

# Preliminary Results of Sensor-Based Onboard Sensing Analysis and Reporting from Fleets During a Two Month Timeframe

Heavy-Duty Diesel Vehicle Inspection and Maintenance Working Group

April 18, 2024

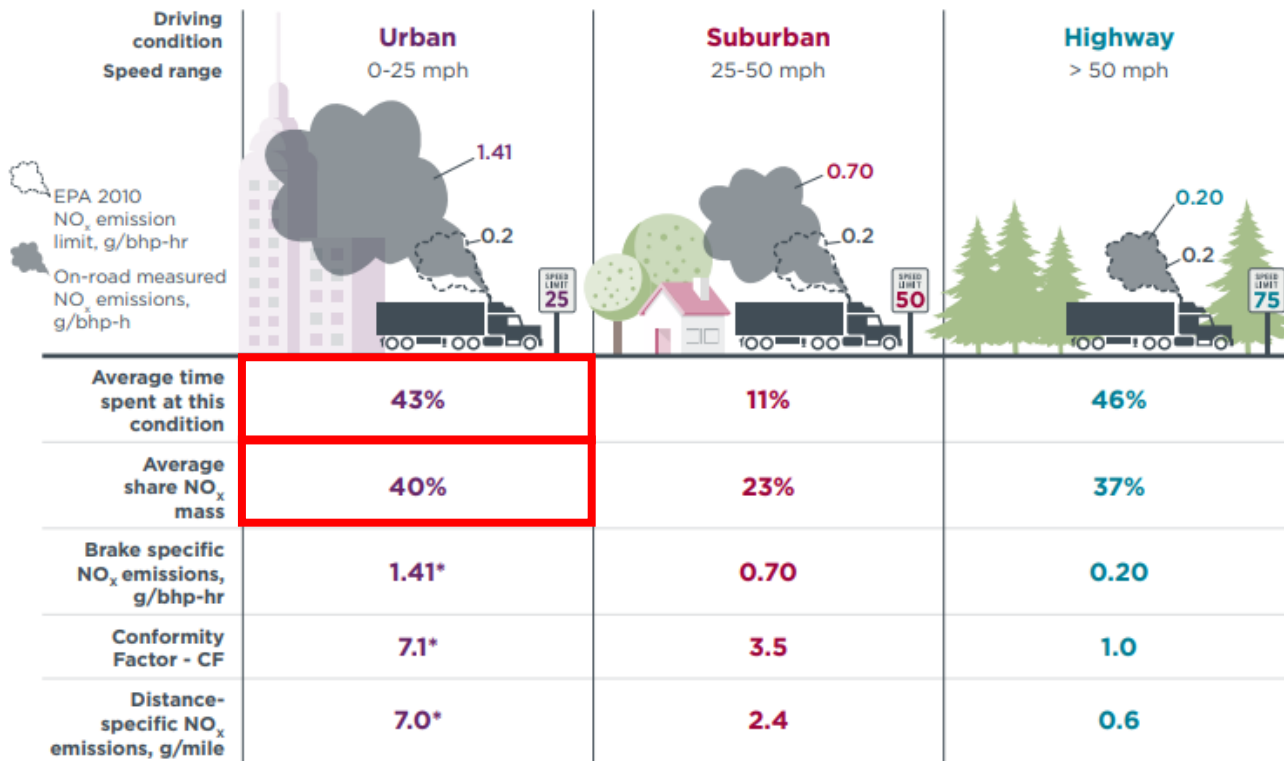
Grace Johnson

George Scora, Zisimos Toumasatos, Jinsuh Jung-Aum, Georgios Karavalakis,  
Thomas D. Durbin, and Kent Johnson

