UNDERSTANDING REAL-WORLD ACTIVITY DATA FOR HEAVY-DUTY VEHICLES - TELEMATICS, PAMS AND PEMS

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Outline

- Background
- New Analysis and Preliminary Findings
- Testing Equipment
- Fields to Record OBD Data
- Future Analysis

Background - Telematics Data

- Telematics refers to any technology that provides a continuous stream of vehicle activity data.
- Challenges include:
  - Providing privacy for vehicle owners
  - Processing massive amounts of data
  - Potential bias in self selecting samples
- Opportunities include:
  - Detailed region-specific activity
  - Extremely large samples
- EPA has obtained heavy-duty telematics results from NREL and CE-CERT.

NREL Heavy-Duty Telematics

- The National Renewable Energy Laboratory (NREL) operates the Fleet DNA clearinghouse of commercial fleet vehicle operating data

- The DNA collects real-world vehicle operation data for medium- and heavy-duty commercial vehicles from a variety of vocations and locations

https://www.nrel.gov/transportation/fleettest-fleet-dna.html

CE-CERT Heavy-Duty Data

- University of California Riverside, Bourns College of Engineering – Center for Environmental Research and Technology (CE-CERT)
  - Instrumented heavy-duty trucks selected by vocation from 19 different groups
  - Sampling was done second-by-second
  - All trucks were 2010 and newer model year
  - Under contract to CARB and supported through CRADA with EPA

CE-CERT and NREL Vehicle Sample Sizes

MOVES		Diesel Vehicles		Days Tested		Avg Days per Vehicle	
SourceTypeID	Description	CE-CERT	NREL	CE-CERT	NREL	CE-CERT	NREL
42	Transit Buses	16	27	1,449	401	90.6	68.5
43	School Buses	6	7	597	230	99.6	118.2
51	Refuse Trucks	30	65	2,765	1,137	92.2	60.0
52	Single Unit Short-Haul	2	146	132	3,588	66.0	25.5
61	Combination Short-Haul	27	160	10,270	5,523	380.4	98.7
62	Combination Long-Haul	9	85	536	4,177	59.6	55.4
	Totals	90	490	15,748	15,056	175.0	62.9

Note:

- Vehicle Sample Size are different but the days of testing are about the same
- The average days of tested on the vehicles is greater in most MOVES sourcetype categories in the CE-CERT dataset

Analysis Issues

- Screening to eliminate bad data
- Identify and account for variations
  - Which factors significantly affect results?
  - Are regional differences important?
  - Are seasonal differences necessary?
- Identify and account for potential vehicle selection bias
  - Do samples include a sufficient number of seldom used and inactive vehicles?
- Some vehicles enter and leave the data collection during the sampling period
- What is the minimum period of data collection to properly determine starts, soaks, and usage distribution patterns?

ARB/University of California Study

Preliminary Data

Different vehicle speed bin and time of use patterns

Speed Bin		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Sum
		8.26	9.55	9.37	7.31	8.67	8.41	8.68	8.74	8.75	7.83	5.74	8.37	0.34	0	0	0	0	0	100
Hour																				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0.10	0.09	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	0.73	0.39	0.12	0.04	0.04	0.03	0.03	0.04	0.02	0.01	0.00	0.00	0.01	0.00	0	0	0	0	0	
5	9.49	1.14	1.65	1.61	1.11	1.19	0.83	0.65	0.46	0.28	0.18	0.13	0.25	0.01	0	0	0	0	0	
6	11.55	1.27	1.60	1.66	0.95	0.91	0.93	0.82	0.60	0.56	0.53	0.46	1.24	0.03	0	0	0	0	0	
7	17.54	1.16	1.29	1.26	0.98	1.16	1.21	1.32	1.47	1.74	1.77	1.49	2.66	0.04	0	0	0	0	0	
8	13.06	1.27	1.56	1.41	0.96	1.05	1.14	1.08	1.02	0.99	1.06	0.80	0.67	0.04	0	0	0	0	0	
9	13.77	1.23	1.55	1.39	1.03	1.22	1.24	1.32	1.25	1.03	0.87	0.59	1.01	0.04	0	0	0	0	0	
10	18.01	0.94	1.10	1.16	1.18	1.55	1.47	1.77	2.08	2.33	1.97	1.20	1.24	0.03	0	0	0	0	0	
11	10.22	0.47	0.43	0.52	0.66	1.00	0.96	1.05	1.20	1.26	1.02	0.78	0.84	0.02	0	0	0	0	0	
12	2.75	0.14	0.13	0.18	0.22	0.29	0.30	0.33	0.33	0.30	0.21	0.11	0.17	0.05	0	0	0	0	0	
13	1.35	0.07	0.06	0.07	0.08	0.12	0.15	0.18	0.17	0.14	0.11	0.07	0.11	0.02	0	0	0	0	0	
14	0.91	0.05	0.03	0.05	0.06	0.10	0.11	0.09	0.09	0.06	0.07	0.06	0.10	0.01	0	0	0	0	0	
15	0.48	0.04	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.07	0.04	0	0	0	0	0	
16	0.05	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0	0	0	0	0	0	0	0	
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sum	100																			100

