVES201X," Assessment and Standards Division, Office of Transportation and Air Quality, Office of Air and Radiation, U.S. Environmental Protection Agency, August 2017, pages 181-182.

in the above EMFAC counts. All motorhomes are therefore assumed to be subject to the HD I/M program.

Buses – All of the bus counts in the above table were also assumed to be greater than 14,000 lbs. GVWR, again based on estimates available in US EPA's MOVES 201X documentation.[60] Using California school bus data from a 1994 report for CARB,[61] the US EPA documentation apportioned 97% of the non-gasoline bus counts to MOVES weight classes of 160 and above. All transit and "other" category buses were assigned to weight classes 400 and 500. One hundred percent of the above EMFAC bus counts were therefore assumed to be greater than 14,000 lbs. GVWR and subject to the HD I/M program.

Fleet Growth – During the assumed 7-year program/contract duration of 2023-2029, estimated HD OBD vehicle growth will occur due to a combination of two factors: increases in the overall HD fleet, and continued growth in the fraction of HD OBD vehicles as older non-OBD vehicles are retired and phased out of operation. Growth in the overall fleet during the next decade is difficult to predict at present due to continued COVID-related uncertainties. However, CARB's 2023 estimate of 600,00 California HD vehicles allows us to project HD fleet size during the assumed program period.

Using the total California non-gasoline HD vehicle counts contained in the above table, including CARB's 2023 estimate, yields results shown in Figure 3-25 below. The slope of the computed trendline equates to an annual HD vehicle growth rate of approximately 1.28%.

Figure 3-25 Projected California HD Vehicle Growth Rate

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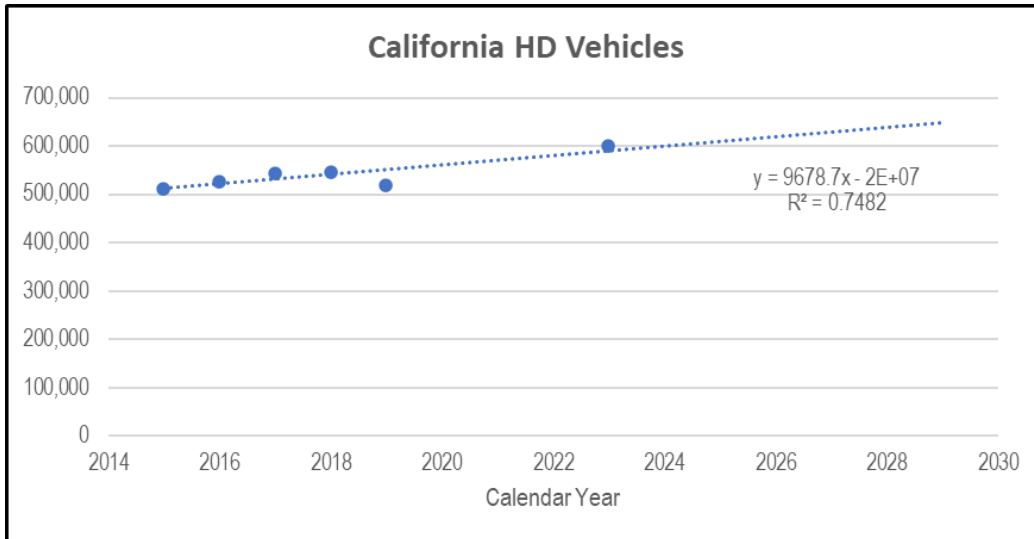
[60] "Population and Activity of On-road Vehicles in MOVES201X," U.S. EPA, August 2017, pages 179-180.

[61] Horie, Y., Tranby, C., and Sidawi, S., Valley Research Corporation, Tables 3-9 & 2-2, OnRoad Motor Vehicle Activity Data: Volume I – Bus Population and Activity Pattern, Final 210 Report, California Air Resources Board Contract A132-182, Northridge, CA: September 1994.

In addition to overall growth in the HD fleet, the other factor impacting OBD inspection counts during the program period is fleet turnover. Limited data are available for the retirement of older HD vehicles, often referred to as vehicle scrappage. The 1980 model year data in the Transportation Energy Data Book (TEDB38.2, Table 3.14), which are considered the most appropriate for use,[62,63] show an average scrappage of approximately 10 percent for the seven oldest model years, aged 24-30, listed in the table.

Additional relevant data are projected sales of new HD vehicles, as shown in TEDB38.2, Table 5.3.[64] The table shows an average annual increase of about 10% in sales of >14,000 lbs. GVWR HD vehicles during the period 2009-2019. Most of these sales are in the Class 8 vehicle category, which is over 33,000 lbs. GVWR.

The combination of older HD vehicle scrappage and new vehicle sales results in an overall fleet turnover rate of 2-8% depending on the specific HD vehicle category, as shown in the applicable figures from U.S. EPA's MOVES201X default database.[65]

Given the above information, **we assumed an overall annual HD OBD fleet growth rate of 6% during the 7-year program/contract period**. Applying this growth rate to the 2023 estimated fleet of 900,000 OBD HD vehicles, with the 450,000 registered in California and another 450,000 out-of-state vehicles assumed above, results in the counts shown in Table 3-6 below. The projected annual average OBD HD fleet size is approximately 1.07 million vehicles.

Table 3-6 Projected Number of HD Vehicles Subject to California OBD Testing

Year	Vehicles
2023	900,000
2024	954,000
2025	1,011,240
2026	1,071,914
2027	1,136,229
2028	1,204,403
2029	1,276,667

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[62] Davis, S. and Boundy, R., "Transportation Energy Data Book (TEDB) Edition 38.2," Oak Ridge National Laboratory (ORNL), Energy and Transportation Science Division, Oak Ridge, TN, August 2020, https://tedb.ornl.gov/, Table 3.14, page 3-19.

[63] An earlier edition of this same source was used by U.S. EPA in establishing HD vehicle scrappage and survivability rates in its MOVES201X default database. See "Population and Activity of On-road Vehicles in MOVES201X," U.S. EPA, August 2017, pages 155-156.

[64] TEDB Edition 38.2, Table 5.3, page 5-5.

[65] "Population and Activity of On-road Vehicles in MOVES201X," U.S. EPA, August 2017, page 39.

4. **Inspection Frequency**. **We assumed that the specified OBD data will be submitted on a quarterly frequency basis**.

5. **HD OBD failure rate**. Given the lack of existing HD OBD programs, predicting vehicle failure rates in the new California program is difficult. A review of reported LD OBD failure rates by several states[66,67,68,69,70,71,72,73,74,75,76,77,78] was performed to assist in the estimation of projected California HD failure rates, along with consideration of projected

[66] "Performance Audit, Department of Environmental Quality—Vehicle Emissions Inspection Program," A Report to the Arizona Legislature, Performance Audit Division, Office of the Auditor General, Report No. 07-12, December 2007.

[67] "Emissions-Related Results From Gasoline-Fueled Motor Vehicles, New Jersey Enhanced Inspection and Maintenance (I/M) Program," 2004-2010 Annual Reports, State of New Jersey, Department of Environmental Protection, https://www.nj.gov/dep/bmvim/bmvim_reports.htm.

[68] "Evaluation of Test Data Collected in 2004 and 2005 from Connecticut's Inspection/Maintenance Program," Connecticut Department of Environmental Protection, prepared by dKC – de la Torre Klausmeier Consulting, October 2006, https://portal.ct.gov/-/media/DEEP/air/mobile/Emissions-Testing/biennialimreport20042005completepdf.pdf.

[69] "2006 and 2007 I/M Program Evaluation," Connecticut Department of Environmental Protection, prepared by dKC – de la Torre Klausmeier Consulting, June 2008, https://portal.ct.gov/-/media/DEEP/air/mobile/Emissions-Testing/biennialimreport20062007completepdf.pdf.

[70] "Biennial Evaluation of Connecticut's Inspection/Maintenance Program 2008-2009 and Annual Data of Connecticut's Inspection/Maintenance Program 2009", Connecticut Department of Environmental Protection, prepared by dKC – de la Torre Klausmeier Consulting, June 2010, https://portal.ct.gov/-/media/DEEP/air/mobile/Emissions-Testing/biennialimreport20082009completepdf.pdf.

[71] "Annual Evaluation of Connecticut's Motor Vehicle Inspection and Maintenance Program, 2010", Connecticut Department of Environmental Protection, prepared by dKC – de la Torre Klausmeier Consulting, June 2011, https://portal.ct.gov/-/media/DEEP/air/mobile/Emissions-Testing/annualimreport2010completepdf.pdf.

[72] "Evaluation of the Texas Inspection and Maintenance Program in the Dallas/Fort Worth and Houston-Galveston Brazoria Nonattainment Areas, 2006", Texas Commission on Environmental Quality, prepared by Eastern Research Group, Inc., November 30, 2006, https://www.tceq.texas.gov/assets/public/implementation/air/ms/IM/2006ProgramEval.pdf.

[73] "2009 Annual Report, Ohio Vehicle Inspection and Maintenance Program," Ohio Environmental Protection Agency, https://www.epa.ohio.gov/Portals/27/echeck/docs/2009%20REPORT.pdf.

[74] "2010 Annual Report, Ohio Vehicle Inspection and Maintenance Program," Ohio Environmental Protection Agency, https://www.epa.state.oh.us/Portals/27/echeck/docs/2010AnnualReport_final_draft.pdf.

[75] "Massachusetts Vehicle Check Inspection and Maintenance Program," 2009-2019 Annual Reports, Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Department of Environmental Protection, https://www.mavehiclecheck.com/motorists-resources.

[76] Wisconsin Vehicle Inspection Program Annual Report 2010," Wisconsin Department of Transportation, http://www.wisconsinvip.org/wivippublic/PDF/Downloads/2010USEPAREPORTFINAL.pdf.

[77] Gateway Vehicle Inspection Program, 2006 and 2008-2016 Annual Reports, Missouri Department of Natural Resources, Division of Environmental Quality, Air Pollution Control Program, https://dnr.mo.gov/pubs/.

[78] 2010-2019 Activity Reports, Motor Vehicle Inspection and Maintenance Program, Nevada Department of Motor Vehicles, Compliance Enforcement Division, https://dmvnv.com/emission.htm.

EMFAC HD OBD deterioration rates under development by CARB, as described later in this section.

OBD was phased in beginning with model year 1994 for LD vehicles, versus beginning with model year 2013 for HD vehicles. To best evaluate likely HD OBD failure rates during the calendar period of 2023-2029, which is 10 years after the introduction of HD OBD, our review focused on reported LD failure rates for calendar years 2004-2010, which is also 10 years after the introduction of LD OBD. More recent California-specific data[79] were also reviewed since older calendar year results were not readily available.

For the calendar year 2004-2010 period, reported LD OBD failure rates vary considerably by state, calendar year (CY), vehicle type, and vehicle model year (MY). Failure rates for some vehicle types and model years ranged as high as 40%, with overall fleetwide failure rates typically in the 7-11% range. Early LD OBD vehicle, e.g., MY1996 failure rates were in the 15-25% range.

Failure rates generally trended lower with newer model years, although some states reported anomalously high failure rates, some as high as 35% for the newest MY being inspected during a CY. While some of this anomaly was likely due to the relatively small sample size of reported results, it also points to possible issues with the OBD systems in newly manufactured vehicles.

A 2000 US EPA report,[80] based on the analysis of OBD data collected in the Wisconsin LD I/M program between August 1998 through December 1999, was also obtained and reviewed. This study is noteworthy due to its analysis of how reported OBD failure rates varied with mileage accumulation. A chart from the 2000 report, shown below in Figure 3-26, demonstrates the strong correlation above 40,000 miles between increasing mileage and higher OBD failure rates.

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[79] Smog Check Executive Summary Reports, California Bureau of Automotive Repair, https://www.bar.ca.gov/Documents/Smog_Check_Executive_Summary_Reports.aspx.

[80] Trimble, T., "Analyses of the OBDII Data Collected From the Wisconsin I/M Lanes," EPA420-R-00-014, Transportation and Regional Programs Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, August 2000.

Figure 3-26 MY1996 Vehicles with MIL On, Wisconsin Vehicle Inspection Program, August 1998 – December 1999
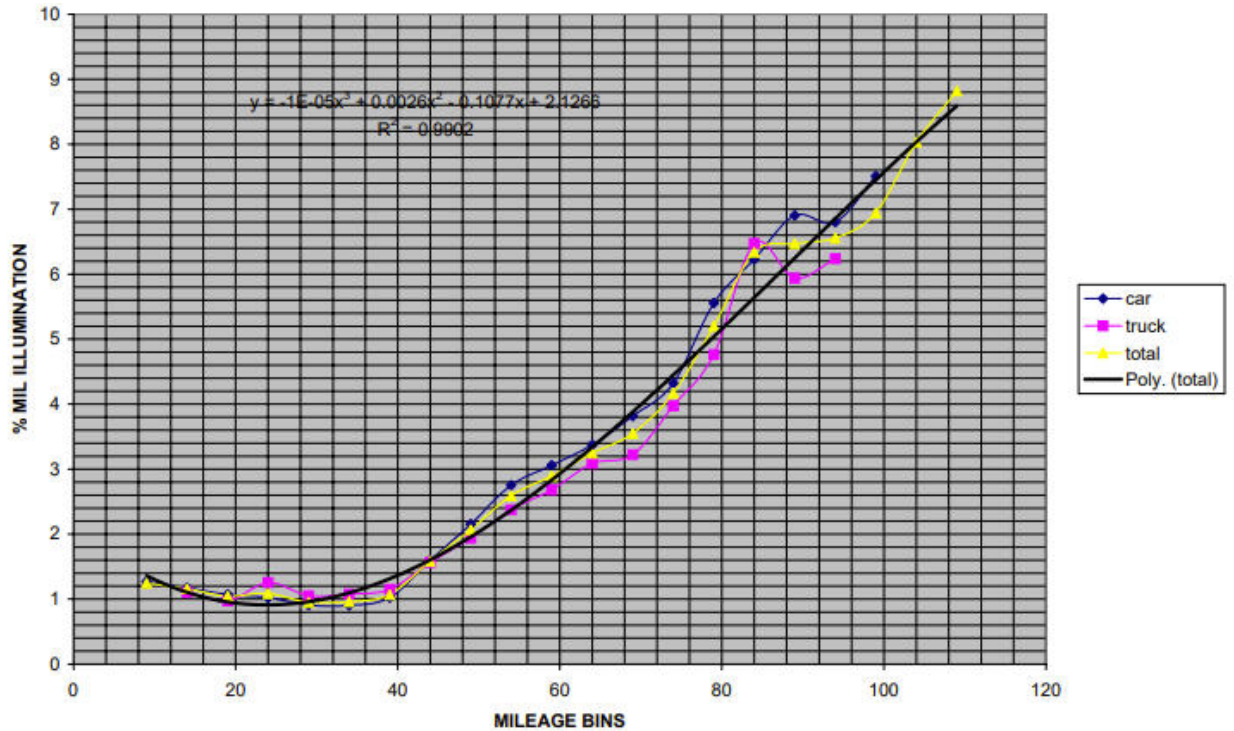
Given that MY1996 vehicles were only 2-3 years old at the time these vehicles were inspected, overall failure rates are still relatively low. However, it is clear that increasing mileage results in a substantial increase in OBD failure rate. This is an important factor to consider in selecting an assumed average failure rate for the HD OBD program, since the non-gasoline heavy duty trucks in the program will accumulate much greater mileages on average, both annually and over their lifetime.

In particular, average vehicle travel by regulatory Class 7-8 combination trucks, those with >26,000 lbs. GVWR designed to be used in combination with one or more trailers, far surpasses the travel of LD vehicles and other trucks. Due to their use for long-haul freight movement, average annual travel for all but the oldest of these trucks is in the 60,000-70,000-mile range, with even 25+ year-old long-haul trucks accumulating more than 35,000 miles per year. [81]

Average lifetime travel for a long-haul truck is in excess of 1.5 million miles, and typically involves the following lifecycle:[82]

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[81] TEDB Edition 38.2, Table 5.2, page 5-4.

[82] Lau, W., "Life Cycle and TCO Analysis of Class-8 Trucks in North America, 2018–2032," Frost & Sullivan Research Service, August 23, 2019, https://store.frost.com/life-cycle-and-tco-analysis-of-class-8-trucks-in-north-america-2018-2032.html.

- Owner #1 – Typically a fleet that drives an average of 480,000 miles;

- Owner #2 – Typically an owner-operator or small-sized fleet that drives an average of 640,000 miles; and

- Owner #3 – Typically an owner-operator that drives 400,000 miles;

Based on the average annual mileages shown in TEDB38.2, Table 5.2, when the HD OBD program begins in 2023, a MY2013 OBD-equipped long-haul truck will have accumulated over 720,000 miles of travel, on average. This will grow to over 1.1 million miles of average accumulated travel for these vehicles by the end of the 7-year program/contract period.

There are two primary factors that we believe will result in increased failure rates among the vehicles subject to the HD OBD program relative to those reported by LD OBD vehicle inspection programs. These are:

1. The unique, first-of-its-kind nature of the program and the resulting unknowns associated with non-gasoline, heavy duty vehicle OBD systems, including the complexity of these emission-control systems.

2. The much higher accumulated travel levels and resulting increased wear/duty levels for the majority of vehicles subject to the program.

We also reviewed deterioration and associated MIL illumination rates to be used in EMFAC2020x for 2013 and newer non-gasoline HDVs. The modeled MIL-on frequency is given by the following equation[83]:

$$\text{MIL On Frequency} = 0.0016 * (\text{Odometer})^{0.37}$$

Where "Odometer" is the truck's accumulated mileage in 100,000-mile bins.

This equation is based on results from CARB's prior Heavy-Duty Truck Deterioration Study[84], and yields the mileage-based projected MIL illumination rates shown in Table 3-7 below.

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[83] EMFAC202x Updates, Mobile Source Analysis Branch, Air Quality Planning and Science Division, California Air Resources Board, July 30, 2020 presentation, page 203, available at https://ww2.arb.ca.gov/sites/default/files/2020-07/EMFAC202x_2nd_Workshop_07302020_ADA.pdf)

[84] Updates to Heavy-Duty Emission Deterioration in EMFAC, Version 3, submitted to the California Air Resources Board July 21, 2020, Agreement No. 17AQP006.

Table 3-7 Mileage-Based MIL Illumination Rates

for MY2013+ Non-Gasoline HDVs

Odometer	MIL Rate
100,000	11.3 %
200,000	14.6 %
300,000	17.0 %
400,000	18.9 %
500,000	20.5 %
600,000	22.0 %
700,000	23.3 %
800,000	24.4 %
900,000	25.5 %
1,000,000	26.6 %

Based on the aforementioned data and considerations, we assumed a 20% average initial failure rate. We also assumed that 25% of initial failures involved repeated retests prior to repair and passing certification, **for an overall per vehicle average retest rate of 25%**. This assumed retest failure rate is based on two factors:

1. This reflects the levels of repeated failures (both on the first and subsequent retests) seen in LD I/M OBD programs when they were first implemented. For example, the New Jersey program reported a first retest OBD failure rate of 20% for calendar year 2004 plus additional subsequent retest failures that add to the total retest failure rate.[85] Other programs have reported similar results.

   Having difficulty in repairing OBD failures, where the mechanic has access to failure code information and other data to help identify the required repair, may seem dubious. However, this is the real-world experience that has been found in the LD I/M programs. We expect the same in the HD I/M program.

2. Data on the effectiveness of repairs made to HD vehicles with OBD failures is extremely limited. In fact, there are relatively few repair effectiveness studies on any type of HD emissions test failures, e.g., on smoke opacity tests.

   One recent study[86] looked at 45 vehicles equipped with selective catalytic reduction (SCR) with either the check-engine-light-on or malfunction-indicator-light (MIL)-on, or both, and in certain repair categories. Emissions were measured

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[85] "Emissions-Related Results From Gasoline-Fueled Motor Vehicles, New Jersey Enhanced Inspection and Maintenance (I/M) Program," 2004 Annual Report, State of New Jersey, Department of Environmental Protection, https://www.nj.gov/dep/bmvim/nj2004_annual_report.pdf, page 31.

[86] Jiang, Y., Yang, J., Tan, Y., Yoon, S., Chang, H., Collins, J., Maldonado, H., Carlock, M., Clark, N., McKain, D., Cocker, D., Karavalakis, G., Johnson, K., Durbin, T., "Evaluation of emissions benefits of OBD-based repairs for potential application in a heavy-duty vehicle Inspection and Maintenance program," *Atmospheric Environment*, 247, 118186, February 2021.

before and after the repairs in this study, and it was concluded that an OBD-based HDV I/M program would provide significant emission benefits.

While not disputing these results, we note that the full range of required HD OBD repairs, particularly on extremely high mileage, older vehicles, will span considerably more failure conditions than those evaluated in HD OBD repair effectiveness studies performed to-date. In the absence of more substantial data specific to HDVs, we conclude that LD OBD retest failure rates are a reasonable predictor of what will be seen in the HD I/M program.

Based on the above assumptions, average annual HD OBD inspections during the assumed program/contract period are 1,071,914 vehicles x 4 tests/year x 1.25 tests/vehicle which is approximately 5.36 million tests per year.

Regarding retesting of failed vehicles, some LD I/M programs provide one free retest for these vehicles. In our cost analysis, we have assumed that all tests, initial and retests, will be paid tests—except for free tests that might be available at kiosk / truck stop facilities. While non-free kiosk / truck stop tests could be offered instead, we assumed that these would be free to be consistent with the HD I/M RFI. A discussion of this issue is included under our #8 assumption below.

6. **Referee inspections**. Per the HD I/M RFI[87], **we assumed that 20,000 referee inspections will be performed per year**. In the LD I/M industry, referee inspections are typically included as a task element under the oversight contractor's scope of work. The cost of these inspections is built into the contractor's overall pricing. Total contractor costs (including for referee inspections), referred to in this report as "common costs," have been applied across the entire fleet subject to HD OBD testing as part of developing estimated per-vehicle costs for each individual test method.

The 20,000 referee inspections assumption is the upper limit stated in the RFI. Dividing this by the estimated annual average subject fleet size of 1.07 million results means it is estimated that approximately 1.9% of vehicles subject to the program will get a referee inspection each year. This is significantly higher than current referee rates in LD I/M programs. However, we think this assumption is reasonable due to the following factors:

- HD OBD vehicles will get four tests per year versus LD OBD vehicles getting one per year or (in many programs) one every other year. This much higher frequency of testing for the HDVs will translate into more referee tests.

- LD referee test rates were significantly higher in the early years after OBD testing was first implemented. We expect the same with HDVs—there will be more referee inspections performed in a brand-new vehicle inspection program.

  This may be particularly true since HDV owners have never been subject to periodic vehicle inspection requirements, whereas vehicle owners in LD OBD

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[87] "HD I/M RFI," CARB, November 18, 2020, page 24.

I/M programs were already used to other periodic (non-OBD-type) I/M inspections.

We also agree with the RFI statement that these can be performed via mobile inspections, not requiring the establishment of a brick-and-mortar station-based network. We recommend that CARB consider a referee model where mobile inspections would be performed at existing highway truck stops, e.g., Pilot, Flying J, other CMV outlets. These facilities are already built, located on the primary routes where CMVs and RVs operate, and are very familiar to CMV and RV owners.

The program oversight contractor could either work with some of these facilities to certify selected facility personnel as referee testers for CMV facilities that offer mechanical services, or have a separate, truly mobile workforce of contractor-employed or certified testers that would perform referee inspections in rented facility work bays.

7. **Additional Oversight Contractor Responsibilities**. Based on CARB guidance[88] plus the contents of the RFI, the responsibilities listed in the following table are also assumed for the program oversight contractor. Costs for each of these have been estimated as part of this analysis.

For completeness, CARB program responsibilities are also listed in Table 3-8 below. The cost of these is not included in this analysis. Other excluded program costs are also listed in the table.

Table 3-8 HD OBD Program Oversight Responsibilities

No.	Program Element
	Contractor Responsibilities
1	Develop/maintain/host central database (VID) and communications network
2	Develop/support VID business intelligence and reporting suite/portal, including fraud detection software
3	Establish/host portals/interfaces (for CARB administrators, truck owners, referee testers, OBD device registration, and third-party testers)
4	Establish/maintain interfaces and communications with other applicable systems
5	Develop/support software for administering the program, including network settings, test system lockouts, user maintenance, etc.
6	Develop/support software for auditing of referee, truck stop, kiosk, third-party testers, and possibly fleet self-testing
7	Establishment of a network of physical testing locations (such as truck stops or kiosks)
8	Procure and maintain test devices for physical test locations (both kiosks and tablet/dongle setups at truck stops)
9	Establish/run mobile referee network

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[88] Private correspondence with CARB staff, "HD OBD program - responsibilities & cost cateogries - 10-9-2020-jhf", October 9, 2020. (Note: "Categories" is misspelled in this filename.)

No.	Program Element
10	Procure and maintain test devices for referee network
11	Establish/run call center operations, which will handle interactions with program stakeholders
12	Send electronic test notifications to vehicle owners of when tests are due. (CARB staff can also input required vehicle tests (e.g., referee test, high emitter follow-up test etc.).
13	Make compliance determinations (based on CARB guidance), issue compliance certificates
14	Send compliance records to California DMV
CARB Responsibilities	
1	OBD device verification testing and certification
2	Contract oversight of program contractor activities, including acceptance testing of VID/network
3	Auditing of referee, truck stops, kiosks, third-party testers, and possibly fleet self-testing
4	Program oversight/enforcement: - Administrative oversight activities - Review of triggers and other fraud/enforcement-related analysis of reported OBD data - Roadside testing, monitoring and high emitter detection. Includes costs of RSD, ALPR, PEAQs and OBD test devices - Review of repair - Field enforcement and related activities (observations, audits, legal cases, etc.) against problem testing sites - Enforcement against non-complying vehicles - issuance of citations, etc. (in cooperation with CHP)
Other Excluded Costs	
1	Develop/support test hardware and software for tablet and kiosk options. These costs would be passed along to the oversight contractor, fleet test facilities and third-party testers as part of their equipment procurement costs.

8. **Compliance Fee**. The cost of the compliance fee is assumed to cover all oversight contractor and CARB costs. Since the latter are not part of this analysis, we cannot calculate an estimated full compliance fee.

Certain underlying assumptions are listed below to ensure these are understood.

– Contractor costs include **an assumed profit margin of 20%**. This profit level reflects the uncertainties inherent in a brand-new vehicle inspection program.

– Per the HD I/M RFI,[89] **tests at physical test locations such as truck stops and kiosks may involve no out-of-pocket costs** to vehicle owners who choose this test method. For the purposes of this analysis, we will assume that it is indeed a no-cost

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[89] "HD I/M RFI," California Air Resources Board, November 18, 2020, page 24.

option, since applying the true cost of implementing and operating this type of HD OBD data collection is estimated to exceed the $30 compliance fee limit specified by California Senate Bill 210. This is discussed in more detail in Section 3.4.2.6, Physical Test Location Testing Costs. Given the SB 210 verbiage, we assumed free testing at these locations to ensure that at least one testing method would meet the specified limit.

9. **Test Method Fleet Penetration Rates**. The study plan for this work task indicated that we would calculate a per-vehicle cost estimate for the HD OBD program. In considering this, it makes the most sense to provide per-vehicle cost estimates for each of the non-free test methods, i.e., fleet self-testing, telematics data reporting, and third-party testing. In order to do this, we must first assume which fraction of the subject fleet will be tested via each method. This will allow us to then assign the appropriate percentage of common costs to each test method, and to calculate the number of inspections over which total costs (common plus test method-specific) will be divided to produce the resulting per-vehicle estimates. Our assumed test method fleet penetration rates are as follows:

   – **Fleet self-testing = 58%**,

   – **Telematics data reporting = 20%**,

   – **Third-party testing = 15%, and**

   – **Physical Test Location (Truck Stop /Kiosk self-testing) = 7%**

As described in Section 3.2, Fleet and Industry Surveys, we performed two separate surveys of California fleets, resulting in a total of 37 responses. Results showed that 43% of the fleets reported they are utilizing some form of telematics service. Regarding HD I/M, 27% - 37% said they would be interested in a telematics solution, 20% to 23% reported they would elect kiosk self-testing, and 43% - 53% preferred onsite testing (including self-testing and third-party testing). The ranges represent differences in responses between an annual program and a quarterly program. Our assumed fleet penetration rates largely follow the survey results, with a couple of notable differences:

- We have assumed a telematics adoption rate slightly lower than the survey results for current or future projected telematics use appear to indicate. However, as noted in this section and in Section 3.4.2.3, Telematics Data Reporting Costs, we believe there are strong reasons supporting a lower penetration rate for this test method. This includes the high cost of telematics data reporting compared to the cost of other reporting alternatives, and the potential perception of "government tracking" of vehicle operations associated with the telematics solution (this perception could persist even with a quarterly, rather than a continuous, reporting program). Two particular issues of significance are being able to use a fleet self-testing device to test many vehicles versus having to buy or lease individual dedicated telematics devices for each vehicle, and also the estimated subscription cost of telematics. The impact of these issues on relative costs between the two test methods could increase the percentage of fleets opting for self-testing instead of telematics.

- We also note that the fraction of HD vehicles that could be back-to-back tested at the assumed number of 20 truck stop / kiosk testing locations is well below the percentage of fleets that reported interest in this test option. Even if continuous testing were assumed for 16 hours per day and 365 days per year at each of these facilities, along with an assumed average test time of 15 minutes, total HD OBD inspections at the 20 locations would be less than 500,000 per year, or about 8.7% of total assumed annual inspections, only roughly one-third of the 20% to 23% of survey respondents who indicated interest in using kiosks for self-testing. For purposes of our cost analysis, we retained the 20 truck stop / kiosk testing location assumption, although other options, including device rentals and concurrent testing with multiple devices, are possible and are being considered by CARB to alleviate any potential testing option bottlenecks and to meet test demand. As we understand CARB is doing, proactively developing approaches to address issues such as this prior to program rollout will prevent program implementation problems.

   A total of 62% of the fleets that responded to our surveys indicated they were interested in some type of self-testing, either onsite or via kiosk, so this is the basis for our assumed combined self-testing rate of 65%, with 58% onsite and 7% kiosks. We increased the combined rate up slightly to account for our reduced telematics test rate.

10. **Other Issues**. Additional HD OBD program assumptions that reflect issues previously identified in the study plan are listed below.

   – **Proof of Program Compliance**. No proof of compliance will be required to be displayed on subject HD vehicles. Enforcement will be registration-based for California-registered vehicles. Per the HD I/M RFI,[90] all vehicles subject to the program and operating in California will be required to carry an applicable compliance certificate to legally operate in the state. Additional details regarding on-road enforcement were previously provided in Section 3.3.3.5, Non-Test Related Fraud Risks and Prevention Techniques.

   – **In-State versus Out-of-State Support**. Many existing LD I/M program oversight and VID contracts in other states are run from out-of-state. Given the virtual nature of the majority of program and VID operations, these states and their contractors have found that it is most efficient to run these contracts from where the contractor's management, VID operations, and programming staffs are headquartered. Doing so ensures the contractor's best qualified staff are available to support the program, rather than trying to rely on possibly lesser experienced staff who have been posted to an in-state satellite office. There are, however, a couple of qualifications to this approach:

      ▪ All operations, including system and software programming as well as call center and mail room operations, should be required to be located within the United

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[90] Ibid, page 12.

States. Other programs have experienced difficulties after hiring contractors who utilized offshore resources for some of these operations.

- ▪ Certain HD OBD program operations will obviously require in-state support. This includes establishment and support of the physical test location testing and referee testing networks and equipment. An in-state program operations manager and office will aid in overseeing these program elements and in effectively communicating with CARB program oversight staff on a regularly scheduled basis.

- – **Recommended System Performance and Security Measures**. System security measures were previously discussed in Section 3.3.3, Preventing Fraud in California's OBD-Based Heavy Duty I/M Program. Regarding system performance measures, other LD I/M and VID programs have taken a variety of approaches to this issue. Some states have explicitly included a number of required service level agreements (SLAs) and hefty monetary performance bonds in their vendor contracts. Others have used a less rigorous approach, instead choosing to follow more of a partnering approach with their contractor.

Regardless of the contractual approaches chosen by individual states to help deliver good system performance, the primary lesson in the I/M industry is the need to hire a qualified contractor with a proven performance record. This is the single best thing that can be done to ensure that the system and program achieve success. Other states have done this by researching vendors' past histories, requiring the submittal of relatively detailed project references and rating forms completed by the vendors' previous customers, and other similar means.

Some other states have also used proposal scoring systems that are weighted to value past performance, rather than weighting technical proposals heavily, with lighter weightings given to past performance and cost. While we understand the need to ensure a vendor's technical proposal is adequate and will deliver the expected performance, in our experience, based on both preparing and reviewing numerous I/M program and system proposals, it is often difficult to distinguish significant differences between competing technical proposals. Most vendors' technical offerings sound good on paper; the key is whether they will actually deliver everything that is promised.

For this reason, we believe higher weightings for past performance, focused particularly on the timeliness, quality, flexibility and partnering relationship delivered in past projects by each vendor, are justified. The need for the first two of these is obvious; the flexibility and partnering maybe less so. But this has been a lesson learned by a number of states, a critical element of a successful I/M program is the hiring of a contractor that is easy to work with and that can adapt quickly to changes in project requirements.

This is particularly true for a new initiative like the HD OBD program. Neither CARB nor the selected contractor will know going into the project exactly how the

program will look like by the end of the contract or what needed changes will be necessary. A contractor that is willing, capable, and eager to work with CARB to make any needed modifications as they are identified will increase program quality, effectiveness, and industry acceptance. Requiring examples of this type of collaboration in the vendor's past performance with corresponding references and appropriate scoring weight rating could be helpful when evaluating the proposals.

A final point on the incorporation of numerous SLAs and higher performance bonds is that these will directly impact the cost of the contract. This does not mean some should not be included in the contract, but an excessive amount will result in higher bid prices. A middle ground approach would be to only include the SLAs that CARB thinks are absolutely necessary, coupled with a requirement that vendors' proposals include any additional SLAs they think would be appropriate.

3.4.1.2   Test Method-Specific Issues

As described in detail in Section 3.3, possible test methods assumed for the new HD OBD program consist of the following: Fleet self-testing, telematics data reporting, physical test location testing (such as at truck stops and kiosks), and third-party testers. Key assumptions about each of these are listed below, along with supporting reasons for their selection.

1. **Fleet self-testing**. Under this test method, any labor costs are assumed to be borne by the individual fleets and are not included in this analysis. Estimated costs for these tests reflect amortized capital and operating costs for the needed test equipment.

   A key fleet self-testing assumption involves how many vehicles can be tested with a single NCC-ROBD device, as defined in CARB's draft HD I/M regulatory concepts document.[91] According to this document, with limited exceptions, most vehicles subject to the HD OBD program will be required to submit a passing OBD test on a quarterly basis during each compliance year.

   CARB's draft regulations allow this passing test to be submitted within 45 days prior to a vehicle's quarterly deadline to meet the periodic testing requirements. This means that even if a fleet has a large number of vehicles that have the same quarterly deadline, a single NCC-ROBD device can be used to test all of them over the 45-day pre-deadline period. Theoretically, if all vehicles were lined up waiting for testing, a single tool could be used to test as many as 2,160 vehicles in each 45-day period, based on a 12-hour workday, assuming the use of multiple technicians to perform the tests with 4 tests/hour and each taking 15 minutes on average over 45 days. Although this 15 minutes is longer than the actual OBD download duration demonstrated during this program, other factors, such as identifying and moving to the truck, acquiring the truck's keys, performing any requisite data entry, redocking the dongle and uploading post-test data (if necessary) and other factors led us to a 15-minute assumption.

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[91] "Draft Heavy-Duty Vehicle Inspection and Maintenance (HD I/M) Regulatory Concepts – December 2020," California Air Resources Board, December 17, 2020.

Since testing for most vehicles is quarterly, this means this single test tool would be used to test the same 2,160 vehicles over four 45-day periods, or for 6 months out of each year. Assuming staggered vehicle registration expiration dates, this means one NCC-ROBD tool could be used to test as many as 3,500 vehicles per year, at the assumed average retest rate of 25%.

In reality, however, the logistics of getting trucks into the fleet facility and scheduling them for their quarterly inspections prior to their vehicle expiration dates will significantly reduce the number of vehicles per NCC-ROBD. In addition, many individual CMV fleets are much smaller, which will further reduce the program-wide average number of annual tests per NCC-ROBD.

Because we have not been able to obtain data on California HD fleet sizes, we decided to perform a bounding analysis for determining the projected cost of fleet self-testing. At the upper end of the cost range, it is assumed that an NCC-ROBD tool will be purchased and used by the owner of a single HD truck. At the lower end of this range, it is assumed that a single NCC-ROBD tool will be used to test 1,800 vehicles per year. This is based on an assumed inspection efficiency rate of approximately 50% of the maximum test capacity of 3,500 vehicles.

2. **Telematics data reporting**. Some technical and logistical issues could increase the cost of collecting raw OBD data in the HD inspection program as envisioned by CARB. The issues that may increase costs include the following:

   – The new and unknown nature among both existing and possible new telematics providers of the HD OBD program and its requirements, as well as the HD OBD data stream itself.

   – Since this program will be limited to trucks that operate in California, a limited market (relative to a typical CMV nationwide market) for HD OBD I/M telematics data collection devices exists. The California fleet, even when out-of-state vehicles operating in California are included, is significantly smaller than the nationwide fleet, and some vendors may be less likely to invest significant upfront resources in a single state's I/M market.

   – Despite repeated approaches over the last 10-15 years by both states with large LD I/M programs and multiple I/M contractors, telematics companies have declined to participate in remote OBD LD endeavors. While the vendors have not revealed their full reasons for doing so, it is reasonable to infer that LD remote OBD is not seen as a sufficient revenue stream to justify the required development resources to bring appropriate devices to market. For whatever reason, this lack of involvement could also translate to the upcoming HD OBD program for some of the telematics vendors.

   – Although a California-style HD OBD program might be subsequently implemented by other states, similar to how other states have adopted other California-first vehicle emissions control programs, this would not likely occur until there are several years of clear demonstration of a successful California program. Additionally, another

factor that will significantly affect possible program adoption by other states is whether the U.S. EPA provides guidance and/or state implementation plan (SIP) modeling emissions credits for HD OBD programs. Until this occurs, widespread HD OBD program adoption appears unlikely. In the meantime, the market for HD OBD telematics devices would remain limited to California.

– At least some segments of the CMV industry may be suspicious and distrustful of government initiatives that could appear to involve tracking of vehicle operations, even with only the periodic CC-ROBD data collection envisioned for the program (once every 7 days or at the first engine key ON past the 7th day, as separate stored data logs[92]) and reporting (four times per year, passing test within 45 days of submission deadline[93]). This suspicion could reduce CC-ROBD program adoption.

– As more telematics vendors enter the California HD I/M market, the competition will serve to reduce costs to users. However, until that happens, fewer telematics vendors could mean less market competition and therefore higher costs to users.

3. **Physical Test Location testing**. This analysis **assumes a network of 20 testing locations (truck stops and kiosks)**, as mentioned in the HD I/M RFI[94] and other CARB HD OBD program development documentation.

4. **Third Party testing**. Similar to fleet self-testing, estimated costs for this test method reflect amortized capital and operating costs for the needed test equipment. In addition, labor costs also need to be included for third-party testing.

According to the job site Indeed, the current average wage for a diesel mechanic in California is $26.80 per hour,[95] not including any associated employee benefits or overhead costs. Assuming annual wage inflation of 2% per year, the average wage for the 2023-2029 program/contract period would be $29.61 per hour. Applying employee benefit and overhead cost percentages of 25% and 10%,[96] respectively, results in a projected fully loaded labor rate of $40 per hour for the program/contract period.

HD OBD tests could be performed very quickly, assuming a fleet has multiple vehicles that need to be inspected in one visit by the third-party tester. A reasonable assumption would be an HD OBD inspection rate of 4 vehicles per hour, using the same 15 minutes/test average time as assumed for fleet self-testing, equivalent to $10 per inspection based on the above loaded labor rate of $40/hr.

However, the above rate assumes fulltime employment, which would not occur due to travel time to reach fleet facilities. As a rough estimate, therefore, we believe an HD

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[92] https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdim/meetings/20210329_draft_proposed_hdim_reg_text.pdf
[93] https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdim/meetings/202100329_hdim_workgroup_presentation.pdf

[94] "HD I/M RFI," California Air Resources Board, November 18, 2020, page 24.

[95] "How much does a Diesel Mechanic make in California?", Indeed.com, https://www.indeed.com/career/diesel-mechanic/salaries/CA, December 24, 2020.

[96] This rate, much lower than typical for a repair shop, reflects the lower overhead for a mobile mechanic.

OBD labor rate of $15-20 per third-party inspection is a reasonable estimate for larger fleets where the significant number of paid tests will offset the unbilled travel time for the tester to reach the fleet facility.

Particularly for smaller fleets, and maybe even for the larger fleets, an alternative pricing model might instead be followed. This would involve a minimum trip fee, e.g., $125 for one hour, with additional hours billed at the same or a lower rate. Using the same inspection rate of 4 vehicles per hour, and an overall average hourly rate of $120/hr, this pricing approach would be equivalent to a per vehicle test fee of $30 per third-party inspection.

Note that both of the above pricing models are for labor-only; test equipment-related costs would be in addition to this.

As a reasonableness check, the above estimate can be compared to current California Smog Check fees for light duty vehicles. These typically range from $25 to $70,[97,98] not including the certificate fee. This cost varies by location, vehicle type, and the type of required smog inspection, with OBD inspections at the lower end of the price range. Projecting LD Smog Check fees using the same inflation factor of 2% per year produces an estimated average low-end -in-shop inspection fee of approximately $28 for the 2023-2029 period. Note that this loaded fee also includes equipment-related costs.

The HD OBD labor-only rate of $15-20 per third-party inspection presented above may seem reasonable compared to this inflation-adjusted LD Smog Check rate. However, we believe that third-party mobile HD OBD testing is likely to be more expensive than existing LD smog checks due to the mobile testers travel costs and lost work time due to such travel. We therefore think the alternative $30 per inspection rate is a more reasonable estimate of likely third-party test fees.

As another check, twenty respondents to fleet surveys conducted for this pilot program provided information regarding per-vehicle test fees they are currently paying for opacity tests. Although these responses include both in-house estimates, which include internal labor cost, and use of outside testing services, they do provide additional data for reference. Table 3-9 below shows the reported test cost ranges provided by the respondents. It is likely the SAE J1667 test requires more time than an OBD scan, including the time to successfully install the equipment, perform the visual inspection and perform the full SAE J1667 snap-acceleration smoke test. We estimate the time for these activities to be approximately 15 minutes (longer than the under 5 minute OBD test). Adding in additional time to warm-up the vehicle prior to the opacity test, plus the other factors listed in Section 3.4.1.2 which affect the total test duration (locating vehicle, acquiring keys, etc.), the total test time could exceed the 15 minute time estimate previously provided for the complete OBD test.

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[97] Hi Tech Smog, Fairfield, California, https://smogcheckfairfield.com/, December 30, 2020.

[98] "Not Just Any Inspection: How Much Will a STAR Smog Check Cost Me," NADA Guide, J.D. Power, https://www.nadaguides.com/Cars/Shopping-Guides/how-much-does-a-star-smog-check-cost.

Table 3-9 Opacity Test Costs Reported by California HD Fleet

Opacity Cost Range	Percentage of Respondents
< $50	15%
$50 - $100	50%
$101 - $150	25%
$151 - $200	10%

Another key assumption with third-party testing involves how many vehicles a single technician will test per week. Determining this involves the question of what size fleets will be typically using third-party testers. With bigger fleets, a tester can stay at the facility and test a number of vehicles in a single visit, which means required travel time is less of a consideration.

Conversely, having to travel to smaller fleet facilities or to test individual owner-operator trucks significantly reduces the number of tests that can be performed in a week. We expect that the larger fleets will use their own technicians, which means third-party testers will be focused on testing smaller fleets and individual trucks.

A related issue is how busy each tester will be, i.e., will they be fully scheduled each week, or will there be down time due to lack of fleet interest in the tester's locality? We expect that they will not be fully busy, but also that market forces will function to keep their test schedule reasonably full.

Given the above factors, we are assuming that an individual third-party tester will average 60 inspections per week, based on 8-hour workdays x 5 days/week x 1.5 tests/hour, and 3,000 inspections per year assuming 60 inspections per week and 50 weeks worked per year. Applying the assumed retest rate of 25% results in a 2,400 vehicles/year (3,000/1.25) third-party testing rate.

3.4.2 Cost Estimates

Similar to the discussion of assumptions in Section 3.4.1, Key Assumptions, cost estimates in this section are divided between those common to all of the test methods and others that apply to the individual test methods. These estimates are based on the assumptions listed in the previous section.

3.4.2.1 Common Costs

Costs in this category include most of those listed under the contractor responsibilities in the HD OBD Program Oversight Responsibilities listed in Table 3-8. Estimated costs for the relevant categories are provided in Table 3-10. Some categories in the previous table have been combined since separate cost estimates cannot be provided within a reasonable degree of precision.

Table 3-10 Cost Estimates of Common HD OBD Program Elements*

No.	Program Element	Estimated Initial Implementation Cost Range	Estimated Annual Ongoing Cost Range for Maintenance, Operation, and Support
1	Develop/maintain/host VID and communications network, program administration and audit software, etc., including: - Business intelligence and reporting suite/portal, including fraud detection - Portals/interfaces (for CARB administrators, truck owners, referee testers, OBD device registration, and third-party testers) - Interfaces and communications with other applicable systems - Software for administering the program, including network settings, test system lockouts, user maintenance, etc. - Software for auditing of referee, truck stops, kiosks, third-party testers, and possibly fleet self-testing - Sending electronic test notifications to vehicle owners of when tests are due. - Making compliance determinations - Sending compliance records to DMV	$2,500,000 - $3,900,000	$1,600,000 - $3,000,000
2	Establish Physical test location testing network**	$1,100,000 - $1,800,000	$2,300,000 - $4,200,000
3	Procure and maintain test devices for truck stops and kiosk test locations**	$1,400,000 - $3,000,000	$320,000 - $720,000
4	Procure and maintain tablet/dongle test devices for truck stop test facilities* and referee network	$2,700,000 - $4,800,000	$700,000 - $1,200,000
5	Establish/run referee network***	$450,000 - $900,000	$1,350,000 - $3,000,000

No.	Program Element	Estimated Initial Implementation Cost Range	Estimated Annual Ongoing Cost Range for Maintenance, Operation, and Support
6	Establish/run call center operations	$800,000 - $1,800,000	$750,000 - $1,500,000
7	Establish/run mail room operations, including mailing out compliance certificates, and receiving and processing correspondence with vehicle and fleet owners	$550,000 - $1,100,000	$700,000 - $1,300,000
	Total Estimated Common Costs	$9,500,000 - $17,300,000	$7,720,000 - $14,920,000

* The cost ranges in this table are admittedly wide. This reflects our view that various bidders may attempt to obtain this program contract, with these bidders ranging from smaller, specialized I/M contractors, who likely have lower costs, to large Information Technology (IT) contractors with higher costs. California also has rigorous oversight programs for state IT and I/M projects which would add further to program costs, with these costs likely magnified if a large IT contractor is involved. Consideration of these factors resulted in the cost ranges provided in the table.

** This would be a common cost since it will be spread across all test methods, in order to enable free, i.e., no-out-of-pocket costs, testing at the truck stop / kiosk facilities.

*** In section 3.4.1.1, we recommend that referee inspections be performed via mobile inspections. However, estimated costs for mobile referee operations cannot be determined at this time. Further analysis would be needed to determine this. The costs included in this table are based on brick-and-mortar referee testing.

The above total estimated common cost ranges can be converted to a per-vehicle annual cost range by:

- Amortizing the initial cost range over the assumed 7-year contract period at a 5% interest rate to convert this to an annualized cost range. The resulting annualized numbers are approximately $1,640,000-$2,990,000.

- Adding the estimated annual ongoing costs to the annual operating costs to compute total estimated annual common costs. The resulting total annual numbers are approximately $9,360,000-$17,914,000.

- Dividing these total estimated annual common costs by the projected annual average OBD HD fleet size of approximately 1.07 million vehicles (Item #3 of Section 3.4.1.1, Common Issues) yields the per-vehicle annual common cost range of $8.73 - $16.71.

Note that these costs include those associated with the contractor responsibilities listed in Table 3-8, but would not include CARB (state) costs such as program oversight and enforcement costs (which would be covered by the cost of a compliance certificate), or other excluded costs listed in Table 3-8.

3.4.2.2   Costing of HD OBD Interrogation Devices

Three types of data sources were used for the costing of HD OBD interrogation devices: (1) a small sample of devices already on the market that we see as comparable; (2) the $3,000

estimate that BAR provided for an enhanced DAD unit/OBD dongle meeting the enhanced specifications on which they are working; and (3) direct team member experience in building LD OBD interrogation devices, which gives us the capability to make informed judgements regarding the complexity and relative cost of building HD OBD devices.