CE-CERT



# In-Use Emissions Vary with Vehicle Operation

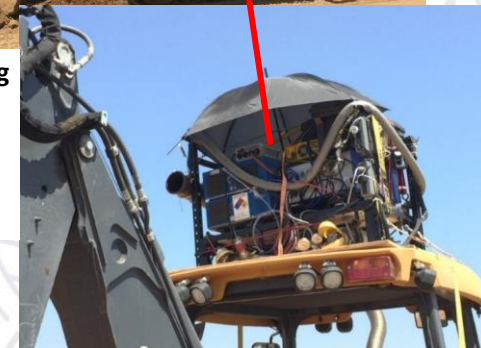
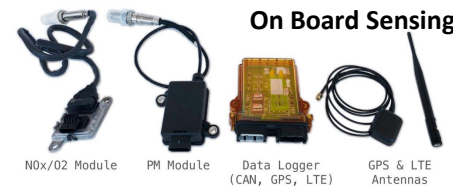


\* Brake and distance specific NO<sub>x</sub> emissions for Urban bin do not include Idle operation, only 1-25 mph operation is included

- 189 tests between 2010 and 2019
- Model Year (MY) 2010-2016 with SCR Technology
- **43%** of the activity is between 0-25 mph
- This represents **40%** of the NO<sub>x</sub> mass

# Laboratory, In-Use Measurement, and On-Board Sensing

- Laboratory 2% accuracy (1 day of data takes weeks/months to set up)
- In-use measurement 5% (1 day of data takes 4-6 hrs to set up)
- On-board sensing 10% (1 year of data takes <1 hr to set up)



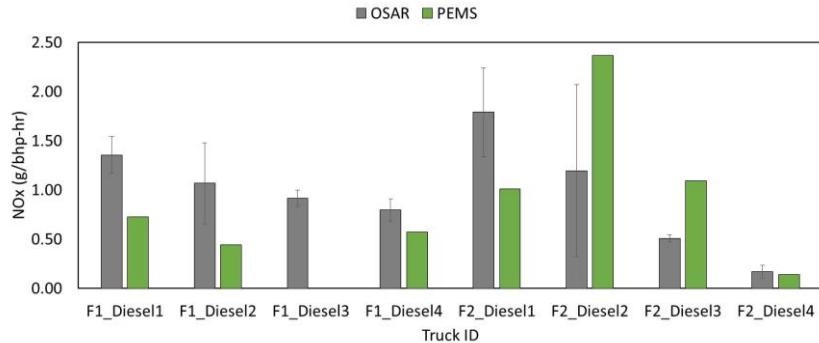
Montes, T., 2018 SAE OBDS Symposium Indianapolis, Diesel OBDS Programs ECARD Division presentation.

Tan, Y., Collins, J., Yoon, S., Herner, J., Henderick, P., Montes, T., Ham, W., Howard, C., Hu, S., Johnson, K., Scora, G., Sandez, D., Durbin, T., 2018. NOx Emission Estimates from the Activity Data of On-Road Heavy-Duty Diesel Vehicles. Presentation at 28th CRC Real World Emissions Workshop, Garden Grove, CA, March.

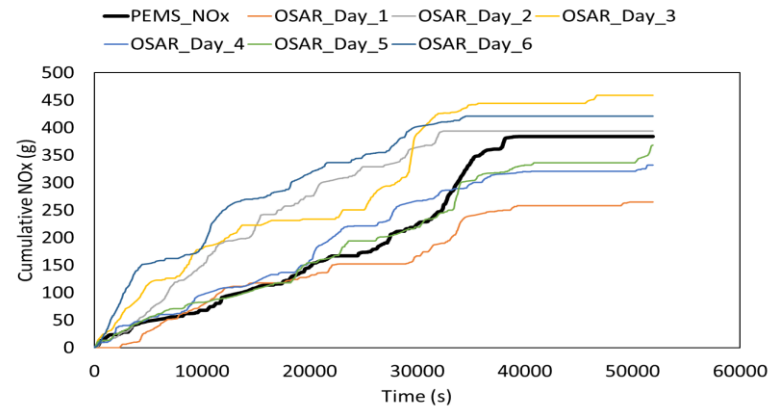
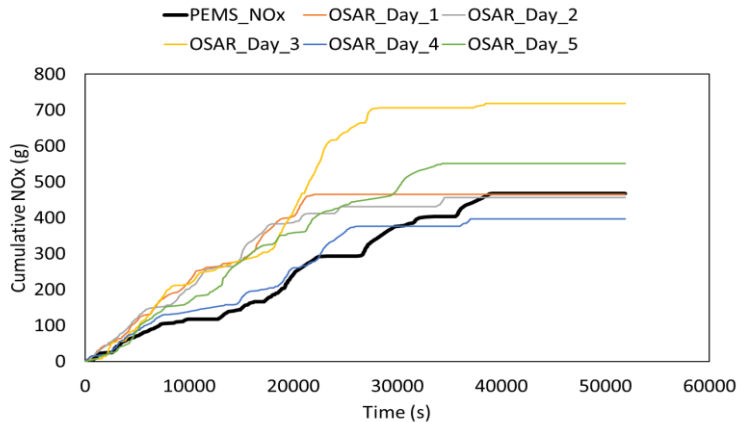
Yang, J., Durbin, T.D., Jiang, Y., Tange, T., Karavalakis, G., Cocker III, D.R., Johnson, K.C., 2018. A comparison of a mini-PEMS and a 1065 compliant PEMS for on-road gaseous and particulate emissions from a light duty diesel truck, Science of the Total Environment, vol. 640-641, 368-376.