VMT Distributions for Refuse Trucks

Speed Bin		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Sum
		0.45	0.92	1.16	1.29	1.55	1.96	2.30	2.88	3.37	4.96	10.85	34.30	25.97	7.60	0.44	0.00	0	0	100
Hour																				
0	3.24	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.08	0.10	0.10	0.28	0.95	1.09	0.36	0.03	0	0	0	
1	3.06	0.01	0.03	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.23	0.77	1.12	0.41	0.03	0.00	0	0	
2	3.13	0.01	0.02	0.02	0.02	0.02	0.03	0.04	0.06	0.08	0.09	0.29	0.80	1.05	0.55	0.05	0	0	0	
3	2.89	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.06	0.12	0.46	1.21	0.83	0.04	0	0	0	
4	2.99	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.05	0.08	0.20	0.79	1.18	0.53	0.02	0	0	0	
5	3.70	0.02	0.04	0.04	0.05	0.06	0.09	0.10	0.10	0.12	0.17	0.37	1.18	0.94	0.40	0.01	0	0	0	
6	4.53	0.02	0.03	0.05	0.07	0.09	0.11	0.13	0.16	0.19	0.29	0.60	1.40	1.04	0.33	0.01	0	0	0	
7	4.16	0.02	0.05	0.07	0.09	0.11	0.13	0.14	0.17	0.19	0.25	0.49	1.44	0.92	0.10	0.00	0	0	0	
8	3.71	0.02	0.05	0.06	0.08	0.09	0.10	0.09	0.13	0.14	0.24	0.48	1.56	0.55	0.11	0.01	0	0	0	
9	4.36	0.02	0.04	0.04	0.05	0.06	0.07	0.10	0.10	0.15	0.30	0.76	1.96	0.69	0.04	0.00	0	0	0	
10	4.32	0.02	0.03	0.04	0.05	0.07	0.09	0.10	0.16	0.16	0.24	0.57	2.02	0.71	0.04	0.00	0	0	0	
11	4.48	0.02	0.04	0.05	0.05	0.06	0.08	0.09	0.11	0.16	0.30	0.70	1.96	0.80	0.05	0.00	0	0	0	
12	4.60	0.02	0.04	0.04	0.04	0.05	0.07	0.09	0.12	0.15	0.26	0.66	2.20	0.77	0.09	0.00	0	0	0	
13	4.92	0.02	0.03	0.05	0.05	0.06	0.08	0.10	0.12	0.13	0.21	0.58	2.38	0.95	0.14	0.02	0	0	0	
14	4.36	0.02	0.05	0.05	0.06	0.08	0.10	0.10	0.12	0.14	0.21	0.42	2.09	0.73	0.20	0.00	0.00	0	0	
15	4.86	0.02	0.06	0.07	0.09	0.10	0.11	0.13	0.16	0.18	0.28	0.55	1.78	1.23	0.09	0.00	0	0	0	
16	4.85	0.02	0.06	0.09	0.10	0.11	0.14	0.16	0.18	0.19	0.27	0.63	1.68	1.17	0.06	0.00	0	0	0	
17	3.91	0.03	0.09	0.10	0.10	0.12	0.14	0.18	0.21	0.21	0.26	0.38	1.04	0.96	0.08	0.01	0	0	0	
18	4.85	0.02	0.05	0.08	0.09	0.11	0.13	0.15	0.17	0.20	0.25	0.42	1.32	1.64	0.23	0.02	0	0	0	
19	4.87	0.02	0.04	0.05	0.05	0.07	0.08	0.10	0.16	0.17	0.24	0.46	1.42	1.58	0.39	0.03	0	0	0	
20	5.22	0.02	0.03	0.04	0.04	0.05	0.07	0.08	0.13	0.18	0.28	0.71	1.84	1.39	0.36	0.01	0.00	0	0	
21	4.69	0.02	0.04	0.04	0.05	0.06	0.08	0.09	0.12	0.16	0.22	0.44	1.38	1.35	0.59	0.03	0.00	0	0	
22	4.46	0.02	0.04	0.04	0.04	0.04	0.05	0.07	0.08	0.11	0.15	0.31	1.04	1.57	0.85	0.05	0	0	0	
23	3.83	0.02	0.03	0.04	0.04	0.05	0.07	0.07	0.07	0.10	0.13	0.21	0.85	1.32	0.78	0.06	0.00	0	0	
Sum	100																			100