The wide difference in costs between the first two of these data sources complicated the effort of developing cost estimates for the CC-ROBD and NCC-ROBD devices. While not privy to internal BAR or vendor pricing information, we believe there are two factors that contribute significantly to the much higher cost estimate associated with the enhanced DAD: (1) the cost of the BAR certification process itself, and (2) the cost of incorporating the enhanced fraud prevention/detection that BAR is building into the new specification.

While we know BAR's current DAD certification process costs $10,000 per attempt, the total cost of certification to vendors and equipment manufacturers also includes the development and manufacturing costs associated with meeting the certification's requirements. BAR has factored this into the estimates for the new generation of devices, but we do not know what the breakdown of those costs is for the vendors.

Regarding enhanced fraud functionality, our programmatic recommendation is that such protection should be a part of the HD OBD program, for the reasons presented in other sections of this report. However, we also understand CARB's interest in deploying lower-cost CC-ROBD and NCC- OBD devices, to increase the acceptability of the overall program to subject HD fleets, owner-operators, and RV owners. Accordingly, the cost estimates provided in the following sections for each type of device reflect the assumption that primary fraud protection/ detection will occur at the VID end, with this functionality not incorporated into the device end.

3.4.2.3 Telematics Data Reporting Costs

During our research for this program, most large telematics companies were generally reticent about providing details regarding their interest in the program, current device capabilities, or potential price points for a program-compliant device. Therefore, the price range of an HD CC-ROBD device/service was estimated based on the available pricing data of existing CMV telematics, which are summarized below.

1. **FMCSA ELD Rulemaking**. As part of the FMCSA's ELD rulemaking in 2015, they conducted a review of the cost of existing CMV driver's HOS logging devices. The review found that then existing electronic logging devices ranged from an annualized price of $165 to $832, with the most popular device priced at $495/truck.[99] The FMCSA's final ELD rule estimated a total annualized cost of $419 for an ELD telematics device.[100]

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[99] "Electronic Logging Devices and Hours of Service Supporting Documents," Supplemental Notice of Proposed Rulemaking, Federal Motor Carrier Safety Administration (FMCSA), DOT, 79 FR 17658, March 28, 2014, https://www.govinfo.gov/content/pkg/FR-2014-03-28/pdf/2014-05827.pdf.

[100] "Electronic Logging Devices and Hours of Service Supporting Documents," Final Rule, Federal Motor Carrier Safety Administration (FMCSA), DOT, 80 FR 78346, December 16, 2015, https://www.govinfo.gov/content/pkg/FR-2015-12-16/pdf/2015-31336.pdf.

While ELD prices have not come down drastically in the past few years since the FMCSA rulemaking, many providers have introduced less expensive fleet management system models that have features designed specifically for the ELD Mandate.

2. **ELD Telematics Costs**. These can be divided into two categories—the initial or upfront cost of obtaining the telematics device and then the annual ongoing cost for the telematics service. Recent listings[101,102] of the top 10 and 20 FMCSA-compliant ELD devices contain the pricing data shown in the following Table 3-11.

Table 3-11 Per Truck Costs of Top ELD Telematics Devices

ELD Name	Upfront Cost	Monthly On-Going Fees
KeepTruckin ELD	$150	$20 or $30 plans
Transflo ELD T7	$99	$25
Omnitracs (IVG) Intelligent Vehicle Gateway Master Pack	$799 or more	$23 or more
Rand McNally – Electronic Logging Device ELD 50	$149	$15 or more
BigRoad DashLink ELD	$0 with Lease	$15.60
J.J. KELLER Encompass ELog Electronic Logging Device	$0 with BYOP* option	$11 or less
Linxup ELD	$250 or $100 with contract	$30 to $50
Gorilla Safety ELD	$0	$10
PeopleNet Display.4	$0 with lease option	$30 to $60
Blue Ink Technology	$295	$0
EROAD Ehubo ELD	$0 for monthly plan	$30 to $60
Ezlogz	$0 with monthly plan	$29.99 per month per unit
Samsara	$99	$33
AT&T Fleet Complete	$0	At least $25
Verizon Connect	$0	$60
CarrierWeb CarrierMate	$700	$30
Garmin ELD (eLog)	$249.99	$0
Teletrac Navman	$0	$45
Pedigree ELD Chrome	$499	$25
Stoneridge EZ-ELD	$169	$15

*BYOP - Bring Your Own Phone

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[101] "Best ELD Device Reviews 2020 – Top 10 Electronic Logging Devices," ELD Reviewer, February 16, 2020, https://eldreviewer.com/eld-reviews/.

[102] "Best ELD Devices 2020 | Top 20 Electronic Logging Devices," Best ELD Devices, January 19, 2019, https://www.bestelddevices.com/best-eld-guide/.

A recent industry review[103] rated the KeepTruckin ELD as the best ELD telematics device on the market, with Garmin eLog in second place and Samsara third. Other ratings also show KeepTruckin ELD at the top of this list.

There is a wide range of FMCSA-compliant choices for ELD telematics, with over 600 devices from about 340 different manufacturers listed on an online registry maintained by the FMCSA.[104] This degree of competition acts to lower ELD prices considerably.

3. **Fleet GPS Tracking\Logistics\Diagnostics (OBD) Devices**. Based on available online reviews,[105,106,107] current fleet management telematics pricing ranges from $14 to $250+ per vehicle per month, with the average being between $25 to $45 per vehicle per month. Verizon, who has the nationwide fleet telematics market share lead with over 1.59 million active subscribers[108] offers prices ranging from $50 to $250 per vehicle per month, with the higher-end priced devices delivering full fleet management capabilities, such as logistics, diagnostics, etc. Other elements of higher priced devices include faster data refresh rates and user-customizable features.

   At the other end of the price range, Quartix, GPS Insight and other vendors provide a much more limited set of fleet telematics offerings, e.g., GPS tracking only, that cost as low as $14 per vehicle per month.[109]

   According to one source,[110] the average cost across multiple industries of connecting a truck via telematics for one year is $624, which consists of an average price of $77.29 in hardware cost and an average monthly price of $45.63. Nearly all vendors require an annual commitment, or an up-front hardware payment, to offset reduced monthly rates. Many vendors are signing customers to 2-year and 3-year contracts.

   Like the ELD-specific share of the market, the full telematics market includes a large number and wide range of manufacturers and offered devices/services. This competition

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[103] "Best ELD Devices for 2021," Tech.co, November 26, 2020, https://tech.co/fleet-management/best-eld-devices.

[104] "Registered ELDs," Federal Motor Carrier Safety Administration, https://eld.fmcsa.dot.gov/List.

[105] "How Much Does GPS Fleet Tracking Cost? The Ultimate Guide 2020," Expert Market, November 27, 2020, https://www.expertmarket.com/fleet-management/costs.

[106] "11 Best Fleet Management and GPS Tracking Software for 2021," Connecteam, September 15, 2020, https://connecteam.com/10-best-fleet-management-software/.

[107] "Top 50 Best Telematics Providers: Compare Systems & Solutions", Fleet Logging, November 16, 2020, https://fleetlogging.com/telematics/.

[108] "Telematics Companies Ranked by ABI Research," Automotive Fleet Magazine, June 5, 2019, https://www.automotive-fleet.com/333259/telematics-companies-ranked-by-abi-research.

[109] "How Much Does GPS Fleet Tracking Cost? The Ultimate Guide 2020," Expert Market, November 27, 2020, https://www.expertmarket.com/fleet-management/costs.

[110] "Telematics Pricing Survey: Why Pay 4.3x More?," Momentum IoT, July 15, 2020, https://momentumiot.com/telematics-pricing.

results in lower prices and considerable innovation in designing new offerings to capture user interest.

4. **Fleet Survey**. As described in Section 3.2, our telephone and online surveys of California fleets included questions about fleet use of telematics devices. This included determining whether telematics services included fleet / logistics management, OBD, ELD/DVIR compliance support, or any combination thereof, and also inquiring about cost ranges and payment periods, i.e., whether the charges are for hardware and/or services and whether payments are one-time or ongoing, and what these costs were. Sixteen fleets, or 43% of all respondents, reported utilizing some form of telematics support, and the services, payment structure, and cost ranges varied widely among respondents, as described in Section 3.2. Consolidated survey responses are provided in Appendices C and D.

5. **California BAR**. The California BAR is currently working on an updated DAD specification for OBD I/M data collection with enhanced fraud protection features. BAR staff[111] provided a rough cost estimate of $3,000 per device for a DAD unit/OBD dongle that will meet this expanded specification. They also noted that transmittal of the raw hex data that CARB wants to collect in the HD OBD program would further increase the cost of CC-ROBD or NCC-ROBD tools or dongle style devices. We are unable to develop a firm estimate of the incremental cost increase associated with this new technology/data collection at this time.

All of the information presented above can create challenges when trying to develop a cost estimate for a telematics device or CC-ROBD tool for the HD OBD program. Important factors to consider include:

- Breadth of data: We are aware of no existing telematics devices that currently collect the full spectrum of HD OBD data that would be required in the HD OBD program, and it is unlikely many vendors are familiar with these data requirements. The development of new technologies and unknowns associated with this means higher costs. It also increases the likelihood that "early adopters", i.e., those device manufacturers who are first into this market, may encounter some level of problems in deploying reliable solutions. Even if one or more telematics vendors say they can build and market such devices, unforeseen issues may arise following initial device deployment.

- Security and cost: With the possible exception of ELD fraud concerns, I/M-related fraud protection features have not typically been a component of telematics services. As mentioned previously, we support incorporating fraud protection features, such as those to be incorporated into BAR's enhanced DAD specifications, into the CC-ROBD devices. However, we also recognize the need to offer more affordable devices in order to ensure program acceptability among subject vehicle owners. In order help ensure program acceptability, it is therefore assumed that fraud detection strategies will be designed into the back-end (VID) analysis, processes, and triggers.

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[111] Private communication with Garrett Torgerson, Supervising Air Quality Engineer, Engineering & Research Branch, California Bureau of Automotive Repair, September 23, 2020.

After considering the above, we have developed an estimated cost range of $300 - $800 per CC-ROBD tool for the HD OBD program. This wide range of estimated costs reflect the large number of unknowns previously described. A device may well cost less than NCC-ROBD device, depending on features that do not need to be integrated into a continuously connected device. However, the extra hardware and development to connect to cellular networks (or other drive-by hotspots), and unknowns of integration with currently in use systems, could drive the cost of this device higher. This cost may drop over time as experience is gained with these devices, additional states decide to implement similar programs and additional vendors decide to enter this market. But we believe our estimate is reasonable for the initial program period of 2023-2029.

A monthly on-going fee of $30 has been assumed for the CC-ROBD tools. This estimate reflects the mid-range of the monthly fees for ELD devices as shown in the previous table. Converting the above device cost estimate to an annualized present value and adding this annual fee results in a total per-vehicle per year estimated cost range of $410 - $500 for HD vehicles using a CC-ROBD tool.

The estimated common cost range presented in Section 3.4.2.1, Common Costs, must be added to the above test method-specific cost estimate. This results in a total estimated per-vehicle annual cost range of $420-515 for CMV and RV owners that choose to submit their required HD OBD data using telematics services. Note that CARB's estimated program oversight and enforcement costs will need to be further added in order to calculate the full estimated cost for this test method.

3.4.2.4   Fleet Self-Testing Costs

The full cost of fleet self-testing would be a combination of labor costs for the service technicians conducting these tests, the initial purchase cost of NCC-ROBD devices, and the ongoing operations and maintenance costs of the devices. As noted in Section 3.4.2, Cost Estimates, labor costs are assumed to be borne by the individual fleets and are not included in this analysis. Estimated costs for these tests therefore are limited to amortized capital and ongoing operating/ maintenance costs for the needed test equipment.

We estimate the cost range of an NCC-ROBD device will be between $400 - $700. Annual operating costs would be lower than those for a CC-ROBD device, since no dedicated telecommunications link would be needed for the NCC-ROBD tool; instead, the tool would communicate with the VID via the fleet facility's Internet connection. Operating costs would simply be any needed maintenance costs, which are expected to be relatively minimal. An annual maintenance cost of $20 has been assumed. Combining the amortized initial capital cost with this annual operating cost results in a total annual estimated cost range of $98-$158 for the NCC-ROBD tool.

In addition, unlike the CC-ROBD tool, which must be installed exclusively on one vehicle, the NCC-ROBD tool can be used to transmit the required OBD data from multiple HD vehicles to the VID, as previously discussed in Section 3.4.1.2. We therefore divided the estimated annual NCC-ROBD tool cost by the 1,800 vehicles/tool/year assumed in that section to produce a per-vehicle estimated cost of $0.05-$0.08.

The estimated common cost range presented in Section 3.4.2.1, Common Costs, must be added to the above test method-specific cost estimate. This results in a total estimated per-vehicle annual cost range of $9 - $17 for HD vehicle owners that choose fleet self-testing to submit their required HD OBD data. The large difference between this and the CC-ROBD costs presented in Section 3.4.2.3 are due to the large economies of scale achieved by sharing a single device among 1,800 vehicles, as opposed to dedicating a device to a single vehicle. As a result, the annual per-vehicle NCC-ROBD cost is due almost entirely to the common costs being applied.

Note that CARB's estimated program oversight and enforcement costs will need to be added in order to calculate the full estimated cost for this test method, since the cost for a Compliance Certificate needs to be factored in.

3.4.2.5   Third-Party Testing Costs

The full cost of third-party testing would be a combination of labor costs for the third-party technicians conducting these tests, the initial purchase cost of NCC-ROBD devices, and the ongoing operations and maintenance costs of the devices. As noted in Section 3.4.1.2, Test Method-Specific Issues, a labor rate of $30 per third-party vehicle inspection is assumed for cost estimation purposes.

Each third-party mobile technician will need a single NCC-ROBD device, which will be used to perform quarterly testing on the 2,400 vehicles assumed for each technician in Section 3.4.2, Cost Estimates. We therefore divided the estimated annual NCC-ROBD tool cost shown in Section 3.4.2.4, Fleet Self-Testing Costs, by this 2,400 vehicles/tool/year estimate to produce a per-vehicle estimated capital cost of $0.04 - $0.06 for third-party testing.

We then need to add in the estimated labor cost for this testing. Multiplying the above $30 per vehicle inspection labor rate by 4 inspections per year results in a total annual labor cost of $120. Compared to the capital cost of $0.04-$0.06, labor therefore is estimated to account for 99.95% or more of total annual third-party testing costs.

The estimated common cost range presented in Section 3.4.2.1, Common Costs, must be added to the above test method-specific cost estimate. This results in a total estimated per-vehicle annual cost range of $129 - $137 for CMV and RV owners that choose to submit their required HD OBD data using third-party testers. Note that CARB's estimated program oversight and enforcement costs will need to be further added in order to calculate the full estimated cost for this test method.

3.4.2.6   Physical Test Location Testing Costs

As noted in Section 3.4.1.1, we have assumed the truck stop / kiosk tests will involve no out-of-pocket costs to vehicle owners who choose this test method. This assumption was made to ensure that at least one testing method would meet the $30 compliance fee limit specified for the HD OBD test by California Senate Bill 210.

To provide CARB with additional insight into this issue, we performed an alternative analysis to estimate the cost of truck stop / kiosk testing if it were not free. Truck stop / kiosk

costs, included in Section 3.4.2.1 as common costs, were instead allocated solely to this test method, annualized, and then divided by the 467,200 tests/year capacity for the 20 locations assumed in the study.

The analysis results show an estimated cost range $7.16 - $13.39 per test (rather than vehicle). Assuming each vehicle must be tested four times per year, this translates into an approximate annual cost range of $29 - $54.

We are unsure whether the $30 maximum should be interpreted as a test fee limit or an annual fee limit. If this is a $30 annual limit, our analysis confirms the need to make this test free in order to stay under the limit. Another approach would be to subsidize truck stop / kiosk testing only partially so that it remains under the $30 limit.

Task 2: OBD/Repair Data Collection

3.5   Per-Vehicle I/M Program Repair Cost Estimates

This section presents the average repair cost results from the methods described in Section 2.2. An overall estimate of repair cost ranges provided by each of the sources is first provided, followed by intermediate repair costs by OEM, and the section concludes with a single estimate of the average repair cost for an emission-related MIL-on condition for a 2013+ heavy-duty truck.

Table 3-12 provides a brief summary of the overall average repair cost ranges provided by each of the sources, based on OEM or aftermarket costing.

Table 3-12 Repair cost ranges presented from each of the two sources and, for Source 1, the cost basis (either OEM or aftermarket)

Source and Cost Estimate Basis	Estimated Repair Cost Range
Source 1 (OEM/Dealer Costs)	$87 - $10,650
Source 1 (Aftermarket/Independent Costs)	$42 - $5,921
Source 2 (Calculated Costs from Labor Hours)	$87 - $3,074

Table 3-13 presents the cost averages by TM&M category estimated by Source 1 for the OEM / dealer pricing basis. Correspondingly, Table 3-14 presents the equivalent costs from this source based on an aftermarket or independent shop pricing basis. It can be seen that many categories have costs listed as NA (not applicable); many repairs in these categories would require aftermarket parts that are not available for legal installation in California, and so no specific average price is given.

Table 3-13 The average repair cost by category from Source 1 for OEM pricing levels

TM&M Category	Cummins	Detroit Diesel	International
Boost Control	$2,623	$2,088	$2,123
EGR	$1,202	$1,343	$2,092
Fuel System Monitoring	$1,598	$2,007	$1,931
NOx Sensor	$1,658	$1,849	$2,125
PM Filter	$2,606	$1,463	$2,742
PM Filter Frequent Regen	$1,872	$1,511	$2,497
Reductant Delivery	$2,292	$1,855	$2,328
SCR Catalyst	$1,490	$2,125	$1,837

Table 3-14 The average repair cost by category from Source 1 for aftermarket/independent shop pricing levels

TM&M Category	Cummins	Detroit Diesel	International
Boost Control	$1,387	$737	$1,096
EGR	$515	$535	$974
Fuel System Monitoring	NA	NA	NA
NOx Sensor	$776	$761	$1173
PM Filter	NA	NA	NA
PM Filter Frequent Regen	$674	$584	$761
Reductant Delivery	NA	NA	NA
SCR Catalyst	NA	NA	NA

Table 3-15 presents the average cost by category and manufacturer from Source 2. As in the previous table, some categories are listed as NA, indicating that some or many repairs in these categories cannot be legally performed using aftermarket parts in California.

Table 3-15 The average repair cost by category from Source 2 for aftermarket/independent shop pricing levels

TM&M Category	Cummins	Detroit Diesel	Other – International and Volvo
Boost Control	$354	$424	$972
EGR	$276	$319	$464
Fuel System Monitoring	NA	NA	NA
NOx Sensor	$334	$329	$503
PM Filter	NA	NA	NA
PM Filter Frequent Regen	$302	$281	$568
Reductant Delivery	NA	NA	NA
SCR Catalyst	NA	NA	NA

ERG directly averaged the three manufacturer categories (International was the third manufacturer for Source 1 and International and Volvo were taken as the third category for Source 2). These values could instead be weighted by manufacture on a sales or market share basis, as desired. Figure 3-27 presents the average cost for the two sources (and cost basis for Source 1) for each TM&M category. The error bars present the 5th and 95th percentile repair costs for all repairs within each category. It can clearly be seen that there is a very wide range of costs within each category, but the costs across categories are relatively similar. Almost all categories have a similar trend in that their cost range at the low end is based on replacing a single sensor and, at the high end, needing to replace an entire significant or central component. For the aftermarket cost basis estimate, a large Red "X" indicates that repairs in the category are not likely to be able to be legally performed with aftermarket parts in California.

Figure 3-27 Average cost by TM&M category for each source and cost basis. Error bars indicate 5th and 95th percentile range of costs that make up the averages in each group.
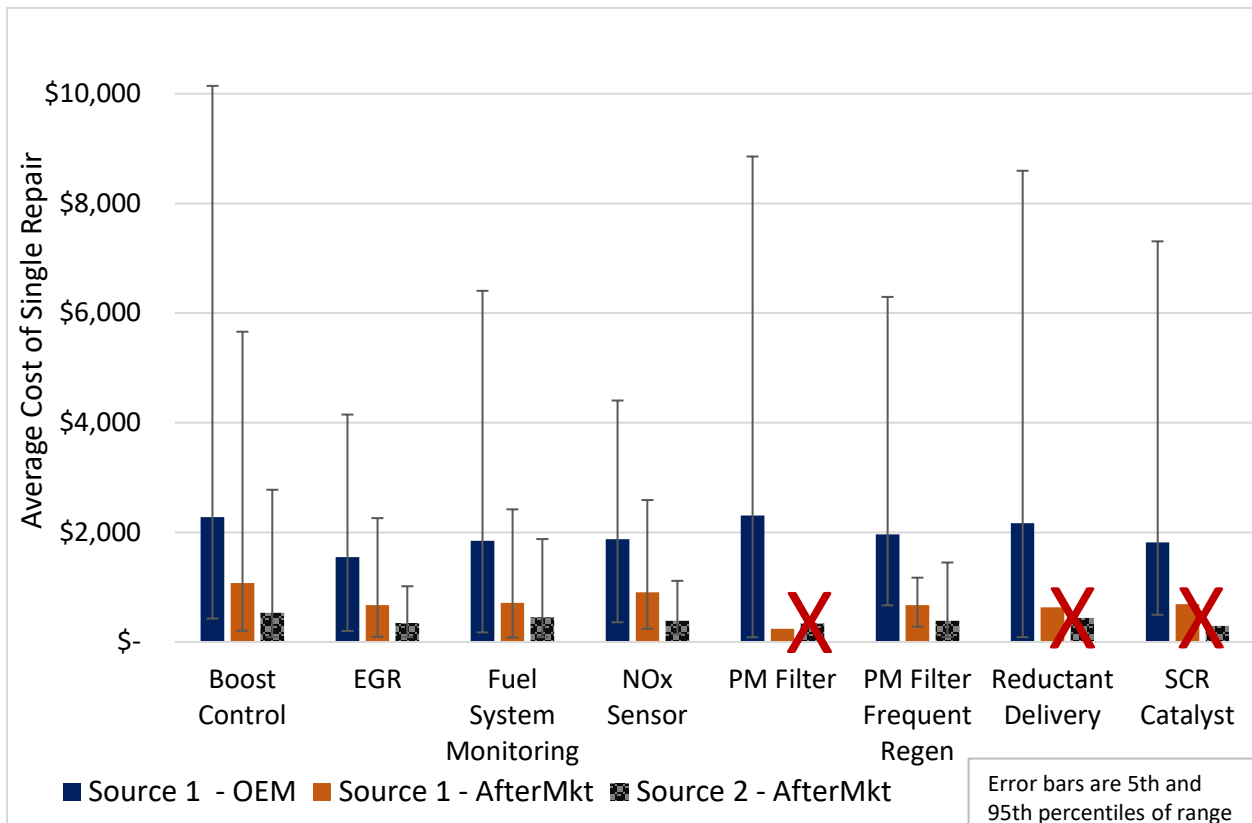
To complete the analysis, ERG used the percentages of TM&M category representation from Table 2-3 (Total SPN counts in each TM&M category) to weight the category-level repair costs and determine a single estimate of the average repair cost of a truck with an emissions-related MIL-on condition. The costs from Figure 3-27 were weighted by Table 2-3 to determine the overall average costs in Table 3-16.

Table 3-16 Overall estimated MIL-On repair cost by repair cost basis

	OEM/Dealer (Source 1)	Aftermarket/Independent (Source 1)	Aftermarket Independent (Source 2)
Overall Average Repair Cost	$1,977	$700	$400

Appendix E includes the specific, finalized, data provided from each of the two cost information sources. A brief summary of the overall cost ranges for all repairs is presented in this section.

It should be noted that, in taking these overall averages by information source and cost basis, that common repairs in some TM&M categories cannot be legally performed with aftermarket parts in California, so the overall cost estimates for aftermarket parts are not applicable. **For this reason, ERG recommends CARB use the OEM/Dealer overall repair cost estimate of $1,977 in future estimates of repair costs of this program**. This estimate does not include any applicable sales tax.

4.0   Discussion and Recommendations

Our work with other states/programs prior to and during this pilot program suggests that HD OBD truck test programs are viable alternatives to traditional opacity test programs and are likely far superior to smoke opacity tests for achieving meaningful air quality benefits. This section provides a discussion of results and findings from this pilot, including discussions with and input from fleets during program surveys and during CARB-hosted workshops and workgroups, and provides recommendations for the upcoming test program. We encourage CARB to continue working with BAR's light-duty Smog Check program staff and other states as they implement the future HD I/M program to ensure missteps are avoided and common and effective strategies are understood and employed.

4.1   Task 1: OBD-Based HD I/M Program Demonstration Results

4.1.1   Test Types and Test Systems

NCC ROBD

The format of the scanned data collected during the pilot program is likely a subset of potential OBD data submission options that may be part of the future HD I/M program. Testing conducted during the pilot study confirmed that acquisition of the data fields necessary to support the program is possible, as data was collected from both SAE J1939 and SAE J1979-compliant systems using various types of data collection devices. Examples of data from both SAE J1939 and SAE J1979-compliant systems are provided in Appendices E and F, respectively. Scan durations during the pilot were reasonable at approximately 3.5 minutes for SAE J1939-compliant systems and less than 1.5 minutes for SAE J1979-complaint systems. Also, due to the decentralized nature of the program, it is not realistic for NCC-ROBD systems to require significant user input (with the exception of possible entry of VIN/driver/owner information since that data that might be needed if an accurate e-VIN is unavailable and to positively match with registration records). Similar to the system developed for this program, testing should be automated, and truck scans should be performed with minimal interaction.

Internal team observations and feedback from our testing partners included the following:

- Testing with a separate laptop, scan equipment and cables is somewhat cumbersome in terms of handling equipment inside the cab. However, we do not envision this will be an issue for the future program, as single-unit test systems will likely be available, either as a handheld unit with a wired connector or a wireless dongle.
- Testing was simple and automated, much simpler and quicker than the current opacity test.
- Test equipment for the future program will need to be ruggedized in order to withstand the rigors of industrial use. Durability testing, and a test system's ability to self-test, are recommended as part of the future test system certification process.
- The diagnostic connectors on HD trucks are frequently broken out of their housing, making them difficult to access and attach for testing. We do expect this could be an issue in the future program, especially during the early years of the program. Although many light-duty programs offer a test bypass (OBD test failure) if the diagnostic connector is inaccessible or non-functional, this may not be necessary for

this HD test program, due to the "self-test" nature of the program (as opposed to centralized or decentralized programs). In this program, an inaccessible connector means the test will just not be performed.

- Locating the diagnostic connector was challenging on some vehicle types. This could pose an issue for self-testing, in cases for which the drivers might not be able to locate the data port and conduct the test, or it could delay operations at self-test kiosks.
- As shown during the fleet surveys, concerns regarding plugging a scan tool into the truck's diagnostic port were limited.
- The truck's idle auto-shutdown feature occasionally interrupted the test in some situations. For these cases, during the test, it was necessary for the individual conducting the test to manipulate the truck's brake and throttle in order to bypass the auto-shutdown and hence prevent the test from stopping when the truck automatically shuts off.

As currently envisioned, the future inspection program will be collecting a large amount of data, with conversion from hex data format to SAE J1939 and SAE J1979-compliant results and units to be performed on the VID. Because of the volume of heavy-duty truck data, especially from the SAE J1939 network with multiple responding controllers, early attention to data collection, transmission and processing measures will be important to effectively resolve any data collection and aggregation issues prior to program implementation.

Criteria for readiness determinations from the various readiness monitors, diagnostic messages and responding controllers could affect program efficacy and acceptance. In the US, light-duty vehicle inspection programs have tailored readiness criteria to avoid failing too many vehicles for a "not-ready" determination. Additionally, other criteria have been established to avoid allowing retest vehicles to pass with malfunctioning components due to slower-setting monitors being not ready, such as a catalyst or evaporative emissions monitor, after a prior failure caused by that component or system. Light-duty programs have frequently utilized vehicle-specific criteria tables to tailor readiness criteria for known exceptions. Application of effective criteria without undue industry burden may be achieved by increasing program stringency over time as more in-program data is collected and analyzed. Also, use of permanent trouble codes is an important component of the overall test disposition.

CC ROBD

The telematics option will likely require some form of initial setup and vehicle / owner registration, but thereafter will not likely require any interaction. As opposed to NCC tools, the CC-ROBD unit would only need to meet the SAE protocol of the vehicle to which it is attached[112]. Care should be taken to ensure data collection requirements remain in alignment with the California Privacy Act, in particular with collection of GPS data, should this be part of the future program.

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[112] Majd, Ehsan, "*Specifications of Remote OBD Systems for Use in CARB's Heavy-Duty Inspection and Maintenance (HD I/M) Program*, CARB's November 16, 2020 HD I/M Workgroup Meeting, page 11.

Due to anticipated program changes and needs over time, we recommend flexible telematics solutions that can receive over-the-air software updates, as needed. Whether a telematics provider designs and manufactures their own equipment or relies on outsourced equipment may affect that provider's ability to offer a flexible (and updateable) program solution.

If a provider offers a telematics solution for this program that is integrated with existing telematics equipment or services, care is warranted to ensure any bundled program solutions are affordable for the industry. And it will also be important to ensure any stand-alone solutions installed in tandem with other OBD-based equipment does not result in ECM interrogation conflicts. This can be evaluated during certification and also through a possible internal CARB program developed to track and monitor any interrogation conflict issues and the affected vehicle and CC-ROBD system types.

4.1.2 Program Implementation Considerations

Test and repair organizations typically rely on immediate test result determinations, and diagnostics, when available, in order to ensure testing is successful and to initiate repairs, when necessary. If test determinations are made at the VID, any delay in the availability of test results could result in industry hardship as multiple trips to the test or repair facility could be required to identify and correct a malfunctioning vehicle and acquire a successful test.

Automated on-road enforcement using ALPR cameras and registration database linking could result in a lagging response and logistical challenges for program enforcement on out-of-state vehicles, including those not registered in the US. For cross-border commerce, program compliance issues could result in development of a number of border transfer stations for transfer of containers and goods from a foreign carrier's truck to a California-certified truck.

Early intervention and correction of truck malfunctions reported by onboard monitoring systems allows proactive maintenance which can serve to minimize escalating repair costs resulting from "cascading" failures. Although this certainly does not apply to all repairs, this does apply to "upstream" failures that tend to contribute to failures of subsequent or downstream systems. This "holistic" maintenance benefit can be occasionally overlooked or understated in I/M programs but should be emphasized in terms of program outreach and messaging. Additionally, a number of emissions-related failures could eventually result in a manufacturer-imposed derate. Proactive maintenance helps prevent inopportune derates and hence increases operational stability and reliability. This can be especially true for a telematics / fleet management solution integrated with this program.

Some feedback was received from fleets and industry advocates suggesting quarterly testing will be burdensome, especially for those fleets who elect to use NCC-ROBD. While the higher mileage accumulation does increase the emissions impact of malfunctioning vehicles, determination of the test frequency to be used in the program should weigh factors such as industry burden, especially as some emissions-related failures may be addressed by OEM-based derates. Tailoring test frequency based on mileage accumulation and / or possibly industry or region may alleviate some hardship for certain industries with lower mileage accumulation and greater compliance challenges.

SAE J1939 and SAE J1979 diagnostic data should accompany test results provided to drivers, fleets and repair facilities, and resources should be provided regarding how to understand and use this diagnostic data in repairing HD vehicles. Mechanic training can be beneficial in ensuring diagnosis and repairs are accurate and effective. Also, collection of repair information that accompanies initial failure diagnostic data and vehicle data can be helpful in building a data repository that can be used in developing a diagnosis and repair recommendation database in the future.

Once a repository of test I/M data has been acquired, it will allow CARB to monitor OEM performance, i.e., long-term durability of powertrains and emissions-control systems, to help understand weak points (high failure rate systems) and ultimately result in increased emission system durability, which can lead to long-term air quality improvements.

Some input provided during fleet surveys and also during the CARB HD I/M workshops and workgroups emphasized that care should be taken in developing program requirements as they pertain to compliance of trucks obtained by loans, trucks under lease, and rental trucks. As an example, although the lessor (leasing company) will be the registered owner of in-program trucks, this company will not likely have knowledge of the truck's program compliance. In this scenario, program compliance might be higher and the program more equitable if the lessee is held responsible for vehicle program compliance. As another example, an out-of-state rental vehicle could be driven into California and receive a notice to correct (NTC) as a result of a remote sensing test. In this scenario, the rental company would likely be held responsible for the renter's non-compliant in-state operation. For long-term renters or lessees, this responsibility could be passed to the renter/lessee. However, this may not be feasible for short-term rentals.

Program enforcement activities should be consistent and aligned with test program objectives and offer real-world flexibility, including grace periods, and possibly extensions, for trucks that fail the I/M test and cannot be repaired in a timely manner, as can occur with parts delays and repair facility backlog.

As much as possible, alignment of test program requirements with the existing BIT program could possibly minimize industry burden. Introduction of the program with fairly lenient standards, including readiness criteria, can also help to minimize unnecessary industry hardship, and allow the program to develop more stringent test and readiness criteria after analysis of data trends and application of necessary test exceptions.

As discussed during different program workgroups, due to the complexities of the shipping and freight industry, requiring vendors, government agencies, commercial companies, and receivers to verify program compliance could be problematic. Industry involvement from these parties as well as from brokers, shippers and freight contractors should be sought during development of program requirements in order to ensure program compliance is maximized in an efficient way that is least burdensome to industry.

Some consideration may be worthwhile regarding possible exemptions and/or financial support for repair assistance, in particular for individual owners / operators or small fleets with limited financial resources. Certainly, revenue for such a program would be required, but a cost

analysis could determine this to be a reasonably cost-effective method of reducing HD truck emissions without an undue financial burden on smaller fleets and individual owners / operators.

A lack of visual inspection for the OBD test, as is performed for the PSIP opacity test, could result in some non-compliance that is not identified by the OBD system, such as missing engine tags, exhaust system leaks downstream of monitoring, etc. Care should be taken to ensure equitable and comprehensive program requirements are applied for all test types. This could involve integrating visual inspections into other test programs, or other solutions altogether.

Care should continue to be taken to ensure enforcement, in particular through remote PEAQS measurements, is sufficiently tailored to prevent identification of vehicles as possible high-emitters that have no emissions-system faults, such as could happen through SCR warmup periods, certain transients, regeneration events, or emissions from trailer refrigeration units. As discussed during workgroup meetings, care in developing test, analysis and identification strategies can reduce the likelihood of these "false identifications". However, it is recognized that remote sensing measurements such as these can be quite beneficial in helping quantify "real-world" emissions from HD vehicles. Approaching appropriate remote sensing emissions cutpoints from the lenient side can minimize these, and increase industry program acceptance.

If any CC-ROBD continuous monitoring options are offered in the future program, we recommend consideration of some form of cumulative mileage monitoring to ensure vehicle operation without the CC-ROBD device can be detected. Although SAE J1939 does have some "dash display" PGNs, odometer is not in the list of available parameters, and since dashboard odometer (total accumulated vehicle mileage) is not available in the SAE J1939-defined datastream, we recommend using SPN 245, Total Vehicle Distance, High Resolution in meters, and SPN 917 (Total Vehicle Distance in kilometers). Prior analysis has generally shown at least one of these parameters to be broadcast on any particular truck, so we recommend collecting both to ensure the needed information is acquired. These are quite helpful in fraud detection, as discontinuities in accumulated distances could indicate vehicle operation without a telematics device installed, and unexpected accumulated distance changes such as large jumps or negative accumulation can indicate clean scanning for non-continuously connected vehicles, in addition to calibration IDs, CVNs, and other module identifiers. Additionally, SPN 1032 (Total ECU Distance) may also be requested, although this value could change on an ECM replacement. For SAE J1979-compliant vehicles, some cumulative parameters that could be used could include Mode 01, PID 0x21 (Distance Traveled while MIL Activated) in conjunction with Mode 01, PID 0x31 (Distance Traveled Since DTCs Cleared) and also Mode 01, PID 0xA6 (Vehicle Odometer Reading).

As discussed with another state implementing a HD vehicle test program, collection of data from trucks immediately as they are purchased can serve as consumer protection and also to help develop profiles that can aid in understanding stock configurations and help identify tampering in the future.

As noted previously, some self-test issues could arise at kiosks, including missing or malfunctioning equipment or a user's inability to use the equipment, locate their vehicle's diagnostic port, or other issues. Early implementation should perhaps include staff support to ensure these self-testing issues are better understood and addressed. In addition, analysis

presented in Section 3.4.1.1 suggests the 20 kiosks currently envisioned for self-testing might not meet industry demand. Kiosk demand and industry acceptance should be monitored, with possible adjustments made as needed such as additional test systems at truck stops to reduce the imbalance, should it occur.

4.2   Program Overview, Potential Security Risks and Opportunities for Fraud

As discussed in the Section 3.3, a non-centralized program such as this does create an opportunity for some degree of program fraud, in particular with the wide variety of test systems and compliance approaches under consideration. With the relatively high costs of HD vehicle emission control systems, the likelihood of program fraud may be increased, but the broad variety of data to be collected in this program, along with on-road ALPR and remote sensing test programs can help identify and prevent such fraud.

Methods for identifying and preventing program fraud are a necessary component of an effective program. However, it will be necessary to specify and design program test equipment to allow implementation of real-time fraud controls, should they be desired in this program. For example, in order to apply real-time lockouts for VIN or other vehicle identifier mismatches, real-time bi-directional communication between an NCC-ROBD device and the VID would be necessary. Alternatively, fraud detection activities can be performed on the VID, but efforts to combat fraud after it has occurred may be less effective than initially preventing it.

4.3   Per-vehicle OBD submission Cost Analysis

Many factors can greatly affect in-program costs, in particular in a program such as this which can utilize various types of test equipment, compliance approaches and also applies to out-of-state vehicles. Large differences in estimated per-vehicle costs for the various test methods are due in part to differences in assumed capital and labor costs, but also due to the test systems themselves and overall assumed fleet penetration / adoption rates. CC-ROBD systems are dedicated to a single truck, as opposed to NCC-ROBD systems that can test hundreds or thousands of trucks annually. These variables are important considerations when considering program test cost projections.

4.4   Task 2: Estimated HDV Program-Related Repair Costs

In the repair cost sections of this report, we have outlined a method to estimate the overall average repair costs for MIL On trucks that would be included in the I/M program. This approach used the limited available data to create as realistic a single estimate as possible to represent the wide variety of repairs that can occur on an in-use truck. The key limitation of this approach was not having access to the prevalence of individual repairs taking place in the on-road fleet. ERG instead developed a method to use SPN prevalence to develop these estimates. Common repairs within a TM&M category were weighted equally and the category-level costs were weighted to determine a final overall estimate. This does result in uncertainty as we do not know the prevalence of the low- and high-cost repairs within each category (and all categories did indicate a wide variation in potential repair costs). The method outlined was the best

approach available given the lack of individual repair frequencies. It was interesting to note that all categories had reasonably similar average repair costs.

ERG compared the costs determined in this work to other past publications or reports that contained estimates of emission-related heavy-duty truck repair costs. In those publications, it was common to see average estimates between approximately $1,700 to $3,500. ERG's OEM/Dealer-level costs (which were the costs that ERG recommends that CARB use in program cost estimate) did fall within this range, albeit at the lower end.

One key aspect of the analysis is that the weighting of each TM&M category depends upon the in-use breakdown of SPNs that occur in the absence of an I/M program. As the program continues, these weightings may shift if repairs in certain categories are more or less likely to reoccur after repair. ERG did not have access any data that would support any determination of how likely malfunctions in different categories would be to reoccur.

In summary, ERG recommends the use of **$1,977** in estimating the cost to repair an emission-related MIL-On condition in a truck that would be included in the I/M program. This cost does not include any applicable sales tax.

5.0 Glossary of terms, Abbreviations and Symbols

AB	Assembly Bill
AI	Artificial intelligence
ALPR	Automated license plate cameras
APR	Annual percentage rate
APT	Advance persistent threat
ATM	Automated teller machine
BAR	Bureau of Automotive Repair
BI/AI	Business intelligence/Artificial intelligence
BIT	Basic Inspection of Terminals
BPS	Border Protection Stations
BYOP	Bring your own phone
CAL-ID	Calibration identification
CAN	Computer area network
CARB	California Air Resources Board
CC-ROBD	Continuously connected remote OBD
CDPHE	Colorado Department of Public Health
CHP	California Highway Patrol
CMV	Commercial motor vehicle operator
CTA	California Trucking Association
CTP	Continuous Testing Program
CVN	Calibration verification number
CVT	Commercial vehicle telematics
CY	Calendar year
DAD	Data acquisition device
DC	District of Columbia
DDoS	Distributed denial of service
DLC	Diagnostic link connector
DM	Diagnostic message
DMV	Department of motor vehicles
DOT	Department of Transportation
DPF	Diesel Particulate Filter
DPS	Department of Public Safety
DTC	Diagnostic trouble code
DVIR	Driver Vehicle Inspection Report
ECM	Engine control module
ECU	Electronic control unit
ELD	Electronic logging device
EMFAC	Emission factor model
EPA	Environmental Protection Agency
ERG	Eastern Research Group
ESN	Engine serial number
eVIN	Electronic vehicle identification number
FMCSA	Federal Motor Carrier Safety Administration
GHG	Greenhouse Gas

GM	General Motors
GPS	Global positioning system
GVWR	Gross Vehicle Weight Rating
HD	Heavy-Duty
HOS	Hours of service
HTTP(S)	Hypertext transfer protocol secure
I/M	Inspection & Maintenance
IOO	Independent owner / operator
IoT	Internet of things
IP	Internet protocol
iPad	iOS-based tablet
IRP	International Registration Plan
IT	Information technology
lbs	Pounds
LD	Light-duty
LEO	Law enforcement officer
MaaS	Mobility-as-a-service
MIL	Malfunction indicator light
MitM	Man-in-the-middle
MY	Model year
NCC-ROBD	Noncontinuously connected remote OBD
NMHC	Non-methane hydrocarbon
NOx	Oxides of nitrogen
NTC	Notice to Correct
O&M	Operations and maintenance
OBD	Onboard diagnostics
OEM	Original equipment manufacturer
OIS	OBD Inspection System
OTA	Over-the-air
PC	Personal computer
PEAQS	Portable emissions acquisition system
PGN	Parameter group number
PID	Parameter identification
PM	Particulate Matter
PSIP	Periodic Smoke Inspection Program
PTO	Power take-off
QA/QC	Quality assurance/Quality control
REAL	Real Emissions Assessment Logging (REAL)
RFI	Request for information
RODS	Record of duty status
RSD	Remote sensing device
RV	Recreational vehicle
SAE	Society of Automotive Engineers
SCR	Selective Catalytic Reduction
SIP	State implementation plan
SLA	Service level agreement

SPN	Suspect parameter number
TCU	Telematics control unit
TSPs	Telematics service providers
TEDB	Transportation Energy Data Book
TM&M	Tampering, malfunction and mal-maintenance
US	United States
VID	Vehicle inspection database
VIN	Vehicle identification number
VIR	Vehicle inspection record
VPN	Virtual private network
WLAN	Wireless local area network
XML	Extensible markup language

Appendix A
Target SAE J1939 and J1979 Variables

Note: The final list of program parameters is subject to change as CARB's program design evolves.

Pilot Study SAE J1939 Parameters (PSIP exemption mandatory in bold)
Data provided on a "by controller" basis

Message	PGN	Description	Comments
DM01	**65226**	**Active DTCs**	
DM02	65227	Previous DTCs	
DM04	65229	Freeze Frame Parameters	
DM05	**65230**	**Diagnostic Readiness 1**	
DM06	**65231**	**Emissions-Related Pending DTCs**	
DM07	58112	Command Non-continuous Test	Test command
DM12	**65236**	**Emissions Related Active DTCs**	
DM19	**54016**	**Calibration Info (Cal ID and CVN)**	Verification / Security
DM20	49664	Monitor Performance Ratio	Monitor vs. operation rate
DM21	**49408**	**Diagnostic Readiness 2**	Distance & minutes traveled while MIL active & since DTCs cleared
DM23	**64949**	**Previous Emission-Related DTCs**	
DM24	64950	SPN Support	Expanded/Mfr-specific
DM25	64951	Expanded Freeze Frame	Expanded/Mfr-specific
DM26	**64952**	**Diagnostic Readiness 3**	Time since start, # of warm-ups since DTCs cleared, monitor status,
DM27	64898	Pending DTCs	
DM28	**64896**	**Permanent DTCs**	These are emissions-related
DM29	40448	Regulated DTC Counts	Pending, Permanent, MIL & PMIL
DM30	41984	Scaled Test Results	Results for DM07
DM31	41728	DTC to Lamp Association	DTC-specific lamp info
DM32	41472	Regulated Exhaust Emission Level Exceedance	Specific DTCs and timers for emission exceedance
DM33	41216	Emission Increasing AECD Active Time	AECD Tracking
DM34	40960	NTE Status	NTE Zone
DM56	64711	MY and Certification Engine Family	
VI	**65260**	**VIN**	Verification/Security
CI	**65269**	**Engine Serial Number (SPN 588)**	From engine controller
AC	60928	Name of controller application	Controller address
ET1	65262	Engine coolant temperature	Live data
CCVS1	65265	Wheel-based vehicle speed	Live data
IC1	65270	Intake manifold #1 pressure	Live data
IC1	65270	Intake manifold #1 temperature	Live data
EEC2	61443	Accelerator pedal position 1	Live data
EEC2	61443	Engine % load at current speed	Live data
EEC1	61444	Actual engine - % torque	Live data
EEC1	61444	Engine speed	Live data
EEC1	61444	Engine torque mode	Live data
IT6	65159	Engine actual ignition timing	Live data
AT1S	64891	Aftrtmnt 1 DPF soot load %	Live data
ESR	34560	Engine Protection Derate Override Command	Derate info added by CARB

Message	PGN	Description	Comments
CTL	52992	Engine Torque Limit Request - Maximum Continuous	Derate info added by CARB
EBC1	61441	Engine Derate Switch	Derate info added by CARB
GC2	61470	Engine Self-Induced Derate Inhibit	Derate info added by CARB
EOI2	61711	Engine Self-Induced Derate Load	Derate info added by CARB
EOI	64914	Engine Derate Request	Derate info added by CARB
TTI1	65204	Trip Time in Derate by Engine	Derate info added by CARB

Pilot Study SAE J1979 Parameters (PSIP exemption mandatory in bold)
Data provided on a "by controller" basis

Mode	PID	Description	Comments
1	**01**	**MIL, DTC count, status of monitors**	
1	02	Freeze frame DTC	
1	**1C**	**OBD Requirements to which vehicle is designed**	
1	**21**	**Distance Travelled While MIL is Activated**	
1	**30**	**Number of Warm-ups Since DTC Cleared**	
1	**31**	**Distance since diagnostic trouble codes cleared**	
1	41	Monitor status (trip-based)	Readiness status of various monitors
1	**4D**	**Minutes Run with MIL Activated**	
1	**4E**	**Time Since DTCs Were Cleared**	Time Since DTC Cleared
1	A6	Odometer	May provide vehicle odometer info
1	ALL	All other live data PIDs	
2	All	Freeze Frame Data	Shows freeze frame data
3	**N/A**	**Stored DTCs**	Confirmed and historical DTCs.
6	N/A	Test Mode	On-board monitoring results
7	**N/A**	**Pending DTCs**	Unconfirmed DTCs
9	**01, 02**	**Vehicle info, VIN**	
9	**03, 04**	**Vehicle info, Cal ID**	
9	**05, 06**	**Vehicle info, CVN**	
9	09, 0A	ECU ID	
9	**0D**	**Engine Serial Number**	
0A	**N/A**	**Permanent DTCs**	Identical format to Mode 3 DTCs but cannot be cleared with a scan tool (Mode 4 command), ECM must clear.