# One Day of PEMS Testing is Not Representative

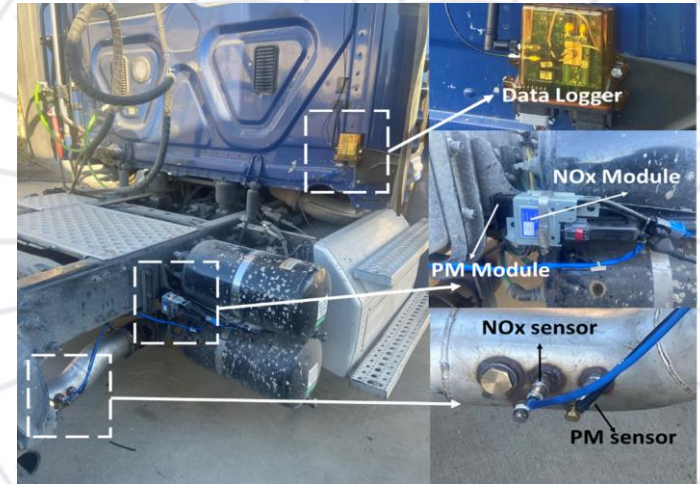
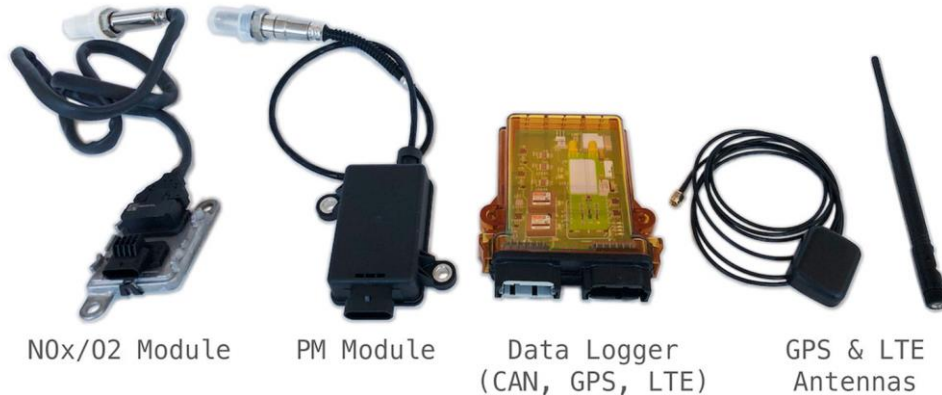


- Emissions change between days on the same vehicle
- PEMS data presented emissions measured on one day
- OSAR data showed several days of continuous monitoring results