VMT Distributions for Line-Haul Trucks

Vocational Differences within a MOVES Source Type

Single Unit Short Haul - Source Type 52

Vocation	Vehicles	Avg. Miles per Day
Concrete	3	96.29
Delivery	1	266.62
Dump Truck	3	101.74
Food Delivery	30	41.93
Linen Delivery	17	63.14
Parcel Delivery	39	47.11
Propane Tank	1	82.66
Shredder	1	65.56
Snow Plow	11	79.46
Towing	4	123.12
Warehouse Delivery	9	65.39

Comb. Unit Short Haul - Source Type 61

Vocation	Vehicles	Avg. Miles per Day
Beverage Delivery	10	88.60
Drayage	28	113.39
Dry Van	3	147.22
Dump Truck	5	159.09
Food Delivery	13	123.80
Local Delivery	7	128.52
Parcel Delivery	6	496.66
Regional Haul	7	131.77
Transfer Truck	29	173.95

Different Vocations and Source Types

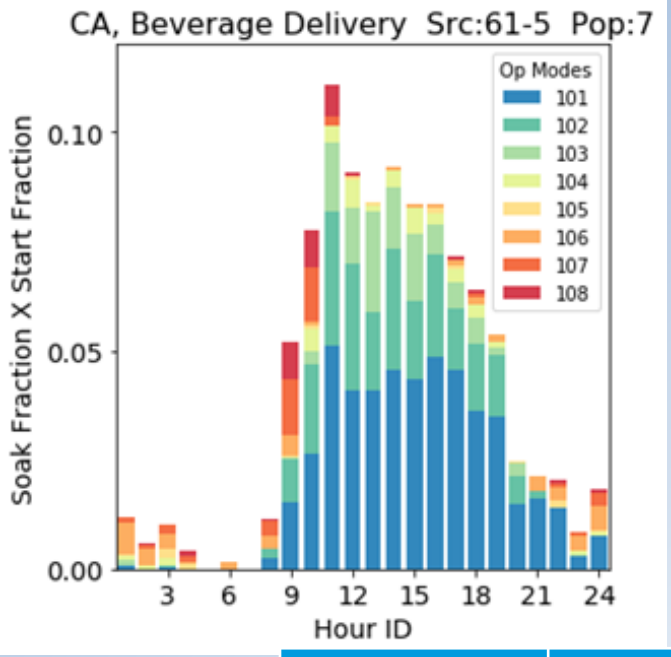
Dump Truck – Source Type 52

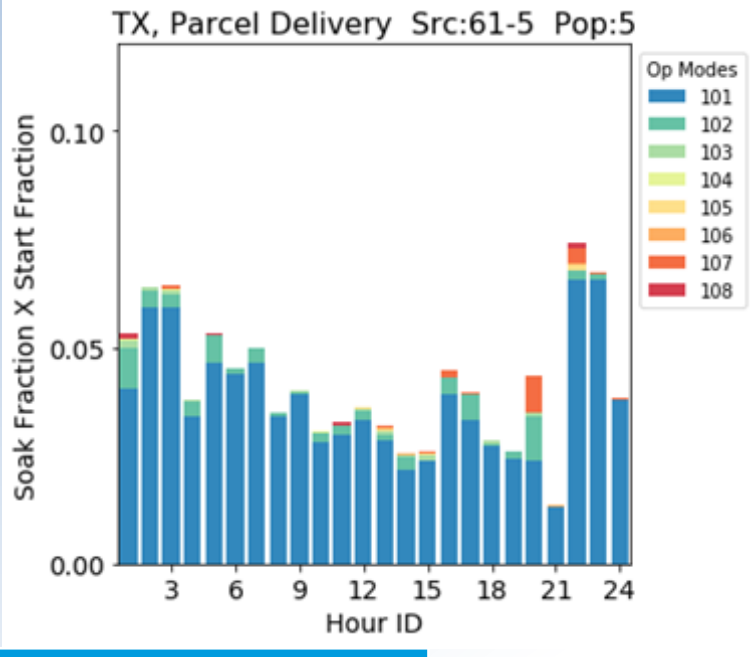
Delivery Truck – Source Type 52

Dump Truck – Source Type 61

Delivery Truck - Source Type 61 or 62

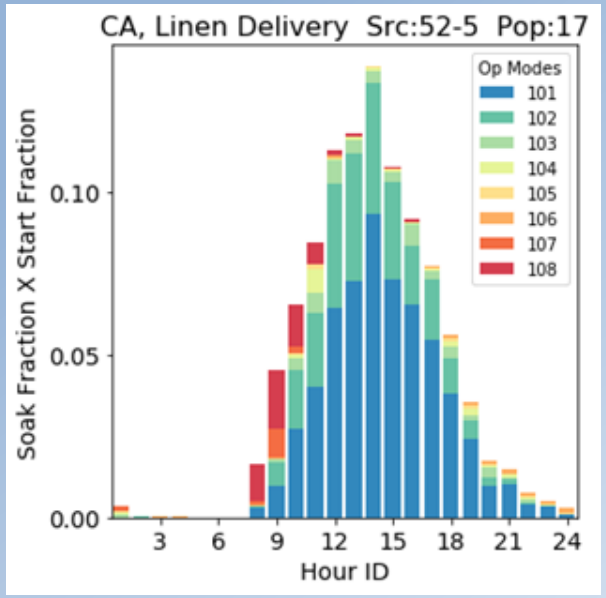
Comb. Short Haul - Source Type 61 Soak Distributions