Appendix B

Summary of Vehicles Tested During OBD Field Evaluation

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Main	2HSCTAPR0AC06xxxx	2010	International	LF617	14.99L	Pass	J1939
Main	1M1AW07Y9DM02xxxx	2013	Mack	CXU	12.7L	Pass	J1939
Main	1M1AW07Y0DM02xxxx	2013	Mack	CXU	12.7L	Pass	J1939
Main	1FUJGLDRXDSBTxxxx	2013	Freightliner	Cascadia	14.8L	Pass	J1939
Main	1FUJGBDV6HLJFxxxx	2017	Freightliner	Cascadia	12.8L	Pass	J1939
Main	1FUJHHDR1KLKHxxxx	2019	Freightliner	Cascadia	14.8L	Fail	J1939
Main	3AKJGLBG9GSHKxxxx	2016	Freightliner	Cascadia	14.9L	Pass	J1939
Main	3AKJHHDR2MSMHxxxx	2021	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3ALACWDT2EDFLxxxx	2014	Freightliner	M2	6.7L	Pass	J1939
Main	1FUBC5DV0MHMKxxxx	2021	Freightliner	M2	12.8L	Pass	J1939
Main	1FUJGEDR0BSAVxxxx	2011	Freightliner	Cascadia	14.8L	Pass	J1939
Main	1FVHCYFE0KHKSxxxx	2019	Freightliner	M2	9L	Pass	J1939
Main	1XPBA47X6GD28xxxx	2016	Peterbilt	579	15L	Pass	J1939
Main	1XPBD49X1FD23xxxx	2015	Peterbilt	579	15L	Pass	J1939
Main	1XPBD49X7JD35xxxx	2018	Peterbilt	579	15L	Pass	J1939
Main	3AKBCYCY5EDFYxxxx	2014	Freightliner	M2	8.9L	Pass	J1939
Main	4UZADRFD7JCKFxxxx	2018	Freightliner	S2C 106	6.7L	Pass	J1939
Main	1FUJGBDV4GLGSxxxx	2016	Freightliner	Cascadia	12.8L	Pass	J1939
Main	1FUJGEDV8GLHNxxxx	2016	Freightliner	Cascadia	12.8L	Pass	J1939
Main	1HTEVTAR5LH85xxxx	2020	International	MV607	8.8L	Pass	J1939
Main	1HTMMMML9FH74xxxx	2015	International	MA025	5.9L	Fail	J1939
Main	1HTMMMMLXJH71xxxx	2018	International	MA025	6.7L	Fail	J1939
Main	1XPBDP9X3ED24xxxx	2014	Peterbilt	579	12.9L	Fail	J1939
Main	3AKJGEDR3ESFJxxxx	2014	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3AKJGEDR4JSJKxxxx	2018	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3AKJGLDR6KDJYxxxx	2019	Freightliner	Cascadia	14.8L	Fail	J1939
Main	3ALACWFC1MDMKxxxx	2021	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC7JDKAxxxx	2018	Freightliner	M2	6.7L	Pass	J1939
Main	3HAEUMML2LL45xxxx	2020	International	MV607	6.7L	Pass	J1939
Main	3HAEUMMN9LL84xxxx	2020	International	MV607	6.7L	Pass	J1939
Main	3WKZD40X4LF41xxxx	2020	Kenworth	T880	15L	Pass	J1939
Main	3ALACXCY0GDHNxxxx	2016	Freightliner	M2	8.9L	Pass	J1939
Main	3HAEUMML2LL43xxxx	2020	International	MV607	6.7L	Pass	J1939
Main	3HAEUMML2LL84xxxx	2020	International	MV607	6.7L	Pass	J1939
Main	3HAEUMML7LL42xxxx	2020	International	MV607	6.7L	Fail	J1939
Main	3HSDJAPR8FN11xxxx	2015	International	LF687	14.99L	Fail	J1939
Main	3HSDZAPR5JN59xxxx	2018	International	LT285	14.99L	Pass	J1939
Main	3HSDZAPRXKN84xxxx	2019	International	LT285	14.99L	Pass	J1939
Main	unknown_vin_1	.				Pass	J1939
Main	1FUJGBDV2KLKExxxx	2019	Freightliner	Cascadia	12.8L	Pass	J1939
Main	1FUJGBDV6GLGSxxxx	2016	Freightliner	Cascadia	12.8L	Pass	J1939
Main	1FUJGLBG6HLJFxxxx	2017	Freightliner	Cascadia	14.9L	Fail	J1939
Main	1FVACWDT9GHHPxxxx	2016	Freightliner	M2	6.7L	Fail	J1939
Main	1FVHCYCY3GHHMxxxx	2016	Freightliner	M2	8.9L	Fail	J1939
Main	1HTMMMML2GH01xxxx	2016	International	MA025	5.9L	Fail	J1939
Main	2NKHHM6X0HM14xxxx	2017	Kenworth	T3 Series	6.7L	Fail	J1939
Main	3AKJGBD49ESFRxxxx	2014	Freightliner	Cascadia	11.9L	Fail	J1939
Main	3AKJGEDR5JSJKxxxx	2018	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3AKJGEDVXESFTxxxx	2014	Freightliner	Cascadia	12.8L	Pass	J1939
Main	3AKJGHDV4LDLRxxxx	2020	Freightliner	Cascadia	12.8L	Pass	J1939
Main	3AKJGLBGXGSHKxxxx	2016	Freightliner	Cascadia	14.9L	Pass	J1939
Main	3AKJGLD5XFSGLxxxx	2015	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3AKJHHDR6LSLPxxxx	2020	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3AKNGED51GSHSxxxx	2016	Freightliner	Cascadia	14.8L	Fail	J1939
Main	3ALACWDT2GDHGxxxx	2016	Freightliner	M2	6.7L	Fail	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Main	3ALACWDT4FDGAxxxx	2015	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWDT5EDFNxxxx	2014	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC0JDJPxxxx	2018	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC2JDJTxxxx	2018	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC2JDKAxxxx	2018	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC6JDJMxxxx	2018	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC8KDKSxxxx	2019	Freightliner	M2	6.7L	Pass	J1939
Main	1M1AN07Y2DM01xxxx	2013	Mack	CHU	12.7L	Fail	J1939
Main	1NKBLJ0X0LR35xxxx	2020	Kenworth	T4 Series	8.9L	Pass	J1939
Main	1NKBLJ0X1FJ44xxxx	2015	Kenworth	T4 Series	8.9L	Pass	J1939
Main	1NKBLJ0X3FJ44xxxx	2015	Kenworth	T4 Series	8.9L	Pass	J1939
Main	1NKBLJ0X6LR35xxxx	2020	Kenworth	T4 Series	8.9L	Fail	J1939
Main	1NKBLJ0X9KR24xxxx	2019	Kenworth	T4 Series	8.9L	Fail	J1939
Main	1XKZA48X4JJ21xxxx	2018	Kenworth	T880	15L	Pass	J1939
Main	1XKZD40X2LJ39xxxx	2020	Kenworth	T880	15L	Pass	J1939
Main	1XKZD49X2JJ19xxxx	2018	Kenworth	T880	15L	Pass	J1939
Main	1XKZD49X3JJ19xxxx	2018	Kenworth	T880	15L	Pass	J1939
Main	1XKZD49X5LJ29xxxx	2020	Kenworth	T880	15L	Fail	J1939
Main	1M1AN07Y0DM01xxxx	2013	Mack	CHU	12.7L	Fail	J1939
Main	1HTEUMML9KH80xxxx	2019	International	MV607	6.7L	Pass	J1939
Main	1HTMMMML2KH58xxxx	2019	International	MA025	6.7L	Pass	J1939
Main	3AKJGLBG9GSHDxxxx	2016	Freightliner	Cascadia	14.9L	Pass	J1939
Main	3AKJGLDR3LSLCxxxx	2020	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3ALACWDT0FDGRxxxx	2015	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWDT5GDHCxxxx	2016	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWDT6FDGAxxxx	2015	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWDT6HDHZxxxx	2017	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWDU2HDHZxxxx	2017	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFB0LDLSxxxx	2020	Freightliner	M2	5.1L	Fail	J1939
Main	3ALACWFC2LDLNxxxx	2020	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC2MDMMxxxx	2021	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC2MDMPxxxx	2021	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFC4JDKAxxxx	2018	Freightliner	M2	6.7L	Fail	J1939
Main	3ALACWFC9LDLMxxxx	2020	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWFE0KDKUxxxx	2019	Freightliner	M2	9L	Pass	J1939
Main	3ALACXDT9EDFVxxxx	2014	Freightliner	M2	6.7L	Pass	J1939
Main	3HAEUMML0LL41xxxx	2020	International	MV607	6.7L	Fail	J1939
Main	3HSDJAPR6HN46xxxx	2017	International	LF687	14.99L	Pass	J1939
Main	3HSDZAPR6KN02xxxx	2019	International	LT625	14.99L	Pass	J1939
Main	4DRBUPWN1LB21xxxx	2020	IC Bus	PB105	8.8L	Pass	J1939
Main	4DRBWTAN1KB53xxxx	2019	IC Bus	PB305	8.8L	Pass	J1939
Main	4UZABRDT7FCFWxxxx	2015	Freightliner	B2 Bus	6.7L	Pass	J1939
Main	4UZABRDT9ECFGxxxx	2014	Freightliner	B2 Bus	6.7L	Pass	J1939
Main	4UZABRDT9FCGFxxxx	2015	Freightliner	B2 Bus	6.7L	Pass	J1939
Main	unknown_vin_2	.				Pass	J1939
Main	unknown_vin_3	.				Pass	J1939
Main	1BAKGCSA1MF37xxxx	2021	Bluebird	BB Conventional	6.7L	Pass	J1939
Main	1BAKGCSA3MF37xxxx	2021	Bluebird	BB Conventional	6.7L	Pass	J1939
Main	1BAKGCSAXMF37xxxx	2021	Bluebird	BB Conventional	6.7L	Pass	J1939
Main	4DRBUAAN1CB39xxxx	2012	IC Bus	PB105	7.6L	Pass	J1939
Main	4DRBUAAN8CB39xxxx	2012	IC Bus	PB105	7.6L	Pass	J1939
Main	4DRBUAANXCB39xxxx	2012	IC Bus	PB105	7.6L	Pass	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Main	4DRBUC8N1LB87xxxx	2020	IC Bus	PB105	6.7L	Pass	J1939
Main	4DRBUC8N2GB12xxxx	2016	IC Bus	PB105	5.9L	Fail	J1939
Main	4DRBUC8N4JB57xxxx	2018	IC Bus	PB105	6.7L	Pass	J1939
Main	4DRBUC8N8LB87xxxx	2020	IC Bus	PB105	6.7L	Pass	J1939
Main	4DRBUC8NXLB87xxxx	2020	IC Bus	PB105	6.7L	Pass	J1939
Main	3HAGRSNT0GL21xxxx	2016	International	SF567	12.4L	Pass	J1939
Main	3HTGRSNT0GN07xxxx	2016	International	SF567	12.4L	Fail	J1939
Main	4P1BAAGF3LA02xxxx	2020	Pierce	Pumper		Pass	J1939
Main	4P1BCAGF5FA01xxxx	2015	Pierce	Aerial		Pass	J1939
Main	12990	.				Fail	J1939
Main	1HTMNMMLXHH47xxxx	2017	International	MH025	6.7L	Pass	J1939
Main	1FVMG3DV8LHKWxxxx	2020	Freightliner	114SD	12.8L	Pass	J1939
Main	1FVMG3DVXLHKWxxxx	2020	Freightliner	114SD	12.8L	Pass	J1939
Main	3HAGSSNT2JL21xxxx	2018	International	SF667	12.4L	Pass	J1939
Main	1M8PDMBA3DPO1xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	1M8PDMBA6DPO1xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	1M8PDMBA7DPO1xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	1M8PDMBAXDPO1xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	5FYD8YU00EB04xxxx	2014	New Flyer	Xcelsior	8.9L	Pass	J1939
Main	5FYD8YU07FB04xxxx	2015	New Flyer	Xcelsior	8.9L	Fail	J1939
Main	5FYD8YU8FB047xxxx	.				Pass	J1939
Main	15GGD271XE118xxxx	2014	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	15GGD2710F118xxxx	2015	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	15GGD2711E118xxxx	2014	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	15GGD2711F118xxxx	2015	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	15GGD2712E118xxxx	2014	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	15GGD2712F118xxxx	2015	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	15GGD2715E118xxxx	2014	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	15GGD2719H118xxxx	2017	Gillig	Low Floor Bus	8.9L	Pass	J1939
Main	unknown_vin_4	.				Pass	J1939
Main	1M8PDBA5DP012xxxx	.				Pass	J1939
Main	1M8PDMBA1DP01xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	1M8PDMBA1DPO1xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	1M8PDMBA2DP01xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	1M8PDMBA2DPO1xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	1M8PDMBA3DPO1xxxx	2013	Motor Coach Industries	102DL3 Intercity	12L	Pass	J1939
Main	3BPDXK0X6LF10xxxx	2020	Peterbilt	520		Pass	J1939
Main	3BPDXK0X8LF10xxxx	2020	Peterbilt	520		Pass	J1939
Main	3BPDXK0X8MF11xxxx	2021	Peterbilt	520		Pass	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Main	3BPDXK0XXMF11xxxx	2021	Peterbilt	520		Pass	J1939
Main	1NPCLK0X0LD66xxxx	2020	Peterbilt	567		Pass	J1939
Main	1NPCLK0X1JD49xxxx	2018	Peterbilt	567		Pass	J1939
Main	1NPCLK0X3JD49xxxx	2018	Peterbilt	567		Fail	J1939
Main	1NPCLK0X3MD74xxxx	2021	Peterbilt	567		Pass	J1939
Main	1NPCLK0X5JD49xxxx	2018	Peterbilt	567		Pass	J1939
Main	1NPCLK0X7JD49xxxx	2018	Peterbilt	567		Pass	J1939
Main	1NPCLK0X8JD49xxxx	2018	Peterbilt	567		Pass	J1939
Main	1NPCLK0X9JD49xxxx	2018	Peterbilt	567		Pass	J1939
Main	1NPCLK0X9LD66xxxx	2020	Peterbilt	567		Pass	J1939
Main	1NPCLK0XXJD49xxxx	2018	Peterbilt	567		Pass	J1939
Main	1NPCXKEXXKD62xxxx	2019	Peterbilt	567		Pass	J1939
Main	3BPDLK0X6LF10xxxx	2020	Peterbilt	520		Pass	J1939
Main	3BPDLK0X6LF10xxxx	2020	Peterbilt	520		Pass	J1939
Main	3BPDXK0X1LF10xxxx	2020	Peterbilt	520		Pass	J1939
Main	3BPDXK0X1MF11xxxx	2021	Peterbilt	520		Pass	J1939
Main	3BPDXK0X3LF10xxxx	2020	Peterbilt	520		Fail	J1939
Main	3BPDXK0X4LF10xxxx	2020	Peterbilt	520		Pass	J1939
Main	1NPTL49X9DD16xxxx	2013	Peterbilt	367	15L	Pass	J1939
Main	1XKYDK9X4MJ44xxxx	2021	Kenworth	T680	10.8L	Pass	J1939
Main	2NP3LJ0X9EM24xxxx	2014	Peterbilt	348	8.9L	Pass	J1939
Main	2NP3LJ9X4JM46xxxx	2018	Peterbilt	348	8.9L	Pass	J1939
Main	2NP3LJ9X6JM48xxxx	2018	Peterbilt	348	8.9L	Pass	J1939
Main	3BKBLJ9X8LF39xxxx	2020	Kenworth	T4 Series	8.9L	Pass	J1939
Main	792245M	.				Pass	J1939
Main	D164190	.				Pass	J1939
Main	1HTMMMML3KH51xxxx	2019	International	MA025	6.7L	Pass	J1939
Main	1HTMMMML8JH46xxxx	2018	International	MA025	6.7L	Pass	J1939
Main	3AKBGGDV9LDLPxxxx	2020	Freightliner	Cascadia	12.8L	Pass	J1939
Main	3AKJGLDR3JSJNxxxx	2018	Freightliner	Cascadia	14.8L	Pass	J1939
Main	3ALACWDT3FDGMxxxx	2015	Freightliner	M2	6.7L	Fail	J1939
Main	3ALACWDT3GDGZxxxx	2016	Freightliner	M2	6.7L	Fail	J1939
Main	3ALACWDT4FDGKxxxx	2015	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWDT5GDGVxxxx	2016	Freightliner	M2	6.7L	Pass	J1939
Main	3ALACWDT9FDGMxxxx	2015	Freightliner	M2	6.7L	Fail	J1939
Main	3ALACWFC0LDLNxxxx	2020	Freightliner	M2	6.7L	Pass	J1939
Main	3HAEUMML3ML47xxxx	2021	International	MV607	6.7L	Fail	J1939
Main	3HAEUMML4LL07xxxx	2020	International	MV607	6.7L	Pass	J1939
Main	3HAMMMML0HL45xxxx	2017	International	MA025	6.7L	Pass	J1939
Main	3HAMMMML5JL46xxxx	2018	International	MA025	6.7L	Pass	J1939
Main	3HSDZAPR3LN29xxxx	2020	International	LT625	14.99L	Pass	J1939
Main	3HSDZTZR9LN31xxxx	2020	International	LT625	13L	Pass	J1939
Main	5FYD8YU01EB04xxxx	2014	New Flyer	Xcelsior	8.9L	Pass	J1939
Main	5FYD8YU02EB04xxxx	2014	New Flyer	Xcelsior	8.9L	Fail	J1939
Main	5FYD8YU07EB04xxxx	2014	New Flyer	Xcelsior	8.9L	Fail	J1939
Main	5FYD8YU07EB04xxxx	2014	New Flyer	Xcelsior	8.9L	Pass	J1939
Main	5FYD8YU07EB04xxxx	2014	New Flyer	Xcelsior	8.9L	Fail	J1939
Main_rtst	5FYD8YU07FB04xxxx	2015	New Flyer	Xcelsior	8.9L	Pass	J1939
Main	1FUJGBDV2FLGGxxxx	2015	Freightliner	Cascadia	12.8L	Pass	J1939
Main	1HTMKTAL4HH18xxxx	2017	International	MA035	8.8L	Pass	J1939
Main	1HTWKAZN18J69xxxx	2008	International	SA637	9.34L	Pass	J1939
Main	1HTWKAZN88J69xxxx	2008	International	SA637	9.34L	Pass	J1939
Main	1HTWMAZN29J08xxxx	2009	International	SR537	9.34L	Pass	J1939
Main	1HTWWAZT18J55xxxx	2008	International	SX537	9.34L	Pass	J1939
Main	1NP9L59X0CD15xxxx	2012	Peterbilt	382	8.9L	Pass	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Main	3FRXF75X08V05xxxx	2008	Ford	F-750	7.2L	Fail	J1939
Main	3HAGRSNT5HL15xxxx	2017	International	SF567	12.4L	Fail	J1939
Main_rtst	3HAGSSNT2JL21xxxx	2018	International	SF667	12.4L	Pass	J1939
Main	3HAGSSNT4JL79xxxx	2018	International	SF667	12.4L	Pass	J1939
Main	3HAWESTN4HL02xxxx	2017	International	SR525	9.3L	Fail	J1939
Main	788711D					Pass	J1939
Main	788713D					Pass	J1939
Main	1FVHG3DV1JHJRxxxx	2018	Freightliner	114SD	12.8L	Pass	J1939
Main	4V4NC9EH2DN13xxxx	2013	Volvo Trucks NA	VNL	12.8L	Pass	J1939
Main	4V4NC9TH5HN93xxxx	2017	Volvo Trucks NA	VNL	15L	Pass	J1939
Main	4V4NC9EG3GN93xxxx	2016	Volvo Trucks NA	VNL	12.8L	Pass	J1979
Main	4V4NC9EH4LN23xxxx	2020	Volvo Trucks NA	VNL	12.8L	Pass	J1979
Main	4V4NC9EH5JN89xxxx	2018	Volvo Trucks NA	VNL	12.8L	Pass	J1979
Main	4V4NC9EH7NN60xxxx	2022	Volvo Trucks NA		6.6L	Pass	J1979
Main	4V4NC9EH9GN96xxxx	2016	Volvo Trucks NA	VNL	12.8L	Pass	J1979
Main	4V4NC9EH9LN23xxxx	2020	Volvo Trucks NA	VNL	12.8L	Pass	J1979
Main	4V4NC9EH3EN16xxxx	2014	Volvo Trucks NA	VNL	12.8L	Fail	J1979
Main	4V4NC9EH3GN97xxxx	2016	Volvo Trucks NA	VNL	12.8L	Pass	J1979
Main	4V4NC9EH3JN89xxxx	2018	Volvo Trucks NA	VNL	12.8L	Pass	J1979
Local	3ALACWDT7EDGAxxxx	2014	FREIGHTLINER		ISB 6.7	Pass	J1939
Local	2NPLHN6X58M75xxxx	2007	Peterbilt	335	PACCAR	Pass	J1939
Local	JALC4W169G700xxxx	2016	Isuzu	Incomplete 4x2 NPR		Pass	Both
Local	5PVNJ8JT0H4S5xxxx	2017	Hino	Conventional Type Tr	7.6 L	Pass	Both
Local	3ALACWDT5FDGTxxxx	2015	FREIGHTLINER	106 MD	ISB (6.7)	Pass	J1939
Local	3ALACWDT2GDHTxxxx	2016	FREIGHTLINER	106 MD	ISB (6.7)	Pass	J1939
Local	3AKJGEBG4GSHAxxxx	2016	FREIGHTLINER	Cascadia	ISX15 450	Pass	J1939
Local	3ALACWDT9GDHDxxxx	2016	FREIGHTLINER	106 MD	ISB (6.7)	Pass	J1939
Local	1HTMMMML4GH21xxxx	2016	Navistar/International	DuraStar 4300	ISX15 450	Fail	J1939
Mtn Pass	1XKYDP9X0JJ21xxxx	2018	Kenworth	T680	12.9L	Fail	J1939
Mtn Pass	1NPCL70X7GD32xxxx	2016	Peterbilt	567		Pass	J1939
Mtn Pass	1xpxd49x6fd28xxxx	.				Fail	J1939
Mtn Pass		2011	Volvo	VNL		Fail	J1939
Mtn Pass	1FUJGLBG2ELFJxxxx	2014	Freightliner	Cascadia	14.9L	Pass	J1939
Mtn Pass	3AKJHHDR5JSGHxxxx	2018		Cascadia	14.8L	Pass	J1939
Mtn Pass		2011	Volvo	VNL		Pass	J1939
Mtn Pass	1XPXD49X0KD61xxxx	2019	Peterbilt	389	15L	Pass	J1939
Mtn Pass	1XKAD49X2CJ32xxxx	2012	Peterbilt	389	15L	Pass	J1939
Mtn Pass	1XKYDP9X2FJ42xxxx	2015	Kenworth	T680	12.9L	Fail	J1939
Mtn Pass	1XPXD49X4LD71xxxx	2020	Peterbilt	389	15L	Pass	J1939
Mtn Pass	3AKJGLDR0HSGVxxxx	2017	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	1FUJGLDR0CSBNxxxx	2012	Freightliner	Cascadia	14.8L	Fail	J1939
Mtn Pass	3AKJGNDRXKDKLxxxx	2019	Freightliner	SD122	14.8L	Pass	J1939
Mtn Pass		2010	Peterbilt	386		Pass	J1939
Mtn Pass	3HSDJSJR3EN03xxxx	2014	International	LF687	13L	Pass	J1939
Mtn Pass	1XKYD49XXMJ43xxxx	2021	Kenworth	T680	15L	Pass	J1939
Mtn Pass		2013	Kenworth			Fail	J1939
Mtn Pass	1XPXDP9X6LD67xxxx	2020	Peterbilt	389	12.9L	Pass	J1939
Mtn Pass	3HSDZAPR5LN10xxxx	2020	International	LT625	14.99	Pass	J1939
Mtn Pass	1xpbd49xxjd46xxxx	.	Peterbilt	579	15L	Pass	J1939
Mtn Pass	3AKJGLDR1JSJXxxxx	2018	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	1XKYD49X0FJ45xxxx	2015	Kenworth	T680	15L	Pass	J1939
Mtn Pass	1XPBD49X7MD74xxxx	2021	Peterbilt	579	15L	Pass	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Mtn Pass	1XPXD49X8FD23xxxx	2015	Peterbilt	389	15L	Pass	J1939
Mtn Pass	5KJBAUDV8KPKExxxx	2019	Western Star	4700	12.8L	Pass	J1939
Mtn Pass	1XPBDP9X4LD67xxxx	2020	Peterbilt	579	12.9L	Pass	J1939
Mtn Pass	3AKJHHDR3KSKJxxxx	2019	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	3AKJGNDV3FDGLxxxx	2015	Freightliner	Coronado	12.8L	Fail	J1939
Mtn Pass	3AKJHHDR3MSMCxxxx	2021	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	3AKJHHDR4KSJXxxxx	2019	Freightliner	Cascadia	14.8L	Fail	J1939
Mtn Pass	2HSCUAPRX9C10xxxx	2009	International	LF627	14.99L	Pass	J1939
Mtn Pass	3AKBGEDV3GSGYxxxx	2016	Freightliner	Cascadia	12.8L	Pass	J1939
Mtn Pass	1XKYD49X6HJ15xxxx	2017	Kenworth	T680	15L	Pass	J1939
Mtn Pass		2016	Kenworth	T680		Pass	J1939
Mtn Pass		2008	Peterbilt	387		Pass	J1939
Mtn Pass	1FUGGLD53ELFKxxxx	2014	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	1XPBD49X4KD63xxxx	2019	Peterbilt	579	15L	Pass	J1939
Mtn Pass	1XKWD49X6GJ11xxxx	2016	Kenworth	W9 Series	15L	Fail	J1939
Mtn Pass	1XPBD49X3LD65xxxx	2020	Peterbilt	579	15L	Pass	J1939
Mtn Pass	1FUJHHDR2KLKNxxxx	2019	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	3HSCXAPR2HN22xxxx	2017	International	LF517	14.99L	Pass	J1939
Mtn Pass	1XKYD49X5LJ22xxxx	2020	Kenworth	T680	15L	Fail	J1939
Mtn Pass	3AKJHHDR0LSLHxxxx	2020	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	3AKJHHDR8KSJWxxxx	.				Pass	J1939
Mtn Pass	3AKJHHDR5MSMHxxxx	.				Pass	J1939
Mtn Pass	1XKYD49X1LJ37xxxx	2020	Kenworth	T680	15L	Pass	J1939
Mtn Pass	3AKJHHDRXLSLPxxxx	.				Pass	J1939
Mtn Pass	3AKJHHDR3KSHDxxxx	.				Fail	J1939
Mtn Pass	1XPBA48X1JD47xxxx	2018	Peterbilt	579	15L	Pass	J1939
Mtn Pass	1XPBD49X8LD65xxxx	2020	Peterbilt	579	15L	Pass	J1939
Mtn Pass	3AKJHHDRXLSKRxxxx	2020	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	3AKJGLD50GSGYxxxx	2016	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	3HSDZAPR5KN56xxxx	2019	International	LT625	14.99L	Pass	J1939
Mtn Pass	3HSDZAPR2LN25xxxx	2020	International	LT625	14.99L	Pass	J1939
Mtn Pass	3HSDZAPR4LN09xxxx	2020	International	LT625	14.99L	Pass	J1939
Mtn Pass	3HSDZAPRXLN89xxxx	2020	International	LT625	14.99L	Pass	J1939
Mtn Pass	5KKHAEBG7CPBUxxxx	2012	Western Star	4900	14.9L	Pass	J1939
Mtn Pass	4V4NC9TH5CN55xxxx	2012	Volvo	VNL	15L	Pass	J1939
Mtn Pass	3HSDJSJRXCN42xxxx	2012	International	LF687	13L	Pass	J1939
Mtn Pass	3HSCXAPRXGN03xxxx	2016	International	LF517	14.99L	Pass	J1939
Mtn Pass	3HSDZAPR6LN86xxxx	2020	International	LT625	14.99L	Pass	J1939
Mtn Pass	4V5NC9UF1EN17xxxx	2014	Volvo	VNL		Pass	J1939
Mtn Pass	1HTMMAAL2DH12xxxx	2013	International	MA025	7.6L	Pass	J1939
Mtn Pass	1XPBDP9X4GD29xxxx	2016	Peterbilt	579	12.9L	Fail	J1939
Mtn Pass	3HSDZAPR7KN04xxxx	2019	International	LT625	14.99L	Pass	J1939
Mtn Pass	3HSCUAPR1AN20xxxx	2010	International	LF627	14.99L	Pass	J1939
Mtn Pass	3HSDZAPR7JN36xxxx	2018	International	LT625	14.99L	Pass	J1939
Mtn Pass	2HSCUAPR59C10xxxx	2009				Pass	J1939
Mtn Pass	3HSDZAPRXLN81xxxx	2020	International	LT625	14.99L	Pass	J1939
Mtn Pass	3HSDZAPR2MN66xxxx	2021	International	LT625	14.99L	Pass	J1939
Mtn Pass	1FVHG3DV4KHKMxxxx	2019	Freightliner	114SD	12.8L	Pass	J1939
Mtn Pass	5KJJBHDR9KLKFxxxx	2019	Western Star	5700	14.8L	Pass	J1939
Mtn Pass		.				Pass	J1939
Mtn Pass	3HSDJAPR1GN28xxxx	2016	International	LF687	14.99L	Pass	J1939
Mtn Pass	5KJJBHD19GLGYxxxx	2016	Western Star	5700	15.6L	Pass	J1939
Mtn Pass	1HTMMMML9JH54xxxx	2018	International	MA025	6.7L	Pass	J1939
Mtn Pass	3HSDZAPR7LN84xxxx	2020	International	LT625	14.99L	Pass	J1939
Mtn Pass	4V4NC9TH2KN21xxxx	2019	Volvo	VNL	15L	Pass	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Mtn Pass	4V4NC9E0CN544xxxx	.				Pass	J1939
Mtn Pass	3AKJHHDR9JSJRxxxx	2018	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	4V4NC9EH5HN96xxxx	2017	Volvo	VNL	12.8L	Fail	Both
Mtn Pass	3HSDZTZR5LN06xxxx	2020	International	LT625	13L	Pass	J1939
Mtn Pass	1XKYDP9XXKJ27xxxx	2019	Kenworth	T680	12.9L	Pass	J1939
Mtn Pass	1FUJGLD52FLGMxxxx	2015	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	3HSDZAPR0MN33xxxx	2021	International	LT625	14.99L	Pass	J1939
Mtn Pass	1XPFDB9XX5N84xxxx	2005	Peterbilt	378		Pass	J1939
Mtn Pass	3AKJHHDR6LSKNxxxx	2020	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	1FUJGLDR6CLBExxxx	2012	Freightliner	Cascadia	14.8L	Pass	J1939
Mtn Pass	1XKYD49X5LJ34xxxx	2020	Kenworth	T680	15L	Pass	J1939
Mtn Pass		2010	Kenworth			Pass	J1939
Mtn Pass	3AKJHHDR6JSHDxxxx	2018	Freightliner	Cascadia	14.8L	Fail	J1939
Mtn Pass	3AKJHHDR6JSHDxxxx	2018	Freightliner	Cascadia	14.8L	Fail	J1939
Mtn Pass	1M1AN2AY2LM00xxxx	2020	Mack	Anthem	11L	Pass	J1979
Mtn Pass	4V4NC9EH3LN23xxxx	2020	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	1M1AN4GY3KM00xxxx	2019	Mack	Anthem	13L	Fail	J1979
Mtn Pass	1M1AW07Y1HM07xxxx	2017	Mack	CXU	12.7L	Pass	J1979
Mtn Pass	5PVNJ8JT6F4S5xxxx	2015	Hino	Conventional Type Truck	7.6L	Pass	J1979
Mtn Pass	4V4NC9EJ5HN98xxxx	2017	Volvo	VNL	12.8L	Pass	J1979
Mtn Pass	4V4NC9EH7KN19xxxx	2019	Volvo	VNL	12.8L	Pass	J1979
Mtn Pass	4V4NC9EH4MN27xxxx	2021	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	4V4NC9EH7GN95xxxx	2016	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	4V4NC9EJ0HN98xxxx	2017	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	1M1AN3GY9LM01xxxx	2020	Mack	Anthem	13L	Pass	J1979
Mtn Pass	5PVNJ8JV9G4S5xxxx	2016	Hino	Conventional Type Truck	7.6L	Pass	J1979
Mtn Pass	5PVNJ8JV2G4S5xxxx	2016	Hino	Conventional Type Truck	7.6L	Pass	J1979
Mtn Pass	4V4NC9EH9HN97xxxx	2017	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	4V4NC9EH0JN99xxxx	2018	Volvo	VNL	12.8L	Pass	J1979
Mtn Pass	4V4NC9EH7HN98xxxx	2017	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	4V4NC9EH8GN94xxxx	2016	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	4V5RC9EH0FN18xxxx	2015	Volvo	VAH	12.8L	Pass	J1979
Mtn Pass	5PVNJ8JV5J4S6xxxx	2018	Hino	Conventional Type Truck	7.6L	Pass	J1979
Mtn Pass	4V4NC9EH7LN25xxxx	2020	Volvo	VNL	12.8L	Pass	J1979
Mtn Pass	4V4N19EJ6GN94xxxx	2016	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	4V4W19EG2MN27xxxx	2021	Volvo	VNR	12.8L	Pass	J1979
Mtn Pass	4V4NC9EH5LN23xxxx	2020	Volvo	VNL	12.8L	Pass	J1979
Mtn Pass	4V4NC9EH7LN26xxxx	2020	Volvo	VNL	12.8L	Pass	J1979
Mtn Pass	4V4NC9EG0EN16xxxx	2014	Volvo	VNL	12.8L	Fail	J1979
Mtn Pass	4V4NC9EH6KN90xxxx	2019	Volvo	VNL	12.8L	Pass	J1979
Mtn Pass	1M1AW09Y7HM08xxxx	2017	Mack	CXU	12.7L	Pass	J1979
Mtn Pass	1XPHD49X6ED23xxxx	2014	Peterbilt	386	15L	Pass	J1939
Mtn Pass		2016	Freightliner			Pass	J1939
Mtn Pass	1XKWD49X8LR39xxxx	2020	Kenworth	W9	15L	Pass	J1939
Rpr Shop	DSBT4994	2013	Freightliner	Cascadia	DD13	N/A	J1939
Rpr Shop	HW067802	2016	MCI	J4500	DD13	N/A	J1939
Rpr Shop	HW068260	2017	MCI	J4500	DD13	N/A	J1939
Rpr Shop	HW067805	2016	MCI	J4500	DD13	N/A	J1939
Rpr Shop	F2041209	2015	Van	TX40	DD13	N/A	J1939
Rpr Shop	JD494647	2018	Peterbilt	389	0	N/A	J1939
Rpr Shop	HJ137790	2016	Kenworth	0	12.0L ISX	N/A	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Rpr Shop	DHFA2426	2013	Freightliner	114SD	8.9L ISL	N/A	J1939
Rpr Shop	JDJV7320	2018	Freightliner	BUSINESS	B6.7	N/A	J1939
Rpr Shop	JDJV7323	2018	Freightliner	BUSINESS	B6.7	N/A	J1939
Rpr Shop	JHJN5164	2018	Freightliner	BUSINESS	B6.7	N/A	J1939
Rpr Shop	DDFB5945	2013	Freightliner	M2 106 MD	ISB	N/A	J1939
Rpr Shop	DHBZ1841	2013	Freightliner	Business Class M2	ISB	N/A	J1939
Rpr Shop	DDFG9713	2013	Freightliner	Business Class M2	isb 325	N/A	J1939
Rpr Shop	DDFG9711	2013	Freightliner	M2	isb 325	N/A	J1939
Rpr Shop	DDFG9712	2013	Freightliner	M2 106 MD	isb 325	N/A	J1939
Rpr Shop	HDJD7067	2017	Freightliner	M2 106 MD	ISB 6.7 260	N/A	J1939
Rpr Shop	FHGT1765	2015	Freightliner	M2	ISB6.7	N/A	J1939
Rpr Shop	HDJG4768	2017	Freightliner	M2	ISB6.7	N/A	J1939
Rpr Shop	HDJG4764	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HDJC2381	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HDJG4762	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HDJC2389	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HDJD7083	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HDJG4763	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HDJG4771	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HDJG4842	2017	Freightliner	M2 106 MD	ISB6.7	N/A	J1939
Rpr Shop	HH746111	2017	International	DuraStar 4300	ISB6.7	N/A	J1939
Rpr Shop	DF289321	2013	Blue Bird	All American/All Canadian	ISC8.3	N/A	J1939
Rpr Shop	EH216613	2014	Other	Xpeditor	ISL	N/A	J1939
Rpr Shop	EM409404	2014	Kenworth	0	ISL9	N/A	J1939
Rpr Shop	EH057678	2014	International	Prostar	ISX	N/A	J1939
Rpr Shop	EW066768	2014	MCI	J4500	ISX	N/A	J1939
Rpr Shop	EH057679	2014	International	Prostar	ISX	N/A	J1939
Rpr Shop	DD211491	2013	Peterbilt	386	ISX15	N/A	J1939
Rpr Shop	EH042307	2014	International	Prostar	ISX15 425ST	N/A	J1939
Rpr Shop	FJ438161	2015	Kenworth	T800	ISX15 450	N/A	J1939
Rpr Shop	EM243969	2014	Peterbilt	337	PX-9	N/A	J1939
Rpr Shop	EM243080	2014	Peterbilt	335	PX-9	N/A	J1939
Rpr Shop	E3010207	2014	Mercedes	TC 417S	471932C0083503	N/A	J1939
Rpr Shop	E3010176	2014	Evobus	TC 417S	471932COO60777	N/A	J1939
Rpr Shop	D3010158	2013	Evobus	TCS 417	DD13	N/A	J1939
Rpr Shop	D3010148	2013	Other	TCS 417	DD13	N/A	J1939
Rpr Shop	DSBY2466	2013	Freightliner	Cascadia	DD13	N/A	J1939
Rpr Shop	D3010151	2013	Other	TCS 417	DD13	N/A	J1939
Rpr Shop	FHGD1907	2015	Freightliner	114SD	DD13	N/A	J1939
Rpr Shop	JSJZ0185	2018	Freightliner	Cascadia	DD13	N/A	J1939
Rpr Shop	EL497229	2013	International	Durastar 4300	A230	N/A	J1939
Rpr Shop	FL512209	2014	International	4300	A230	N/A	J1939
Rpr Shop	GH207539	2016	International	TA005	MaxxfForce 7	N/A	J1939
Rpr Shop	EL034703	2014	International	DuraStar 4400	MaxxForce DT	N/A	J1939
Rpr Shop	FM047240	2015	Mack	CXU613	MP8-415C	N/A	J1939
Rpr Shop	GM077071	2016	Mack	CXU613	MP8-415C	N/A	J1939
Rpr Shop	EL497121	2013	International	4300	A230	N/A	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Rpr Shop	EL497127	2014	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	EL497099	2013	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	EL497110	2013	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	EL497132	2013	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	EL497123	2013	International	4300	A230	N/A	J1939
Rpr Shop	EL497026	2013	International	4300	A230	N/A	J1939
Rpr Shop	FL512222	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512186	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512244	2014	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512262	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512190	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512185	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512187	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512188	2014	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512216	2014	Navistar	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512192	2015	International	4300	A230	N/A	J1939
Rpr Shop	FL512223	2014	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512225	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512228	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512221	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512265	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512239	2014	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512219	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512208	2014	International	4300	A230	N/A	J1939
Rpr Shop	FL512229	2015	International	4300	A230	N/A	J1939
Rpr Shop	FL512227	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512220	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512232	2015	International	4300	A230	N/A	J1939
Rpr Shop	FL512259	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512263	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512231	2015	International	4300	A230	N/A	J1939
Rpr Shop	FL512261	2015	International	4300	A230	N/A	J1939

Source	VIN	MY	Make	Model	Engine	Pass/Fail	Protocol
Rpr Shop	FL512226	2015	International	4300	A230	N/A	J1939
Rpr Shop	FL512248	2015	International	4300	A230	N/A	J1939
Rpr Shop	FL512224	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512243	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512184	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512230	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512183	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	FL512251	2015	International	DuraStar 4300	A230	N/A	J1939
Rpr Shop	EL034708	2014	International	DuraStar 4400	A270	N/A	J1939
Rpr Shop	EL034709	2014	International	DuraStar 4400	A270	N/A	J1939
Rpr Shop	EL034706	2014	International	DuraStar 4400	MaxxForce DT	N/A	J1939
Rpr Shop	EM182896	2014	Peterbilt	PB348	ISL9 300	N/A	J1939
Rpr Shop	EM235561	2014	Peterbilt	348	ISL9 350	N/A	J1939
Rpr Shop	FM256426	2015	Peterbilt	348	ISl9 350	N/A	J1939
Rpr Shop	FM253887	2015	Peterbilt	337	ISL9 350	N/A	J1939
Rpr Shop	DD196662	2013	Peterbilt	384	MX	N/A	J1939
Rpr Shop	ED223848	2014	Peterbilt	388	MX13	N/A	J1939
Rpr Shop	GFF11996	2016	Kenworth	T4 Series	PX-9	N/A	J1939
Rpr Shop	FN909732	2015	Volvo	0	0	N/A	J1939
Rpr Shop	EC712669	2014	Prevost	H345	131060629	N/A	J1939
Rpr Shop	GC713072	2016	Prevost	H345	131112095	N/A	J1939
Rpr Shop	DN145211	2013	Volvo	VMN	D13	N/A	J1939
Rpr Shop	GC713354	2016	PCI	H3-45	D13	N/A	J1939
Rpr Shop	H9737333	2017	PCI	X3-45	D13	N/A	J1939
Rpr Shop	H9737334	2017	PCI	X3-45	D13	N/A	J1939
Rpr Shop	CDBP5819	2013	0	0	0	N/A	J1939
Rpr Shop	FJ459249	2017	Kenworth	0	0	N/A	J1939

Appendix C

Compiled Responses from ERG Phone/E-mail Fleet Survey

CARB Heavy Duty OBD Study Fleet Interview – Emission Control Testing Option Preferences

Senate Bill 210 requires the California Air Resources Board (CARB) to implement a comprehensive heavy-duty inspection and maintenance (HD I/M) program for non-gasoline heavy-duty vehicles with gross vehicle weight rating (GVWR) greater than 14,000 pounds. This survey is being performed to gather information regarding industry preferences for this program, and to identify ways of implementing the program that is most acceptable for the HD truck industry. Results will be anonymized by ERG prior to submission to CARB, so this is an opportunity to provide anonymized feedback in a way that could help shape the future program.

Anonymized fleet responses from telephone / e-mail interviews are provided below. Text responses are provided with bulletized lists to distinguish fleets.

Interview Date: Various (Fall 2020)   Contact Name: Various

Establishment Name: Various   Fleet Size: Seven fleets and organizations, ranging in sizes from approximately 100 vehicles to 2000 vehicles

Service Type: All service types were represented in the responses (local delivery, in-state operation and delivery, and Interstate operation)

1) Is your fleet currently subject to the annual opacity testing?
   Yes **(6)**   No **(0)**   Unknown or no answer   **(1)**

   a. If yes, do you currently perform your own annual opacity testing, or do you pay another person / organization to test your truck(s) / fleet?
   Self-testing **(5)**   Outside Test Services **(2)**   Unknown or no answer   **(1)**
- **We do our own as a component of BIT testing**
- **We do both self-testing and use of outside services, depending on facility size within our organization**

2) For those currently required to comply with opacity testing, can you please provide an estimate of your current per-truck annual smoke opacity testing fees?

- **Unknown, as this is done as part of BIT testing program. They purchased the opacity equipment.**
- **$141.00**
- **$50-$75 per truck: Generally outside contractor fees are $50, but internal costs are estimated at $75/truck (excluding purchase of the Red Mountain opacity meters which this fleet owns).**
- **$136.85**
- **done internally, so costs are for approx. 1 hour in shop, including time to bring truck in, set up, run test, create documentation, approx. $110, plus time for opacity tester maintenance (bulb replacement, etc.)**

3) CARB is planning on implementing a heavy-duty truck OBD program (i.e., a program in which 2013 and newer trucks are tested by way of an electronic engine scan through the truck's data port) within the next few years. Once this is implemented, would you be interested in performing your own (internal fleet) testing, or having testing performed for you? (please circle best answer)
   a.   perform your own testing, or **(4)**
   b.   paying for testing / certification services **(1)**
   c.   Unknown or no answer **(0)**

- **We will continue to do testing themselves for their trucks and the rental/leasing trucks. They do not intend on providing outside testing services**
- **We will probably treat this like the current opacity program (self-testing for some, outside contractor for smaller facilities might be a possibility)**

4) If you might be interested in performing your own fleet testing for the upcoming OBD program, which of the following options might be most preferable? (please circle best answer)
   a.   Purchase of handheld test equipment (i.e., a configurable test device with a PC or tablet computer to perform diagnostics and display results) that would provide results to CARB **(2)**
   b.   Purchase of a small device that simply plugs into the truck's port with no or minimal configuration (perhaps with an associated cell-phone application) that would somehow automatically upload test results to the program (one-time scan whenever necessary)
   c.   Visiting an automated self-testing kiosk to perform your own testing whenever necessary, or
   d.   Use of a device that stays connected to your truck's data port (like an electronic logging device) that continually monitors your truck, eliminating the need to perform periodic testing (Note that this "continuous monitoring" device might be integrated with your ELD or telematics/fleet management device.) **(3)**
   e.   Unknown or no answer **(1)**

- **We would have our trucks continuously-monitored, but would only report to CARB as periodically required. We prefer a 90-day test frequency to continuous monitoring**
- **We select option a, but said option d might also be an option if integrated with ELD or telematics / fleet management device**
- **Tough to answer. We would really like to see our current test equipment (Cummins Insite and now Volvo test equipment) to be able to provide results necessary for program compliance, rather than having to buy other equipment. We use data from scan equipment to test and repair our own equipment. Otherwise, something like Red Mountain or done with data on a laptop. Regarding 4d, we envision we would probably opt for one-time testing, rather than continuous telematics monitoring. This could change in the future, though.**
- **We would be mostly interested in doing the telematics option. We currently have Verizon telematics on our fleet, and our LD fleet is participating in the BAR CTP (continuous testing program) for LD OBDII. Results are sent to BAR daily. This is the type of program we would like for the HDV program.**

5) If option d above is of interest (continuous testing), what amount of time would you feel comfortable with to repair a vehicle after an emissions fault is displayed? _____ (days)

- **Although 45 days is reasonable, a "grace period" should be offered for non-compliance, i.e., if a truck comes into kiosk on day 89 for a 90-day test program and is found to fail, it should have a grace period allowed for repair.**
- **1 to 2 days**
- **Fleet 5: N/A, option d not currently of interest**
- **Fleet 6: -1 day**
- **Fleet 7: 40 days, but with a fleet as large as Fleet 7, there would be a need for exemptions (more time) for part delays, inoperative vehicles, etc. Program should have mechanism for additional time as needed and still be in compliance.**

6) CARB is considering a 90-day test frequency for the aforementioned truck test program. Would this test frequency influence the above test choice? (periodic testing vs. continuous / telematics)?
   a. No change of above answer **(3)**
   b. I would instead do continuous / telematics logging **(1)**
   c. I would do periodic testing on the required schedule **(2)**

- **Fleet contact and I discussed the 90-day test frequency with respect to alignment with 90-day BIT requirement but mis-alignment with annual registration, but legislation requires this to have registration denial. There is some variation for the 90-day BIT frequency based on leased vs. owned, mileage, etc.**
- **The fleet that selected "b" would prefer to have this service integrated with their existing Verizon service**

7) What is the maximum price you would be willing to pay for a program-compliant (state certified) hand-held configurable test device with a tablet/PC system that displays results?
- **Proprietary, since their telematics company is their subsidiary, they would telematically-instrument trucks and would not use the handheld device.**
- **$2,000**
- **$0 preferable, but probably something comparable to the Cummins Insite ($600 / year) or less.**
- **The most cost effective**
- **Tough to say, as this fleet is more interested in telematics option, but perhaps equivalent to cost of opacity meter, say $2500 (less annual maintenance costs).**

8) What is the maximum one-time price you would be willing to pay for a program-compliant (state certified) device with minimal configuration requirements? $_____
- **$1,000**
- **N/A**
- **$150.00**

- **Tough to say, we are more interested in telematics option, but perhaps equivalent to cost of opacity meter, say $2500 (less annual maintenance costs).**

9) Does your fleet currently have telematics / fleet management service?
   a. Yes **(6)**
   b. No **(1)**
   - **One has a telematics company as a subsidiary, so costs are internal**
   - **One uses Qualcom GPS/Telematics**
   - **One uses People net + on class 8 trucks, includes diagnostics**
   - **One uses Verizon Telematics**

10) If yes to 9 (if your fleet does have a telematics / fleet management service):
   a. What do you currently pay for the service ($/truck/month)? Does the cost include hardware cost? If not, what is the hardware cost (please note and circle)?
      i. Service Cost:
         - **$44.25 / month**
         - **$50 / month**
      ii. Hardware Cost:
         - **$799 one time**
   b. Do you use the service for logistics management or vehicle diagnostics, or both?
      i. Logistics management **(3)**
      ii. Vehicle diagnostics
      iii. Both **(3)**
      iv. Other (please describe)_____
   - **Only for logistics management at this time with our telematics provider. We are looking to upgrade system but held off due to the pandemic. Current telematics is just tracking (location), no ECM data.**
   - **We pay roughly $190k annually for instrumenting approximately 1000 vehicles with Verizon telematics, including warranty, equipment hardware, on-going service and cellular costs, etc.**

11) Would you be interested in performing testing services for other fleets and independent owners / operators?
   Yes **(1)**   No **(5)**   Unknown or no answer **(0)**
   - **Fleet 1 would generally not be interested in performing outside services, might do as courtesy for customers in for repairs, similar to the smoke testing they do at their facilities. They are primarily doing internal testing only.**

12) Do you have any concern with plugging an external electronic device (e.g., handheld test equipment or dongle) to your truck's OBD port? If so, what are your concerns? Do you have any suggestions on how we could alleviate your concern(s) in an HD I/M program?
   - **No**
   - **No**

- **No**
- **No issues, fine as long as it is done in the proper manner, in particular if the program uses a "Y" connector to listen in, so mechanics could attach and access the ECM without removing and losing the device**
- **We have had issues with electronic devices interacting with truck and triggering codes / MIL. We have concerns with this for both telematics (continuously-connected) and one-time scans.**
- **Certain vehicles have exhibited problems as interrogation devices mess with the computer, so we use another device that simulates a node on CAN network to eliminate problems (Intermotive Vehicle Controls "Break Out Box Enhanced 4xx"). We have had problems with Dodge and Ford F550 trucks, and the interference will cause the vehicle to enter derate mode. Contact provide document regarding this device. (ERG note: this device allows multiple devices to be on a 1979 OBDII vehicle network with just one connection to the OBDII connector).**

13) Can you provide an estimate of your current per-truck annual maintenance and repair costs (*non-emission related*) for your model year 2013 and newer trucks?