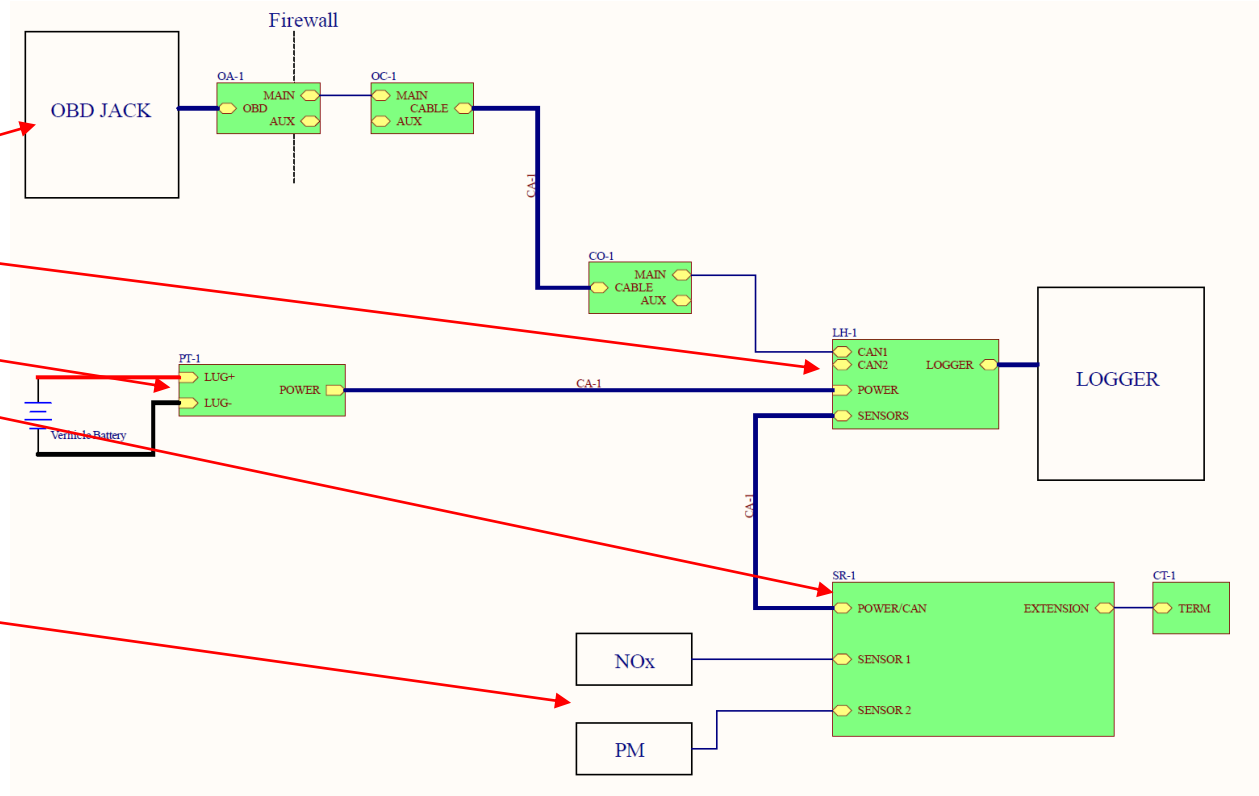


- The Onboard Sensing Analysis and Reporting (OSAR) system was developed for continuous monitoring of diesel and natural gas technologies on an annual basis
- OSAR started out as a consortium-lead research initiative, but has now grown to over nine funded programs
- OSAR includes
  - NO<sub>x</sub>, PM, GPS, CAN, and other sensors
  - Auto starting and shutdown to capture cold starts and all truck operation



Main components:

- OBD jack: OA-1
- OSAR Logger: Emtrac-6, LH-1
- Power supply: PT-1
- Sensor connections: SR-1, CT-1
- NOx Sensor
- NH<sub>3</sub> Sensor
- CO<sub>2</sub> Sensor
- PM Sensor
- Extension Cables: CA-1



Just add the bungs to the exhaust, install sensors, and wire harness. No on-site calibration needed. Installation and data is good for a year or more.