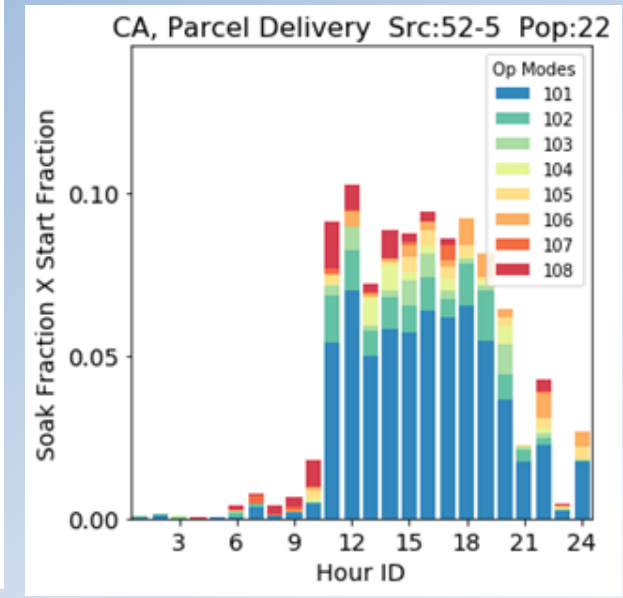


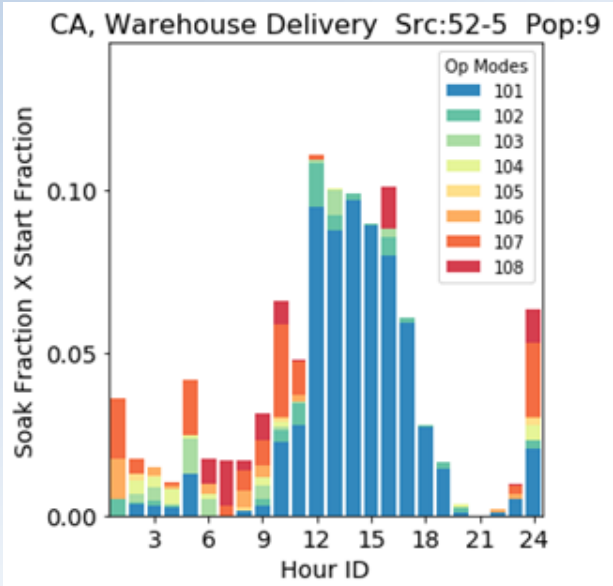


opModeID	Description
101	Soak Time < 6 minutes
102	6 minutes <= Soak Time < 30 minutes
103	30 minutes <= Soak Time < 60 minutes
104	60 minutes <= Soak Time < 90 minutes
105	90 minutes <= Soak Time < 120 minutes
106	120 minutes <= Soak Time < 360 minutes
107	360 minutes <= Soak Time < 720 minutes
108	720 minutes <= Soak Time

Single Unit Short Haul - Source Type 52 Soak Distributions







opModeID	Description
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103	30 minutes <= Soak Time < 60 minutes
104	60 minutes <= Soak Time < 90 minutes
105	90 minutes <= Soak Time < 120 minutes
106	120 minutes <= Soak Time < 360 minutes
107	360 minutes <= Soak Time < 720 minutes
108	720 minutes <= Soak Time

Suite of Tools to Measure Activity and Emissions

Laboratory Testing:
Chassis and/or Engine
Dynamometer

Equipment Only Costs:

~$3,000,000+

Portable Emissions Measurement Systems (PEMS) - **Real World**

~$200,000-$300,000

Screening Tools: mini-PEMS
Real World

~$20,000-$30,000

Portable Activity Measurement Systems (PAMS) – **Real World**

~$600 -$1,000

Suite of Tools: PAMS

Portable Activity Measurement Systems (PAMS)

- Small data loggers interface with on-board vehicle computers to gather very detailed activity and engine parameters in "real-world" operations from light-duty, heavy-duty, and nonroad
  - Activity: vehicle miles traveled distribution, number of starts, soak periods
  - Engine: Engine RPM, engine load, aftertreatment

- Major advancements:
  - Cellular PAMS Data Loggers