☐ < $1,000 **(2)**	☐ $10,000- $15,000 **(1)**	☐ $25,000 - $30,000
☐ $1,000 - $5,000 **(1)**	☐ $15,000- $20,000	☐ $30,000 - $35,000
☐ $5,000 - $10,000 **(2)**	☐ $20,000 - $25,000	☐ $35,000+

- **The fleet to which these costs pertain is relatively new (generally less than 5 years old). Most of the expenses are associated with tires, brakes, filters, etc.**
- **Ready-mix truck annual non-emission repair and maintenance costs are high, > $35,000, the other vehicles are $20k to $25k.**

14) Can you provide an estimate of your current per-truck annual *emissions-related* repair costs for your model year 2013 and newer trucks?

☐ < $1,000 **(2)**	☐ $10,000- $15,000	☐ $25,000 - $30,000
☐ $1,000 - $5,000 **(4)**	☐ $15,000- $20,000 **(1)**	☐ $30,000 - $35,000
☐ $5,000 - $10,000	☐ $20,000 - $25,000	☐ $35,000+

- **Same fleet (generally < 5 years old), $1k to $5k average, but repair costs can be anomalistic (i.e., some quite high, i.e., a 1-box replacement (i.e., Detroit Diesel 1-box is the SCR catalyst, the diesel oxidation catalyst (DOC), diesel particulate filter (DPF) and diesel exhaust fluid (DEF) into one compact component), which can be $12-$15k. Emission-related codes are more common than non-emissions codes**
- **$15k-$20k for emission-related repairs, CARB has been pushing Cummins to reimburse for warranty emission repairs, which Fleet 5 appreciates. The Cummins / Kenworths have had a variety of issues, a lot of wiring and sensors, like DEF sensors, tank level, quality, so Fleet 5 is trying Volvos, they have 6 Volvos, all roughly 80k miles, no failures. Seem reliable.**
- **Contact talked about adjusting driving patterns to help prevent failures (rotate 21 dump trucks between the plants so they can get OTR time and regenerate their DPF), reduce downtime.**
- **No cost provided on phone, but fleet contact did indicate that their biggest cost is usually the NOx sensor**

15) For model year 2013 and newer trucks, how frequently do you address emissions-related repairs? (please remember, your answers will be anonymized, and this information is being requested to determine how much emissions reduction the program will provide)
    a. Always **(5)**
    b. Only when other repairs are being performed
    c. Only when a repairs are necessary to prevent or correct a derate / limp mode operation? **(2)**
    d. Other (please describe) **(1)**

- **For the option d selection, we address check engine light repairs**
- **Emission-related repairs are always addressed, and repair types are across the board. These are common.**

16) Can you provide an estimate of the percentage of emissions-related malfunctions (malfunction indicator light illuminated) result in an eventual derate / limp mode operation for your 2013 and newer trucks?

| ☐ < 25% **(3)** | ☐ 51% - 75% **(1)** |
| ☐ 25% - 50% **(3)** | ☐ 76% - 100% |

- **Contact at one fleet indicated he is unaware of anything that doesn't go into a derate at some point**

17) Do you have any program recommendations, preferences, or other thoughts / input that you'd like to see in the upcoming program?

- **We recommend not rushing program development, otherwise the program could be compromised. Could seek necessary additional time needed through some administrative or legislative process to ensure program is implemented properly. Problems could arise due to California Privacy Act, other obstacles. Ensure enforcement is consistent and aligned with test program, offer real-world flexibility, including grace period for trucks that fail the test, and testing alignment with the BIT program. Also, as is done for the truck and bus rule, for leases longer than one year, the driver can have an illuminated MIL and the lease company will not know. Even though the lessor is the registered owner, the lessee should be responsible for the truck compliance, not the lease company.**
- **We already have a process to call in rental/leased trucks for BIT testing (75 days after previous BIT, two weeks to get trucks re-tested), OBD program should be integrated into this.**
- **Our telematics organization will be used for program support, we may get set-up for out-of-state vehicles traveling into California (geofencing). If program certification is necessary, telematics will indeed develop certified systems (note that ELDs are not certified by FMSCA, so certification of this telematics solution is somewhat different). This telematics solution is already integrated into our systems.**
- **Our recommendation is to have the state provide training on the equipment that will be required to conduct the test. Allow the fleets to be able to do their own testing and get the manufacturers to supply the training to identify MIL light triggers and what the repair or remediation of the triggers is so that the fleets avoid long down times related to parts and shop availability. If the state provided a kiosk at large fleet locations, and train the mechanics, we feel you would get better data.**
- **Periodic DPF maintenance and DEF filter replacements**

- **#1: Program test frequency, recommend keeping it an annual. This is going to be a huge time eater, we do not even currently have sufficient mechanics / labor, let alone to do this additional testing load at 4 times per year. This will be a huge burden on the company.**
- **#2: Utilize Cummins Insite software / equipment (or other manufacturer / OEM equipment), stay with existing software / equipment, perhaps just develop software that interfaces on the back end (laptop) and utilizes stock OEM equipment. Or, use a generic J1939 pass-through device that can be used for other purposes.**
- **Testing costs could be prohibitive with many trucks. We will probably opt for single scans / tests (when needed), rather than telematics. Some diagnostics will be necessary to diagnose emission-related faults (Paccar systems), emissions-related faults are not always mechanical (they can be due to air filters, software-related and such).**
- **In the past, emission-related faults would frequently result in derates, but this is less common now (manufacturers seem to be starting to get away from derates), largely due to software improvements, fewer faults. Earlier faults were sometimes software-related.**
- **Please ensure the necessary information to correct a fault be provided by the CARB program (SPNs/FMI/OC), We will still need to use OEM-specific diagnostic tools to diagnose and repair trucks.**
- **We would love to keep the program in-house (do our own testing / telematics), and we would like the program to be cost effective and aligned with the BAR LDV CTP program.**

Appendix D

Compiled Responses from ERG/CARB Online Fleet Survey

CARB Survey, all data

CARB Heavy Duty OBD Study Fleet Interview

March 4th, 2021, 2:05 pm EST

Number of Responses, by Day
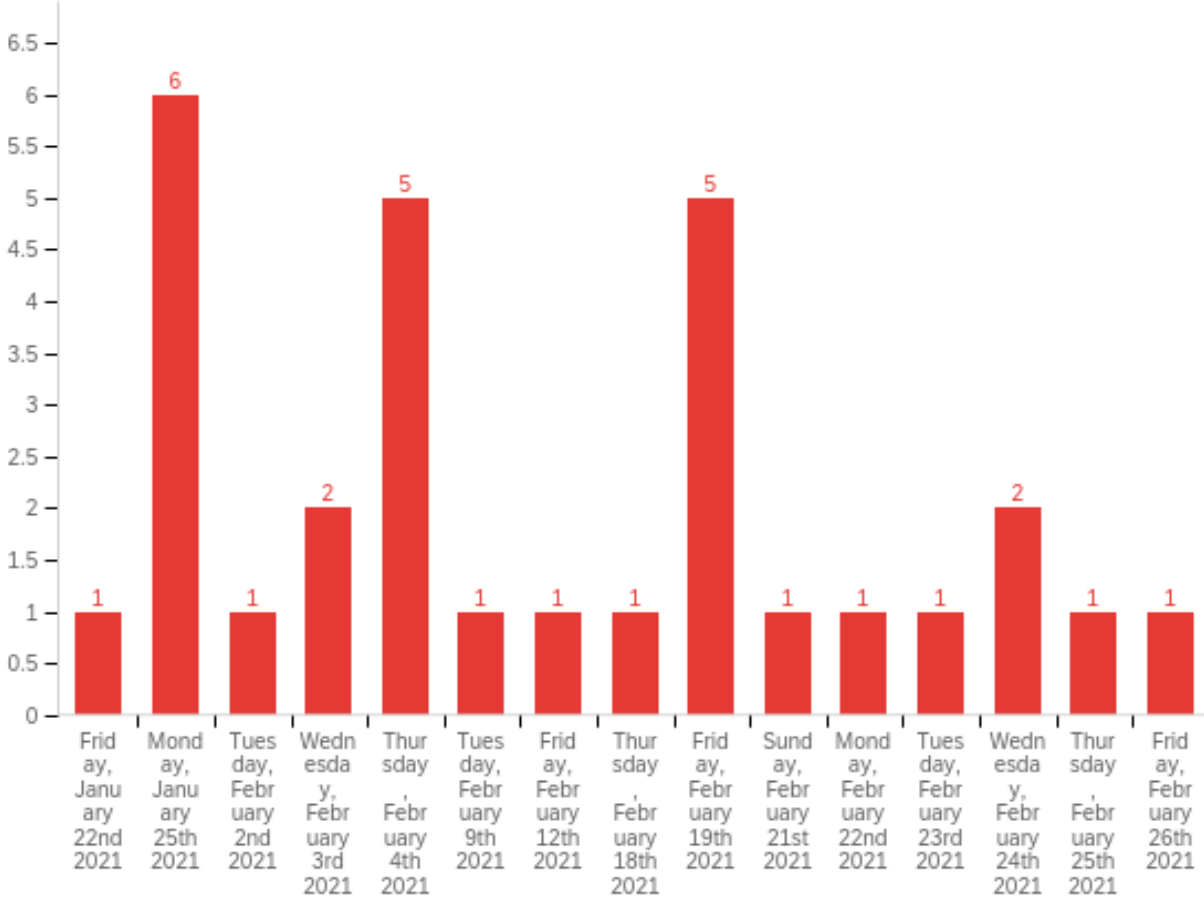
1) How many heavy-duty vehicles (gross vehicle weight rating greater than 14,000 pounds) are in your fleet?
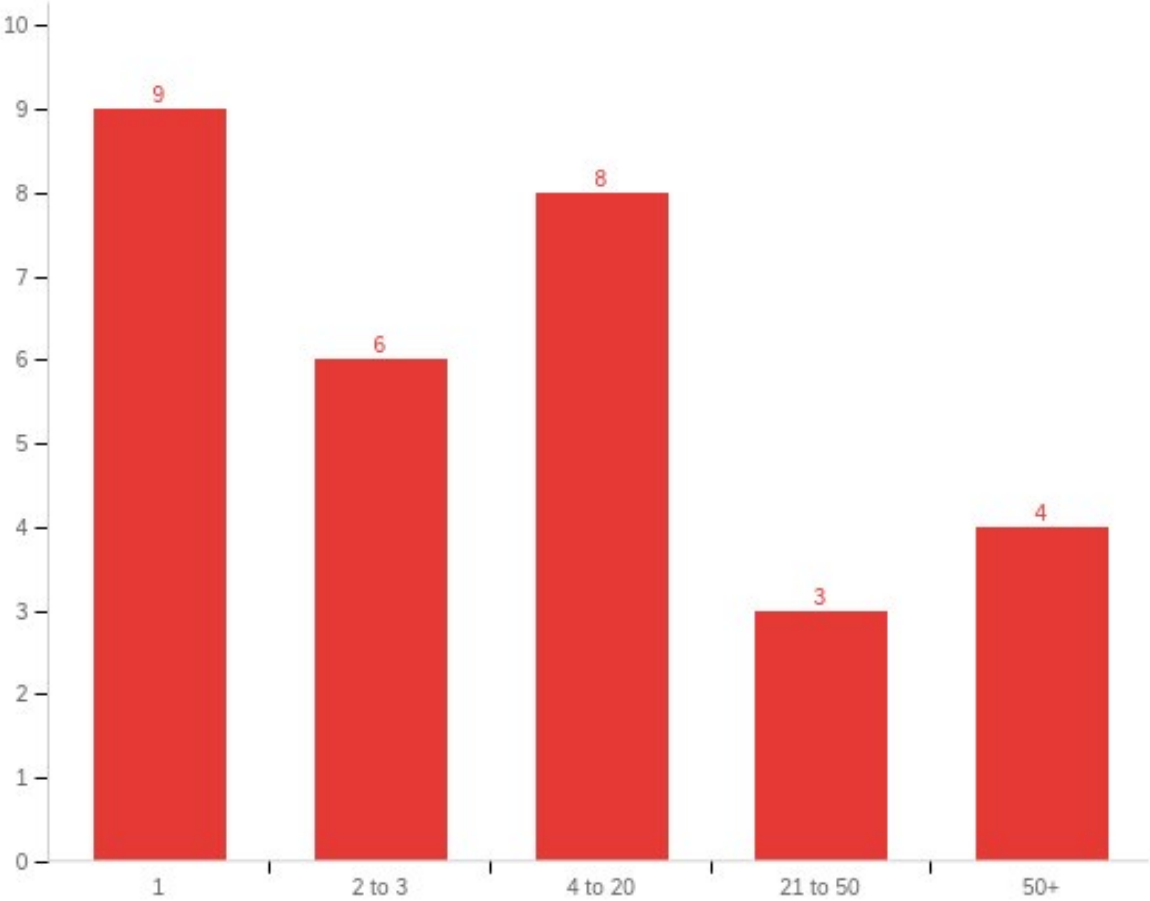
Answer	%	Count
1	30%	9
2 to 3	20%	6
4 to 20	27%	8
21 to 50	10%	3
50+	13%	4
Total	100%	30

2) What is the average age of heavy-duty vehicles in your fleet?
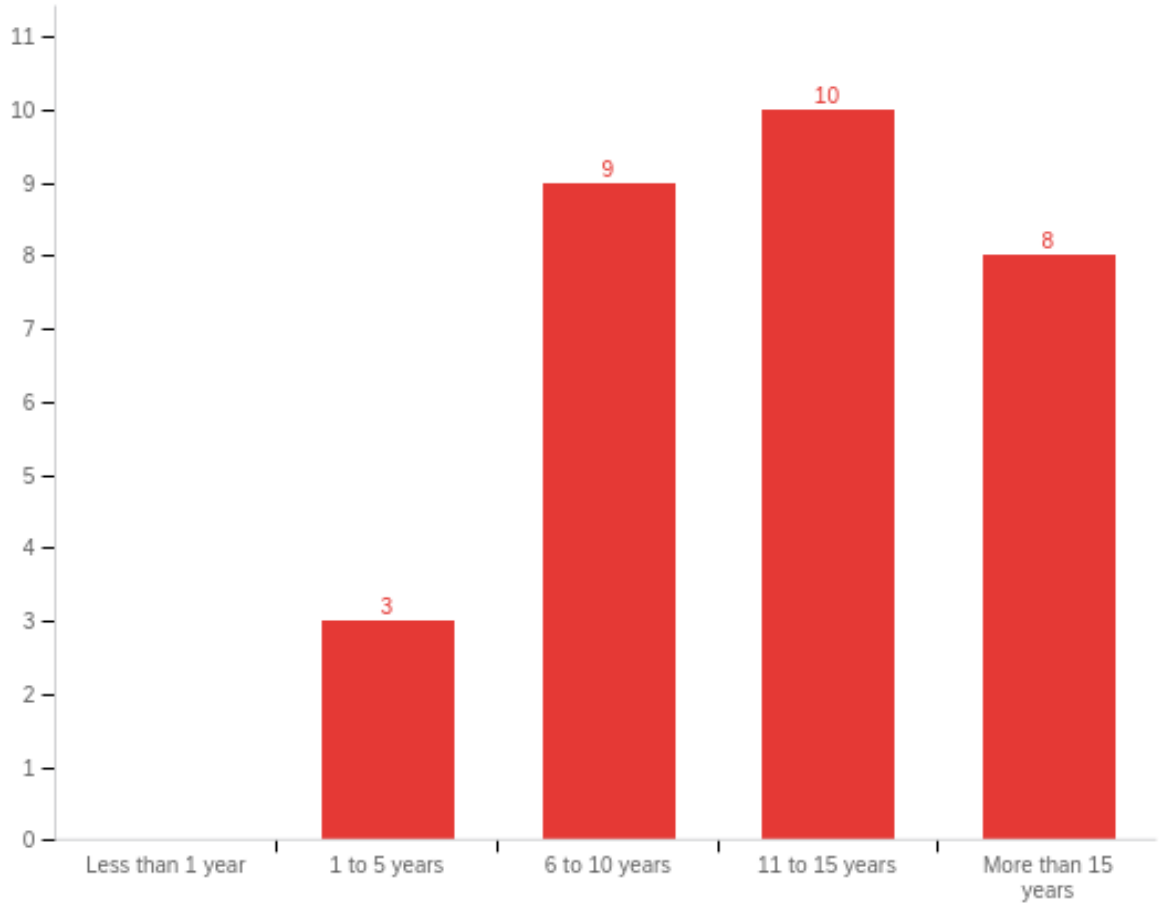
Answer	%	Count
Less than 1 year	0%	0
1 to 5 years	10%	3
6 to 10 years	30%	9
11 to 15 years	33%	10
More than 15 years	27%	8
Total	100%	30

3) What is/are your fleet service type(s)? (Select all that apply.)
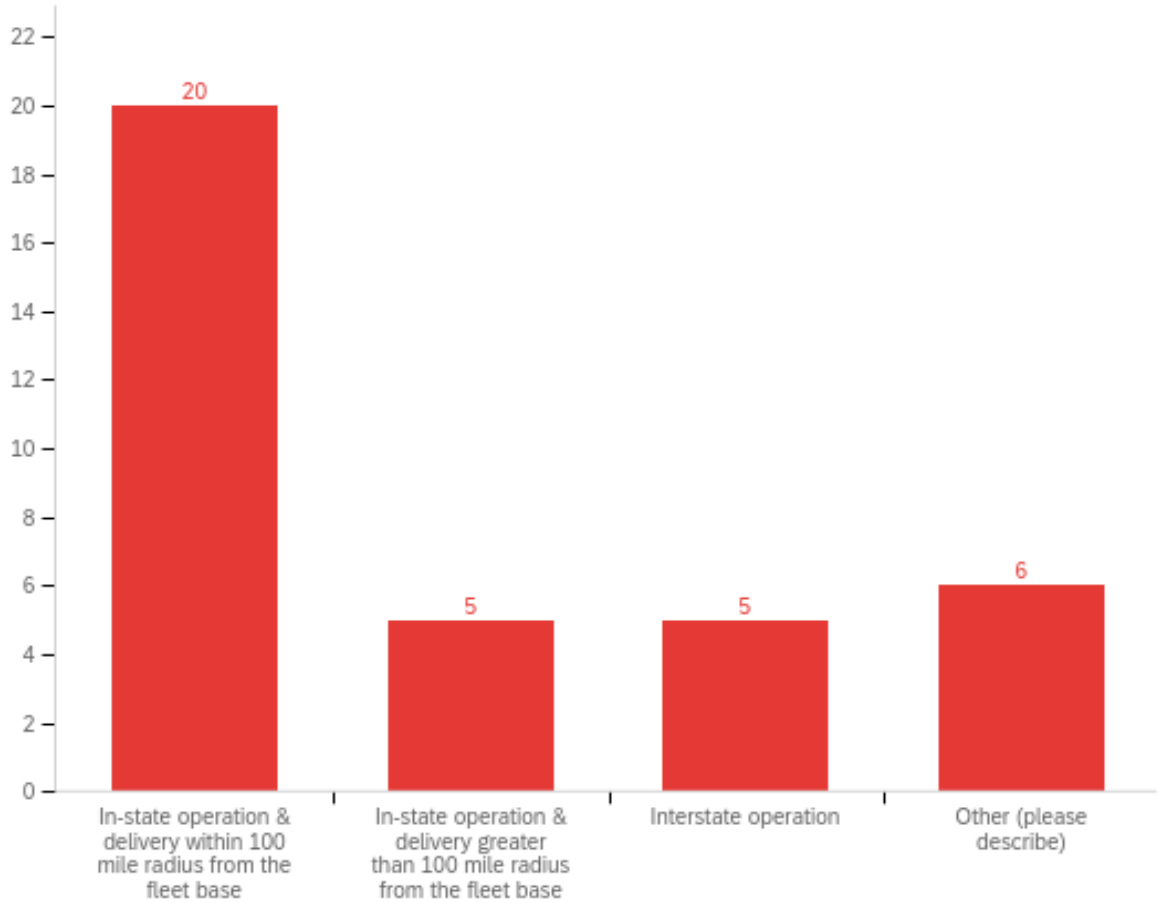
Answer	%	Count
In-state operation & delivery within 100 mile radius from the fleet base	56%	20
In-state operation & delivery greater than 100 mile radius from the fleet base	14%	5
Interstate operation	14%	5
Other (please describe)	17%	6
Total	100%	36

Other (please describe) - Text
government fleet
fleet mechanic.
Local Government fleet operating within 100 mile radius from the fleet base
Local
In-state operation within a 100 mile radius only.
Delivery of water to my Ranch

4) What is the typical Gross Vehicle Weight Rating (GVWR) of your vehicle(s)?
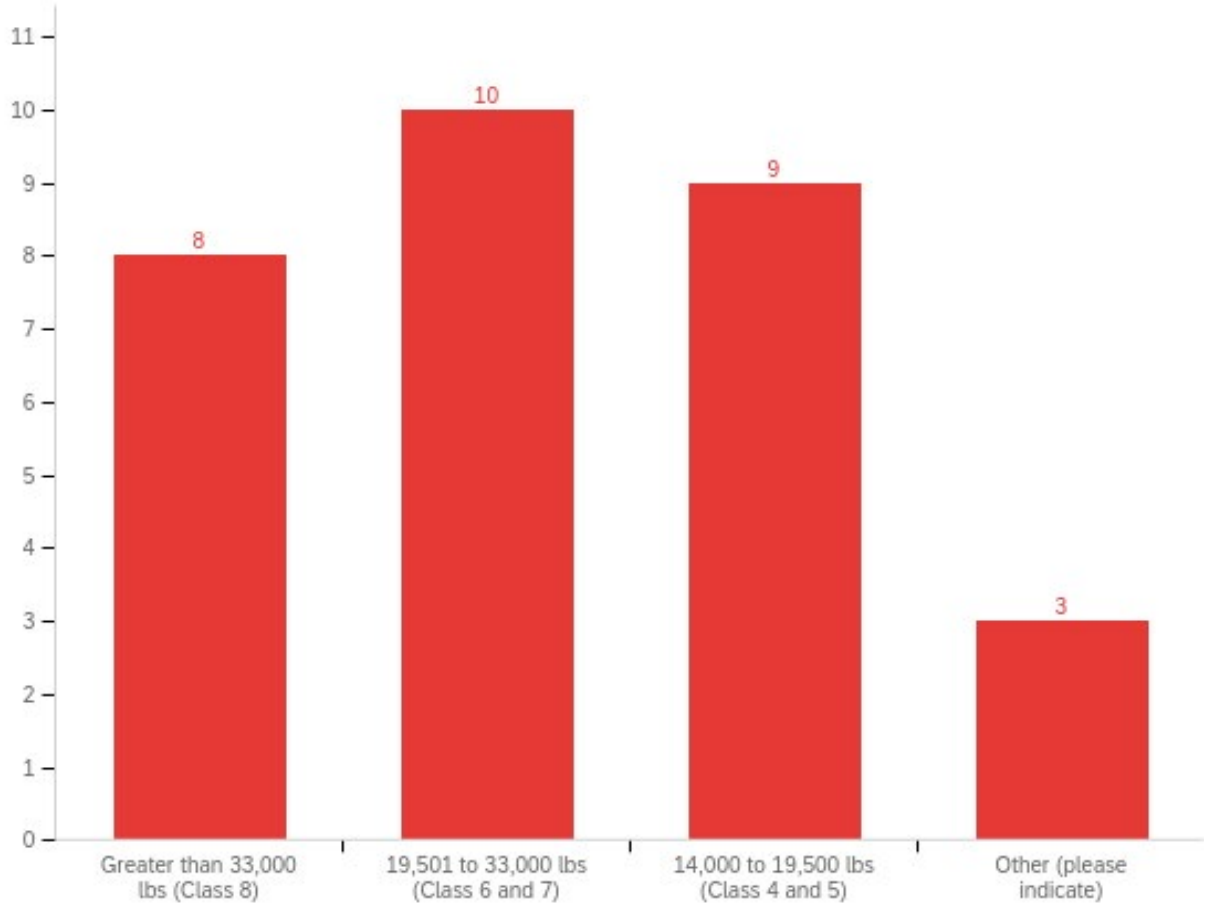
Answer	%	Count
Greater than 33,000 lbs (Class 8)	27%	8
19,501 to 33,000 lbs (Class 6 and 7)	33%	10
14,000 to 19,500 lbs (Class 4 and 5)	30%	9
Other (please indicate)	10%	3
Total	100%	30

Other (please indicate) - Text

9,582 lbs

2 AX UNLADEN WEIGHT =   23,880

6000 to 14000

5) Does your fleet currently subscribe to a telematics / fleet management service?
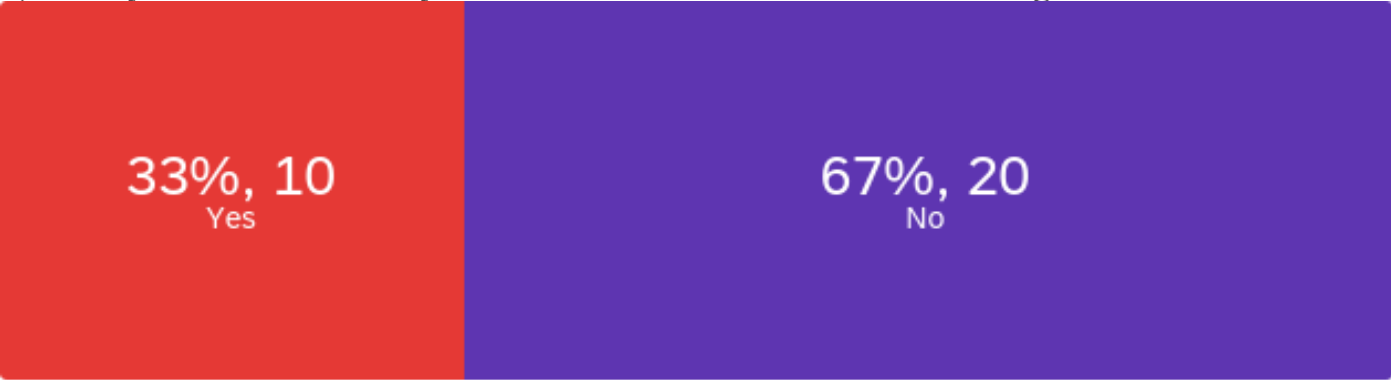
33%, 10
Yes

67%, 20
No

Yes (10)   No (20)

Answer	%	Count
Yes	33%	10
No	67%	20
Total	100%	30

5a. Who is your service provider?
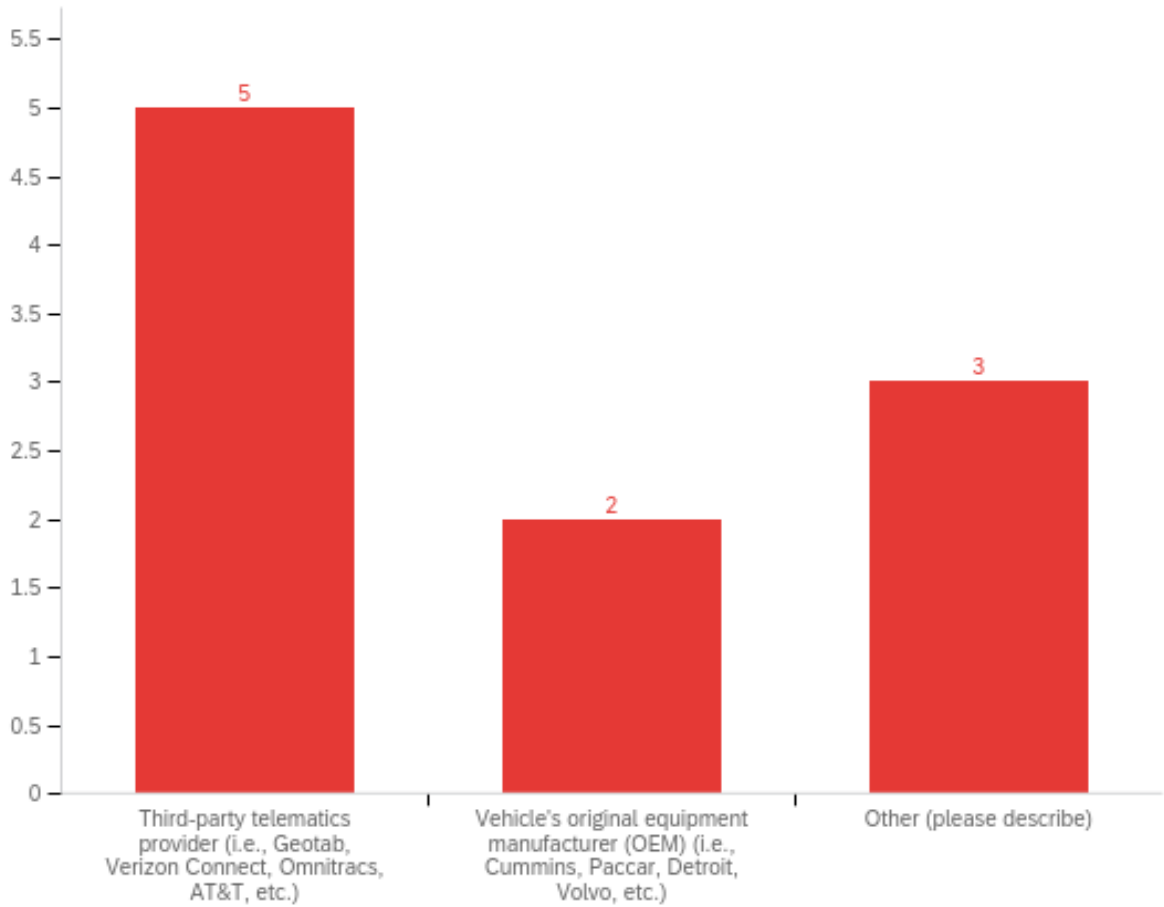
Answer	%	Count
Third-party telematics provider (i.e., Geotab, Verizon Connect, Omnitracs, AT&T, etc.)	50%	5
Vehicle's original equipment manufacturer (OEM) (i.e., Cummins, Paccar, Detroit, Volvo, etc.)	20%	2
Other (please describe)	30%	3
Total	100%	10

Other (please describe) - Text

company mechanic.

Teletrac, Inc.

Partial implementation with Verizon and moving to Geotab.

5b. What do you use the service for? (Select all that apply.)
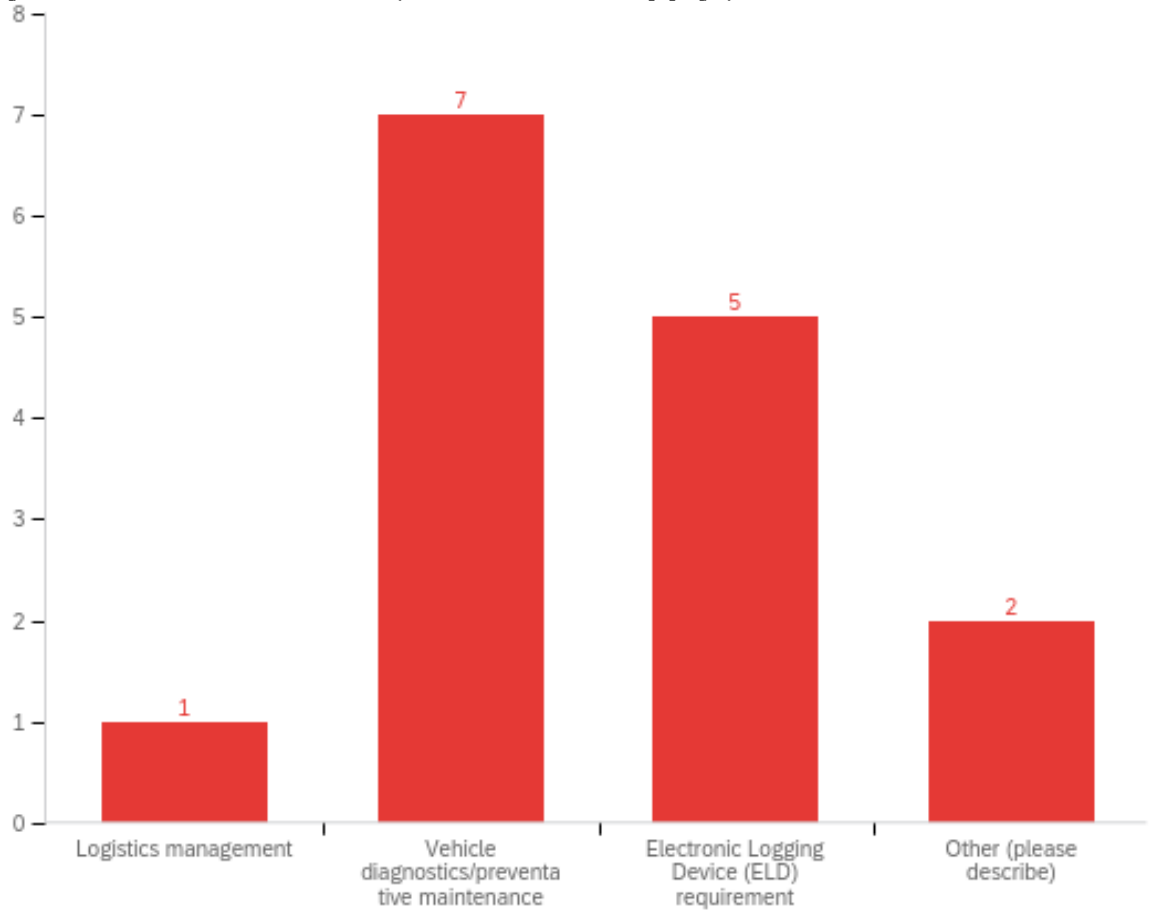
Answer	%	Count
Logistics management	7%	1
Vehicle diagnostics/preventative maintenance	47%	7
Electronic Logging Device (ELD) requirement	33%	5
Other (please describe)	13%	2
Total	100%	15

Other (please describe) - Text
Electronic DVIR
Both Logistics and vehicle diagnostics.

5c. What do you currently pay for the service ($/vehicle/month)?
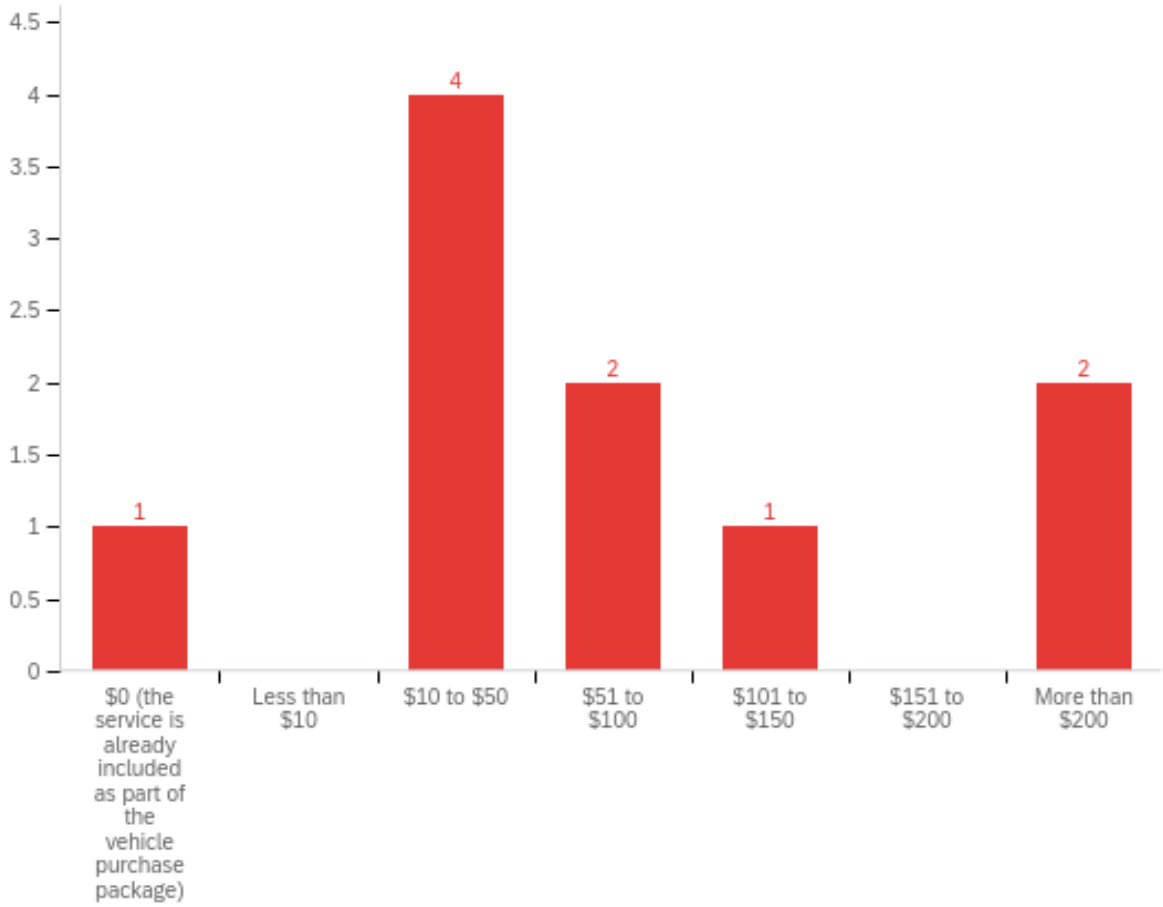
Answer	%	Count
$0 (the service is already included as part of the vehicle purchase package)	10%	1
Less than $10	0%	0
$10 to $50	40%	4
$51 to $100	20%	2
$101 to $150	10%	1
$151 to $200	0%	0
More than $200	20%	2
Total	100%	10

5d. Does the above monthly cost include hardware costs?
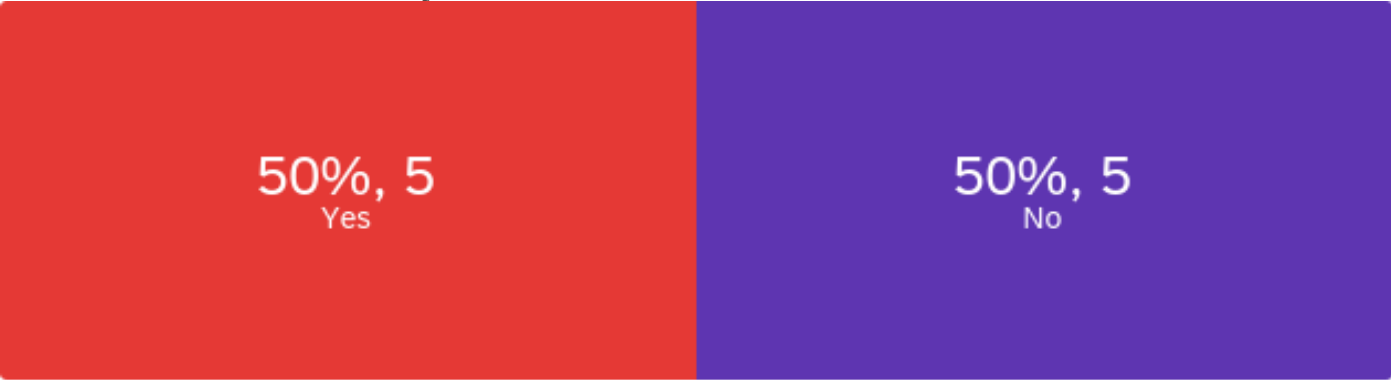
Yes (5) ■ **No (5)**

Answer	%	Count
Yes	50%	5
No	50%	5
Total	100%	10

Select Hardware Cost Amount:
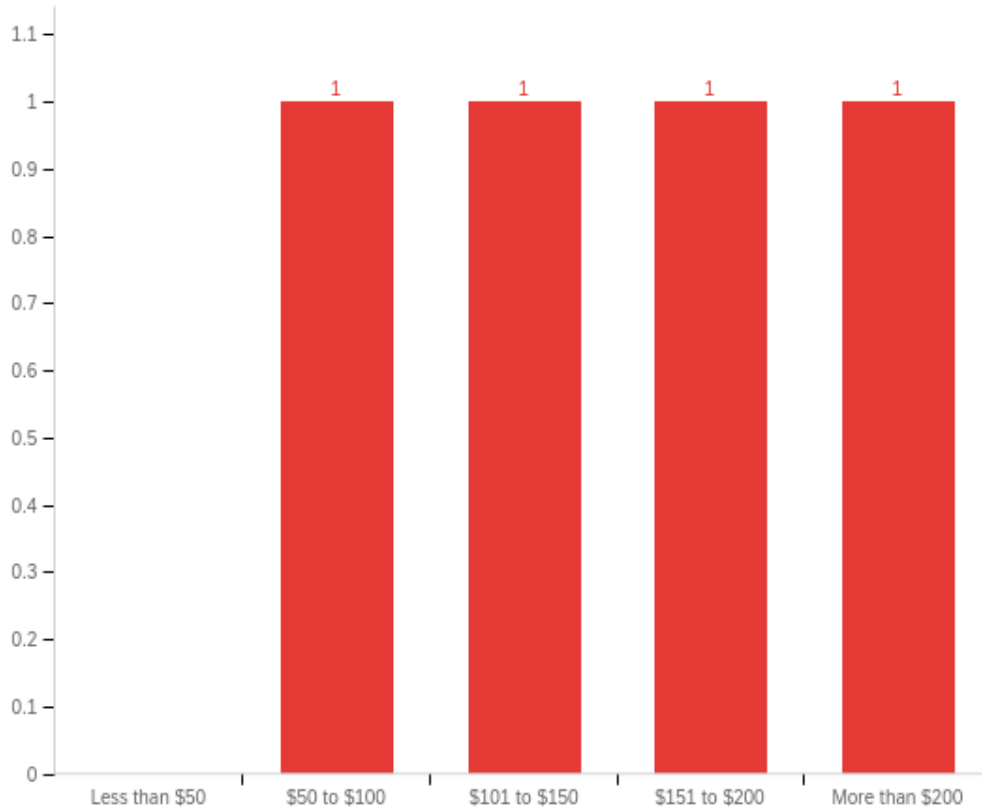
Answer	%	Count
Less than $50	0%	0
$50 to $100	25%	1
$101 to $150	25%	1
$151 to $200	25%	1
More than $200	25%	1
Total	100%	4

#	Question	One-time cost		Monthly cost		Yearly cost		Other (please describe)		Total
1	Less than $50	0%	0	0%	0	0%	0	0%	0	0
4	$50 to $100	100%	1	0%	0	0%	0	0%	0	1
5	$101 to $150	0%	0	100%	1	0%	0	0%	0	1
6	$151 to $200	100%	1	0%	0	0%	0	0%	0	1
7	More than $200	100%	1	0%	0	0%	0	0%	0	1

Select Hardware Cost Type:
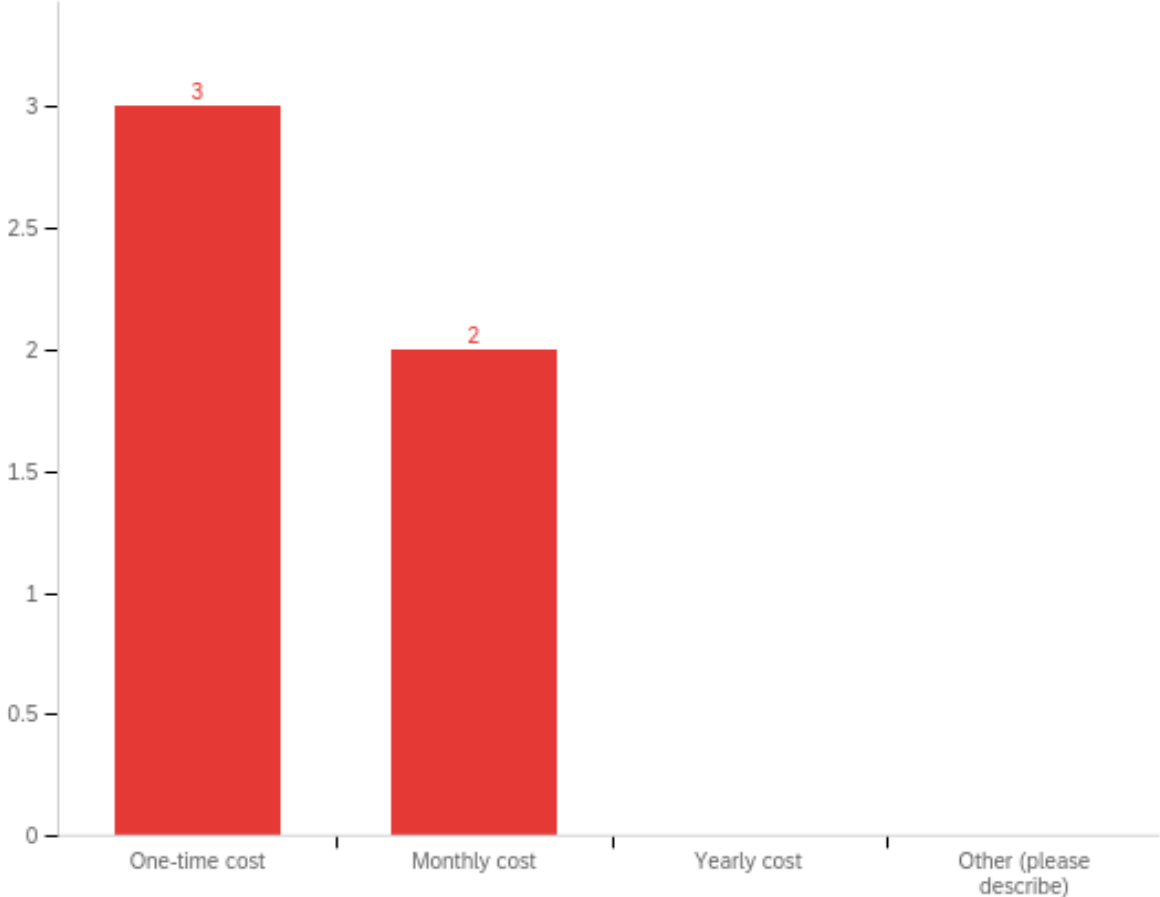
Answer	%	Count
One-time cost	60%	3
Monthly cost	40%	2
Yearly cost	0%	0
Other (please describe)	0%	0
Total	100%	5

Other (please describe) - Text

6) Have you experienced any negative vehicle issues when trying to connect to the vehicle's electronic control unit (ECU) while operating an external device such as an Electronic Logging Device (ELD), telematics devices, diagnostic scantool, etc?
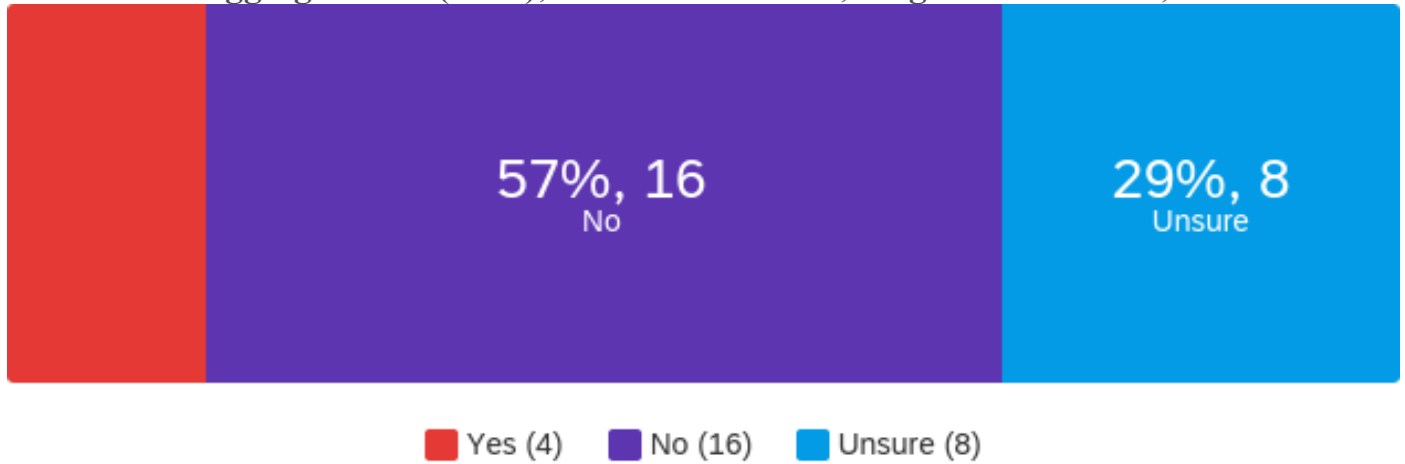
Answer	%	Count
Yes (please describe)	14%	4
No	57%	16
Unsure	29%	8
Total	100%	28

Yes (please describe) - Text

We had a couple of 2019 F-550 that are equipped with the Altec JEMS ePTO unit have check engine lights with our Geotab devices plugged in, too many devices trying to communicate on the diagnostic link.

Phantom trouble codes, phantom pending trouble codes, body module malfunctions, and dead batteries from the CAN system continue to communicate with modules due to confusing information through the telematics device connection.

I've been unable to connect a scan tool to paccar engines in the past. Seems like an issue with the 9pin connector changes with newer trucks using faster CAN speeds.

Connection to the truck drops. Or log gets stuck and does not record driving properly. Drivers not able to go off duty and log stay on duty

7) If possible, please provide an estimate of your current annual per-vehicle repair costs for your fleet (excluding typical fleet operation and maintenance costs).
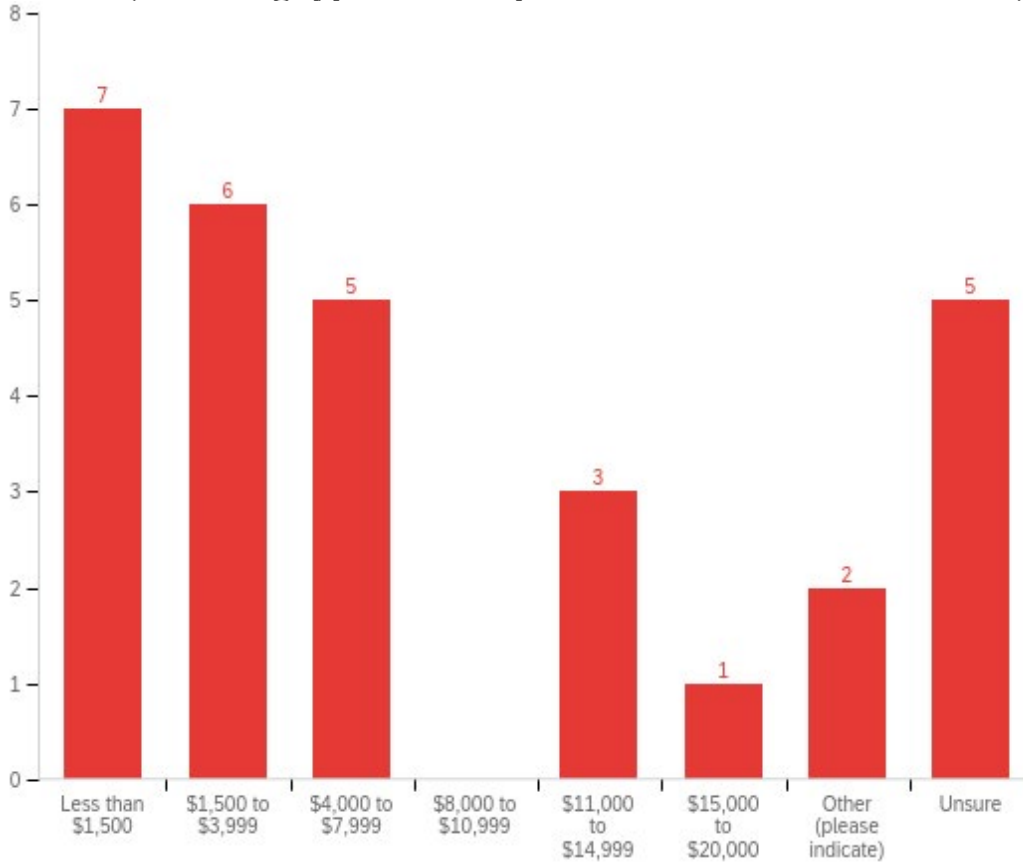
Answer	%	Count
Less than $1,500	24%	7
$1,500 to $3,999	21%	6
$4,000 to $7,999	17%	5
$8,000 to $10,999	0%	0
$11,000 to $14,999	10%	3
$15,000 to $20,000	3%	1
Other (please indicate)	7%	2
Unsure	17%	5
Total	100%	29

Other (please indicate) - Text

80,000 - trailers included

This varies depending on the type of vehicle and application.

8) When one of your vehicle's experiences downtime due to repair, how long does it typically take to get the issue resolved?
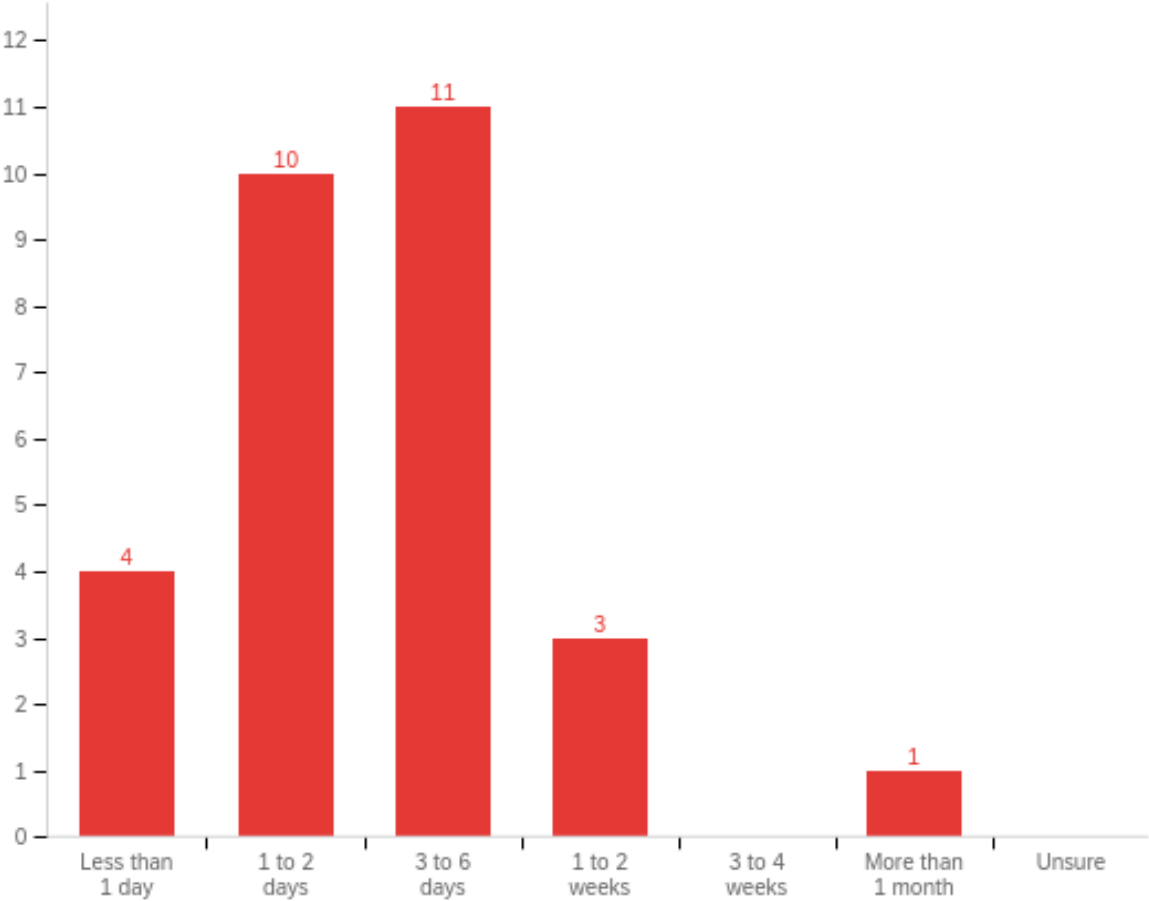
Answer	%	Count
Less than 1 day	14%	4
1 to 2 days	34%	10
3 to 6 days	38%	11
1 to 2 weeks	10%	3
3 to 4 weeks	0%	0
More than 1 month	3%	1
Unsure	0%	0
Total	100%	29

9) Do you do the repair in house or go to an independent/dealer repair shop?
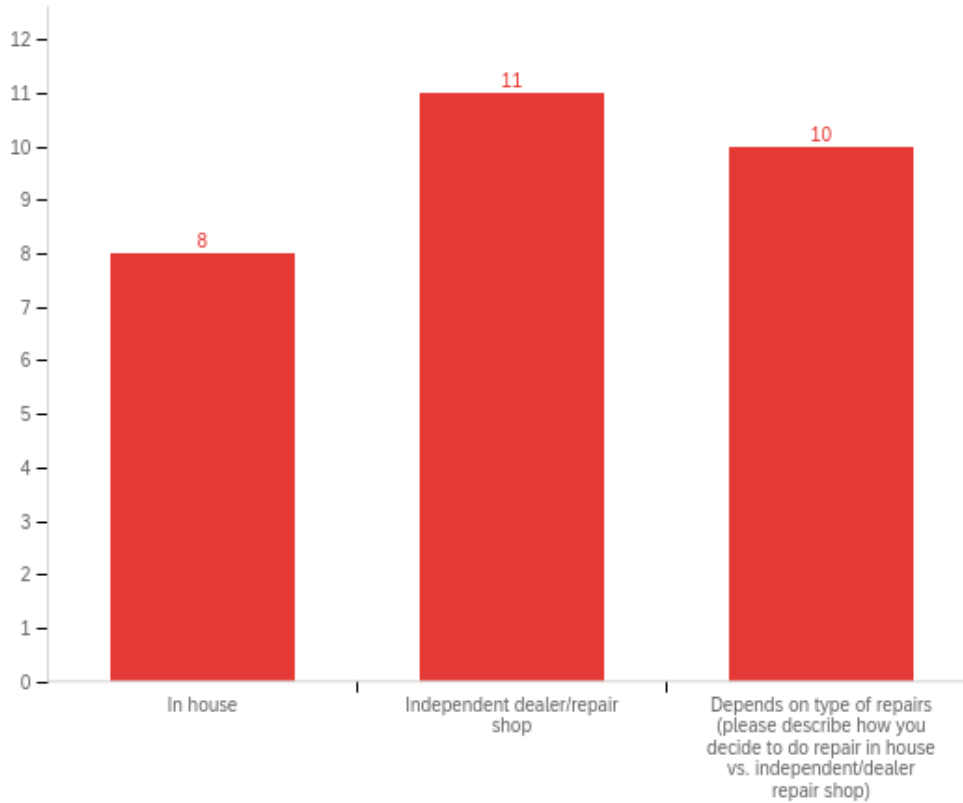
Answer	%	Count
In house	28%	8
Independent dealer/repair shop	38%	11
Depends on type of repairs (please describe how you decide to do repair in house vs. independent/dealer repair shop)	34%	10
Total	100%	29

Depends on type of repairs (please describe how you decide to do repair in house vs. independent/dealer repair shop) - Text

depending on time, procedures or specialty tools needed for the repair.

We do both in house and out sourced vender. Decision to choose is driven by time availability in house to do repair.

The decision depends on staff and shop availability, tooling required and work load. This isn't a subject for an either or answer.

Minor repairs done in-house. Major repairs (rebuilds/repairs) done by diesel outside mechanics.

Major repairs are typically outsourced.

As a tech there are many diagnostic tests that only dealer level service tools can perform. In those cases we are forced to send out. Otherwise we repair in house. RIGHT TO REPAIR!!!

10) What typically leads to the vehicle repair downtime? (Select all that apply.)
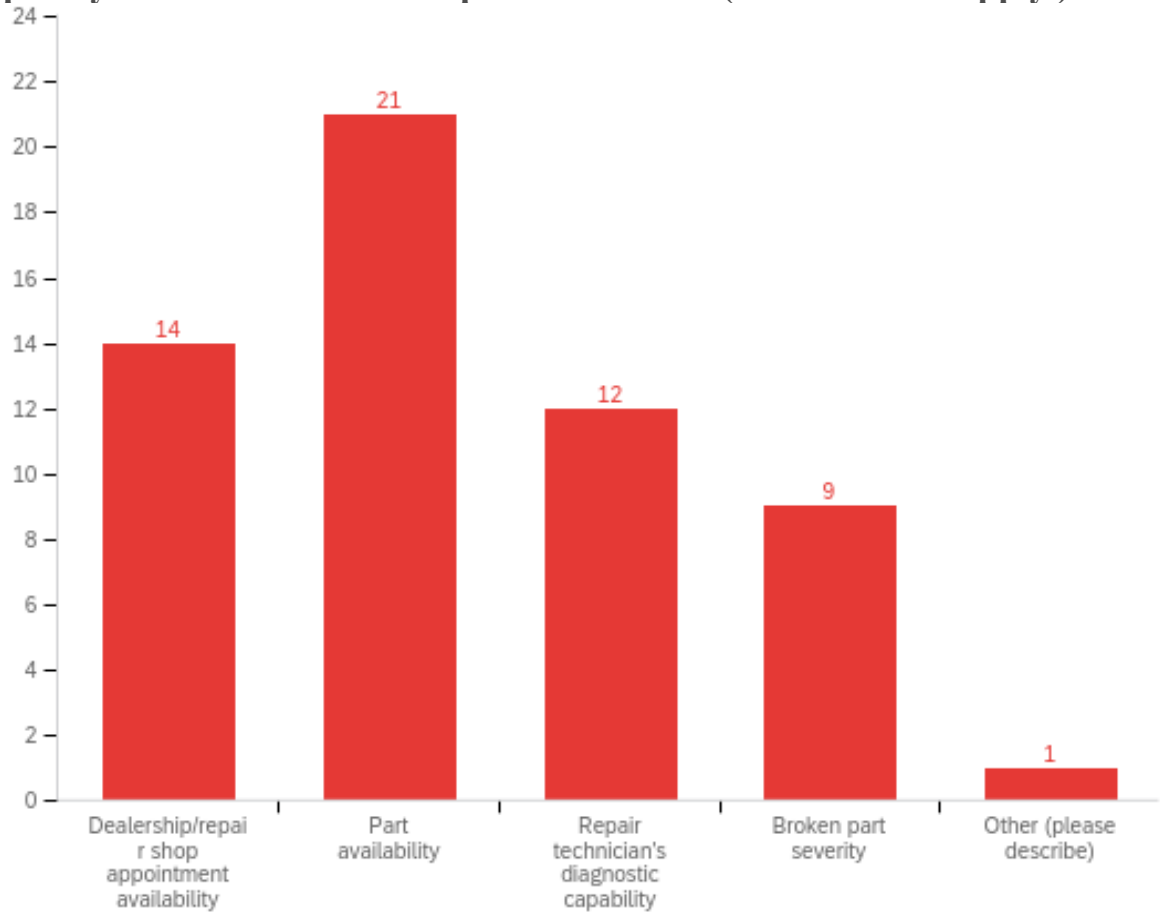
Answer	%	Count
Dealership/repair shop appointment availability	25%	14
Part availability	37%	21
Repair technician's diagnostic capability	21%	12
Broken part severity	16%	9
Other (please describe)	2%	1
Total	100%	57

Other (please describe) - Text
Regular Maintnance not need by mecanic

11) If possible, please provide an estimate of your current per-truck annual smoke opacity testing cost?
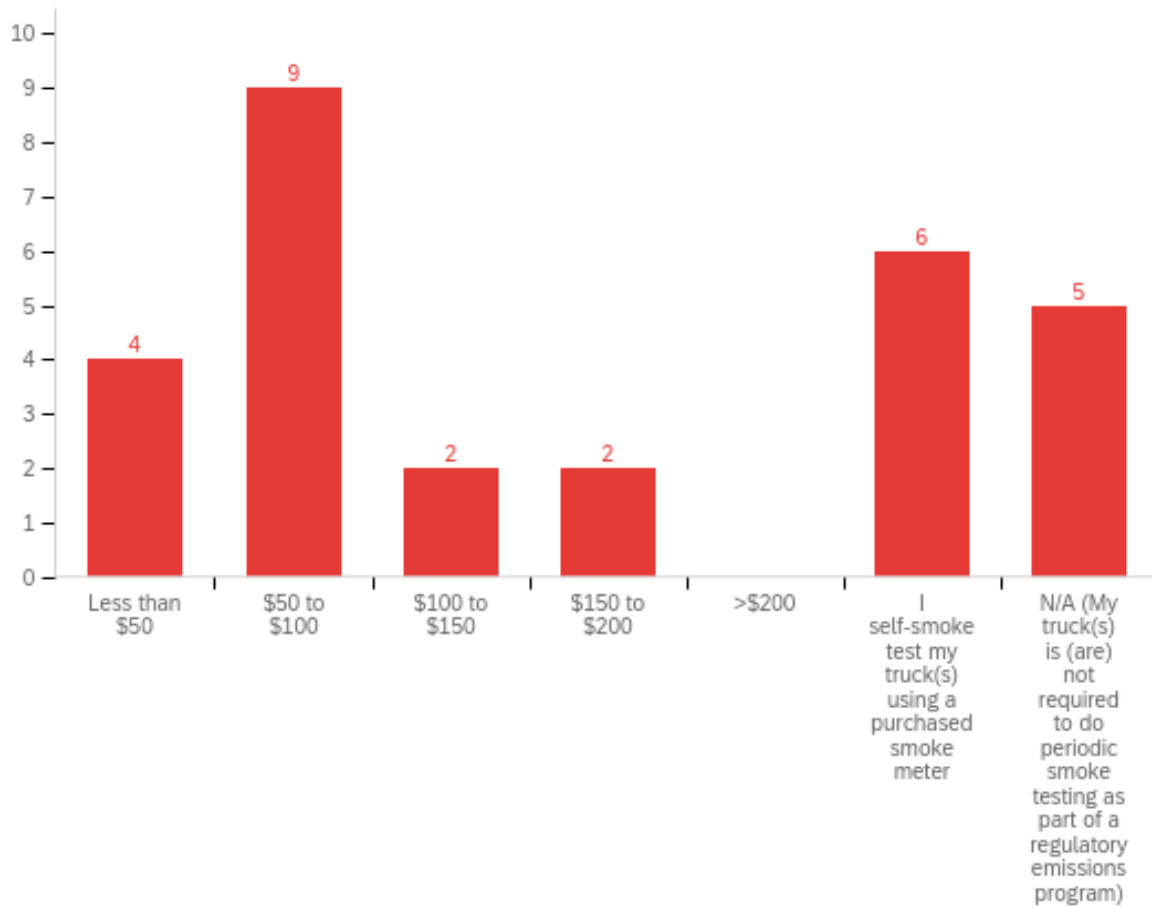
Answer	%	Count
Less than $50	14%	4
$50 to $100	32%	9
$100 to $150	7%	2
$150 to $200	7%	2
>$200	0%	0
I self-smoke test my truck(s) using a purchased smoke meter	21%	6
N/A (My truck(s) is (are) not required to do periodic smoke testing as part of a regulatory emissions program)	18%	5
Total	100%	28

12) As part of the future heavy-duty inspection and maintenance (HD I/M) program, CARB is considering a requirement of periodic submission of a vehicle's Onboard Diagnostic (OBD) data for compliance purposes, which is analogous to the current OBD testing requirement in the Smog Check program for light-duty vehicles in California. If such a requirement is developed, what would be your preferred data submission approach if the data submission is required once per year? (Please select best answer.)
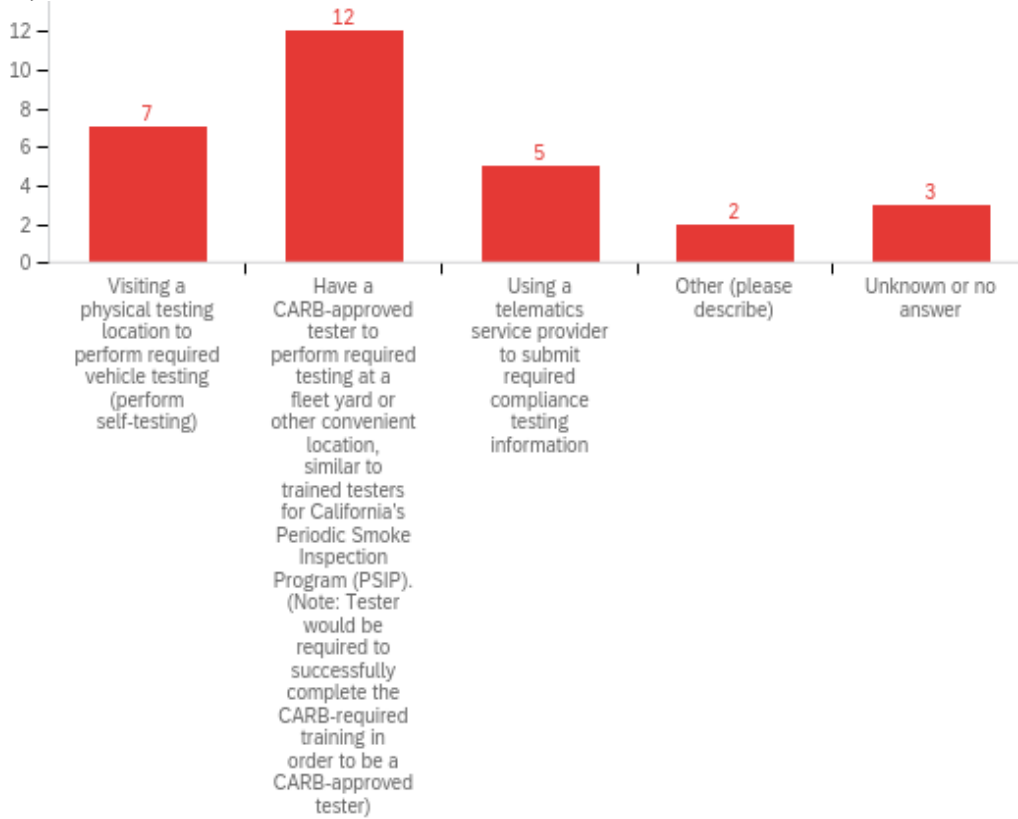
Answer	%	Count
Visiting a physical testing location to perform required vehicle testing (perform self-testing)	24%	7
Have a CARB-approved tester to perform required testing at a fleet yard or other convenient location, similar to trained testers for California's Periodic Smoke Inspection Program (PSIP). (Note: Tester would be required to successfully complete the CARB-required training in order to be a CARB-approved tester)	41%	12
Using a telematics service provider to submit required compliance testing information	17%	5
Other (please describe)	7%	2
Unknown or no answer	10%	3
Total	100%	29

Other (please describe) - Text

The ability for a mobile service to come to our facility and perform the required inspection

Never.

13) Similar to the testing frequency of California's Basic Inspection Terminal (BIT) inspection, a future HD I/M program could have OBD emissions testing requirements every 90 days. Would such a testing frequency influence the testing option that you would prefer to use to comply with the program?
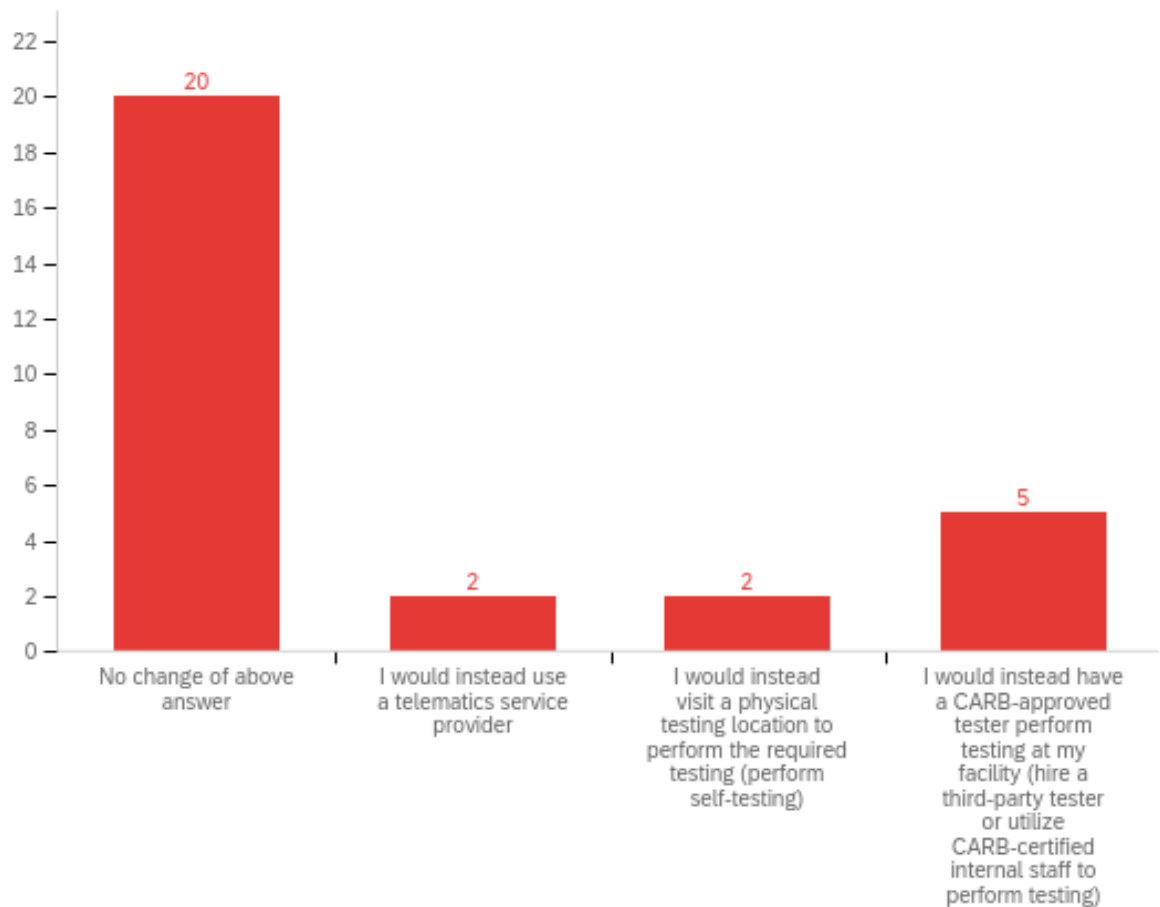
Answer	%	Count
No change of above answer	69%	20
I would instead use a telematics service provider	7%	2
I would instead visit a physical testing location to perform the required testing (perform self-testing)	7%	2
I would instead have a CARB-approved tester perform testing at my facility (hire a third-party tester or utilize CARB-certified internal staff to perform testing)	17%	5
Total	100%	29

14) Do you have any program recommendations, preferences, or other thoughts / input that you'd like to share related to the development of a HD I/M program?

Every 90 days?? Current smoke testing once per year requires scheduling of downtime (for 70 trucks) and travel (600 miles driving) for an entire weekend with a company CARB certified tester (me). Outsourcing this work is not practical for our fleet. Telematics for trucks with that capability is worth investigating but still only covers a third of our trucks. We successfully run another third of trucks as retrofits in Nox Exempt territory which will require continued smoke testing. Suggest doing some more investigation on how this will effect older (but perfectly legal) operators running in Nox Exempt counties, do these need to meet the same 90 day requirements as full compliance counties?

Testing every 90 days is too frequent to take a vehicle out of service for testing.

no

Your survey is too generic to be of much value. Typical GVWR of a fleet is not a one weight class answer. Our fleet has a large number of vehicles in all classes. GPS hardware costs vary by vehicle and application. Maintenance costs vary by type of equipment and uses. Times for repairs vary depending on what the repair is being performed, parts availability and staffing.

All of my pre- 2012 year of manufacture HD Ag Exempt trucks record less than 5,000 miles use each year. These pre-2012 HD trucks with mileage limitations should continue to be exempt from the regulations due to the limited annual use for the purpose of harvest.

a) Consider two used Class 8 tractors. Assuming both vehicles have an equivalent age, mileage, and planned future use, how much would you value a residual emissions warranty of 200,000 miles on a used vehicle when you make the vehicle purchase decision?
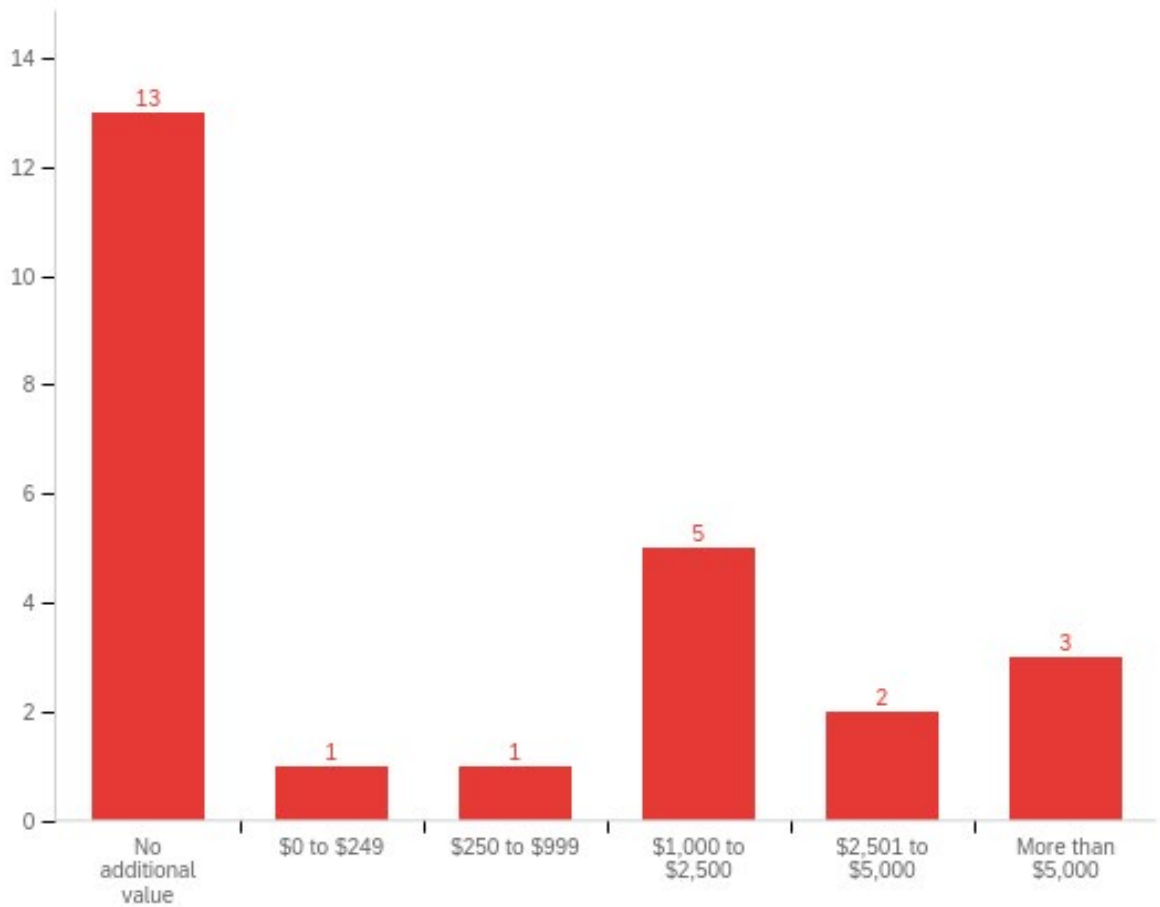
Answer	%	Count
No additional value	52%	13
$0 to $249	4%	1
$250 to $999	4%	1
$1,000 to $2,500	20%	5
$2,501 to $5,000	8%	2
More than $5,000	12%	3
Total	100%	25

b) In the past have you ever purchased an extended emissions warranty from a dealer or another warranty company for either a new or used Class 8 tractor?
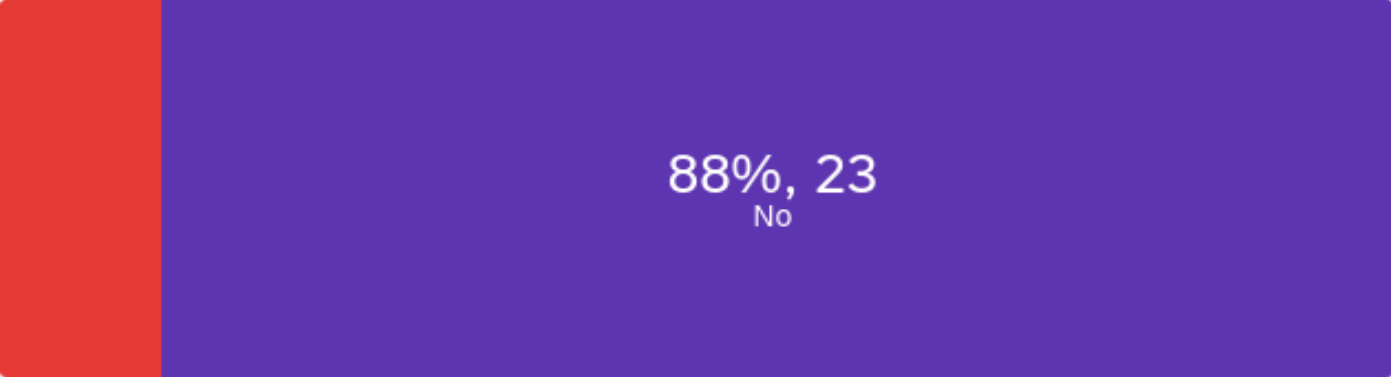
88%, 23
No

Yes (3)   No (23)

Answer	%	Count
Yes	12%	3
No	88%	23
Total	100%	26

c) Would you be willing to provide your contact information for CARB to follow-up with you on your purchasing experience?

Yes (2)　　No (1)

#	Answer	%	Count
1	Yes (please provide contact information below)	67%	2
2	No	33%	1
	Total	100%	3

16) CARB staff is seeking to understand how much of a premium value a used heavy-duty vehicle has if it also has a transferable extended emissions warranty versus the same used heavy-duty vehicle without that emissions warranty. Would you be willing to participate in a separate survey to help further our understanding of the value of extended emissions warranty?

17%, 5 Yes	83%, 24 No
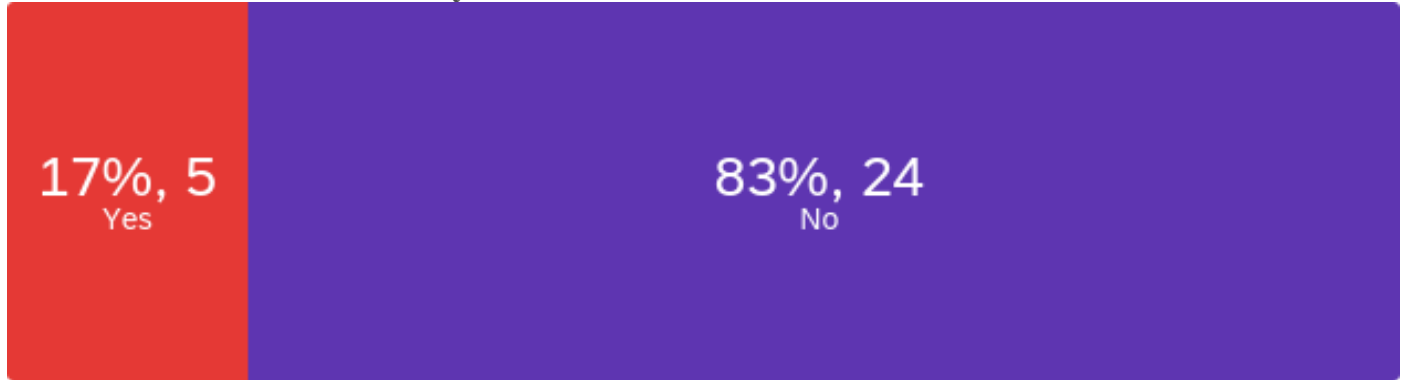
Yes (5)　　No (24)

Answer	%	Count
Yes (please confirm contact information below)	17%	5
No	83%	24
Total	100%	29

Appendix E

Repair Cost Estimates Provided by Contributing Sources

Repair Cost Estimates from Source 1

Costs for given repairs from this source are presented in terms of each of the three engine manufacturers and in terms of OE (original equipment), indicating OE parts and dealer-level labor costs, and aftermarket, indicating aftermarket parts costs and independent repair shop labor price levels. These costs represent the final values after ERG revisited the original costs with the Source (as described in the report).

Problem or Failed Component	Needed Repair or Options	Cummins OE Quote	Cummins Aftermarket Quote	Detroit Diesel OE Quote	Detroit Diesel Aftermarket Quote	International/ Maxxforce OE Quote	International/ Maxxforce Aftermarket Quote
Ambient pressure sensor	Replace sensor	$569.90	$223.44	$512.00	$278.55	$537.92	$326.91
Intake manifold pressure sensor	Replace sensor	$489.24	$203.23	$671.02	$228.37	$648.00	$272.89
Intake or turbo temperature sensor	Replace sensor	$471.84	$244.05	$569.18	$242.51	$543.64	$246.80
Fuel pump or fuel pump actuator failure	Replace fuel pump	$7,807.50	$4,012.50	$5,515.00	$2,300.75	$2,515.00	$822.20
Fuel pump or fuel pump actuator failure	Replace fuel quantity control valve	NA	NA	$5,515.00	$2,300.75	$5116.90	$1,256.83
Fuel pump or fuel pump actuator failure	Replace actuator (pump)	$1,448.14	$651.96	NA	NA	NA	NA
Fuel rail pressure sensor	Replace sensor	$719.02	$286.82	$962.22	$497.47	$916.50	$249.16
Fuel rail pressure relief valve	Replace fuel valve (relief valve)	$1,329.30	$696.65	$924.98	$422.00	$1,808.82	$931.92
Fuel rail pressure relief valve	Replace fuel rail	$1,459.90	$590.42	$1,798.00	$1,014.68	$3,021.52	$1,174.15
Engine fuel injector(s) or fuel rail external leak	Replace injector seals	$867.50	$387.46	$956.38	$437.68	$956.96	$458.60
Engine fuel injector(s) or fuel rail external leak	Replace injectors	$2,487.50	$1,134.00	$1,865.00	$1,009.50	$2,094.10	$907.63

Problem or Failed Component	Needed Repair or Options	Cummins OE Quote	Cummins Aftermarket Quote	Detroit Diesel OE Quote	Detroit Diesel Aftermarket Quote	International/ Maxxforce OE Quote	International/ Maxxforce Aftermarket Quote
High Pressure/Injection pump	Replace HP injector pump			$6,215.00	$2,640.75		
EGR position sensor	Replace sensor	$424.00	$197.49	$1,190.00	$328.65	$2,009.98	$382.06
EGR actuator motor	Replace EGR valve / actuator	$1,324.98	$477.11	$1,425.00	$572.30	$3,173.32	$1,007.92
DEF temperature sensor	Replace sensor	$1,728.02	$660.96	$914.20	$228.37	$744.90	$256.76
EGR differential pressure sensor	Replace sensor	$999.54	$286.88	$638.18	$372.37	$350.00	$374.86
SCR Inlet Nox sensor	Replace sensor	$994.44	$741.62	$1,349.90	$604.27	$1,465.66	$614.20
EGR leak	Replace gaskets (Gasket, Engine Head Set)	$422.42	$216.76	$2,503.00	$844.49	$1,200.44	$505.42
EGR leak	Entire EGR	$2,048.00	$1,004.83	$2,678.00	$929.49	$3,493.60	$1,260.00
EGR valve failure	EGR Valves (each)	$1,149.98	$392.11	$1,448.00	$812.95	$1,748.00	$1,229.01
EGR valve failure	Replace EGR valve assembly KIT	$3,867.00	$1,589.42	$1,915.00	$646.63	$4,492.40	$2,751.65
SCR outlet Nox Sensor	Replace NOx sensor	$1,467.44	$712.73	$1,199.98	$729.68	$350.00	$676.95
Aftertreatment pressure buildup/clog	Perform a stationary regen	$175.00	$85.00	$175.00	$85.00	$175.00	$85.00
DPF inlet pressure sensor	Replace sensor	$667.98	$278.47	$785.84	$418.83	$765.16	$300.58
Clogged DPF (ie non-"regenable")	Replace DPF	$4,441.70	Not Allowed in CA	$3,859.00	Not Allowed in CA	$7,165.70	Not Allowed in CA
DEF doser unit/valve or wiring	Replace doser injector	$1,454.98	$640.90	$1,797.62	$998.63	$1,639.96	$607.83

Problem or Failed Component	Needed Repair or Options	Cummins OE Quote	Cummins Aftermarket Quote	Detroit Diesel OE Quote	Detroit Diesel Aftermarket Quote	International/ Maxxforce OE Quote	International/ Maxxforce Aftermarket Quote
DEF doser unit/valve or wiring	Replace Doser Pump	$2,207.78	$837.64	$1,739.36	$924.50	$6,812.26	$3,680.00
DEF heater failure	Replace DEF heater	$2,510.00	$1,143.19	$2,236.26	$1,082.47	$3,212.80	$1,089.92
DEF plumbing problem or leak	Repair or replace DEF lines	$611.88	$312.70	$818.10	$467.98	$823.48	$534.79
DEF quality sensor	Replace sensor	$1,728.02	$660.96	$914.20	$228.37	$744.90	$256.76
DPF outlet pressure sensor	Replace sensor	$667.98	$278.47	$785.84	$418.83	$765.16	$300.58
Excessive DEF deposits in decomposition tube	Clean decomposition tube	$87.50	$42.50	$87.50	$42.50	$87.50	$42.50
Excessive DEF deposits in decomposition tube	Replace entire SCR	$9,277.88	Not Allowed in CA		Not Allowed in CA	$5,044.80	Not Allowed in CA
DPF cracked or broken	Replace DPF	$4,441.70	Not Allowed in CA	$3,859.00	Not Allowed in CA	$7,165.70	Not Allowed in CA
DEF filter	Replace DEF filter	$257.50	$119.95	$275.56	$112.17	$227.62	$139.76
SCR poisoning/failure	Replace SCR catalyst	$3,057.48	Not Allowed in CA	$7,912.50	Not Allowed in CA	$3,937.08	Not Allowed in CA
Intake throttle valve position sensor	Replace sensor	$424.00	$206.72	$350.00	$170.00	$932.10	$268.51
Intake throttle valve assembly	Replace intake throttle valve	$1,159.98	$691.16	$648.00	$299.43	$3,315.00	$1,856.76
Exhaust fuel injector failure	Replace exhaust fuel injector	$2,400.00	$1,164.98	$911.80	$388.79	$2,034.22	$1,036.66
Engine fuel injector internal leakage (ie into cylinder)	Clean or replace fuel injector(s)	$2,137.50	$1,037.48	$1,515.00	$839.50	$1,919.10	$822.63

Problem or Failed Component	Needed Repair or Options	Cummins OE Quote	Cummins Aftermarket Quote	Detroit Diesel OE Quote	Detroit Diesel Aftermarket Quote	International/ Maxxforce OE Quote	International/ Maxxforce Aftermarket Quote
Engine Oil Separator	Replace or clean separator	$197.40	$89.31	$637.50	$374.83	$204.64	$100.93
LP side fuel lift pump	Replace lift pump	$667.74	$327.73	$612.50	$297.50	$1,616.12	$787.06
SCR Inlet Temperature Sensor	Exhaust Gas Sensor	$621.18	$253.50	$1,190.00	$328.65	$615.36	$286.82
SCR Inlet Temperature Sensor	Exhaust Gas Temp Sensor	$646.94	$303.52	$1,190.00	$328.65	$615.36	$286.82
SCR outlet temperature sensor	Replace sensor	$646.94	$303.52	$1,190.00	$328.65	$615.36	$286.82
PM sensor	Replace sensor	$1,089.96	$545.75	$689.98	$353.70	$765.16	$300.58
NH3 sensor or wiring	Replace sensor	$1,414.50	$949.49	$986.76	$601.95	$1,025.64	$418.83
Turbo VGT actuator	Replace actuator	$3,706.74	$1,898.50	$3,365.28	$716.50	$2,861.20	$1,754.87
Turbocharger Failure	Replace turbo	$10,650.00	$5,920.80	$4,315.00	$1,919.65	$5,578.62	$3,305.67
Fuel filter replacement (all if multiple)	Replace fuel filter(s)	$210.70	$ 57.60	$142.82	$ 75.37	$289.76	$ 91.90
Collapsed or obstructed fuel pickup lines	Replace fuel sending unit/fuel lines/clear obstruction	$577.22	$322.13	$1,026.58	$375.24	$927.50	$388.58
ECM	Reflash? Replace?	$2,750.00	$933.19	$2,850.00	$1,422.50	$2,148.40	$834.66

Repair Estimates from Source 2

Repair estimates from this source are presented in labor hours required for each repair. This source indicated to use an average labor rate of $145/hr. The source did not have a way to specifically estimate parts costs, but indicated that a good estimate for total repair costs including parts and labor is to directly double the labor costs. Labor hours are presented in terms of engine manufacturer (for the calculations in the report, and to be comparable with the Source 1, International and Volvo were grouped together in "Other"). In many cases, the source provided ranges of costs within a manufacturer and repair. Cells with missing values indicate that the source did not provide a cost estimate for the given repair.