  - Created a "Dashboard" to monitor data logger and vehicle
    - "Real-time" notification of issues with data logger and/or vehicle
    - Allows for "Real-time" data analysis

Mini-PEMS/PAMS Data Logger: Data Fields

Allows for Modeling Analysis on:

Date/Time Clock: Key On/Off Date and Time **GPS or ECU**: Vehicle Speed	• Soak times, starts, idle times, vehicle miles traveled, speed distributions, drive cycle development, use patterns, etc. • Able to calculate VSP by vehicle speed and acceleration
Additional ECU Fields: Engine RPM, torque %, MAF, etc. Aftertreatment Operation (temps, NOx ppm, etc.) Intake Manifold Air Flowrate or Absolute Pressure, Fuel Rate	• Characterize engine and aftertreatment operation • Able to use equations for calculating exhaust flow • Able to calculate NOx in ppm or grams by VSP (kW/ton), g/mile or as Brake-Specific Emissions (g/bhp-hr)
GPS Fields: Latitude, longitude, altitude, vehicle speed	• Able to cross-check ECU's vehicle speed and acceleration w/ GPS • Identify emissions in specific locations such as within ports, county or city boundaries, or by road types • Road Grade load by altitude or enhanced with GIS maps
Hybrids/PHEVs/EVs Fields: SOC, Battery Life, Current to/from battery	• Able to determine energy used and generated, mode of operation
External Flowmeter	• Able to cross check ECU's MAF/MAP equations w/ independent flow measurement • ECU interface not needed if flowmeter used, but lose engine data
Additional ECU Fields: Mode $06 Messages	• Able to gather On Board Diagnostic messages, DTCs and Monitor Readiness