Problem or Failed Component	Cummins (13' – 17')	Cummins (18')	Detroit Diesel (14' – 16')	Detroit Diesel ('17)	International/Maxxforce ('13+)	Volvo ('13+)
DPF Replacement Filter	1.6 to 3.7	1.6 to 3.7	0.9	0.9	.9 to 2.3	1.9
DPF Inlet Pressure Sensor	0.3	0.3	0.6	0.6	1.2	.6 to 1.2
DPF Outlet Pressure Sensor	0.3	0.6	0.5	0.6	1.2	.6 to 1.2
Particulate Matter Sensor						
DEF Unit	1.2	1.2	1.3	1.3	1.2	1.0 to 1.5
DEF Doser #7 Injector	.6 to 1.6	.6 to 1.6	1.3	1.3	0.8	1
DEF Filter	.5 to 1.2	.5 to 1.2			0.5	0.5
DEF Heater	0.9	0.9			0.9	0.9
DEF Quality Senor						
DEF Temp Sensor	0.9	0.9	3.2	3.2	1.3	0.6 to 1.2
DEF Lines			1.2 to 4.3	1.2 to 4.3	1.3	
EGR Activator Motor			2	2		
EGR Differential Pressure Sensor	0.7	0.7	0.6	0.6	0.9	0.6
EGR Position Sensor	0.7	0.7			1.2	0.6
EGR Valve Replacement	2.9	2	2		.9 to 3.9	2.3 to 4.0
SCR Inlet NOx Sensor	0.5	0.5	0.7	0.7	.9 to 1.7	.6 to 1.7
SCR Outlet NOx Sensor	0.5	0.5	0.7	0.7	.5 to 2.7	.6 to 1.7
SCR Inlet Temp Sensor	0.5	0.5	0.6	0.6	0.6	0.6
SCR Outlet Temp. Sensor	0.5	0.5	0.6	0.6	0.6	0.6
SCR NH3 Sensor	0.5	0.5			0.5	

Problem or Failed Component	Cummins (13' – 17')	Cummins (18')	Detroit Diesel (14' – 16')	Detroit Diesel ('17)	International/Maxxforce ('13+)	Volvo ('13+)
SCR Catalyst Replacement	1.3	1.3	.9 to 4.8	1.5 to 4.8	1.5 to 2.6	1.2 to 1.0
Turbo Replacement	2.4 to 4.5	2.4 to 4.5	2.2 to 6.5	2.2 to 6.5	4.5 to 10.6	3.7
VGT Actuator	2.2	0.5			0.5	1.9 to 3.9
Turbo Temp Sensor	0.3	0.3	0.5	0.5		
Intake Manifold Component Replacement						
Intake Throttle Valve Ass.	0.6	0.6	0.6	0.6	2.3	
Intake Throttle Valve Position Sensor	0.3	0.3	0.3			
Intake Manifold Pressure Sensor	0.5	0.5	0.5		0.7	
Barometric (Ambient) Air Pressure Sensor #1	0.5	0.5	0.5			
Engine Fuel Injectors (6)	1.3 to 2.4	1.3 to 2.4	6.7 to 8.3	6.7 to 8.3	4.5 to 5.2	5.6 to 8.0
Fuel Rail	1.2	1.2	2.2	2.2	5	
Fuel Rail Pressure Relief Valve	0.6	0.6	.3 to .9		1.4	
Fuel Rail Pressure Sensor	0.5	0.5	0.5	0.5	1.3	0.5
HP/Injector Pump	2.4	1.5	1.5	1.5	4.5 to 5.2	1.2
Fuel Pump Activator	0.6	0.6				0.6
Fuel Filter (All if Multiple)	0.3	0.6	0.7	0.7	1	0.6

Appendix F

Example DrewLinQ SAE J1939 Data Files

Sample DrewLinQ output file

SAE J1939 protocol, 2016 Freightliner Cascadia, 12.8L

Log file: basic application log output showing queries of the parameters

Spnlog file: parameter bytes decoded into spns

Xml file: the representation of the data in xml based on CARB's data schema that was available when the application was developed

Log file:

```
(00:00.000) j1939_obd_xml2 version: 1.0.14.0
(00:00.046) Wednesday, November 18, 2020 9:08:38 AM
(00:00.047) selected test: ALL TESTS
(00:00.048) determine network nodes by reading DM1
(00:07.118)  0x00
(00:07.118)  0x01
(00:07.132)  0x03
(00:07.133)  0x0B
(00:07.134)  0x17
(00:07.136)  0x21
(00:07.137)  0x25
(00:07.139)  0x31
(00:07.141)  0x3D
(00:07.142)  0x47
(00:07.146)  0x4A
(00:07.147) OK
(00:07.675) ----------
(00:07.675) start test DM1
(00:07.677)  pgn: 65226 (0xFECA)
(00:07.678)  broadcast pgn (period 1000ms)
(00:07.678)   read
(00:11.723)   18 FE CA 00 03 FF 00 00 00 00 FF FF
(00:11.723)   18 FE CA 01 03 FF 00 00 00 00 FF FF
(00:11.739)   18 FE CA 03 F7 FF 33 02 0E 06 FF FF
(00:11.741)   18 FE CA 0B 04 FF 23 03 04 01 FF FF
(00:11.742)   18 FE CA 17 FF FF 00 00 00 00 FF FF
(00:11.743)   10 FE CA 21 00 FF 00 00 00 00 FF FF
(00:11.752)   10 FE CA 25 00 FF 00 00 00 00 FF FF
(00:11.755)   10 FE CA 31 00 FF 00 00 00 00 FF FF
(00:11.755)   18 FE CA 3D 03 FF 00 00 00 00 FF FF
(00:11.755)   10 FE CA 47 00 FF 6F F2 E4 01 FF FF
(00:12.669) ----------
(00:12.673) start test VI
(00:12.677)  pgn: 65260 (0xFEEC)
(00:12.680)  non-broadcast pgn
(00:12.682)   request
(00:16.201)   18 EA FF D1 EC FE 00
(00:16.201)   response
(00:16.218)   00 FE EC 00 31 46 55 4A 47 42 44 56 36 47 4C 47 53 30 34 36 38 2A
(00:16.418) ----------
(00:16.420) start test CI
(00:16.422)  pgn: 65259 (0xFEEB)
(00:16.425)  non-broadcast pgn
(00:16.426)   request
(00:20.445)   18 EA FF D1 EB FE 00
(00:20.445)   response
(00:20.459)   00 FE EB 00 44 54 44 53 43 2A 34 37 31 4E 31 33 2A 53 30 33 31 35 32 34 32 2A 20 20 20 20 20 20 20 20 20 20 2A
(00:20.462)   00 FE EB 03 45 41 54 4F 4E 2A 46 4F 28 4D 29 2D 78 78 45 33 31 30 43 2D 4C 41 53 2A 4B 31 31 30 31 36 36 32 2A 2A
(00:20.466)   00 FE EB 0B 4D 45 52 57 42 2A 41 42 53 20 34 30 30 38 36 36 34 35 31 30 2A 37 36 38 31 30 36 38 33 32 30 2A 2A
(00:20.469)   00 FE EB 17 44 54 4E 41 2A 49 43 55 33 50 2D 32 30 31 33 2A 2A 2A
(00:20.472)   00 FE EB 4A 5A 4F 4E 41 52 2A 44 54 4E 41 20 54 50 2C 20 44 54 4E 41 20 54 65 6C 65 6D 61 74 69 63 73 20 50 6C 61 74 66 6F 72 6D 2A 30 30 31 31 36 34 36 36 30 30 2A 2A
(00:20.690) ----------
(00:20.692) start test AC
(00:20.694)  pgn: 60928 (0xEE00)
(00:20.696)  non-broadcast pgn
(00:20.698)   request
(00:23.155)   18 EA FF D1 00 EE 00
(00:23.160)   response
(00:23.163)    no response
(00:23.167)  second pass for unresponsive nodes
(00:25.696)   requests
(00:25.707)   18 EA 00 D1 00 EE 00
(00:25.714)   18 EA 01 D1 00 EE 00
(00:25.716)   18 EA 03 D1 00 EE 00
(00:25.720)   18 EA 0B D1 00 EE 00
(00:25.722)   18 EA 17 D1 00 EE 00
(00:25.725)   18 EA 21 D1 00 EE 00
(00:25.728)   18 EA 25 D1 00 EE 00
(00:25.730)   18 EA 31 D1 00 EE 00
```

```
(00:25.733)     18 EA 3D D1 00 EE 00
(00:25.735)     18 EA 47 D1 00 EE 00
(00:25.738)     18 EA 4A D1 00 EE 00
(00:25.740)    responses
(00:25.743)     no response
(00:25.745)     no response
(00:25.747)     no response
(00:25.750)     no response
(00:25.752)     no response
(00:25.754)     no response
(00:25.756)     no response
(00:25.758)     no response
(00:25.760)     no response
(00:25.762)     no response
(00:25.765)     no response
(00:25.941) ----------
(00:25.943) start test DM5
(00:25.945)  pgn: 65230 (0xFECE)
(00:25.947)  non-broadcast pgn
(00:25.949)   request
(00:28.362)     18 EA FF D1 CE FE 00
(00:28.362)   response
(00:28.376)     18 FE CE 00 00 00 14 00 00 00 00 00
(00:28.379)     18 FE CE 01 00 02 14 07 A0 02 20 00
(00:28.380)     18 FE CE 3D 00 03 14 04 20 1C 00 00
(00:28.587) ----------
(00:28.590) start test DM6
(00:28.592)  pgn: 65231 (0xFECF)
(00:28.594)  non-broadcast pgn
(00:28.596)   request
(00:31.017)     18 EA FF D1 CF FE 00
(00:31.028)   response
(00:31.036)     18 FE CF 01 03 FF 00 00 00 00 FF FF
(00:31.038)     18 FE CF 3D 03 FF 00 00 00 00 FF FF
(00:31.236) ----------
(00:31.238) start test DM12
(00:31.240)  pgn: 65236 (0xFED4)
(00:31.242)  non-broadcast pgn
(00:31.245)   request
(00:33.666)     18 EA FF D1 D4 FE 00
(00:33.666)   response
(00:33.681)     18 FE D4 01 03 FF 00 00 00 00 FF FF
(00:33.685)     18 FE D4 3D 03 FF 00 00 00 00 FF FF
(00:33.903) ----------
(00:33.904) start test DM19
(00:33.911)  pgn: 54016 (0xD300)
(00:33.921)  non-broadcast pgn
(00:33.923)   request
(00:36.352)     18 EA FF D1 00 D3 00
(00:36.352)   response
(00:36.367)     00 D3 FF 00 68 42 7A 55 30 59 30 30 52 30 30 30 30 44 45 54 52 4F 49 54
(00:36.370)     00 D3 FF 01 2C D7 36 70 31 34 37 30 30 31 4E 41 49 30 30 30 30 30 30 34
(00:36.371)     00 D3 FF 3D A8 38 91 4C 32 35 76 30 30 31 4E 33 36 30 30 30 30 30 32 20 8A 5E C1 45 4E 4F 78 2D 53 57 37
30 31 30 20 41 54 49 31 00 93 7D D4 4A 4E 4F 78 2D 53 57 37 30 31 30 20 41 54 4F 31 00
(00:36.376)  second pass for unresponsive nodes
(00:38.896)   requests
(00:38.896)     18 EA 03 D1 00 D3 00
(00:38.910)     18 EA 0B D1 00 D3 00
(00:38.913)     18 EA 17 D1 00 D3 00
(00:38.915)     18 EA 21 D1 00 D3 00
(00:38.920)     18 EA 25 D1 00 D3 00
(00:38.921)     18 EA 31 D1 00 D3 00
(00:38.927)     18 EA 47 D1 00 D3 00
(00:38.931)     18 EA 4A D1 00 D3 00
(00:38.935)   responses
(00:38.939)    NegativeAck
(00:38.942)     18 E8 FF 03 01 FF FF FF D1 00 D3 00
(00:38.943)     no response
(00:38.949)     no response
(00:38.953)     no response
(00:38.954)     no response
(00:38.959)     no response
(00:38.962)     no response
(00:38.964)    NegativeAck
(00:38.967)     18 E8 FF 4A 01 00 FF FF D1 00 D3 00
(00:39.162) ----------
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(00:39.164) start test DM20
(00:39.166)  pgn: 49664 (0xC200)
(00:39.169)  non-broadcast pgn
(00:39.171)   request
(00:41.579)    18 EA FF D1 00 C2 00
(00:41.586)   response
(00:41.590)    00 C2 FF 01 6D 2A CD 13 FF FF FF FF FF FF FF FF FF FF FF FF FF FF C6 14 F8 00 00 CC 13 F2 0B F8 A3 03 CC
13 FF FF FF FF FF FF FF C9 14 F8 0A 01 CC 13 FF FF FF FF FF FF FF FF EF 0B F8 77 04 CC 13
(00:41.596)    00 C2 FF 3D 6B 2A C5 13 CA 14 F8 FD 02 06 01 B8 12 F8 16 01 C5 13 FF FF FF FF FF FF FF FF FF FF FF FF
FF F8 0B F8 92 02 06 01 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
(00:41.607)  second pass for unresponsive nodes
(00:44.140)   requests
(00:44.152)    18 EA 00 D1 00 C2 00
(00:44.155)    18 EA 03 D1 00 C2 00
(00:44.157)    18 EA 0B D1 00 C2 00
(00:44.162)    18 EA 17 D1 00 C2 00
(00:44.163)    18 EA 21 D1 00 C2 00
(00:44.169)    18 EA 25 D1 00 C2 00
(00:44.171)    18 EA 31 D1 00 C2 00
(00:44.175)    18 EA 47 D1 00 C2 00
(00:44.179)    18 EA 4A D1 00 C2 00
(00:44.180)   responses
(00:44.186)    NegativeAck
(00:44.187)    18 E8 FF 00 01 FF FF FF D1 00 C2 00
(00:44.193)    NegativeAck
(00:44.197)    18 E8 FF 03 01 FF FF FF D1 00 C2 00
(00:44.200)    no response
(00:44.202)    no response
(00:44.205)    no response
(00:44.207)    no response
(00:44.210)    no response
(00:44.212)    no response
(00:44.214)    NegativeAck
(00:44.216)    18 E8 FF 4A 01 00 FF FF D1 00 C2 00
(00:44.404) ----------
(00:44.407) start test DM21
(00:44.409)  pgn: 49408 (0xC100)
(00:44.411)  non-broadcast pgn
(00:44.414)   request
(00:46.832)    18 EA FF D1 00 C1 00
(00:46.832)   response
(00:46.846)    no response
(00:46.849)  second pass for unresponsive nodes
(00:49.364)   requests
(00:49.364)    18 EA 00 D1 00 C1 00
(00:49.378)    18 EA 01 D1 00 C1 00
(00:49.381)    18 EA 03 D1 00 C1 00
(00:49.383)    18 EA 0B D1 00 C1 00
(00:49.387)    18 EA 17 D1 00 C1 00
(00:49.390)    18 EA 21 D1 00 C1 00
(00:49.393)    18 EA 25 D1 00 C1 00
(00:49.396)    18 EA 31 D1 00 C1 00
(00:49.399)    18 EA 3D D1 00 C1 00
(00:49.402)    18 EA 47 D1 00 C1 00
(00:49.405)    18 EA 4A D1 00 C1 00
(00:49.409)   responses
(00:49.412)    NegativeAck
(00:49.415)    18 E8 FF 00 01 FF FF FF D1 00 C1 00
(00:49.418)    18 C1 D1 01 FF FF FF FF 00 00 D2 D8
(00:49.420)    NegativeAck
(00:49.426)    18 E8 FF 03 01 FF FF FF D1 00 C1 00
(00:49.427)    no response
(00:49.432)    no response
(00:49.435)    no response
(00:49.437)    no response
(00:49.440)    no response
(00:49.442)    18 C1 D1 3D FF FF FF FF 00 00 D2 D8
(00:49.444)    no response
(00:49.446)    NegativeAck
(00:49.449)    18 E8 FF 4A 01 00 FF FF D1 00 C1 00
(00:49.641) ----------
(00:49.643) start test DM23
(00:49.645)  pgn: 64949 (0xFDB5)
(00:49.647)  non-broadcast pgn
(00:49.649)   request
(00:52.065)    18 EA FF D1 B5 FD 00
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(00:52.065)     response
(00:52.078)      18 FD B5 01 03 FF 00 00 00 00 FF FF
(00:52.081)      18 FD B5 3D 03 FF 00 00 00 00 FF FF
(00:52.277) ----------
(00:52.279) start test DM24
(00:52.281)  pgn: 64950 (0xFDB6)
(00:52.283)  non-broadcast pgn
(00:52.285)   request
(00:54.692)      18 EA FF D1 B6 FD 00
(00:54.702)    response
(00:54.705)      00 FD B6 3D BE 00 1E 02 5C 00 1E 01 00 02 1E 01 6E 00 1E 01 AF 00 1E 02 E5 0C 1E 02 54 00 1E 02 6C 00 1E
01 A8 00 1E 02 33 00 1E 01 5E 00 1E 01 9C 05 1E 02 64 06 1E 02 46 0A 1E 02 EB 0D 1E 01 84 00 1E 02 CD 15 1C 02 E7 0A 1E
02 1B 00 1E 02 88 0D 1E 02 B7 00 1E 02 9D 00 1E 02 AA 0C 1C 02 1A 0E 1C 02 AE 0C 1E 02 B3 0C 1C 02 A4 00 1E 02 67 00 1E
02 9D 06 1E 01 66 00 1E 01 01 02 1E 01 5B 00 1E 01 1B 02 1E 01 1C 02 1E 01 1D 02 1E 01 1E 02 1E 01 1F 02 1E 01 CB 14 1E
01 AE 00 1E 01 ED 0F 1E 02 90 0C 1C 02 08 11 1E 02 0B 11 1E 02 19 0E 1C 02 D7 0B 1E 01 EE 10 1E 01 E1 06 1A 01 98 0D 1E
02 C1 0D 1C 01 60 00 1E 01 9B 01 1E 02 D0 03 1E 01 74 0E 1E 01 C2 14 1E 02 85 05 1E 02 86 05 1E 02 87 05 1E 02 88 05 1E
02 89 05 1E 02 8A 05 1E 02 16 11 1E 02 C0 14 1E 02 9A 0C 19 02 B2 0C 1D 02 F0 0B 1B 02 24 0D 1B 02 7F 0E 1B 02 81 0E 1B
02 60 0F 1B 02 0C 11 1B 02 15 15 1B 02 E1 1C 1D 02
(00:54.989) ----------
(00:54.991) start test DM25
(00:54.993)  pgn: 64951 (0xFDB7)
(00:54.995)  non-broadcast pgn
(00:54.998)   request
(00:59.027)      18 EA FF D1 B7 FD 00
(00:59.033)    response
(00:59.036)      18 FD B7 01 00 00 00 00 00 FF FF FF
(00:59.039)      18 FD B7 3D 00 00 00 00 00 FF FF FF
(00:59.238) ----------
(00:59.241) start test DM26
(00:59.243)  pgn: 64952 (0xFDB8)
(00:59.245)  non-broadcast pgn
(00:59.247)   request
(01:01.655)      18 EA FF D1 B8 FD 00
(01:01.655)    response
(01:01.670)      18 FD B8 01 00 00 A3 07 A0 02 20 00
(01:01.673)      18 FD B8 3D 00 00 A5 04 20 1C 00 00
(01:01.877) ----------
(01:01.879) start test DM28
(01:01.881)  pgn: 64896 (0xFD80)
(01:01.883)  non-broadcast pgn
(01:01.886)   request
(01:04.297)      18 EA FF D1 80 FD 00
(01:04.297)    response
(01:04.314)      18 FD 80 01 03 FF 00 00 00 00 FF FF
(01:04.318)      18 FD 80 3D 03 FF 00 00 00 00 FF FF
(01:04.512) ----------
(01:04.514) start test DM29
(01:04.516)  pgn: 40448 (0x9E00)
(01:04.518)  non-broadcast pgn
(01:04.521)   request
(01:06.933)      18 EA FF D1 00 9E 00
(01:06.933)    response
(01:06.948)    no response
(01:06.951)  second pass for unresponsive nodes
(01:09.471)   requests
(01:09.487)      18 EA 00 D1 00 9E 00
(01:09.489)      18 EA 01 D1 00 9E 00
(01:09.492)      18 EA 03 D1 00 9E 00
(01:09.495)      18 EA 0B D1 00 9E 00
(01:09.498)      18 EA 17 D1 00 9E 00
(01:09.501)      18 EA 21 D1 00 9E 00
(01:09.504)      18 EA 25 D1 00 9E 00
(01:09.507)      18 EA 31 D1 00 9E 00
(01:09.510)      18 EA 3D D1 00 9E 00
(01:09.513)      18 EA 47 D1 00 9E 00
(01:09.515)      18 EA 4A D1 00 9E 00
(01:09.518)   responses
(01:09.521)    NegativeAck
(01:09.523)      18 E8 FF 00 01 FF FF FF D1 00 9E 00
(01:09.525)      18 9E D1 01 00 00 00 00 00 FF FF FF
(01:09.527)    NegativeAck
(01:09.529)      18 E8 FF 03 01 FF FF FF D1 00 9E 00
(01:09.531)    no response
(01:09.534)    no response
(01:09.535)    no response
(01:09.537)    no response
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(01:09.540)    no response
(01:09.542)    18 9E D1 3D 00 00 00 00 00 FF FF FF
(01:09.545)    no response
(01:09.547)    NegativeAck
(01:09.549)    18 E8 FF 4A 01 00 FF FF D1 00 9E 00
(01:09.749) ----------
(01:09.753) start test DM33
(01:09.755)  pgn: 41216 (0xA100)
(01:09.757)  non-broadcast pgn
(01:09.759)   request
(01:12.171)    18 EA FF D1 00 A1 00
(01:12.171)   response
(01:12.186)    00 A1 FF 01 01 52 7B 00 00 21 13 00 00
(01:12.189)    00 A1 FF 3D 02 3E 00 00 00 FF FF FF FF 03 FE A1 07 00 FF FF FF FF 04 0E D1 01 00 FF FF FF FF
(01:12.192)  second pass for unresponsive nodes
(01:14.715)   requests
(01:14.715)    18 EA 00 D1 00 A1 00
(01:14.732)    18 EA 03 D1 00 A1 00
(01:14.736)    18 EA 0B D1 00 A1 00
(01:14.739)    18 EA 17 D1 00 A1 00
(01:14.741)    18 EA 21 D1 00 A1 00
(01:14.744)    18 EA 25 D1 00 A1 00
(01:14.747)    18 EA 31 D1 00 A1 00
(01:14.750)    18 EA 47 D1 00 A1 00
(01:14.752)    18 EA 4A D1 00 A1 00
(01:14.754)   responses
(01:14.759)    NegativeAck
(01:14.760)    18 E8 FF 00 01 FF FF FF D1 00 A1 00
(01:14.766)    NegativeAck
(01:14.770)    18 E8 FF 03 01 FF FF FF D1 00 A1 00
(01:14.771)    no response
(01:14.776)    no response
(01:14.779)    no response
(01:14.782)    no response
(01:14.784)    no response
(01:14.786)    no response
(01:14.789)    NegativeAck
(01:14.791)    18 E8 FF 4A 01 00 FF FF D1 00 A1 00
(01:14.978) ----------
(01:14.980) start test DM34
(01:14.982)  pgn: 40960 (0xA000)
(01:14.985)  non-broadcast pgn
(01:14.987)   request
(01:17.393)    18 EA FF D1 00 A0 00
(01:17.403)   response
(01:17.409)    no response
(01:17.412)  second pass for unresponsive nodes
(01:19.935)   requests
(01:19.935)    18 EA 00 D1 00 A0 00
(01:19.951)    18 EA 01 D1 00 A0 00
(01:19.955)    18 EA 03 D1 00 A0 00
(01:19.959)    18 EA 0B D1 00 A0 00
(01:19.962)    18 EA 17 D1 00 A0 00
(01:19.964)    18 EA 21 D1 00 A0 00
(01:19.967)    18 EA 25 D1 00 A0 00
(01:19.971)    18 EA 31 D1 00 A0 00
(01:19.972)    18 EA 3D D1 00 A0 00
(01:19.977)    18 EA 47 D1 00 A0 00
(01:19.978)    18 EA 4A D1 00 A0 00
(01:19.983)   responses
(01:19.987)    NegativeAck
(01:19.988)    18 E8 FF 00 01 FF FF FF D1 00 A0 00
(01:19.991)    18 A0 D1 01 00 00 FF FF FF FF FF FF
(01:19.993)    NegativeAck
(01:19.996)    18 E8 FF 03 01 FF FF FF D1 00 A0 00
(01:19.998)    no response
(01:20.000)    no response
(01:20.003)    no response
(01:20.005)    no response
(01:20.007)    no response
(01:20.009)    NegativeAck
(01:20.011)    18 E8 FF 3D 01 FF FF FF D1 00 A0 00
(01:20.014)    no response
(01:20.016)    NegativeAck
(01:20.018)    18 E8 FF 4A 01 00 FF FF D1 00 A0 00
(01:20.206) ----------
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(01:20.208) start test DM56
(01:20.210)  pgn: 64711 (0xFCC7)
(01:20.212)  non-broadcast pgn
(01:20.214)   request
(01:22.640)    18 EA FF D1 C7 FC 00
(01:22.645)   response
(01:22.648)    no response
(01:22.850) ----------
(01:22.852) start test EEC1
(01:22.854)  pgn: 61444 (0xF004)
(01:22.856)  broadcast pgn (period 50ms)
(01:22.858)   read
(01:23.015)    0C F0 04 00 01 7D 7D 00 00 00 F0 7D
(01:23.024)    0C F0 04 21 FF FF FF FF FF FF FF FF
(01:23.253) ----------
(01:23.255) start test EEC2
(01:23.257)  pgn: 61443 (0xF003)
(01:23.259)  broadcast pgn (period 50ms)
(01:23.261)   read
(01:23.383)    0C F0 03 00 DD 00 00 FF FF FF 00 FF
(01:23.630) ----------
(01:23.632) start test EEC3
(01:23.634)  pgn: 65247 (0xFEDF)
(01:23.636)  broadcast pgn (period 250ms)
(01:23.638)   read
(01:24.154)    18 FE DF 00 7D 00 13 FF 7D 00 00 FF
(01:24.400) ----------
(01:24.402) start test ET1
(01:24.405)  pgn: 65262 (0xFEEE)
(01:24.407)  broadcast pgn (period 1000ms)
(01:24.409)   read
(01:26.436)    18 FE EE 00 34 34 A0 23 FF FF 38 FF
(01:26.729) ----------
(01:26.731) start test CCVS1
(01:26.733)  pgn: 65265 (0xFEF1)
(01:26.736)  broadcast pgn (period 100ms)
(01:26.739)   read
(01:26.951)    18 FE F1 00 C7 00 00 C0 00 00 00 30
(01:26.951)    18 FE F1 17 F7 FF FF FF FF FF FF FF
(01:26.966)    14 FE F1 21 F7 FF FF CF FF FF FF FF
(01:26.970)    14 FE F1 31 CF FF FF F3 00 FF FF 30
(01:27.254) ----------
(01:27.255) start test IC1
(01:27.258)  pgn: 65270 (0xFEF6)
(01:27.261)  broadcast pgn (period 500ms)
(01:27.263)   read
(01:28.283)    18 FE F6 00 FF 00 38 29 FF 50 24 FF
(01:28.283)    18 FE F6 21 FF FF FF FF FF FF FF FF
(01:28.515) ----------
(01:28.517) start test EC1
(01:28.520)  pgn: 65251 (0xFEE3)
(01:28.522)  broadcast pgn (period 5000ms)
(01:28.525)   read
(01:38.562)    00 FE E3 00 00 13 B9 80 33 CF 20 1B C4 C0 26 E1 60 2B D9 99 35 FF FF 83 09 80 4D 32 FF FF FF FF FF FF 04
01 FF FF FF FF FF FF FF
(01:38.772) ----------
(01:38.773) start test IT6
(01:38.776)  pgn: 65159 (0xFE87)
(01:38.778)  non-broadcast pgn
(01:38.781)   request
(01:41.198)    18 EA FF D1 87 FE 00
(01:41.207)   response
(01:41.213)    1C FE 87 01 FF FF FF FF FF FF 00 64
(01:41.438) ----------
(01:41.440) start test AT1S1
(01:41.442)  pgn: 64891 (0xFD7B)
(01:41.444)  non-broadcast pgn
(01:41.446)   request
(01:43.863)    18 EA FF D1 7B FD 00
(01:43.863)   response
(01:43.879)    18 FD 7B 3D 26 FF 00 00 00 00 B0 04
(01:44.096) ----------
(01:44.099) start test A1DEFI1
(01:44.101)  pgn: 64923 (0xFD9B)
(01:44.103)  broadcast pgn (period 1000ms)
(01:44.106)   read
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(01:46.143)    18 FD 9B 3D FF FF FF FF FF FF FF FF
(01:46.347) ----------
(01:46.350) start test GHGTL
(01:46.352)  pgn: 64252 (0xFAFC)
(01:46.354)  non-broadcast pgn
(01:46.356)   request
(01:48.770)    18 EA FF D1 FC FA 00
(01:48.770)   response
(01:48.788)    no response
(01:48.998) ----------
(01:49.002) start test 1GHGTS
(01:49.006)  pgn: 64253 (0xFAFD)
(01:49.009)  non-broadcast pgn
(01:49.012)   request
(01:51.436)    18 EA FF D1 FD FA 00
(01:51.446)   response
(01:51.448)    no response
(01:51.651) ----------
(01:51.653) start test 1GHGTA
(01:51.655)  pgn: 64254 (0xFAFE)
(01:51.657)  non-broadcast pgn
(01:51.659)   request
(01:54.078)    18 EA FF D1 FE FA 00
(01:54.090)   response
(01:54.093)    no response
(01:54.290) ----------
(01:54.293) start test NTFCEA
(01:54.295)  pgn: 64258 (0xFB02)
(01:54.297)  non-broadcast pgn
(01:54.299)   request
(01:56.713)    18 EA FF D1 02 FB 00
(01:56.713)   response
(01:56.730)    no response
(01:56.942) ----------
(01:56.944) start test NTEHEA
(01:56.946)  pgn: 64259 (0xFB03)
(01:56.948)  non-broadcast pgn
(01:56.950)   request
(01:59.384)    18 EA FF D1 03 FB 00
(01:59.387)   response
(01:59.390)    no response
(01:59.581) ----------
(01:59.583) start test NTVMEA
(01:59.585)  pgn: 64260 (0xFB04)
(01:59.588)  non-broadcast pgn
(01:59.589)   request
(02:02.001)    18 EA FF D1 04 FB 00
(02:02.001)   response
(02:02.015)    no response
(02:02.259) ----------
(02:02.261) start test NTEEEA
(02:02.263)  pgn: 64261 (0xFB05)
(02:02.265)  non-broadcast pgn
(02:02.267)   request
(02:04.684)    18 EA FF D1 05 FB 00
(02:04.693)   response
(02:04.700)    no response
(02:04.930) ----------
(02:04.931) start test NTFCV
(02:04.934)  pgn: 64262 (0xFB06)
(02:04.937)  non-broadcast pgn
(02:04.938)   request
(02:07.392)    18 EA FF D1 06 FB 00
(02:07.401)   response
(02:07.408)    no response
(02:07.612) ----------
(02:07.614) start test NTEHV
(02:07.616)  pgn: 64263 (0xFB07)
(02:07.618)  non-broadcast pgn
(02:07.621)   request
(02:10.036)    18 EA FF D1 07 FB 00
(02:10.036)   response
(02:10.055)    no response
(02:10.258) ----------
(02:10.260) start test NTVMV
(02:10.262)  pgn: 64264 (0xFB08)
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(02:10.264)   non-broadcast pgn
(02:10.266)    request
(02:12.684)     18 EA FF D1 08 FB 00
(02:12.690)    response
(02:12.693)     no response
(02:12.903) ----------
(02:12.905) start test NTEEV
(02:12.908)  pgn: 64265 (0xFB09)
(02:12.909)  non-broadcast pgn
(02:12.912)    request
(02:15.326)     18 EA FF D1 09 FB 00
(02:15.338)    response
(02:15.341)     no response
(02:15.531) ----------
(02:15.533) start test NTENV
(02:15.535)  pgn: 64266 (0xFB0A)
(02:15.538)  non-broadcast pgn
(02:15.540)    request
(02:17.953)     18 EA FF D1 0A FB 00
(02:17.965)    response
(02:17.968)     no response
(02:18.174) ----------
(02:18.176) start test NTSNV
(02:18.178)  pgn: 64267 (0xFB0B)
(02:18.180)  non-broadcast pgn
(02:18.182)    request
(02:20.615)     18 EA FF D1 0B FB 00
(02:20.618)    response
(02:20.622)     no response
(02:20.813) ----------
(02:20.815) start test NTFCS
(02:20.817)  pgn: 64268 (0xFB0C)
(02:20.819)  non-broadcast pgn
(02:20.821)    request
(02:23.230)     18 EA FF D1 0C FB 00
(02:23.230)    response
(02:23.245)     no response
(02:23.447) ----------
(02:23.449) start test NTEHS
(02:23.451)  pgn: 64269 (0xFB0D)
(02:23.453)  non-broadcast pgn
(02:23.456)    request
(02:25.870)     18 EA FF D1 0D FB 00
(02:25.870)    response
(02:25.888)     no response
(02:26.103) ----------
(02:26.105) start test NTVMS
(02:26.107)  pgn: 64270 (0xFB0E)
(02:26.109)  non-broadcast pgn
(02:26.111)    request
(02:28.572)     18 EA FF D1 0E FB 00
(02:28.580)    response
(02:28.582)     no response
(02:28.783) ----------
(02:28.785) start test NTEES
(02:28.788)  pgn: 64271 (0xFB0F)
(02:28.791)  non-broadcast pgn
(02:28.793)    request
(02:31.217)     18 EA FF D1 0F FB 00
(02:31.217)    response
(02:31.230)     no response
(02:31.449) ----------
(02:31.451) start test NTENS
(02:31.453)  pgn: 64272 (0xFB10)
(02:31.455)  non-broadcast pgn
(02:31.457)    request
(02:33.874)     18 EA FF D1 10 FB 00
(02:33.881)    response
(02:33.886)     no response
(02:34.114) ----------
(02:34.116) start test NTSNS
(02:34.119)  pgn: 64273 (0xFB11)
(02:34.122)  non-broadcast pgn
(02:34.124)    request
(02:36.541)     18 EA FF D1 11 FB 00
(02:36.541)    response
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(02:36.557)    no response
(02:36.747) ----------
(02:36.749) start test NTFCA
(02:36.751)  pgn: 64274 (0xFB12)
(02:36.753)  non-broadcast pgn
(02:36.754)   request
(02:39.161)    18 EA FF D1 12 FB 00
(02:39.172)   response
(02:39.173)    no response
(02:39.364) ----------
(02:39.366) start test NTEHA
(02:39.368)  pgn: 64275 (0xFB13)
(02:39.370)  non-broadcast pgn
(02:39.372)   request
(02:41.802)    18 EA FF D1 13 FB 00
(02:41.810)   response
(02:41.816)    no response
(02:42.049) ----------
(02:42.051) start test NTVMA
(02:42.053)  pgn: 64276 (0xFB14)
(02:42.055)  non-broadcast pgn
(02:42.057)   request
(02:44.470)    18 EA FF D1 14 FB 00
(02:44.470)   response
(02:44.485)    no response
(02:44.679) ----------
(02:44.681) start test NTEEA
(02:44.683)  pgn: 64277 (0xFB15)
(02:44.685)  non-broadcast pgn
(02:44.687)   request
(02:47.094)    18 EA FF D1 15 FB 00
(02:47.107)   response
(02:47.109)    no response
(02:47.346) ----------
(02:47.346) start test NTENA
(02:47.349)  pgn: 64278 (0xFB16)
(02:47.352)  non-broadcast pgn
(02:47.356)   request
(02:49.785)    18 EA FF D1 16 FB 00
(02:49.785)   response
(02:49.796)    no response
(02:49.996) ----------
(02:49.998) start test NTSNA
(02:50.000)  pgn: 64279 (0xFB17)
(02:50.002)  non-broadcast pgn
(02:50.005)   request
(02:52.417)    18 EA FF D1 17 FB 00
(02:52.417)   response
(02:52.431)    no response
(02:52.622) ----------
(02:52.624) start test ESR
(02:52.626)  pgn: 34560 (0x8700)
(02:52.628)  broadcast pgn (period 1000ms)
(02:52.630)   read
(02:54.645)    00 87 00 03 FF FF FF FF FF FC FF FF
(02:54.654)  second pass for unresponsive nodes
(02:57.204)   requests
(02:57.212)    18 EA 00 D1 00 87 00
(02:57.218)    18 EA 01 D1 00 87 00
(02:57.222)    18 EA 0B D1 00 87 00
(02:57.225)    18 EA 17 D1 00 87 00
(02:57.228)    18 EA 21 D1 00 87 00
(02:57.231)    18 EA 25 D1 00 87 00
(02:57.234)    18 EA 31 D1 00 87 00
(02:57.237)    18 EA 3D D1 00 87 00
(02:57.240)    18 EA 47 D1 00 87 00
(02:57.243)    18 EA 4A D1 00 87 00
(02:57.244)   responses
(02:57.250)    NegativeAck
(02:57.252)    18 E8 FF 00 01 FF FF FF D1 00 87 00
(02:57.257)    NegativeAck
(02:57.260)    18 E8 FF 01 01 FF FF FF D1 00 87 00
(02:57.263)    no response
(02:57.265)    no response
(02:57.268)    no response
(02:57.270)    no response
```

```
(02:57.272)    no response
(02:57.274)    NegativeAck
(02:57.277)    18 E8 FF 3D 01 FF FF FF D1 00 87 00
(02:57.279)    no response
(02:57.281)    NegativeAck
(02:57.283)    18 E8 FF 4A 01 00 FF FF D1 00 87 00
(02:57.475) ----------
(02:57.478) start test DM32
(02:57.480)  pgn: 41472 (0xA200)
(02:57.482)  non-broadcast pgn
(02:57.484)   request
(02:59.905)    18 EA FF D1 00 A2 00
(02:59.914)   response
(02:59.923)    no response
(02:59.926)  second pass for unresponsive nodes
(03:02.441)   requests
(03:02.441)    18 EA 00 D1 00 A2 00
(03:02.457)    18 EA 01 D1 00 A2 00
(03:02.464)    18 EA 03 D1 00 A2 00
(03:02.476)    18 EA 0B D1 00 A2 00
(03:02.478)    18 EA 17 D1 00 A2 00
(03:02.491)    18 EA 21 D1 00 A2 00
(03:02.493)    18 EA 25 D1 00 A2 00
(03:02.498)    18 EA 31 D1 00 A2 00
(03:02.506)    18 EA 3D D1 00 A2 00
(03:02.510)    18 EA 47 D1 00 A2 00
(03:02.514)    18 EA 4A D1 00 A2 00
(03:02.517)   responses
(03:02.518)    NegativeAck
(03:02.523)    18 E8 FF 00 01 FF FF FF D1 00 A2 00
(03:02.526)    NegativeAck
(03:02.528)    18 E8 FF 01 01 FF FF FF D1 00 A2 00
(03:02.531)    NegativeAck
(03:02.533)    18 E8 FF 03 01 FF FF FF D1 00 A2 00
(03:02.535)    no response
(03:02.537)    no response
(03:02.539)    no response
(03:02.541)    no response
(03:02.543)    no response
(03:02.545)    NegativeAck
(03:02.547)    18 E8 FF 3D 01 FF FF FF D1 00 A2 00
(03:02.550)    no response
(03:02.552)    NegativeAck
(03:02.554)    18 E8 FF 4A 01 00 FF FF D1 00 A2 00
(03:02.748) ----------
(03:02.750) start test CTL
(03:02.752)  pgn: 52992 (0xCF00)
(03:02.754)  broadcast pgn (period 5000ms)
(03:02.756)   read
(03:12.778)    no response
(03:12.794)  second pass for unresponsive nodes
(03:15.321)   requests
(03:15.331)    18 EA 00 D1 00 CF 00
(03:15.337)    18 EA 01 D1 00 CF 00
(03:15.340)    18 EA 03 D1 00 CF 00
(03:15.343)    18 EA 0B D1 00 CF 00
(03:15.346)    18 EA 17 D1 00 CF 00
(03:15.349)    18 EA 21 D1 00 CF 00
(03:15.352)    18 EA 25 D1 00 CF 00
(03:15.356)    18 EA 31 D1 00 CF 00
(03:15.359)    18 EA 3D D1 00 CF 00
(03:15.362)    18 EA 47 D1 00 CF 00
(03:15.365)    18 EA 4A D1 00 CF 00
(03:15.368)   responses
(03:15.370)    NegativeAck
(03:15.373)    18 E8 FF 00 01 FF FF FF D1 00 CF 00
(03:15.375)    NegativeAck
(03:15.377)    18 E8 FF 01 01 FF FF FF D1 00 CF 00
(03:15.379)    NegativeAck
(03:15.382)    18 E8 FF 03 01 FF FF FF D1 00 CF 00
(03:15.384)    no response
(03:15.386)    no response
(03:15.388)    no response
(03:15.390)    no response
(03:15.392)    no response
(03:15.394)    NegativeAck
```

```
(03:15.396)     18 E8 FF 3D 01 FF FF FF D1 00 CF 00
(03:15.398)    no response
(03:15.400)    NegativeAck
(03:15.403)     18 E8 FF 4A 01 00 FF FF D1 00 CF 00
(03:15.584) ----------
(03:15.586) start test EBC1
(03:15.588)  pgn: 61441 (0xF001)
(03:15.590)  broadcast pgn (period 100ms)
(03:15.592)   read
(03:15.812)     18 F0 01 0B 00 00 D0 FF FF 5C FF FF
(03:15.812)     14 F0 01 31 FF FF FF FF 00 FF FF FF
(03:16.027) ----------
(03:16.028) start test GC2
(03:16.031)  pgn: 61470 (0xF01E)
(03:16.033)  broadcast pgn (period 20ms)
(03:16.035)   read
(03:16.356)    no response
(03:16.577) ----------
(03:16.579) start test EOI
(03:16.581)  pgn: 64914 (0xFD92)
(03:16.583)  broadcast pgn (period 250ms)
(03:16.585)   read
(03:17.096)    no response
(03:17.321) ----------
(03:17.323) start test EOI2
(03:17.325)  pgn: 61711 (0xF10F)
(03:17.328)  broadcast pgn (period 100ms)
(03:17.330)   read
(03:17.560)    no response
(03:17.816) ----------
(03:17.818) start test TTI1
(03:17.820)  pgn: 65204 (0xFEB4)
(03:17.823)  non-broadcast pgn
(03:17.825)   request
(03:20.242)     18 EA FF D1 B4 FE 00
(03:20.242)   response
(03:20.257)    no response
(03:20.473) ----------
(03:20.482) generate XML
(03:20.523) ----------
END
```

SPN Log File

```
DM1
 source address: 0x00
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM1
 source address: 0x01
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM1
 source address: 0x03
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: F7 FF 33 02 0E 06 FF FF
 lampMalfunctionIndicatorStatus_1213: 3
 lampRedStopStatus_623: 3
 lampAmberWarningStatus_624: 1
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 dtc[0]
  [Anti-Lock Braking (ABS) Active]
  spn: 563
  fmi: 14
  oc: 6
  cm: 0

DM1
 source address: 0x0B
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 04 FF 23 03 04 01 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 1
 lampProtectStatus_987: 0
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 dtc[0]
  [Relay Diagonal 2]
  spn: 803
  fmi: 4
  oc: 1
  cm: 0

DM1
 source address: 0x17
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
```

```
 data bytes: FF FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 3
 lampRedStopStatus_623: 3
 lampAmberWarningStatus_624: 3
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM1
 source address: 0x21
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 00 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 0
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM1
 source address: 0x25
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 00 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 0
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM1
 source address: 0x31
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 00 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 0
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM1
 source address: 0x3D
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM1
 source address: 0x47
 pgn: 65226 (0xFECA)
 description: Active Diagnostic Trouble Codes (DTCs)
 data bytes: 00 FF 6F F2 E4 01 FF FF
```

```
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 0
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 dtc[0]
  [Manufacturer Assignable SPN]
  spn: 520815
  fmi: 4
  oc: 1
  cm: 0

VI
 source address: 0x00
 pgn: 65260 (0xFEEC)
 label: Vehicle Identification
 data bytes: 31 46 55 4A 47 42 44 56 36 47 4C 47 53 30 34 36 38 2A
 spn: 237
  label: Vehicle Identification Number
  bytes: 31 46 55 4A 47 42 44 56 36 47 4C 47 53 30 34 36 38 2A
  value: 1FUJGBDV6GLGS0468*

CI
 source address: 0x00
 pgn: 65259 (0xFEEB)
 label: Component Identification
 data bytes: 44 54 44 53 43 2A 34 37 31 4E 31 33 2A 53 30 33 31 35 32 34 32 2A 20 20 20 20 20 20 20 20 20 20 2A
 spn: 586
  label: Make
  bytes: 44 54 44 53 43
  value: DTDSC
 spn: 587
  label: Model
  bytes: 34 37 31 4E 31 33
  value: 471N13
 spn: 588
  label: Serial Number
  bytes: 53 30 33 31 35 32 34 32
  value: S0315242
 spn: 233
  label: Unit Number (Power Unit)
  bytes: 20 20 20 20 20 20 20 20 20 20
  value:

CI
 source address: 0x03
 pgn: 65259 (0xFEEB)
 label: Component Identification
 data bytes: 45 41 54 4F 4E 2A 46 4F 28 4D 29 2D 78 78 45 33 31 30 43 2D 4C 41 53 2A 4B 31 31 30 31 36 36 32 2A 2A
 spn: 586
  label: Make
  bytes: 45 41 54 4F 4E
  value: EATON
 spn: 587
  label: Model
  bytes: 46 4F 28 4D 29 2D 78 78 45 33 31 30 43 2D 4C 41 53
  value: FO(M)-xxE310C-LAS
 spn: 588
  label: Serial Number
  bytes: 4B 31 31 30 31 36 36 32
  value: K1101662
 spn: 233
  label: Unit Number (Power Unit)
  value:

CI
 source address: 0x0B
 pgn: 65259 (0xFEEB)
 label: Component Identification
 data bytes: 4D 45 52 57 42 2A 41 42 53 20 34 30 30 38 36 36 34 35 31 30 2A 37 36 38 31 30 36 38 33 32 30 2A 2A
 spn: 586
  label: Make
  bytes: 4D 45 52 57 42
```

```
   value: MERWB
 spn: 587
  label: Model
  bytes: 41 42 53 20 34 30 30 38 36 36 34 35 31 30
  value: ABS 4008664510
 spn: 588
  label: Serial Number
  bytes: 37 36 38 31 30 36 38 33 32 30
  value: 7681068320
 spn: 233
  label: Unit Number (Power Unit)
  value:

CI
 source address: 0x17
 pgn: 65259 (0xFEEB)
 label: Component Identification
 data bytes: 44 54 4E 41 2A 49 43 55 33 50 2D 32 30 31 33 2A 2A 2A
 spn: 586
  label: Make
  bytes: 44 54 4E 41
  value: DTNA
 spn: 587
  label: Model
  bytes: 49 43 55 33 50 2D 32 30 31 33
  value: ICU3P-2013
 spn: 588
  label: Serial Number
  value:
 spn: 233
  label: Unit Number (Power Unit)
  value:

CI
 source address: 0x4A
 pgn: 65259 (0xFEEB)
 label: Component Identification
 data bytes: 5A 4F 4E 41 52 2A 44 54 4E 41 20 54 50 2C 20 44 54 4E 41 20 54 65 6C 65 6D 61 74 69 63 73 20 50 6C 61 74 66
6F 72 6D 2A 30 30 31 31 36 34 36 36 30 30 2A 2A
 spn: 586
  label: Make
  bytes: 5A 4F 4E 41 52
  value: ZONAR
 spn: 587
  label: Model
  bytes: 44 54 4E 41 20 54 50 2C 20 44 54 4E 41 20 54 65 6C 65 6D 61 74 69 63 73 20 50 6C 61 74 66 6F 72 6D
  value: DTNA TP, DTNA Telematics Platform
 spn: 588
  label: Serial Number
  bytes: 30 30 31 31 36 34 36 36 30 30
  value: 0011646600
 spn: 233
  label: Unit Number (Power Unit)
  value:

DM5
 source address: 0x00
 pgn: 65230 (0xFECE)
 description: Diagnostic Readiness 1
 data bytes: 00 00 14 00 00 00 00 00
 activeTroubleCodes_1218: 0
 previouslyActiveTroubleCodes_1219: 0
 obdCompliance_1220: 20
 cmSystemsSupportStatus_1221: 0
 misfireSupport_1221: False
 fuelSystemSupport_1221: False
 comprehensiveComponentSupport_1221: False
 misfireStatus_1221: False
 fuelSystemStatus_1221: False
 comprehensiveComponentStatus_1221: False
 catalystMonitoringSupport_1222: False
 heatedCatalystMonitoringSupport_1222: False
 evaporativeSystemMonitoringSupport_1222: False
 secondaryAirSystemMonitoringSupport_1222: False
 acSystemRefrigerantMonitoringSupport_1222: False
 exhaustGasSensorMonitoringSupport_1222: False
```

```
exhaustGasSensorHeaterMonitoringSupport_1222: False
egrVvtSystemMonitoringSupport_1222: False
coldStartAidSystemMonitoringSupport_1222: False
boostPressureControlSystemMonitoringSupport_1222: False
dieselParticulateFilterMonitoringSupport_1222: False
noxConvertingCatalysMonitoringSupport_1222: False
nmhcConvertingCatalysMonitoringSupport_1222: False
catalystMonitoringStatus_1223: False
heatedCatalystMonitoringStatus_1223: False
evaporativeSystemMonitoringStatus_1223: False
secondaryAirSystemMonitoringStatus_1223: False
acSystemRefrigerantMonitoringStatus_1223: False
exhaustGasSensorMonitoringStatus_1223: False
exhaustGasSensorHeaterMonitoringStatus_1223: False
egrVvtSystemMonitoringStatus_1223: False
coldStartAidSystemMonitoringStatus_1223: False
boostPressureControlSystemMonitoringStatus_1223: False
dieselParticulateFilterMonitoringStatus_1223: False
noxConvertingCatalysMonitoringStatus_1223: False
nmhcConvertingCatalysMonitoringStatus_1223: False

DM5
 source address: 0x01
 pgn: 65230 (0xFECE)
 description: Diagnostic Readiness 1
 data bytes: 00 02 14 07 A0 02 20 00
 activeTroubleCodes_1218: 0
 previouslyActiveTroubleCodes_1219: 2
 obdCompliance_1220: 20
 cmSystemsSupportStatus_1221: 7
 misfireSupport_1221: True
 fuelSystemSupport_1221: True
 comprehensiveComponentSupport_1221: True
 misfireStatus_1221: False
 fuelSystemStatus_1221: False
 comprehensiveComponentStatus_1221: False
 catalystMonitoringSupport_1222: False
 heatedCatalystMonitoringSupport_1222: False
 evaporativeSystemMonitoringSupport_1222: False
 secondaryAirSystemMonitoringSupport_1222: False
 acSystemRefrigerantMonitoringSupport_1222: False
 exhaustGasSensorMonitoringSupport_1222: True
 exhaustGasSensorHeaterMonitoringSupport_1222: False
 egrVvtSystemMonitoringSupport_1222: True
 coldStartAidSystemMonitoringSupport_1222: False
 boostPressureControlSystemMonitoringSupport_1222: True
 dieselParticulateFilterMonitoringSupport_1222: False
 noxConvertingCatalysMonitoringSupport_1222: False
 nmhcConvertingCatalysMonitoringSupport_1222: False
 catalystMonitoringStatus_1223: False
 heatedCatalystMonitoringStatus_1223: False
 evaporativeSystemMonitoringStatus_1223: False
 secondaryAirSystemMonitoringStatus_1223: False
 acSystemRefrigerantMonitoringStatus_1223: False
 exhaustGasSensorMonitoringStatus_1223: True
 exhaustGasSensorHeaterMonitoringStatus_1223: False
 egrVvtSystemMonitoringStatus_1223: False
 coldStartAidSystemMonitoringStatus_1223: False
 boostPressureControlSystemMonitoringStatus_1223: False
 dieselParticulateFilterMonitoringStatus_1223: False
 noxConvertingCatalysMonitoringStatus_1223: False
 nmhcConvertingCatalysMonitoringStatus_1223: False

DM5
 source address: 0x3D
 pgn: 65230 (0xFECE)
 description: Diagnostic Readiness 1
 data bytes: 00 03 14 04 20 1C 00 00
 activeTroubleCodes_1218: 0
 previouslyActiveTroubleCodes_1219: 3
 obdCompliance_1220: 20
 cmSystemsSupportStatus_1221: 4
 misfireSupport_1221: False
 fuelSystemSupport_1221: False
 comprehensiveComponentSupport_1221: True
 misfireStatus_1221: False
```

```
 fuelSystemStatus_1221: False
 comprehensiveComponentStatus_1221: False
 catalystMonitoringSupport_1222: False
 heatedCatalystMonitoringSupport_1222: False
 evaporativeSystemMonitoringSupport_1222: False
 secondaryAirSystemMonitoringSupport_1222: False
 acSystemRefrigerantMonitoringSupport_1222: False
 exhaustGasSensorMonitoringSupport_1222: True
 exhaustGasSensorHeaterMonitoringSupport_1222: False
 egrVvtSystemMonitoringSupport_1222: False
 coldStartAidSystemMonitoringSupport_1222: False
 boostPressureControlSystemMonitoringSupport_1222: False
 dieselParticulateFilterMonitoringSupport_1222: True
 noxConvertingCatalysMonitoringSupport_1222: True
 nmhcConvertingCatalysMonitoringSupport_1222: True
 catalystMonitoringStatus_1223: False
 heatedCatalystMonitoringStatus_1223: False
 evaporativeSystemMonitoringStatus_1223: False
 secondaryAirSystemMonitoringStatus_1223: False
 acSystemRefrigerantMonitoringStatus_1223: False
 exhaustGasSensorMonitoringStatus_1223: False
 exhaustGasSensorHeaterMonitoringStatus_1223: False
 egrVvtSystemMonitoringStatus_1223: False
 coldStartAidSystemMonitoringStatus_1223: False
 boostPressureControlSystemMonitoringStatus_1223: False
 dieselParticulateFilterMonitoringStatus_1223: False
 noxConvertingCatalysMonitoringStatus_1223: False
 nmhcConvertingCatalysMonitoringStatus_1223: False

DM6
 source address: 0x01
 pgn: 65231 (0xFECF)
 description: Emission Related Pending DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM6
 source address: 0x3D
 pgn: 65231 (0xFECF)
 description: Emission Related Pending DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM12
 source address: 0x01
 pgn: 65236 (0xFED4)
 description: Emissions Related Active DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM12
 source address: 0x3D
```

```
 pgn: 65236 (0xFED4)
 description: Emissions Related Active DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM19
 source address: 0x00
 pgn: 54016 (0xD300)
 description: Calibration Information
 data bytes: 68 42 7A 55 30 59 30 30 52 30 30 30 30 44 45 54 52 4F 49 54
 calibration info[0]
  calibrationVerificationNumber: 1434075752
  calibrationId: 0Y00R0000DETROIT

DM19
 source address: 0x01
 pgn: 54016 (0xD300)
 description: Calibration Information
 data bytes: 2C D7 36 70 31 34 37 30 30 31 4E 41 49 30 30 30 30 30 30 34
 calibration info[0]
  calibrationVerificationNumber: 1882642220
  calibrationId: 147001NAI0000004

DM19
 source address: 0x3D
 pgn: 54016 (0xD300)
 description: Calibration Information
 data bytes: A8 38 91 4C 32 35 76 30 30 31 4E 33 36 30 30 30 30 30 32 30 8A 5E C1 45 4E 4F 78 2D 53 57 37 30 31 30 20 41
54 49 31 00 93 7D D4 4A 4E 4F 78 2D 53 57 37 30 31 30 20 41 54 4F 31 00
 calibration info[0]
  calibrationVerificationNumber: 1284585640
  calibrationId: 25v001N360000020
 calibration info[1]
  calibrationVerificationNumber: 1170300554
  calibrationId: NOx-SW7010 ATI1
 calibration info[2]
  calibrationVerificationNumber: 1255439763
  calibrationId: NOx-SW7010 ATO1

DM20
 source address: 0x01
 pgn: 49664 (0xC200)
 description: Monitor Performance Ratio
 data bytes: 6D 2A CD 13 FF FF FF FF FF FF FF FF FF FF FF FF FF FF C6 14 F8 00 00 CC 13 F2 0B F8 A3 03 CC 13 FF FF FF FF
FF FF FF C9 14 F8 0A 01 CC 13 FF FF FF FF FF FF FF EF 0B F8 77 04 CC 13
 ignitionCycleCounter_3048: 10861
 obdMonitoringConditionsEncountered_3049: 5069
 app system monitor[0]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[1]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[2]
  spn: 5318
  numerator: 0
  denominator: 5068
 app system monitor[3]
  spn: 3058
  numerator: 931
  denominator: 5068
 app system monitor[4]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[5]
```

```
  spn: 5321
  numerator: 266
  denominator: 5068
 app system monitor[6]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[7]
  spn: 3055
  numerator: 1143
  denominator: 5068

DM20
 source address: 0x3D
 pgn: 49664 (0xC200)
 description: Monitor Performance Ratio
 data bytes: 6B 2A C5 13 CA 14 F8 FD 02 06 01 B8 12 F8 16 01 C5 13 FF FF FF FF FF FF FF FF FF FF FF FF FF FF F8 0B F8 92
02 06 01 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
 ignitionCycleCounter_3048: 10859
 obdMonitoringConditionsEncountered_3049: 5061
 app system monitor[0]
  spn: 5322
  numerator: 765
  denominator: 262
 app system monitor[1]
  spn: 4792
  numerator: 278
  denominator: 5061
 app system monitor[2]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[3]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[4]
  spn: 3064
  numerator: 658
  denominator: 262
 app system monitor[5]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[6]
  spn: 524287
  numerator: 65535
  denominator: 65535
 app system monitor[7]
  spn: 524287
  numerator: 65535
  denominator: 65535

DM21
 source address: 0x01
 pgn: 49408 (0xC100)
 description: Diagnostic Readiness 2
 data bytes: FF FF FF FF 00 00 D2 D8
 distanceTraveledWhileMilIsActivated_3069: 65535
 distanceSinceDtcsCleared_3294: 65535
 minutesAccumulatedWhileMilIsActivated_3295: 0
 timeSinceDiagnosticTroubleCodesCleared_3296: 55506

DM21
 source address: 0x3D
 pgn: 49408 (0xC100)
 description: Diagnostic Readiness 2
 data bytes: FF FF FF FF 00 00 D2 D8
 distanceTraveledWhileMilIsActivated_3069: 65535
 distanceSinceDtcsCleared_3294: 65535
 minutesAccumulatedWhileMilIsActivated_3295: 0
 timeSinceDiagnosticTroubleCodesCleared_3296: 55506

DM23
 source address: 0x01
 pgn: 64949 (0xFDB5)
```

```
 description: Emission Related Previously Active DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM23
 source address: 0x3D
 pgn: 64949 (0xFDB5)
 description: Emission Related Previously Active DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM24
 source address: 0x3D
 pgn: 64950 (0xFDB6)
 description: SPN Support
 data bytes: BE 00 1E 02 5C 00 1E 01 00 02 1E 01 6E 00 1E 01 AF 00 1E 02 E5 0C 1E 02 54 00 1E 02 6C 00 1E 01 A8 00 1E 02
 33 00 1E 01 5E 00 1E 01 9C 05 1E 02 64 06 1E 02 46 0A 1E 02 EB 0D 1E 01 84 00 1E 02 CD 15 1C 02 E7 0A 1E 02 1B 00 1E 02
 88 0D 1E 02 B7 00 1E 02 9D 00 1E 02 AA 0C 1C 02 1A 0E 1C 02 AE 0C 1E 02 B3 0C 1C 02 A4 00 1E 02 67 00 1E 02 9D 06 1E 01
 66 00 1E 01 01 02 1E 01 5B 00 1E 01 1B 02 1E 01 1C 02 1E 01 1D 02 1E 01 1E 02 1E 01 1F 02 1E 01 CB 14 1E 01 AE 00 1E 01
 ED 0F 1E 02 90 0C 1C 02 08 11 1E 02 0B 11 1E 02 19 0E 1C 02 D7 0B 1E 01 EE 10 1E 01 E1 06 1A 01 98 0D 1E 02 C1 0D 1C 01
 60 00 1E 01 9B 01 1E 02 D0 03 1E 01 74 0E 1E 01 C2 14 1E 02 85 05 1E 02 86 05 1E 02 87 05 1E 02 88 05 1E 02 89 05 1E 02
 8A 05 1E 02 16 11 1E 02 C0 14 1E 02 9A 0C 19 02 B2 0C 1D 02 F0 0B 1B 02 24 0D 1B 02 7F 0E 1B 02 81 0E 1B 02 60 0F 1B 02
 0C 11 1B 02 15 15 1B 02 E1 1C 1D 02
 supported spn[0]
  spnNum_3297: 190
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
 supported spn[1]
  spnNum_3297: 92
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
 supported spn[2]
  spnNum_3297: 512
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
 supported spn[3]
  spnNum_3297: 110
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
 supported spn[4]
  spnNum_3297: 175
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
 supported spn[5]
  spnNum_3297: 3301
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
 supported spn[6]
```

```
  spnNum_3297: 84
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[7]
  spnNum_3297: 108
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[8]
  spnNum_3297: 168
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[9]
  spnNum_3297: 51
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[10]
  spnNum_3297: 94
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[11]
  spnNum_3297: 1436
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[12]
  spnNum_3297: 1636
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[13]
  spnNum_3297: 2630
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[14]
  spnNum_3297: 3563
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[15]
  spnNum_3297: 132
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[16]
  spnNum_3297: 5581
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: False
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[17]
  spnNum_3297: 2791
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[18]
  spnNum_3297: 27
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
```

```
 spnDataLength_4103: 2
supported spn[19]
 spnNum_3297: 3464
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[20]
 spnNum_3297: 183
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[21]
 spnNum_3297: 157
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[22]
 spnNum_3297: 3242
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: False
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[23]
 spnNum_3297: 3610
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: False
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[24]
 spnNum_3297: 3246
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[25]
 spnNum_3297: 3251
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: False
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[26]
 spnNum_3297: 164
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[27]
 spnNum_3297: 103
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[28]
 spnNum_3297: 1693
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[29]
 spnNum_3297: 102
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[30]
 spnNum_3297: 513
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[31]
 spnNum_3297: 91
 spnSupportedInExpandedFreezeFrame_4100: False
```

```
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[32]
 spnNum_3297: 539
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[33]
 spnNum_3297: 540
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[34]
 spnNum_3297: 541
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[35]
 spnNum_3297: 542
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[36]
 spnNum_3297: 543
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[37]
 spnNum_3297: 5323
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[38]
 spnNum_3297: 174
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 1
supported spn[39]
 spnNum_3297: 4077
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[40]
 spnNum_3297: 3216
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: False
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[41]
 spnNum_3297: 4360
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[42]
 spnNum_3297: 4363
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[43]
 spnNum_3297: 3609
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: False
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[44]
```

```
  spnNum_3297: 3031
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[45]
  spnNum_3297: 4334
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[46]
  spnNum_3297: 1761
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: False
  spnDataLength_4103: 1
supported spn[47]
  spnNum_3297: 3480
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[48]
  spnNum_3297: 3521
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: False
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[49]
  spnNum_3297: 96
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[50]
  spnNum_3297: 411
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[51]
  spnNum_3297: 976
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[52]
  spnNum_3297: 3700
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 1
supported spn[53]
  spnNum_3297: 5314
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[54]
  spnNum_3297: 1413
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[55]
  spnNum_3297: 1414
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2
supported spn[56]
  spnNum_3297: 1415
  spnSupportedInExpandedFreezeFrame_4100: False
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: True
```

```
 spnDataLength_4103: 2
supported spn[57]
 spnNum_3297: 1416
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[58]
 spnNum_3297: 1417
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[59]
 spnNum_3297: 1418
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[60]
 spnNum_3297: 4374
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[61]
 spnNum_3297: 5312
 spnSupportedInExpandedFreezeFrame_4100: False
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[62]
 spnNum_3297: 3226
 spnSupportedInExpandedFreezeFrame_4100: True
 spnSupportedInDataStream_4101: False
 spnSupportedInScaledTestResults_4102: False
 spnDataLength_4103: 2
supported spn[63]
 spnNum_3297: 3250
 spnSupportedInExpandedFreezeFrame_4100: True
 spnSupportedInDataStream_4101: False
 spnSupportedInScaledTestResults_4102: True
 spnDataLength_4103: 2
supported spn[64]
 spnNum_3297: 3056
 spnSupportedInExpandedFreezeFrame_4100: True
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: False
 spnDataLength_4103: 2
supported spn[65]
 spnNum_3297: 3364
 spnSupportedInExpandedFreezeFrame_4100: True
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: False
 spnDataLength_4103: 2
supported spn[66]
 spnNum_3297: 3711
 spnSupportedInExpandedFreezeFrame_4100: True
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: False
 spnDataLength_4103: 2
supported spn[67]
 spnNum_3297: 3713
 spnSupportedInExpandedFreezeFrame_4100: True
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: False
 spnDataLength_4103: 2
supported spn[68]
 spnNum_3297: 3936
 spnSupportedInExpandedFreezeFrame_4100: True
 spnSupportedInDataStream_4101: True
 spnSupportedInScaledTestResults_4102: False
 spnDataLength_4103: 2
supported spn[69]
 spnNum_3297: 4364
 spnSupportedInExpandedFreezeFrame_4100: True
```

```
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: False
  spnDataLength_4103: 2
 supported spn[70]
  spnNum_3297: 5397
  spnSupportedInExpandedFreezeFrame_4100: True
  spnSupportedInDataStream_4101: True
  spnSupportedInScaledTestResults_4102: False
  spnDataLength_4103: 2
 supported spn[71]
  spnNum_3297: 7393
  spnSupportedInExpandedFreezeFrame_4100: True
  spnSupportedInDataStream_4101: False
  spnSupportedInScaledTestResults_4102: True
  spnDataLength_4103: 2

DM25
 source address: 0x01
 pgn: 64951 (0xFDB7)
 description: Expanded Freeze Frame
 data bytes: 00 00 00 00 00 FF FF FF
 [no expanded freeze frame spns]

DM25
 source address: 0x3D
 pgn: 64951 (0xFDB7)
 description: Expanded Freeze Frame
 data bytes: 00 00 00 00 00 FF FF FF
 [no expanded freeze frame spns]

DM26
 source address: 0x01
 pgn: 64952 (0xFDB8)
 description: Diagnostic Readiness 3
 data bytes: 00 00 A3 07 A0 02 20 00
 timeSinceEngineStart_3301: 0
 numberOfWarmupsSinceDtcsCleared_3302: 163
 misfireMonitoringEnabled_3303: True
 fuelSystemMonitoringEnabled_3303: True
 comprehensiveComponentMonitoringEnabled_3303: True
 misfireMonitoringCompleted_3303: False
 fuelSystemMonitoringCompleted_3303: False
 comprehensiveComponentMonitoringCompleted_3303: False
 coldStartAidSystemMonitoringEnabled_3304: False
 boostPressureControlSystemMonitoringEnabled_3304: True
 dpfMonitoringEnabled_3304: False
 noxConvertingCatalystMonitoringEnabled_3304: False
 nmhcConvertingCatalystMonitoringEnabled_3304: False
 catalystMonitoringEnabled_3304: False
 heatedCatalystMonitoringEnabled_3304: False
 evaporativeSystemMonitoringEnabled_3304: False
 secondaryAirSystemMonitoringEnabled_3304: False
 acSystemRefrigerantMonitoringEnabled_3304: False
 exhaustGasSensorMonitoringEnabled_3304: True
 exhaustGasSensorHeaterMonitoringEnabled_3304: False
 egrVvtSystemMonitoringEnabled_3304: True
 coldStartAidSystemMonitoringStatus_3305: False
 boostPressureControlSystemMonitoringStatus_3305: False
 dpfMonitoringStatus_3305: False
 noxConvertingCatalystMonitoringStatus_3305: False
 nmhcConvertingCatalystMonitoringStatus_3305: False
 catalystMonitoringStatus_3305: False
 heatedCatalystMonitoringStatus_3305: False
 evaporativeSystemMonitoringStatus_3305: False
 secondaryAirSystemMonitoringStatus_3305: False
 acSystemRefrigerantMonitoringStatus_3305: False
 exhaustGasSensorMonitoringStatus_3305: True
 exhaustGasSensorHeaterMonitoringStatus_3305: False
 egrVvtSystemMonitoringStatus_3305: False

DM26
 source address: 0x3D
 pgn: 64952 (0xFDB8)
 description: Diagnostic Readiness 3
 data bytes: 00 00 A5 04 20 1C 00 00
 timeSinceEngineStart_3301: 0
```

```
numberOfWarmupsSinceDtcsCleared_3302: 165
misfireMonitoringEnabled_3303: False
fuelSystemMonitoringEnabled_3303: False
comprehensiveComponentMonitoringEnabled_3303: True
misfireMonitoringCompleted_3303: False
fuelSystemMonitoringCompleted_3303: False
comprehensiveComponentMonitoringCompleted_3303: False
coldStartAidSystemMonitoringEnabled_3304: False
boostPressureControlSystemMonitoringEnabled_3304: False
dpfMonitoringEnabled_3304: True
noxConvertingCatalystMonitoringEnabled_3304: True
nmhcConvertingCatalystMonitoringEnabled_3304: True
catalystMonitoringEnabled_3304: False
heatedCatalystMonitoringEnabled_3304: False
evaporativeSystemMonitoringEnabled_3304: False
secondaryAirSystemMonitoringEnabled_3304: False
acSystemRefrigerantMonitoringEnabled_3304: False
exhaustGasSensorMonitoringEnabled_3304: True
exhaustGasSensorHeaterMonitoringEnabled_3304: False
egrVvtSystemMonitoringEnabled_3304: False
coldStartAidSystemMonitoringStatus_3305: False
boostPressureControlSystemMonitoringStatus_3305: False
dpfMonitoringStatus_3305: False
noxConvertingCatalystMonitoringStatus_3305: False
nmhcConvertingCatalystMonitoringStatus_3305: False
catalystMonitoringStatus_3305: False
heatedCatalystMonitoringStatus_3305: False
evaporativeSystemMonitoringStatus_3305: False
secondaryAirSystemMonitoringStatus_3305: False
acSystemRefrigerantMonitoringStatus_3305: False
exhaustGasSensorMonitoringStatus_3305: False
exhaustGasSensorHeaterMonitoringStatus_3305: False
egrVvtSystemMonitoringStatus_3305: False

DM28
 source address: 0x01
 pgn: 64896 (0xFD80)
 description: Permanent DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM28
 source address: 0x3D
 pgn: 64896 (0xFD80)
 description: Permanent DTCs
 data bytes: 03 FF 00 00 00 00 FF FF
 lampMalfunctionIndicatorStatus_1213: 0
 lampRedStopStatus_623: 0
 lampAmberWarningStatus_624: 0
 lampProtectStatus_987: 3
 flashMalfunctionIndicator_3038: 3
 flashRedStop_3039: 3
 flashAmberWarning_3040: 3
 flashProtect_3041: 3
 [no dtcs]

DM29
 source address: 0x01
 pgn: 40448 (0x9E00)
 description: Regulated DTC Counts (Pending, Permanent, MIL-On, PMIL-On)
 data bytes: 00 00 00 00 00 FF FF FF
 pendingDtcs_4104: 0
 allPendingDtcs_4105: 0
 milOnDtcs_4106: 0
 previouslyMilOnDtcs_4107: 0
 permanentDtcs_4108: 0

DM29
```

```
 source address: 0x3D
 pgn: 40448 (0x9E00)
 description: Regulated DTC Counts (Pending, Permanent, MIL-On, PMIL-On)
 data bytes: 00 00 00 00 00 FF FF FF
 pendingDtcs_4104: 0
 allPendingDtcs_4105: 0
 milOnDtcs_4106: 0
 previouslyMilOnDtcs_4107: 0
 permanentDtcs_4108: 0

DM33
 source address: 0x01
 pgn: 41216 (0xA100)
 description: Emission Increasing Auxiliary Emission Control Device Active Time
 data bytes: 01 52 7B 00 00 21 13 00 00
 ei-aecd[0]
  eiAecdNumber: 1
  eiAecdEngineHoursTimer1: 31570
  eiAecdEngineHoursTimer2: 4897

DM33
 source address: 0x3D
 pgn: 41216 (0xA100)
 description: Emission Increasing Auxiliary Emission Control Device Active Time
 data bytes: 02 3E 00 00 00 FF FF FF FF 03 FE A1 07 00 FF FF FF FF 04 0E D1 01 00 FF FF FF FF
 ei-aecd[0]
  eiAecdNumber: 2
  eiAecdEngineHoursTimer1: 62
  eiAecdEngineHoursTimer2: 4294967295
 ei-aecd[1]
  eiAecdNumber: 3
  eiAecdEngineHoursTimer1: 500222
  eiAecdEngineHoursTimer2: 4294967295
 ei-aecd[2]
  eiAecdNumber: 4
  eiAecdEngineHoursTimer1: 119054
  eiAecdEngineHoursTimer2: 4294967295

DM34
 source address: 0x01
 pgn: 40960 (0xA000)
 description: NTE Status
 data bytes: 00 00 FF FF FF FF FF FF
 noxNteControlAreaStatus_4127: 0
 manufacturerSpecificNoxNteCarveOutAreaStatus_4128: 0
 noxNteDeficiencyAreaStatus_4129: 0
 pmNteControlAreaStatus_4130: 0
 manufacturerSpecificPmNteCarveOutAreaStatus_4131: 0
 pmNteDeficiencyAreaStatus_4132: 0

EEC1
 source address: 0x00
 pgn: 61444 (0xF004)
 label: Electronic Engine Controller 1
 data bytes: 01 7D 7D 00 00 00 F0 7D
 spn: 899
  label: Engine Torque Mode
  bytes: 01
  value: 1
 spn: 4154
  label: Actual Engine - Percent Torque (Fractional)
  bytes: 00
  value: 0.000 %
 spn: 512
  label: Driver's Demand Engine - Percent Torque
  bytes: 7D
  value: 0 %
 spn: 513
  label: Actual Engine - Percent Torque
  bytes: 7D
  value: 0 %
 spn: 190
  label: Engine Speed
  bytes: 00 00
  value: 0.000 rpm
 spn: 1483
```

```
  label: Source Address of Controlling Device for Engine Control
  bytes: 00
  value: 0 SA
 spn: 1675
  label: Engine Starter Mode
  bytes: 00
  value: 0
 spn: 2432
  label: Engine Demand – Percent Torque
  bytes: 7D
  value: 0 %

EEC1
 source address: 0x21
 pgn: 61444 (0xF004)
 label: Electronic Engine Controller 1
 data bytes: FF FF FF FF FF FF FF FF
 spn: 899
  label: Engine Torque Mode
  bytes: 0F
  value: 15
 spn: 4154
  label: Actual Engine - Percent Torque (Fractional)
  bytes: 0F
  value: 0.875 %
 spn: 512
  label: Driver's Demand Engine - Percent Torque
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 513
  label: Actual Engine - Percent Torque
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 190
  label: Engine Speed
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
 spn: 1483
  label: Source Address of Controlling Device for Engine Control
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 1675
  label: Engine Starter Mode
  bytes: 0F
  value: 15
 spn: 2432
  label: Engine Demand – Percent Torque
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF

EEC2
 source address: 0x00
 pgn: 61443 (0xF003)
 label: Electronic Engine Controller 2
 data bytes: DD 00 00 FF FF FF 00 FF
 spn: 558
  label: Accelerator Pedal 1 Low Idle Switch
  bytes: 01
  value: 1
 spn: 559
  label: Accelerator Pedal Kickdown Switch
  bytes: 03
  value: 3
 spn: 1437
  label: Road Speed Limit Status
  bytes: 01
  value: 1
 spn: 2970
  label: Accelerator Pedal 2 Low Idle Switch
  bytes: 03
  value: 3
```

```
spn: 91
 label: Accelerator Pedal Position 1
 bytes: 00
 value: 0.0 %
spn: 92
 label: Engine Percent Load At Current Speed
 bytes: 00
 value: 0 %
spn: 974
 label: Remote Accelerator Pedal Position
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 29
 label: Accelerator Pedal 2 Position
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 2979
 label: Vehicle Acceleration Rate Limit Status
 bytes: 03
 value: 3
spn: 5021
 label: Momentary Engine Maximum Power Enable Feedback
 bytes: 03
 value: 3
spn: 5399
 label: DPF Thermal Management Active
 bytes: 03
 value: 3
spn: 5400
 label: SCR Thermal Management Active
 bytes: 03
 value: 3
spn: 3357
 label: Actual Maximum Available Engine - Percent Torque
 bytes: 00
 value: 0.0 %
spn: 5398
 label: Estimated Pumping - Percent Torque
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF

EEC3
 source address: 0x00
 pgn: 65247 (0xFEDF)
 label: Electronic Engine Controller 3
 data bytes: 7D 00 13 FF 7D 00 00 FF
 spn: 514
  label: Nominal Friction - Percent Torque
  bytes: 7D
  value: 0 %
 spn: 515
  label: Engine's Desired Operating Speed
  bytes: 00 13
  value: 608.000 rpm
 spn: 519
  label: Engine's Desired Operating Speed Asymmetry Adjustment
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 2978
  label: Estimated Engine Parasitic Losses - Percent Torque
  bytes: 7D
  value: 0 %
 spn: 3236
  label: Aftertreatment 1 Exhaust Gas Mass Flow Rate
  bytes: 00 00
  value: 0.0 kg/h
 spn: 3237
  label: Aftertreatment 1 Intake Dew Point
  bytes: 03
  value: 3
 spn: 3238
  label: Aftertreatment 1 Exhaust Dew Point
```

```
   bytes: 03
   value: 3
  spn: 3239
   label: Aftertreatment 2 Intake Dew Point
   bytes: 03
   value: 3
  spn: 3240
   label: Aftertreatment 2 Exhaust Dew Point
   bytes: 03
   value: 3

ET1
 source address: 0x00
 pgn: 65262 (0xFEEE)
 label: Engine Temperature 1
 data bytes: 34 34 A0 23 FF FF 38 FF
  spn: 110
   label: Engine Coolant Temperature
   bytes: 34
   value: 12 °C
  spn: 174
   label: Engine Fuel 1 Temperature 1
   bytes: 34
   value: 12 °C
  spn: 175
   label: Engine Oil Temperature 1
   bytes: A0 23
   value: 12.00000 °C
  spn: 176
   label: Engine Turbocharger 1 Oil Temperature
   bytes: FF FF
   error: NotAvailableOrNotRequested
   errorMsg: not available or not requested bytes 0xFFxx
  spn: 52
   label: Engine Intercooler Temperature
   bytes: 38
   value: 16 °C
  spn: 1134
   label: Engine Charge Air Cooler Thermostat Opening
   bytes: FF
   error: NotAvailableOrNotRequested
   errorMsg: not available or not requested byte 0xFF

CCVS1
 source address: 0x00
 pgn: 65265 (0xFEF1)
 label: Cruise Control/Vehicle Speed 1
 data bytes: C7 00 00 C0 00 00 00 30
  spn: 69
   label: Two Speed Axle Switch
   bytes: 03
   value: 3
  spn: 70
   label: Parking Brake Switch
   bytes: 01
   value: 1
  spn: 1633
   label: Cruise Control Pause Switch
   bytes: 00
   value: 0
  spn: 3807
   label: Park Brake Release Inhibit Request
   bytes: 03
   value: 3
  spn: 84
   label: Wheel-Based Vehicle Speed
   bytes: 00 00
   value: 0.00000000 km/h
  spn: 595
   label: Cruise Control Active
   bytes: 00
   value: 0
  spn: 596
   label: Cruise Control Enable Switch
   bytes: 00
   value: 0
```

```
spn: 597
 label: Brake Switch
 bytes: 00
 value: 0
spn: 598
 label: Clutch Switch
 bytes: 03
 value: 3
spn: 599
 label: Cruise Control Set Switch
 bytes: 00
 value: 0
spn: 600
 label: Cruise Control Coast (Decelerate) Switch
 bytes: 00
 value: 0
spn: 601
 label: Cruise Control Resume Switch
 bytes: 00
 value: 0
spn: 602
 label: Cruise Control Accelerate Switch
 bytes: 00
 value: 0
spn: 86
 label: Cruise Control Set Speed
 bytes: 00
 value: 0 km/h
spn: 976
 label: PTO Governor State
 bytes: 00
 value: 0
spn: 527
 label: Cruise Control States
 bytes: 00
 value: 0
spn: 968
 label: Engine Idle Increment Switch
 bytes: 00
 value: 0
spn: 967
 label: Engine Idle Decrement Switch
 bytes: 00
 value: 0
spn: 966
 label: Engine Diagnostic Test Mode Switch
 bytes: 03
 value: 3
spn: 1237
 label: Engine Shutdown Override Switch
 bytes: 00
 value: 0

CCVS1
 source address: 0x17
 pgn: 65265 (0xFEF1)
 label: Cruise Control/Vehicle Speed 1
 data bytes: F7 FF FF FF FF FF FF FF
spn: 69
 label: Two Speed Axle Switch
 bytes: 03
 value: 3
spn: 70
 label: Parking Brake Switch
 bytes: 01
 value: 1
spn: 1633
 label: Cruise Control Pause Switch
 bytes: 03
 value: 3
spn: 3807
 label: Park Brake Release Inhibit Request
 bytes: 03
 value: 3
spn: 84
 label: Wheel-Based Vehicle Speed
```

```
 bytes: FF FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested bytes 0xFFxx
spn: 595
 label: Cruise Control Active
 bytes: 03
 value: 3
spn: 596
 label: Cruise Control Enable Switch
 bytes: 03
 value: 3
spn: 597
 label: Brake Switch
 bytes: 03
 value: 3
spn: 598
 label: Clutch Switch
 bytes: 03
 value: 3
spn: 599
 label: Cruise Control Set Switch
 bytes: 03
 value: 3
spn: 600
 label: Cruise Control Coast (Decelerate) Switch
 bytes: 03
 value: 3
spn: 601
 label: Cruise Control Resume Switch
 bytes: 03
 value: 3
spn: 602
 label: Cruise Control Accelerate Switch
 bytes: 03
 value: 3
spn: 86
 label: Cruise Control Set Speed
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 976
 label: PTO Governor State
 bytes: 1F
 value: 31
spn: 527
 label: Cruise Control States
 bytes: 07
 value: 7
spn: 968
 label: Engine Idle Increment Switch
 bytes: 03
 value: 3
spn: 967
 label: Engine Idle Decrement Switch
 bytes: 03
 value: 3
spn: 966
 label: Engine Diagnostic Test Mode Switch
 bytes: 03
 value: 3
spn: 1237
 label: Engine Shutdown Override Switch
 bytes: 03
 value: 3

CCVS1
 source address: 0x21
 pgn: 65265 (0xFEF1)
 label: Cruise Control/Vehicle Speed 1
 data bytes: F7 FF FF CF FF FF FF FF
 spn: 69
  label: Two Speed Axle Switch
  bytes: 03
  value: 3
 spn: 70
  label: Parking Brake Switch
```

```
 bytes: 01
 value: 1
spn: 1633
 label: Cruise Control Pause Switch
 bytes: 03
 value: 3
spn: 3807
 label: Park Brake Release Inhibit Request
 bytes: 03
 value: 3
spn: 84
 label: Wheel-Based Vehicle Speed
 bytes: FF FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested bytes 0xFFxx
spn: 595
 label: Cruise Control Active
 bytes: 03
 value: 3
spn: 596
 label: Cruise Control Enable Switch
 bytes: 03
 value: 3
spn: 597
 label: Brake Switch
 bytes: 00
 value: 0
spn: 598
 label: Clutch Switch
 bytes: 03
 value: 3
spn: 599
 label: Cruise Control Set Switch
 bytes: 03
 value: 3
spn: 600
 label: Cruise Control Coast (Decelerate) Switch
 bytes: 03
 value: 3
spn: 601
 label: Cruise Control Resume Switch
 bytes: 03
 value: 3
spn: 602
 label: Cruise Control Accelerate Switch
 bytes: 03
 value: 3
spn: 86
 label: Cruise Control Set Speed
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 976
 label: PTO Governor State
 bytes: 1F
 value: 31
spn: 527
 label: Cruise Control States
 bytes: 07
 value: 7
spn: 968
 label: Engine Idle Increment Switch
 bytes: 03
 value: 3
spn: 967
 label: Engine Idle Decrement Switch
 bytes: 03
 value: 3
spn: 966
 label: Engine Diagnostic Test Mode Switch
 bytes: 03
 value: 3
spn: 1237
 label: Engine Shutdown Override Switch
 bytes: 03
 value: 3
```

```
CCVS1
 source address: 0x31
 pgn: 65265 (0xFEF1)
 label: Cruise Control/Vehicle Speed 1
 data bytes: CF FF FF F3 00 FF FF 30
 spn: 69
  label: Two Speed Axle Switch
  bytes: 03
  value: 3
 spn: 70
  label: Parking Brake Switch
  bytes: 03
  value: 3
 spn: 1633
  label: Cruise Control Pause Switch
  bytes: 00
  value: 0
 spn: 3807
  label: Park Brake Release Inhibit Request
  bytes: 03
  value: 3
 spn: 84
  label: Wheel-Based Vehicle Speed
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
 spn: 595
  label: Cruise Control Active
  bytes: 03
  value: 3
 spn: 596
  label: Cruise Control Enable Switch
  bytes: 00
  value: 0
 spn: 597
  label: Brake Switch
  bytes: 03
  value: 3
 spn: 598
  label: Clutch Switch
  bytes: 03
  value: 3
 spn: 599
  label: Cruise Control Set Switch
  bytes: 00
  value: 0
 spn: 600
  label: Cruise Control Coast (Decelerate) Switch
  bytes: 00
  value: 0
 spn: 601
  label: Cruise Control Resume Switch
  bytes: 00
  value: 0
 spn: 602
  label: Cruise Control Accelerate Switch
  bytes: 00
  value: 0
 spn: 86
  label: Cruise Control Set Speed
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 976
  label: PTO Governor State
  bytes: 1F
  value: 31
 spn: 527
  label: Cruise Control States
  bytes: 07
  value: 7
 spn: 968
  label: Engine Idle Increment Switch
  bytes: 00
  value: 0
```

```
  spn: 967
   label: Engine Idle Decrement Switch
   bytes: 00
   value: 0
  spn: 966
   label: Engine Diagnostic Test Mode Switch
   bytes: 03
   value: 3
  spn: 1237
   label: Engine Shutdown Override Switch
   bytes: 00
   value: 0

IC1
 source address: 0x00
 pgn: 65270 (0xFEF6)
 label: Intake/Exhaust Conditions 1
 data bytes: FF 00 38 29 FF 50 24 FF
 spn: 81
  label: Aftertreatment 1 Diesel Particulate Filter Intake Pressure (use SPN 3609)
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 102
  label: Engine Intake Manifold #1 Pressure
  bytes: 00
  value: 0 kPa
 spn: 105
  label: Engine Intake Manifold 1 Temperature
  bytes: 38
  value: 16 °C
 spn: 106
  label: Engine Intake Air Pressure
  bytes: 29
  value: 82 kPa
 spn: 107
  label: Engine Air Filter 1 Differential Pressure
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 173
  label: Engine Exhaust Temperature
  bytes: 50 24
  value: 17.50000 °C
 spn: 112
  label: Engine Coolant Filter Differential Pressure
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF

IC1
 source address: 0x21
 pgn: 65270 (0xFEF6)
 label: Intake/Exhaust Conditions 1
 data bytes: FF FF FF FF FF FF FF FF
 spn: 81
  label: Aftertreatment 1 Diesel Particulate Filter Intake Pressure (use SPN 3609)
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 102
  label: Engine Intake Manifold #1 Pressure
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 105
  label: Engine Intake Manifold 1 Temperature
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 106
  label: Engine Intake Air Pressure
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 107
```

```
  label: Engine Air Filter 1 Differential Pressure
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 173
  label: Engine Exhaust Temperature
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
 spn: 112
  label: Engine Coolant Filter Differential Pressure
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF

EC1
 source address: 0x00
 pgn: 65251 (0xFEE3)
 label: Engine Configuration 1
 data bytes: 00 13 B9 80 33 CF 20 1B C4 C0 26 E1 60 2B D9 99 35 FF FF 83 09 80 4D 32 FF FF FF FF FF FF 04 01 FF FF FF FF
FF FF FF
 spn: 188
  label: Engine Speed At Idle, Point 1
  bytes: 00 13
  value: 608.000 rpm
 spn: 539
  label: Engine Percent Torque At Idle, Point 1
  bytes: B9
  value: 60 %
 spn: 528
  label: Engine Speed At Point 2
  bytes: 80 33
  value: 1648.000 rpm
 spn: 540
  label: Engine Percent Torque At Point 2
  bytes: CF
  value: 82 %
 spn: 529
  label: Engine Speed At Point 3
  bytes: 20 1B
  value: 868.000 rpm
 spn: 541
  label: Engine Percent Torque At Point 3
  bytes: C4
  value: 71 %
 spn: 530
  label: Engine Speed At Point 4
  bytes: C0 26
  value: 1240.000 rpm
 spn: 542
  label: Engine Percent Torque At Point 4
  bytes: E1
  value: 100 %
 spn: 531
  label: Engine Speed At Point 5
  bytes: 60 2B
  value: 1388.000 rpm
 spn: 543
  label: Engine Percent Torque At Point 5
  bytes: D9
  value: 92 %
 spn: 532
  label: Engine Speed At High Idle, Point 6
  bytes: 99 35
  value: 1715.125 rpm
 spn: 545
  label: Engine Gain (Kp) Of The Endspeed Governor
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
 spn: 544
  label: Engine Reference Torque
  bytes: 83 09
  value: 2435 Nm
 spn: 533
  label: Engine Maximum Momentary Override Speed, Point 7
```

```
 bytes: 80 4D
 value: 2480.000 rpm
spn: 534
 label: Engine Maximum Momentary Override Time Limit
 bytes: 32
 value: 5.0 s
spn: 535
 label: Engine Requested Speed Control Range Lower Limit
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 536
 label: Engine Requested Speed Control Range Upper Limit
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 537
 label: Engine Requested Torque Control Range Lower Limit
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 538
 label: Engine Requested Torque Control Range Upper Limit
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 1712
 label: Engine Requested Speed Control Range Upper Limit (Extended Range)
 bytes: FF FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested bytes 0xFFxx
spn: 1794
 label: Engine Moment of Inertia
 bytes: 04 01
 value: 1.040 kg•m²
spn: 1846
 label: Engine Default Torque Limit
 bytes: FF FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested bytes 0xFFxx
spn: 3344
 label: Support Variable Rate TSC1 Message
 bytes: FF
 value: 255
spn: 3345
 label: Support TSC1 Control Purpose Group 1
 bytes: FF
 value: 255
spn: 3346
 label: Support TSC1 Control Purpose Group 2
 bytes: FF
 value: 255
spn: 3347
 label: Support TSC1 Control Purpose Group 3
 bytes: FF
 value: 255
spn: 3348
 label: Support TSC1 Control Purpose Group 4
 bytes: FF
 value: 255
spn: 7828
 label: Engine Default Idle Torque Limit
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF

IT6
 source address: 0x01
 pgn: 65159 (0xFE87)
 label: Ignition Timing 6
 data bytes: FF FF FF FF FF FF 00 64
 spn: 1433
  label: Engine Desired Ignition Timing 1
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
```

```
 spn: 1434
  label: Engine Desired Ignition Timing 2
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
 spn: 1435
  label: Engine Desired Ignition Timing 3
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
 spn: 1436
  label: Engine Actual Ignition Timing
  bytes: 00 64
  value: 0.0000000 deg

AT1S1
 source address: 0x3D
 pgn: 64891 (0xFD7B)
 label: Aftertreatment 1 Service 1
 data bytes: 26 FF 00 00 00 00 B0 04
 spn: 3719
  label: Aftertreatment 1 Diesel Particulate Filter Soot Load Percent
  bytes: 26
  value: 38 %
 spn: 3720
  label: Aftertreatment 1 Diesel Particulate Filter Ash Load Percent
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 3721
  label: Aftertreatment 1 Diesel Particulate Filter Time Since Last Active Regeneration
  bytes: 00 00 00 00
  value: 0 s
 spn: 5466
  label: Aftertreatment 1 Diesel Particulate Filter Soot Load Regeneration Threshold
  bytes: B0 04
  value: 3.0000 %

A1DEFI1
 source address: 0x3D
 pgn: 64923 (0xFD9B)
 label: Aftertreatment 1 Diesel Exhaust Fluid Information 1
 data bytes: FF FF FF FF FF FF FF FF
 spn: 3515
  label: Aftertreatment 1 Diesel Exhaust Fluid Temperature 2
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 3516
  label: Aftertreatment 1 Diesel Exhaust Fluid Concentration
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 3518
  label: Aftertreatment 1 Diesel Exhaust Fluid Conductivity
  bytes: FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested byte 0xFF
 spn: 3519
  label: Aftertreatment 1 Diesel Exhaust Fluid Temperature 2 Preliminary FMI
  bytes: 1F
  value: 31 binary
 spn: 3520
  label: Aftertreatment 1 Diesel Exhaust Fluid Properties Preliminary FMI
  bytes: 1F
  value: 31 binary
 spn: 3521
  label: Aftertreatment 1 Diesel Exhaust Fluid Property
  bytes: 0F
  value: 15
 spn: 7346
  label: Diesel Exhaust Fluid Speed of Sound
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
```

```
ESR
 source address: 0x03
 pgn: 34560 (0x8700)
 label: Engine State Requests
 data bytes: FF FF FF FF FF FC FF FF
 spn: 5793
  label: Desired Engine Fueling State
  bytes: 03
  value: 3
 spn: 6833
  label: Engine Gaseous Fuel Usage Inhibited
  bytes: 03
  value: 3
 spn: 9173
  label: Engine Protection Derate Override Command
  bytes: 03
  value: 3
 spn: 6317
  label: Requested Fuel Type
  bytes: FF
  value: 255
 spn: 6715
  label: Engine Gaseous Fuel Supply Desired Pressure
  bytes: FF FF
  error: NotAvailableOrNotRequested
  errorMsg: not available or not requested bytes 0xFFxx
 spn: 7789
  label: Engine Fueling Desired Reason
  bytes: FF
  value: 255
 spn: 7829
  label: Transmission Idle Governor Fueling Inhibit
  bytes: 00
  value: 0
 spn: 8614
  label: Engine Shutdown Command
  bytes: 03
  value: 3
 spn: 7855
  label: Engine Fueling Not Desired Reason
  bytes: FF
  value: 255

EBC1
 source address: 0x0B
 pgn: 61441 (0xF001)
 label: Electronic Brake Controller 1
 data bytes: 00 00 D0 FF FF 5C FF FF
 spn: 561
  label: ASR Engine Control Active
  bytes: 00
  value: 0
 spn: 562
  label: ASR Brake Control Active
  bytes: 00
  value: 0
 spn: 563
  label: Anti-Lock Braking (ABS) Active
  bytes: 00
  value: 0
 spn: 1121
  label: EBS Brake Switch
  bytes: 00
  value: 0
 spn: 521
  label: Brake Pedal Position
  bytes: 00
  value: 0.0 %
 spn: 575
  label: ABS Off-road Switch
  bytes: 00
  value: 0
 spn: 576
  label: ASR Off-road Switch
  bytes: 00
  value: 0
```

```
spn: 577
 label: ASR "Hill Holder" Switch
 bytes: 01
 value: 1
spn: 1238
 label: Traction Control Override Switch
 bytes: 03
 value: 3
spn: 972
 label: Accelerator Interlock Switch
 bytes: 03
 value: 3
spn: 971
 label: Engine Derate Switch
 bytes: 03
 value: 3
spn: 970
 label: Engine Auxiliary Shutdown Switch
 bytes: 03
 value: 3
spn: 969
 label: Remote Accelerator Enable Switch
 bytes: 03
 value: 3
spn: 973
 label: Engine Retarder Selection
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 1243
 label: ABS Fully Operational
 bytes: 00
 value: 0
spn: 1439
 label: EBS Red Warning Signal
 bytes: 03
 value: 3
spn: 1438
 label: ABS/EBS Amber Warning Signal (Powered Vehicle)
 bytes: 01
 value: 1
spn: 1793
 label: ATC/ASR Information Signal
 bytes: 01
 value: 1
spn: 1481
 label: Source Address of Controlling Device for Brake Control
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 7941
 label: Railroad Mode Switch
 bytes: 03
 value: 3
spn: 2911
 label: Halt brake switch
 bytes: 03
 value: 3
spn: 1836
 label: Trailer ABS Status
 bytes: 03
 value: 3
spn: 1792
 label: Tractor-Mounted Trailer ABS Warning Signal
 bytes: 03
 value: 3

EBC1
 source address: 0x31
 pgn: 61441 (0xF001)
 label: Electronic Brake Controller 1
 data bytes: FF FF FF FF 00 FF FF FF
 spn: 561
  label: ASR Engine Control Active
  bytes: 03
  value: 3
```

```
spn: 562
 label: ASR Brake Control Active
 bytes: 03
 value: 3
spn: 563
 label: Anti-Lock Braking (ABS) Active
 bytes: 03
 value: 3
spn: 1121
 label: EBS Brake Switch
 bytes: 03
 value: 3
spn: 521
 label: Brake Pedal Position
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 575
 label: ABS Off-road Switch
 bytes: 03
 value: 3
spn: 576
 label: ASR Off-road Switch
 bytes: 03
 value: 3
spn: 577
 label: ASR "Hill Holder" Switch
 bytes: 03
 value: 3
spn: 1238
 label: Traction Control Override Switch
 bytes: 03
 value: 3
spn: 972
 label: Accelerator Interlock Switch
 bytes: 03
 value: 3
spn: 971
 label: Engine Derate Switch
 bytes: 03
 value: 3
spn: 970
 label: Engine Auxiliary Shutdown Switch
 bytes: 03
 value: 3
spn: 969
 label: Remote Accelerator Enable Switch
 bytes: 03
 value: 3
spn: 973
 label: Engine Retarder Selection
 bytes: 00
 value: 0.0 %
spn: 1243
 label: ABS Fully Operational
 bytes: 03
 value: 3
spn: 1439
 label: EBS Red Warning Signal
 bytes: 03
 value: 3
spn: 1438
 label: ABS/EBS Amber Warning Signal (Powered Vehicle)
 bytes: 03
 value: 3
spn: 1793
 label: ATC/ASR Information Signal
 bytes: 03
 value: 3
spn: 1481
 label: Source Address of Controlling Device for Brake Control
 bytes: FF
 error: NotAvailableOrNotRequested
 errorMsg: not available or not requested byte 0xFF
spn: 7941
 label: Railroad Mode Switch
```

```
 bytes: 03
 value: 3
spn: 2911
 label: Halt brake switch
 bytes: 03
 value: 3
spn: 1836
 label: Trailer ABS Status
 bytes: 03
 value: 3
spn: 1792
 label: Tractor-Mounted Trailer ABS Warning Signal
 bytes: 03
 value: 3
```

XML File:

```xml
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<J1939RemoteOBDCollection>
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<DeviceSN>DrewLinQ #003355</DeviceSN>
<CollectionDateTime>2020-11-18 09:11:59</CollectionDateTime></Hdr>
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<VI_237_VIN>1FUJGBDV6GLGS0468</VI_237_VIN>
<VI_588_EngineSN>S0315242</VI_588_EngineSN></VI>
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   <DM1_623_RSL>N</DM1_623_RSL>
   <DM1_624_AWL>N</DM1_624_AWL>
   <DM1_987_PL>N</DM1_987_PL>
</DM1>
<DM5>
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   <DM5_1219_PrevActDTCCounts>0</DM5_1219_PrevActDTCCounts>
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   <DM5_1223_NOxConvertingCatalyst_Status>N</DM5_1223_NOxConvertingCatalyst_Status>
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   <IC1_102_DSIntakeManifoldP>0</IC1_102_DSIntakeManifoldP>
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   <DM32_4123_DRDTCsTimeUntilDerate />
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```xml
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  <EOI2_8435_DREngSelfIndDerateLoad />
  <EOI2_8436_DREngPowerDerateRqst />
  <EOI_3644_DREngDerateRqst />
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  <DM1_987_PL>N</DM1_987_PL>
</DM1>
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```xml
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```xml
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</DM33>
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  <IC1_102_DSIntakeManifoldP />
  <IC1_105_DSIntakeManifoldT />
  <EEC2_91_DSAccPedalPos />
  <EEC2_92_DSEngPercLoad />
  <EEC1_513_DSActPercTorque />
  <EC1_544_EngRefTorque />
  <EEC3_514_FrictionTorque />
  <EEC1_190_DSEngSpeed />
  <EEC1_899_DSEngTorqueMode />
  <IT6_1436_DSEngActIgnTiming />
  <AT1S_3719_DSDPFSootLoadPercA />
  <AT1S_5466_DSDPFSootLoadPercB />
  <A1DEFI1_3516_ATUreaConc />
</DataStream>
<REALData>
</REALData>
<Derate>
  <ESR_9173_DREPDerateOverride />
  <DM32_4123_DRDTCsTimeUntilDerate />
  <CTL_1787_DREngTorqueLimitRqstMax />
  <EBC1_971_DREngDerateSwitch />
  <GC2_8429_DREngSelfIndDerateInhibit />
  <EOI2_8435_DREngSelfIndDerateLoad />
  <EOI2_8436_DREngPowerDerateRqst />
  <EOI_3644_DREngDerateRqst />
  <TTI1_1027_DRTripTimeInDeratebyEng />
</Derate>
</ECU>
<ECU>
```

```xml
<ECU_ModuleAddress>4A</ECU_ModuleAddress><VI>
<VI_237_VIN />
<VI_588_EngineSN>0011646600</VI_588_EngineSN></VI>
<DataStream>
  <ET1_110_DSEngCoolantTemp />
  <CCVS1_84_DSWBasedSpeed />
  <IC1_102_DSIntakeManifoldP />
  <IC1_105_DSIntakeManifoldT />
  <EEC2_91_DSAccPedalPos />
  <EEC2_92_DSEngPercLoad />
  <EEC1_513_DSActPercTorque />
  <EC1_544_EngRefTorque />
  <EEC3_514_FrictionTorque />
  <EEC1_190_DSEngSpeed />
  <EEC1_899_DSEngTorqueMode />
  <IT6_1436_DSEngActIgnTiming />
  <AT1S_3719_DSDPFSootLoadPercA />
  <AT1S_5466_DSDPFSootLoadPercB />
  <A1DEFI1_3516_ATUreaConc />
</DataStream>
<REALData>
</REALData>
<Derate>
  <ESR_9173_DREPDerateOverride />
  <DM32_4123_DRDTCsTimeUntilDerate />
  <CTL_1787_DREngTorqueLimitRqstMax />
  <EBC1_971_DREngDerateSwitch />
  <GC2_8429_DREngSelfIndDerateInhibit />
  <EOI2_8435_DREngSelfIndDerateLoad />
  <EOI2_8436_DREngPowerDerateRqst />
  <EOI_3644_DREngDerateRqst />
  <TTI1_1027_DRTripTimeInDeratebyEng />
</Derate>
</ECU>
</J1939RemoteOBDCollection>
```