Note: All Data Gathered at 1Hz – second-by-second

On Board Diagnostic Messages
HDVs GVWR > 14,000 lbs

As the Heavy-Duty OBD regulations have been implemented recently, it is important for the instrumentation to evolve and gather this data

Model Year	OBD
2007 and later	Required engine manufacturer diagnostics (EMD) systems
2010 – 2012	Full OBD for engine rating with highest weighted sales and extrapolated OBD for all other ratings; and exempted from standardization requirements
2013 – 2015	Full OBD for all engines ratings subject to MY2010-2012 OBD requirements; • Full OBD for engine ratings within each OBD group w/ highest projected weighted sales; • Extrapolate OBD for other ratings and engines; and • More strict monitoring threshold values
2016 and later	Full OBD on all engines

OBD Monitors

Monitor	Thresholds				
	Model Year	NMHC	CO	NOx	PM
	Diesel				
NOx Catalyst System	2010 - 2012			+0.6	
	2013+			+0.3	
Diesel Particulate Filter (DPF) System	2010 - 2012	2.5x			0.05/+0.04
	2013+	2.0x			0.05/+0.04
Air-Fuel Ratio Sensor Upstream	2010 - 2012	2.5x	2.5x	+0.3	0.03/+0.02
	2013+	2.0x	2.0x	+0.3	0.03/+0.02
Air-Fuel Ratio Sensor Downstream	2010 - 2012	2.5x		+0.3	0.05/+0.04
	2013+	2.0x		+0.3	0.05/+0.04
NOx Sensor	2010 - 2012			+0.6	0.05/+0.04
	2013+			+0.3	0.05/+0.04
Other Monitors w/ Emission Thresholds	2010 - 2012	2.5x	2.5x	+0.3	0.03/+0.02
	2013+	2.0x	2.0x	+0.3	0.03/+0.02
	Gasoline				
Catalyst Converter System	2010+	1.75x		1.75x	
Other Monitors w/ Emission Thresholds	2010+	1.5x	1.5x	1.5x	
Evaporative Emissions	2010+	0.150" leak			

Legend:

- **2.0x means a multiple of 2.0 times the applicable emission standard or family emission limit (FEL)**
- **+0.3 means the standard or FEL plus 0.3**
- **0.05/+0.04 means an absolute level of 0.05 g/hp-hr or an additive level of the standard or FEL plus 0.04, whichever level is higher**

Important Diagnostic Messages to Record

DM Description	HDV J1939 DM/PGN
Active DTCs	DM1/ (65226)
Previously Active DTCs (Historic)	DM2/(65227)
Pending Emission Related DTCs	DM6/(65231)
Previously Active Emission Related DTCs	DM23/(64949)
All Pending DTCs	DM27/(64898)
All Permanent DTCs	DM28/(64896)
Regulated Exhaust Emissions Exceedance	DM32/(41472)

Existing HD Vehicle Diagnostics:

- **Monitor Readiness**
- **MIL light On**
- **DTCs – Active Only**

DM	Controller	Controller Name	SPN	SPN Name	FMI	FMI Name	Count
DM27	0	Engine #1	3226	Aftertreatment 1 Outlet NOx 1	10	Abnormal Rate of Change	0

Findings

- Key tools are being developed for researchers to use to better understand how new technologies are being used in real-world:
  - Suite of Tools (Lab, PEMS, mini-PEMS and PAMS)
  - New DMs/DTCs required to be monitored and recorded
  - New testing methodologies and procedures are being used to reduce cost

Future Analysis

- Larger datasets are needed to better understand how medium and heavy-duty vehicles using new technologies are being used in real-world:
  - Need more activity data including engine parameters, DMs/DTCs and GPS to improve:
    - Vocation, Regional and Seasonal Usage Patterns
    - Longitudinal data for aging vehicles, maintenance, warranty issues through DMs/DTCs
    - Second-by-second data
  - Need to compare how different engine/electric technologies, modes and management software are being used.

Questions

Contact Information

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Other Slides