Appendix G

Example DrewLinQ SAE J1979 Data Files

Sample DrewLinQ output file
SAE J1979 protocol, 2014 Volvo VN Series Volvo D13 Diesel
Log file: basic application log output showing queries of the parameters
Pidlog file: parameter bytes decoded into pids
Xml file: the representation of the data in xml based on CARB's data schema that was available when the application was developed

Log file:

```
(00:00.000) j1979_obd_xml2 version: 1.0.2.0
(00:00.031) Friday, March 12, 2021 9:00:27 AM
(00:00.031) selected test: ALL TESTS
(00:00.031) determine vehicle protocol
(00:13.787) protocol = ICAN29bt500
(00:13.787) ok
(00:13.787) ----------
(00:13.787) Service 01, PID 01
(00:14.574) 2 nodes responded
(00:14.574) [0]
(00:14.574)  address: 11
(00:14.574)  data bytes: 00 0C 00 00
(00:14.574) [1]
(00:14.574)  address: 10
(00:14.574)  data bytes: 81 2F EB EB
(00:14.668) ----------
(00:14.668) Service 01, PID 04
(00:15.434) 2 nodes responded
(00:15.434) [0]
(00:15.434)  address: 11
(00:15.434)  data bytes: 3D
(00:15.434) [1]
(00:15.434)  address: 10
(00:15.434)  data bytes: 3D
(00:15.465) ----------
(00:15.481) Service 01, PID 0C
(00:16.252) 2 nodes responded
(00:16.252) [0]
(00:16.252)  address: 11
(00:16.252)  data bytes: 09 FE
(00:16.252) [1]
(00:16.252)  address: 10
(00:16.252)  data bytes: 0A 06
(00:16.283) ----------
(00:16.299) Service 01, PID 0D
(00:17.082) 2 nodes responded
(00:17.082) [0]
(00:17.082)  address: 11
(00:17.082)  data bytes: 00
(00:17.082) [1]
(00:17.082)  address: 10
(00:17.082)  data bytes: 00
(00:17.113) ----------
(00:17.129) Service 01, PID 1C
(00:17.895) 1 node responded
(00:17.895)  address: 10
(00:17.895)  data bytes: 14
(00:17.942) ----------
(00:17.942) Service 01, PID 21
(00:18.713) 2 nodes responded
(00:18.713) [0]
(00:18.713)  address: 11
(00:18.713)  data bytes: 00 00
(00:18.713) [1]
(00:18.713)  address: 10
(00:18.713)  data bytes: 00 00
(00:18.744) ----------
(00:18.760) Service 01, PID 30
(00:19.549) 2 nodes responded
(00:19.549) [0]
(00:19.549)  address: 11
(00:19.549)  data bytes: 01
(00:19.549) [1]
(00:19.549)  address: 10
(00:19.549)  data bytes: 01
(00:19.580) ----------
(00:19.595) Service 01, PID 31
(00:20.369) 2 nodes responded
(00:20.369) [0]
(00:20.369)  address: 11
(00:20.369)  data bytes: 00 00
(00:20.369) [1]
(00:20.369)  address: 10
```

```
(00:20.369)  data bytes: 00 00
(00:20.400) ----------
(00:20.416) Service 01, PID 41
(00:21.206) 2 nodes responded
(00:21.206) [0]
(00:21.206)  address: 11
(00:21.206)  data bytes: 00 4C 00 00
(00:21.206) [1]
(00:21.206)  address: 10
(00:21.206)  data bytes: 00 7F EB EB
(00:21.253) ----------
(00:21.269) Service 01, PID 49
(00:22.032) 2 nodes responded
(00:22.032) [0]
(00:22.032)  address: 11
(00:22.032)  data bytes: 00
(00:22.032) [1]
(00:22.032)  address: 10
(00:22.032)  data bytes: 00
(00:22.063) ----------
(00:22.079) Service 01, PID 4D
(00:22.877) 2 nodes responded
(00:22.877) [0]
(00:22.877)  address: 11
(00:22.877)  data bytes: 00 00
(00:22.877) [1]
(00:22.877)  address: 10
(00:22.877)  data bytes: 00 03
(00:22.908) ----------
(00:22.924) Service 01, PID 4E
(00:23.687) 2 nodes responded
(00:23.687) [0]
(00:23.687)  address: 11
(00:23.687)  data bytes: FF FF
(00:23.687) [1]
(00:23.687)  address: 10
(00:23.687)  data bytes: 00 4A
(00:23.718) ----------
(00:23.734) Service 01, PID 62
(00:24.516) 1 node responded
(00:24.516)  address: 10
(00:24.516)  data bytes: 8B
(00:24.531) ----------
(00:24.547) Service 01, PID 67
(00:25.335) 2 nodes responded
(00:25.335) [0]
(00:25.335)  address: 11
(00:25.335)  data bytes: 01 2F 00
(00:25.335) [1]
(00:25.335)  address: 10
(00:25.335)  data bytes: 01 2F 00
(00:25.382) ----------
(00:25.382) Service 01, PID 68
(00:26.172) 1 node responded
(00:26.172)  address: 10
(00:26.172)  data bytes: 03 3D 2F 00 00 00 00
(00:26.203) ----------
(00:26.219) Service 01, PID 81
(00:27.091) 1 node responded
(00:27.091)  address: 10
(00:27.091)  data bytes: 07 00 08 8E 38 00 00 00 00 00 40 00 00 00 00 00 00 00 00 00 00 AC 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00
(00:27.138) ----------
(00:27.154) Service 01, PID 87
(00:27.935) 1 node responded
(00:27.935)  address: 10
(00:27.935)  data bytes: 01 0A F3 00 00
(00:27.967) ----------
(00:27.967) Service 01, PID 88
(00:28.750) 1 node responded
(00:28.750)  address: 10
(00:28.750)  data bytes: 00 00 08 00 00 16 E8 00 00 00 00 00 00
(00:28.781) ----------
(00:28.797) Service 03
(00:29.567) 2 nodes responded
(00:29.567) [0]
```

```
(00:29.567)  address: 11
(00:29.567)  data bytes: 00
(00:29.567) [1]
(00:29.567)  address: 10
(00:29.567)  data bytes: 01 C0 80
(00:29.646) ----------
(00:29.661) Service 06
(00:29.677)  get supported pids
(00:29.692)  read service $06 pid $00
(00:30.450)  1 node responded
(00:30.450)   address: 10
(00:30.450)   data bytes: C0 00 00 01
(00:30.465)  read service $06 pid $20
(00:31.213)  1 node responded
(00:31.213)   address: 10
(00:31.213)   data bytes: 80 00 80 01
(00:31.213)  read service $06 pid $40
(00:31.995)  1 node responded
(00:31.995)   address: 10
(00:31.995)   data bytes: C0 00 00 01
(00:31.995)  read service $06 pid $60
(00:32.767)  1 node responded
(00:32.767)   address: 10
(00:32.767)   data bytes: 00 00 00 01
(00:32.767)  read service $06 pid $80
(00:33.548)  1 node responded
(00:33.548)   address: 10
(00:33.548)   data bytes: 88 00 01 01
(00:33.548)  read service $06 pid $A0
(00:34.338)  1 node responded
(00:34.338)   address: 10
(00:34.338)   data bytes: FE 00 40 00
(00:34.338)  supported pids: 0x01, 0x02, 0x21, 0x31, 0x41, 0x42, 0x81, 0x85, 0x98, 0xA1, 0xA2, 0xA3, 0xA4, 0xA5, 0xA6,
0xA7, 0xB2
(00:34.354)  read service $06 pid $01
(00:35.126)  1 node responded
(00:35.126)   address: 10
(00:35.126)   data bytes: 01 80 84 00 00 00 00 00 00 01 81 02 00 00 00 00 00 00 01 93 33 00 00 00 00 00 00
(00:35.126)  read service $06 pid $02
(00:35.894)  1 node responded
(00:35.894)   address: 10
(00:35.894)   data bytes: 02 8D 02 00 00 00 00 00 00 02 81 02 00 00 00 00 00 00
(00:35.894)  read service $06 pid $21
(00:36.657)  1 node responded
(00:36.657)   address: 10
(00:36.657)   data bytes: 21 99 2E 00 00 00 00 00 00 21 9C 20 00 00 00 00 00 00
(00:36.657)  read service $06 pid $31
(00:37.421)  1 node responded
(00:37.421)   address: 10
(00:37.421)   data bytes: 31 83 2F 00 00 00 00 00 00 31 84 2F 00 00 00 00 00 00 31 85 05 00 00 00 00 00 00
(00:37.421)  read service $06 pid $41
(00:38.194)  1 node responded
(00:38.194)   address: 10
(00:38.194)   data bytes: 41 9E 11 00 0B 00 00 17 70
(00:38.194)  read service $06 pid $42
(00:38.967)  1 node responded
(00:38.967)   address: 10
(00:38.967)   data bytes: 42 9E 11 00 00 00 00 00 00
(00:38.967)  read service $06 pid $81
(00:39.847)  1 node responded
(00:39.847)   address: 10
(00:39.847)   data bytes: 81 86 39 00 00 00 00 00 00 81 87 39 00 00 00 00 00 00 81 88 39 00 00 00 00 00 00 81 89 39 00 00
00 00 00 00 81 8A 39 00 00 00 00 00 00 81 8B 39 00 00 00 00 00 00 81 8C 2F 00 00 00 00 00 00
(00:39.847)  read service $06 pid $85
(00:40.625)  1 node responded
(00:40.625)   address: 10
(00:40.625)   data bytes: 85 95 18 00 00 00 00 00 00 85 96 18 00 00 00 00 00 00 85 97 18 00 00 00 00 00 00
(00:40.625)  read service $06 pid $98
(00:41.406)  1 node responded
(00:41.406)   address: 10
(00:41.406)   data bytes: 98 98 2F 00 00 00 00 00 00
(00:41.406)  read service $06 pid $A1
(00:42.178)  1 node responded
(00:42.178)   address: 10
(00:42.178)   data bytes: A1 0B 24 00 00 00 00 FF FF A1 0C 24 00 00 00 00 FF FF
(00:42.178)  read service $06 pid $A2
```

```
(00:42.950)  1 node responded
(00:42.950)   address: 10
(00:42.950)   data bytes: A2 0B 24 00 00 00 00 FF FF A2 0C 24 00 00 00 00 FF FF
(00:42.950)   read service $06 pid $A3
(00:43.729)  1 node responded
(00:43.729)   address: 10
(00:43.729)   data bytes: A3 0B 24 00 00 00 00 FF FF A3 0C 24 00 00 00 00 FF FF
(00:43.729)   read service $06 pid $A4
(00:44.510)  1 node responded
(00:44.510)   address: 10
(00:44.510)   data bytes: A4 0B 24 00 00 00 00 FF FF A4 0C 24 00 00 00 00 FF FF
(00:44.510)   read service $06 pid $A5
(00:45.290)  1 node responded
(00:45.290)   address: 10
(00:45.290)   data bytes: A5 0B 24 00 00 00 00 FF FF A5 0C 24 00 00 00 00 FF FF
(00:45.290)   read service $06 pid $A6
(00:46.084)  1 node responded
(00:46.084)   address: 10
(00:46.084)   data bytes: A6 0B 24 00 00 00 00 FF FF A6 0C 24 00 00 00 00 FF FF
(00:46.084)   read service $06 pid $A7
(00:46.863)  1 node responded
(00:46.863)   address: 10
(00:46.863)   data bytes: A7 0B 24 00 00 00 00 FF FF A7 0C 24 00 00 00 00 FF FF
(00:46.863)   read service $06 pid $B2
(00:47.735)  1 node responded
(00:47.735)   address: 10
(00:47.735)   data bytes: B2 8E 17 00 00 00 00 00 00 B2 9A 04 00 00 00 00 00 00 B2 9B 20 00 00 00 00 00 00 B2 9D 20 00 00
00 00 00 00
(00:47.782) ----------
(00:47.798) Service 07
(00:48.570) 2 nodes responded
(00:48.570) [0]
(00:48.570)  address: 10
(00:48.570)  data bytes: 01 C0 80
(00:48.570) [1]
(00:48.570)  address: 11
(00:48.570)  data bytes: 01 C0 80
(00:48.602) ----------
(00:48.617) Service 09, PID 02
(00:49.383) 1 node responded
(00:49.383)  address: 10
(00:49.383)  data bytes: 01 34 56 34 4E 43 39 45 48 33 45 4E 31 36 31 30 38 34
(00:49.414) ----------
(00:49.430) Service 09, PID 04
(00:50.553) 2 nodes responded
(00:50.553) [0]
(00:50.553)  address: 11
(00:50.553)  data bytes: 02 32 31 39 32 32 39 30 34 2E 30 30 30 30 34 32 32 31 39 31 32 30 30 34 2E 30 30 30 30 32
36
(00:50.553) [1]
(00:50.553)  address: 10
(00:50.553)  data bytes: 07 32 31 39 35 30 38 39 37 2E 30 30 30 30 35 36 32 31 39 35 31 34 39 36 2E 30 30 30 30 30 38
34 30 32 32 38 30 32 30 31 32 34 00 00 00 00 00 00 4E 4F 78 2D 53 57 37 30 30 39 20 41 54 49 31 00 3F 3F 3F 3F 3F 3F 3F
3F 3F 3F 3F 3F 3F 3F 3F 3F 32 33 30 38 39 32 33 35 50 30 31 20 00 00 00 00 32 31 39 39 30 33 32 38 2E 30 30 30 30 30 30
38
(00:50.600) ----------
(00:50.615) Service 09, PID 06
(00:51.373) 2 nodes responded
(00:51.373) [0]
(00:51.373)  address: 11
(00:51.373)  data bytes: 02 E6 C0 39 74 8C A8 AC 21
(00:51.373) [1]
(00:51.373)  address: 10
(00:51.373)  data bytes: 07 DE 85 D6 F6 FC 8F 8D 1D 03 AA EB 63 2F 2A 2D 35 00 00 00 00 FF 7F 85 11 D1 A2 81 B7
(00:51.420) ----------
(00:51.420) Service 09, PID 0A
(00:52.202) 2 nodes responded
(00:52.202) [0]
(00:52.202)  address: 10
(00:52.202)  data bytes: 01 45 43 4D 00 2D 45 6E 67 69 6E 65 43 6F 6E 74 72 6F 6C 00 00
(00:52.202) [1]
(00:52.202)  address: 11
(00:52.202)  data bytes: 01 52 44 43 4D 2D 52 65 64 75 63 74 61 6E 74 43 74 72 6C 00 00
(00:52.233) ----------
(00:52.249) Service 09, PID 0B
(00:53.143) 1 node responded
```

```
(00:53.143)  address: 10
(00:53.143)  data bytes: 12 0A 38 14 25 01 16 01 B7 02 2D 0A 38 00 00 00 00 00 D2 01 B7 00 92 0A 38 00 CA 0A 10 04 CC 0A
38 07 5D 0A 38
(00:53.174) ----------
(00:53.190) Service 09, PID 0D
(00:53.980) 1 node responded
(00:53.980)  address: 10
(00:53.980)  data bytes: 01 00 00 00 00 00 00 00 30 31 33 31 30 32 38 32 36 32
(00:53.996) ----------
(00:54.011) Service 09, PID 41
(00:54.683) failed: DADTimedOut (1)
(00:54.683) ----------
(00:54.699) Service 09, PID 42
(00:55.371) failed: DADTimedOut (1)
(00:55.371) ----------
(00:55.386) Service 09, PID 43
(00:56.038) failed: DADTimedOut (1)
(00:56.038) ----------
(00:56.054) Service 09, PID 44
(00:56.717) failed: DADTimedOut (1)
(00:56.717) ----------
(00:56.732) Service 09, PID 45
(00:57.396) failed: DADTimedOut (1)
(00:57.396) ----------
(00:57.412) Service 09, PID 46
(00:58.084) failed: DADTimedOut (1)
(00:58.084) ----------
(00:58.099) Service 09, PID 61
(00:58.775) failed: DADTimedOut (1)
(00:58.775) ----------
(00:58.791) Service 09, PID 62
(00:59.454) failed: DADTimedOut (1)
(00:59.454) ----------
(00:59.470) Service 09, PID 63
(01:00.142) failed: DADTimedOut (1)
(01:00.142) ----------
(01:00.158) Service 09, PID 64
(01:00.830) failed: DADTimedOut (1)
(01:00.830) ----------
(01:00.845) Service 09, PID 65
(01:01.508) failed: DADTimedOut (1)
(01:01.508) ----------
(01:01.524) Service 09, PID 66
(01:02.196) failed: DADTimedOut (1)
(01:02.196) ----------
(01:02.211) Service 09, PID 67
(01:02.881) failed: DADTimedOut (1)
(01:02.881) ----------
(01:02.897) Service 09, PID 68
(01:03.571) failed: DADTimedOut (1)
(01:03.571) ----------
(01:03.587) Service 09, PID 69
(01:04.265) failed: DADTimedOut (1)
(01:04.281) ----------
(01:04.297) Service 09, PID 6A
(01:04.944) failed: DADTimedOut (1)
(01:04.944) ----------
(01:04.960) Service 09, PID 6B
(01:05.623) failed: DADTimedOut (1)
(01:05.623) ----------
(01:05.638) Service 09, PID 6C
(01:06.310) failed: DADTimedOut (1)
(01:06.310) ----------
(01:06.326) Service 09, PID 6D
(01:06.998) failed: DADTimedOut (1)
(01:06.998) ----------
(01:07.013) Service 09, PID 6E
(01:07.685) failed: DADTimedOut (1)
(01:07.685) ----------
(01:07.701) Service 09, PID 6F
(01:08.362) failed: DADTimedOut (1)
(01:08.362) ----------
(01:08.378) Service 09, PID 70
(01:09.056) failed: DADTimedOut (1)
(01:09.056) ----------
(01:09.071) Service 09, PID 71
```

```
(01:09.750) failed: DADTimedOut (1)
(01:09.750) ----------
(01:09.765) Service 09, PID 72
(01:10.442) failed: DADTimedOut (1)
(01:10.442) ----------
(01:10.458) Service 09, PID 73
(01:11.130) failed: DADTimedOut (1)
(01:11.130) ----------
(01:11.145) Service 09, PID 74
(01:11.818) failed: DADTimedOut (1)
(01:11.818) ----------
(01:11.834) Service 09, PID 75
(01:12.497) failed: DADTimedOut (1)
(01:12.497) ----------
(01:12.512) Service 09, PID 76
(01:13.163) failed: DADTimedOut (1)
(01:13.163) ----------
(01:13.178) Service 0A
(01:13.957) 2 nodes responded
(01:13.957) [0]
(01:13.957)  address: 11
(01:13.957)  data bytes: 00
(01:13.957) [1]
(01:13.957)  address: 10
(01:13.957)  data bytes: 08 C0 80 D1 6F C2 9D C2 9E 26 98 04 01 22 5E 20 EE
(01:14.051) ----------
(01:14.066) generate XML
(01:14.145) ----------
END
```

PID Log File

```
Service 01, PID 01
 node address: 11
 description: Monitor status since DTCs cleared
 data bytes: 00 0C 00 00
 mil: False
 dtcCount: 0
 isDiesel: True
 componentsTestAvailable: True
 componentsTestComplete: False
 fuelSystemTestAvailable: False
 fuelSystemTestComplete: False
 misfireTestAvailable: False
 misfireTestComplete: False
 [non-diesel parameters]
 egrSystemTestAvailable: False
 egrSystemTestComplete: False
 oxygenSensorHeaterTestAvailable: False
 oxygenSensorHeaterTestComplete: False
 oxygenSensorTestAvailable: False
 oxygenSensorTestComplete: False
 acRefrigerantTestAvailable: False
 acRefrigerantTestComplete: False
 secondaryAirSystemTestAvailable: False
 secondaryAirSystemTestComplete: False
 evapSystemTestAvailable: False
 evapSystemTestComplete: False
 heatedCatalystTestAvailable: False
 heatedCatalystTestComplete: False
 catalystTestAvailable: False
 catalystTestComplete: False

Service 01, PID 01
 node address: 10
 description: Monitor status since DTCs cleared
 data bytes: 81 2F EB EB
 mil: True
 dtcCount: 1
 isDiesel: True
 componentsTestAvailable: True
 componentsTestComplete: False
 fuelSystemTestAvailable: True
 fuelSystemTestComplete: True
 misfireTestAvailable: True
 misfireTestComplete: False
 [non-diesel parameters]
 egrSystemTestAvailable: False
 egrSystemTestComplete: False
 oxygenSensorHeaterTestAvailable: False
 oxygenSensorHeaterTestComplete: False
 oxygenSensorTestAvailable: False
 oxygenSensorTestComplete: False
 acRefrigerantTestAvailable: False
 acRefrigerantTestComplete: False
 secondaryAirSystemTestAvailable: False
 secondaryAirSystemTestComplete: False
 evapSystemTestAvailable: False
 evapSystemTestComplete: False
 heatedCatalystTestAvailable: False
 heatedCatalystTestComplete: False
 catalystTestAvailable: False
 catalystTestComplete: False

Service 01, PID 04
 node address: 11
 description: Calculated engine load
 data bytes: 3D
 value: 23 %

Service 01, PID 04
 node address: 10
 description: Calculated engine load
 data bytes: 3D
 value: 23 %
```

```
Service 01, PID 0C
 node address: 11
 description: Engine speed
 data bytes: 09 FE
 value: 639.5 rpm

Service 01, PID 0C
 node address: 10
 description: Engine speed
 data bytes: 0A 06
 value: 641.5 rpm

Service 01, PID 0D
 node address: 11
 description: Vehicle speed
 data bytes: 00
 value: 0 km/h

Service 01, PID 0D
 node address: 10
 description: Vehicle speed
 data bytes: 00
 value: 0 km/h

Service 01, PID 1C
 node address: 10
 description: OBD standards this vehicle conforms to
 data bytes: 14
 obdStandard: 20 (Heavy Duty On-Board Diagnostics (HD OBD))

Service 01, PID 21
 node address: 11
 description: Distance traveled with malfunction indicator lamp (MIL) on
 data bytes: 00 00
 value: 0 km

Service 01, PID 21
 node address: 10
 description: Distance traveled with malfunction indicator lamp (MIL) on
 data bytes: 00 00
 value: 0 km

Service 01, PID 30
 node address: 11
 description: Warm-ups since codes cleared
 data bytes: 01
 value: 1 count

Service 01, PID 30
 node address: 10
 description: Warm-ups since codes cleared
 data bytes: 01
 value: 1 count

Service 01, PID 1F
 node address: 11
 description: Distance traveled since codes cleared
 data bytes: 00 00
 value: 0 km

Service 01, PID 1F
 node address: 10
 description: Distance traveled since codes cleared
 data bytes: 00 00
 value: 0 km

Service 01, PID 41
 node address: 11
 description: Monitor status this drive cycle
 data bytes: 00 4C 00 00
 isDiesel: True
 componentsTestAvailable: True
 componentsTestComplete: True
 fuelSystemTestAvailable: False
 fuelSystemTestComplete: False
 misfireTestAvailable: False
```

```
 misfireTestComplete: False
 [non-diesel parameters]
 egrSystemTestAvailable: False
 egrSystemTestComplete: False
 oxygenSensorHeaterTestAvailable: False
 oxygenSensorHeaterTestComplete: False
 oxygenSensorTestAvailable: False
 oxygenSensorTestComplete: False
 acRefrigerantTestAvailable: False
 acRefrigerantTestComplete: False
 secondaryAirSystemTestAvailable: False
 secondaryAirSystemTestComplete: False
 evapSystemTestAvailable: False
 evapSystemTestComplete: False
 heatedCatalystTestAvailable: False
 heatedCatalystTestComplete: False
 catalystTestAvailable: False
 catalystTestComplete: False

Service 01, PID 41
 node address: 10
 description: Monitor status this drive cycle
 data bytes: 00 7F EB EB
 isDiesel: True
 componentsTestAvailable: True
 componentsTestComplete: True
 fuelSystemTestAvailable: True
 fuelSystemTestComplete: True
 misfireTestAvailable: True
 misfireTestComplete: True
 [non-diesel parameters]
 egrSystemTestAvailable: False
 egrSystemTestComplete: False
 oxygenSensorHeaterTestAvailable: False
 oxygenSensorHeaterTestComplete: False
 oxygenSensorTestAvailable: False
 oxygenSensorTestComplete: False
 acRefrigerantTestAvailable: False
 acRefrigerantTestComplete: False
 secondaryAirSystemTestAvailable: False
 secondaryAirSystemTestComplete: False
 evapSystemTestAvailable: False
 evapSystemTestComplete: False
 heatedCatalystTestAvailable: False
 heatedCatalystTestComplete: False
 catalystTestAvailable: False
 catalystTestComplete: False

Service 01, PID 49
 node address: 11
 description: Accelerator pedal position D
 data bytes: 00
 value: 0 %

Service 01, PID 49
 node address: 10
 description: Accelerator pedal position D
 data bytes: 00
 value: 0 %

Service 01, PID 4D
 node address: 11
 description: Time run with MIL on
 data bytes: 00 00
 value: 0 minutes

Service 01, PID 4D
 node address: 10
 description: Time run with MIL on
 data bytes: 00 03
 value: 3 minutes

Service 01, PID 4E
 node address: 11
 description: Time since trouble codes cleared
 data bytes: FF FF
```

```
 value: 65535 minutes

Service 01, PID 4E
 node address: 10
 description: Time since trouble codes cleared
 data bytes: 00 4A
 value: 74 minutes

Service 01, PID 62
 node address: 10
 description: Actual engine - percent torque
 data bytes: 8B
 value: 14 %

Service 01, PID 67
 node address: 11
 description: Engine coolant temperature
 data bytes: 01 2F 00
 ectSensor1Supported: True
 ectSensor2Supported: False
 engineCoolantTemperature1: 7 ˚C
 engineCoolantTemperature2: -40 ˚C

Service 01, PID 67
 node address: 10
 description: Engine coolant temperature
 data bytes: 01 2F 00
 ectSensor1Supported: True
 ectSensor2Supported: False
 engineCoolantTemperature1: 7 ˚C
 engineCoolantTemperature2: -40 ˚C

Service 01, PID 68
 node address: 10
 description: Intake air temperature sensor
 data bytes: 03 3D 2F 00 00 00 00
 iatBank1Sensor1Supported: True
 iatBank1Sensor2Supported: True
 iatBank1Sensor3Supported: False
 iatBank2Sensor1Supported: False
 iatBank2Sensor2Supported: False
 iatBank2Sensor3Supported: False
 iatBank1Sensor1Temperature: 21 ˚C
 iatBank1Sensor2Temperature: 7 ˚C
 iatBank1Sensor3Temperature: -40 ˚C
 iatBank2Sensor1Temperature: -40 ˚C
 iatBank2Sensor2Temperature: -40 ˚C
 iatBank2Sensor3Temperature: -40 ˚C

Service 01, PID 81
 node address: 10
 description: Engine run time for Auxiliary Emissions Control Device (AECD)
 data bytes: 07 00 08 8E 38 00 00 00 00 00 40 00 00 00 00 00 00 00 00 00 AC 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00
 totalRunTimeAecd1Supported: True
 totalRunTimeAecd2Supported: True
 totalRunTimeAecd3Supported: True
 totalRunTimeAecd4Supported: False
 totalRunTimeAecd5Supported: False
 totalRunTimeAecd1Timer1: 560696 sec
 totalRunTimeAecd1Timer2: 0 sec
 totalRunTimeAecd2Timer1: 560696 sec
 totalRunTimeAecd2Timer2: 0 sec
 totalRunTimeAecd3Timer1: 560696 sec
 totalRunTimeAecd3Timer2: 0 sec
 totalRunTimeAecd4Timer1: 560696 sec
 totalRunTimeAecd4Timer2: 0 sec
 totalRunTimeAecd5Timer1: 560696 sec
 totalRunTimeAecd5Timer2: 0 sec

Service 01, PID 87
 node address: 10
 description: Intake manifold absolute pressure
 data bytes: 01 0A F3 00 00
 imapASupported: True
 imapBSupported: False
```

```
 imapA: 87.59375 kPa
 imapA: 0 kPa

Service 01, PID 88
 node address: 10
 description: SCR Induce System
 data bytes: 00 00 08 00 00 16 E8 00 00 00 00 00 00
 scrInducementSystemActualState: 0
 scrInducementSystemState10kHistory: 0
 scrInducementSystemState20kHistory: 0
 scrInducementSystemState30kHistory: 8
 scrInducementSystemState40kHistory: 0
 distanceTravelled10k: 5864 km
 distanceTravelledInducementActive10k: 0 km
 distanceTravelledInducementActive20k: 0 km
 distanceTravelledInducementActive30k: 0 km
 distanceTravelledInducementActive40k: 0 km

Service 03, PID 00
 node address: 11
 description: Request trouble codes
 data bytes: 00
 0 dtcs:

Service 03, PID 00
 node address: 10
 description: Request trouble codes
 data bytes: 01 C0 80
 1 dtcs:
  U0080

Service 06, PID 00
 node address: 10
 description: Request on-board monitoring test results for continuously and non-continuously monitored systems
 data bytes:
  01 80 84 00 00 00 00 00 00 01 81 02 00 00 00 00 00 00 01 93 33 00 00 00 00 00 00
  02 8D 02 00 00 00 00 00 00 02 81 02 00 00 00 00 00 00
  21 99 2E 00 00 00 00 00 00 21 9C 20 00 00 00 00 00 00
  31 83 2F 00 00 00 00 00 00 31 84 2F 00 00 00 00 00 00 31 85 05 00 00 00 00 00 00
  41 9E 11 00 0B 00 00 17 70
  42 9E 11 00 00 00 00 00 00
  81 86 39 00 00 00 00 00 00 81 87 39 00 00 00 00 00 00 81 88 39 00 00 00 00 00 00 81 89 39 00 00 00 00 00 00 81 8A 39 00
00 00 00 00 00 81 8B 39 00 00 00 00 00 00 81 8C 2F 00 00 00 00 00 00
  85 95 18 00 00 00 00 00 00 85 96 18 00 00 00 00 00 00 85 97 18 00 00 00 00 00 00
  98 98 2F 00 00 00 00 00 00
  A1 0B 24 00 00 00 00 FF FF A1 0C 24 00 00 00 00 FF FF
  A2 0B 24 00 00 00 00 FF FF A2 0C 24 00 00 00 00 FF FF
  A3 0B 24 00 00 00 00 FF FF A3 0C 24 00 00 00 00 FF FF
  A4 0B 24 00 00 00 00 FF FF A4 0C 24 00 00 00 00 FF FF
  A5 0B 24 00 00 00 00 FF FF A5 0C 24 00 00 00 00 FF FF
  A6 0B 24 00 00 00 00 FF FF A6 0C 24 00 00 00 00 FF FF
  A7 0B 24 00 00 00 00 FF FF A7 0C 24 00 00 00 00 FF FF
  B2 8E 17 00 00 00 00 00 00 B2 9A 04 00 00 00 00 00 00 B2 9B 20 00 00 00 00 00 00 B2 9D 20 00 00 00 00 00 00
 41 test results:
  [0]
   obdMonitorId: 1
   stdDefinedTestid: 128
   unitAndScalingId: 132
   testValue: 0
   minTestLimit: 0
   maxTestLimit: 0
  [1]
   obdMonitorId: 1
   stdDefinedTestid: 129
   unitAndScalingId: 2
   testValue: 0
   minTestLimit: 0
   maxTestLimit: 0
  [2]
   obdMonitorId: 1
   stdDefinedTestid: 147
   unitAndScalingId: 51
   testValue: 0
   minTestLimit: 0
   maxTestLimit: 0
  [3]
```

```
 obdMonitorId: 2
 stdDefinedTestid: 141
 unitAndScalingId: 2
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[4]
 obdMonitorId: 2
 stdDefinedTestid: 129
 unitAndScalingId: 2
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[5]
 obdMonitorId: 33
 stdDefinedTestid: 153
 unitAndScalingId: 46
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[6]
 obdMonitorId: 33
 stdDefinedTestid: 156
 unitAndScalingId: 32
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[7]
 obdMonitorId: 49
 stdDefinedTestid: 131
 unitAndScalingId: 47
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[8]
 obdMonitorId: 49
 stdDefinedTestid: 132
 unitAndScalingId: 47
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[9]
 obdMonitorId: 49
 stdDefinedTestid: 133
 unitAndScalingId: 5
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[10]
 obdMonitorId: 65
 stdDefinedTestid: 158
 unitAndScalingId: 17
 testValue: 11
 minTestLimit: 0
 maxTestLimit: 6000
[11]
 obdMonitorId: 66
 stdDefinedTestid: 158
 unitAndScalingId: 17
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[12]
 obdMonitorId: 129
 stdDefinedTestid: 134
 unitAndScalingId: 57
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[13]
 obdMonitorId: 129
 stdDefinedTestid: 135
 unitAndScalingId: 57
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
```

```
[14]
 obdMonitorId: 129
 stdDefinedTestid: 136
 unitAndScalingId: 57
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[15]
 obdMonitorId: 129
 stdDefinedTestid: 137
 unitAndScalingId: 57
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[16]
 obdMonitorId: 129
 stdDefinedTestid: 138
 unitAndScalingId: 57
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[17]
 obdMonitorId: 129
 stdDefinedTestid: 139
 unitAndScalingId: 57
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[18]
 obdMonitorId: 129
 stdDefinedTestid: 140
 unitAndScalingId: 47
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[19]
 obdMonitorId: 133
 stdDefinedTestid: 149
 unitAndScalingId: 24
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[20]
 obdMonitorId: 133
 stdDefinedTestid: 150
 unitAndScalingId: 24
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[21]
 obdMonitorId: 133
 stdDefinedTestid: 151
 unitAndScalingId: 24
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[22]
 obdMonitorId: 152
 stdDefinedTestid: 152
 unitAndScalingId: 47
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 0
[23]
 obdMonitorId: 161
 stdDefinedTestid: 11
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[24]
 obdMonitorId: 161
 stdDefinedTestid: 12
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
```

```
 maxTestLimit: 65535
[25]
 obdMonitorId: 162
 stdDefinedTestid: 11
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[26]
 obdMonitorId: 162
 stdDefinedTestid: 12
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[27]
 obdMonitorId: 163
 stdDefinedTestid: 11
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[28]
 obdMonitorId: 163
 stdDefinedTestid: 12
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[29]
 obdMonitorId: 164
 stdDefinedTestid: 11
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[30]
 obdMonitorId: 164
 stdDefinedTestid: 12
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[31]
 obdMonitorId: 165
 stdDefinedTestid: 11
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[32]
 obdMonitorId: 165
 stdDefinedTestid: 12
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[33]
 obdMonitorId: 166
 stdDefinedTestid: 11
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[34]
 obdMonitorId: 166
 stdDefinedTestid: 12
 unitAndScalingId: 36
 testValue: 0
 minTestLimit: 0
 maxTestLimit: 65535
[35]
 obdMonitorId: 167
 stdDefinedTestid: 11
 unitAndScalingId: 36
 testValue: 0
```

```
     minTestLimit: 0
     maxTestLimit: 65535
    [36]
     obdMonitorId: 167
     stdDefinedTestid: 12
     unitAndScalingId: 36
     testValue: 0
     minTestLimit: 0
     maxTestLimit: 65535
    [37]
     obdMonitorId: 178
     stdDefinedTestid: 142
     unitAndScalingId: 23
     testValue: 0
     minTestLimit: 0
     maxTestLimit: 0
    [38]
     obdMonitorId: 178
     stdDefinedTestid: 154
     unitAndScalingId: 4
     testValue: 0
     minTestLimit: 0
     maxTestLimit: 0
    [39]
     obdMonitorId: 178
     stdDefinedTestid: 155
     unitAndScalingId: 32
     testValue: 0
     minTestLimit: 0
     maxTestLimit: 0
    [40]
     obdMonitorId: 178
     stdDefinedTestid: 157
     unitAndScalingId: 32
     testValue: 0
     minTestLimit: 0
     maxTestLimit: 0
Service 07, PID 00
 node address: 10
 description: Request trouble codes
 data bytes: 01 C0 80
 1 dtcs:
  U0080

Service 07, PID 00
 node address: 11
 description: Request trouble codes
 data bytes: 01 C0 80
 1 dtcs:
  U0080

Service 09, PID 02
 node address: 10
 description: Vehicle Identification Number
 data bytes: 34 56 34 4E 43 39 45 48 33 45 4E 31 36 31 30 38 34
 string: 4V4NC9EH3EN161084

Service 09, PID 04
 node address: 11
 description: Calibration Identifications
 data bytes: 32 31 39 32 32 39 30 34 2E 30 30 30 30 34 32 32 31 39 31 32 30 30 34 2E 30 30 30 30 32 36
 2 calibrationIds:
 21922904.0000042
 21912004.0000026

Service 09, PID 04
 node address: 10
 description: Calibration Identifications
 data bytes: 32 31 39 35 30 38 39 37 2E 30 30 30 30 35 36 32 31 39 35 31 34 39 36 2E 30 30 30 30 38 34 30 32 32 38
 30 32 30 31 32 34 00 00 00 00 00 00 4E 4F 78 2D 53 57 37 30 30 39 20 41 54 49 31 00 3F 3F 3F 3F 3F 3F 3F 3F 3F 3F 3F 3F
 3F 3F 3F 3F 32 33 30 38 39 32 33 35 50 30 31 20 00 00 00 00 32 31 39 39 30 33 32 38 2E 30 30 30 30 30 30 38
 7 calibrationIds:
 21950897.0000056
 21951496.0000084
 0228020124
```

```
 NOx-SW7009 ATI1
 ????????????????
 23089235P01
 21990328.0000008

Service 09, PID 06
 node address: 11
 description: Calibration Verification Numbers
 data bytes: E6 C0 39 74 8C A8 AC 21
2 calibrationVerificationNumbers:
 0xE6C03974
 0x8CA8AC21

Service 09, PID 06
 node address: 10
 description: Calibration Verification Numbers
 data bytes: DE 85 D6 F6 FC 8F 8D 1D 03 AA EB 63 2F 2A 2D 35 00 00 00 00 FF 7F 85 11 D1 A2 81 B7
7 calibrationVerificationNumbers:
 0xDE85D6F6
 0xFC8F8D1D
 0x03AAEB63
 0x2F2A2D35
 0x00000000
 0xFF7F8511
 0xD1A281B7

Service 09, PID 0A
 node address: 10
 description: ECUNAME
 data bytes: 45 43 4D 00 2D 45 6E 67 69 6E 65 43 6F 6E 74 72 6F 6C 00 00
 string: ECM-EngineControl

Service 09, PID 0A
 node address: 11
 description: ECUNAME
 data bytes: 52 44 43 4D 2D 52 65 64 75 63 74 61 6E 74 43 74 72 6C 00 00
 string: RDCM-ReductantCtrl

Service 09, PID 0B
 node address: 10
 description: In-use Performance Tracking for compression ignition engines
 data bytes: 12 0A 38 14 25 01 16 01 B7 02 2D 0A 38 00 00 00 00 00 D2 01 B7 00 92 0A 38 00 CA 0A 10 04 CC 0A 38 07 5D 0A
38
 obdMonitoringConditionsEncounteredCounts: 2616 counts
 ignitionCycleCounter: 5157 counts
 nmhcCatalystMonitorCompletionCounts: 278 counts
 nmhcCatalystMonitorConditionsEncounteredCounts: 439 counts
 noxScrCatalystMonitorCompletionCounts: 557 counts
 noxScrCatalystMonitorConditionsEncounteredCounts: 2616 counts
 noxAdsorberMonitorCompletionConditionCounts: 0 counts
 noxAdsorberMonitorConditionsEncounteredCounts: 0 counts
 pmFilterMonitorCompletionConditionCounts: 210 counts
 pmFilterMonitorConditionsEncounteredCounts: 439 counts
 egrVvtMonitorCompletionConditionCounts: 202 counts
 egrVvtMonitorConditionsEncounteredCounts: 2576 counts
 boostPressureMonitorCompletionConditionCounts: 1228 counts
 boostPressureMonitorConditionsEncounteredCounts: 2616 counts
 fuelMonitorCompletionConditionCounts: 1885 counts
 fuelMonitorConditionsEncounteredCounts: 2616 counts

Service 09, PID 0D
 node address: 10
 description: Engine Serial Number
 data bytes: 01 00 00 00 00 00 00 00 30 31 33 31 30 32 38 32 36 32
 string: 0131028262

Service 0A, PID 00
 node address: 11
 description: Request trouble codes
 data bytes: 00
 0 dtcs:

Service 0A, PID 00
 node address: 10
 description: Request trouble codes
 data bytes: 08 C0 80 D1 6F C2 9D C2 9E 26 98 04 01 22 5E 20 EE
```

```
8 dtcs:
 U0080
 U116F
 U029D
 U029E
 P2698
 P0401 (Exhaust Gas Recirculation Flow Insufficient Detected)
 P225E
 P20EE
```

XML File:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<J1979RemoteOBDCollection>
<Hdr>
<VIN>4V4NC9EH3EN161084</VIN><DeviceName>DrewLinQ</DeviceName>
<DeviceSN>DrewLinQ #003357</DeviceSN>
<CollectionDateTime>2021-03-12 09:01:41</CollectionDateTime>
<VehicleProtocol>ICAN29bt500</VehicleProtocol></Hdr>
<ECU>
<ECU_ModuleAddress>11</ECU_ModuleAddress>
<Readiness>
  <RDS_ComponentsTest_PID01_Supported>Y</RDS_ComponentsTest_PID01_Supported>
  <RDS_ComponentsTest_PID01_Complete>N</RDS_ComponentsTest_PID01_Complete>
  <RDS_ComponentsTest_PID41_Supported>Y</RDS_ComponentsTest_PID41_Supported>
  <RDS_ComponentsTest_PID41_Complete>Y</RDS_ComponentsTest_PID41_Complete>
  <RDS_FuelSystem_PID01_Supported>N</RDS_FuelSystem_PID01_Supported>
  <RDS_FuelSystem_PID01_Complete>N</RDS_FuelSystem_PID01_Complete>
  <RDS_FuelSystem_PID41_Enabled>N</RDS_FuelSystem_PID41_Enabled>
  <RDS_FuelSystem_PID41_Complete>N</RDS_FuelSystem_PID41_Complete>
  <RDS_Misfire_PID01_Supported>N</RDS_Misfire_PID01_Supported>
  <RDS_Misfire_PID01_Complete>N</RDS_Misfire_PID01_Complete>
  <RDS_Misfire_PID41_Enabled>N</RDS_Misfire_PID41_Enabled>
  <RDS_Misfire_PID41_Complete>N</RDS_Misfire_PID41_Complete>
  <RDS_EgrSystem_PID01_Supported>N</RDS_EgrSystem_PID01_Supported>
  <RDS_EgrSystem_PID01_Complete>N</RDS_EgrSystem_PID01_Complete>
  <RDS_EgrSystem_PID41_Enabled>N</RDS_EgrSystem_PID41_Enabled>
  <RDS_EgrSystem_PID41_Complete>N</RDS_EgrSystem_PID41_Complete>
  <RDS_OxygenSensorHeater_PID01_Supported>N</RDS_OxygenSensorHeater_PID01_Supported>
  <RDS_OxygenSensorHeater_PID01_Complete>N</RDS_OxygenSensorHeater_PID01_Complete>
  <RDS_OxygenSensorHeater_PID41_Enabled>N</RDS_OxygenSensorHeater_PID41_Enabled>
  <RDS_OxygenSensorHeater_PID41_Complete>N</RDS_OxygenSensorHeater_PID41_Complete>
  <RDS_OxygenSensor_PID01_Supported>N</RDS_OxygenSensor_PID01_Supported>
  <RDS_OxygenSensor_PID01_Complete>N</RDS_OxygenSensor_PID01_Complete>
  <RDS_OxygenSensor_PID41_Enabled>N</RDS_OxygenSensor_PID41_Enabled>
  <RDS_OxygenSensor_PID41_Complete>N</RDS_OxygenSensor_PID41_Complete>
  <RDS_AcRefrigerant_PID01_Supported>N</RDS_AcRefrigerant_PID01_Supported>
  <RDS_AcRefrigerant_PID01_Complete>N</RDS_AcRefrigerant_PID01_Complete>
  <RDS_AcRefrigerant_PID41_Enabled>N</RDS_AcRefrigerant_PID41_Enabled>
  <RDS_AcRefrigerant_PID41_Complete>N</RDS_AcRefrigerant_PID41_Complete>
  <RDS_SecondaryAirSystem_PID01_Supported>N</RDS_SecondaryAirSystem_PID01_Supported>
  <RDS_SecondaryAirSystem_PID01_Complete>N</RDS_SecondaryAirSystem_PID01_Complete>
  <RDS_SecondaryAirSystem_PID41_Enabled>N</RDS_SecondaryAirSystem_PID41_Enabled>
  <RDS_SecondaryAirSystem_PID41_Complete>N</RDS_SecondaryAirSystem_PID41_Complete>
  <RDS_EvapSystem_PID01_Supported>N</RDS_EvapSystem_PID01_Supported>
  <RDS_EvapSystem_PID01_Complete>N</RDS_EvapSystem_PID01_Complete>
  <RDS_EvapSystem_PID41_Enabled>N</RDS_EvapSystem_PID41_Enabled>
  <RDS_EvapSystem_PID41_Complete>N</RDS_EvapSystem_PID41_Complete>
  <RDS_HeatedCatalyst_PID01_Supported>N</RDS_HeatedCatalyst_PID01_Supported>
  <RDS_HeatedCatalyst_PID01_Complete>N</RDS_HeatedCatalyst_PID01_Complete>
  <RDS_HeatedCatalyst_PID41_Enabled>N</RDS_HeatedCatalyst_PID41_Enabled>
  <RDS_HeatedCatalyst_PID41_Complete>N</RDS_HeatedCatalyst_PID41_Complete>
  <RDS_Catalyst_PID01_Supported>N</RDS_Catalyst_PID01_Supported>
  <RDS_Catalyst_PID01_Complete>N</RDS_Catalyst_PID01_Complete>
  <RDS_Catalyst_PID41_Enabled>N</RDS_Catalyst_PID41_Enabled>
  <RDS_Catalyst_PID41_Complete>N</RDS_Catalyst_PID41_Complete>
  <RDS_EgrVvtSystem_PID01_Supported>N</RDS_EgrVvtSystem_PID01_Supported>
  <RDS_EgrVvtSystem_PID01_Complete>N</RDS_EgrVvtSystem_PID01_Complete>
  <RDS_EgrVvtSystem_PID41_Enabled>N</RDS_EgrVvtSystem_PID41_Enabled>
  <RDS_EgrVvtSystem_PID41_Complete>N</RDS_EgrVvtSystem_PID41_Complete>
  <RDS_PmFilterMonitoring_PID01_Supported>N</RDS_PmFilterMonitoring_PID01_Supported>
  <RDS_PmFilterMonitoring_PID01_Complete>N</RDS_PmFilterMonitoring_PID01_Complete>
  <RDS_PmFilterMonitoring_PID41_Enabled>N</RDS_PmFilterMonitoring_PID41_Enabled>
  <RDS_PmFilterMonitoring_PID41_Complete>N</RDS_PmFilterMonitoring_PID41_Complete>
  <RDS_ExhaustGasSensor_PID01_Supported>N</RDS_ExhaustGasSensor_PID01_Supported>
  <RDS_ExhaustGasSensor_PID01_Complete>N</RDS_ExhaustGasSensor_PID01_Complete>
  <RDS_ExhaustGasSensor_PID41_Enabled>N</RDS_ExhaustGasSensor_PID41_Enabled>
  <RDS_ExhaustGasSensor_PID41_Complete>N</RDS_ExhaustGasSensor_PID41_Complete>
  <RDS_BoostPressure_PID01_Supported>N</RDS_BoostPressure_PID01_Supported>
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