Full system fits in this box including wire harness and bungs



We have about 40 systems ready for installation

In partnership with



For more information on EmTrac: [pt@emisense.com](mailto:pt@emisense.com)









# Installation of OBD Jack

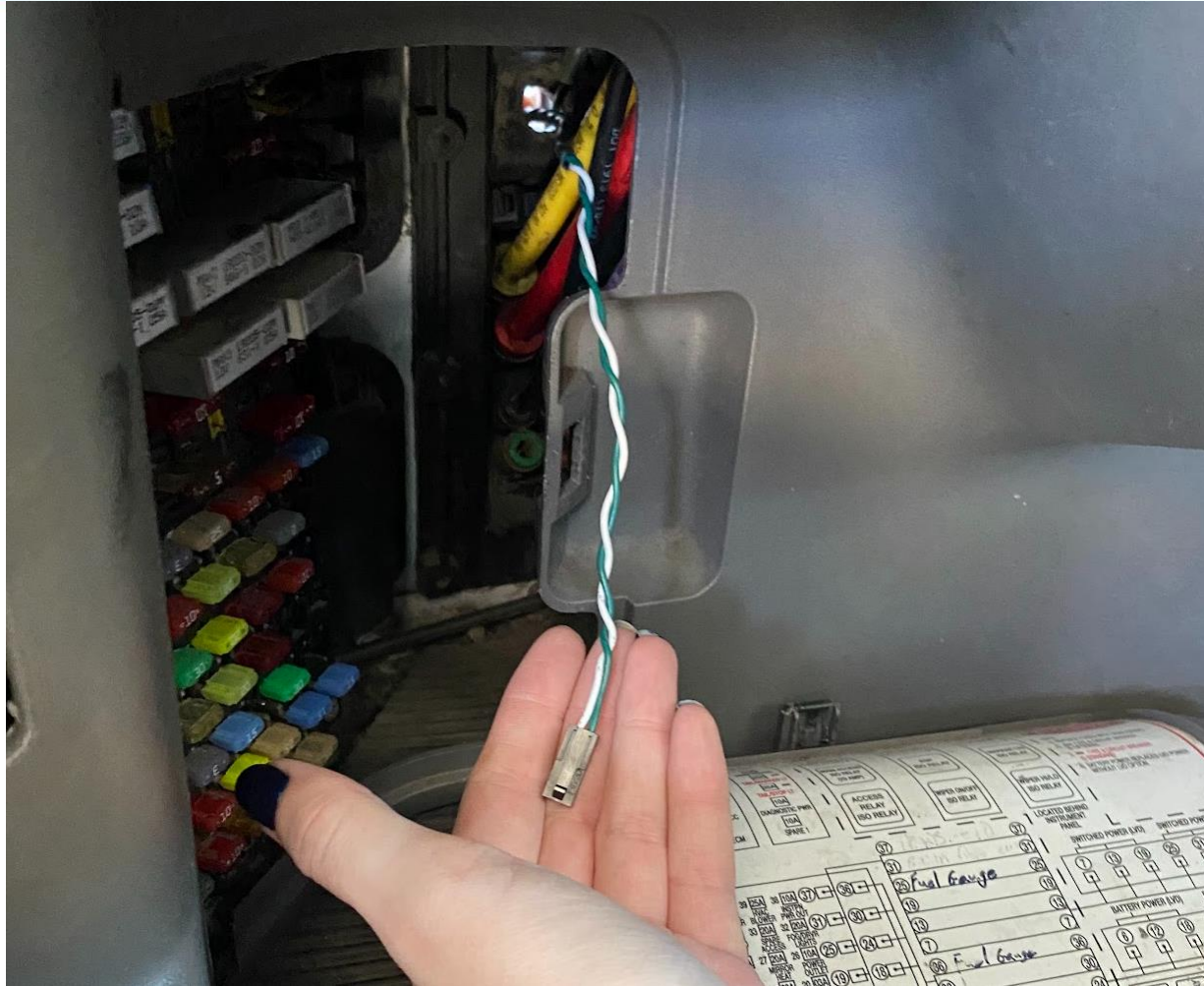




# Installation of OBD Jack

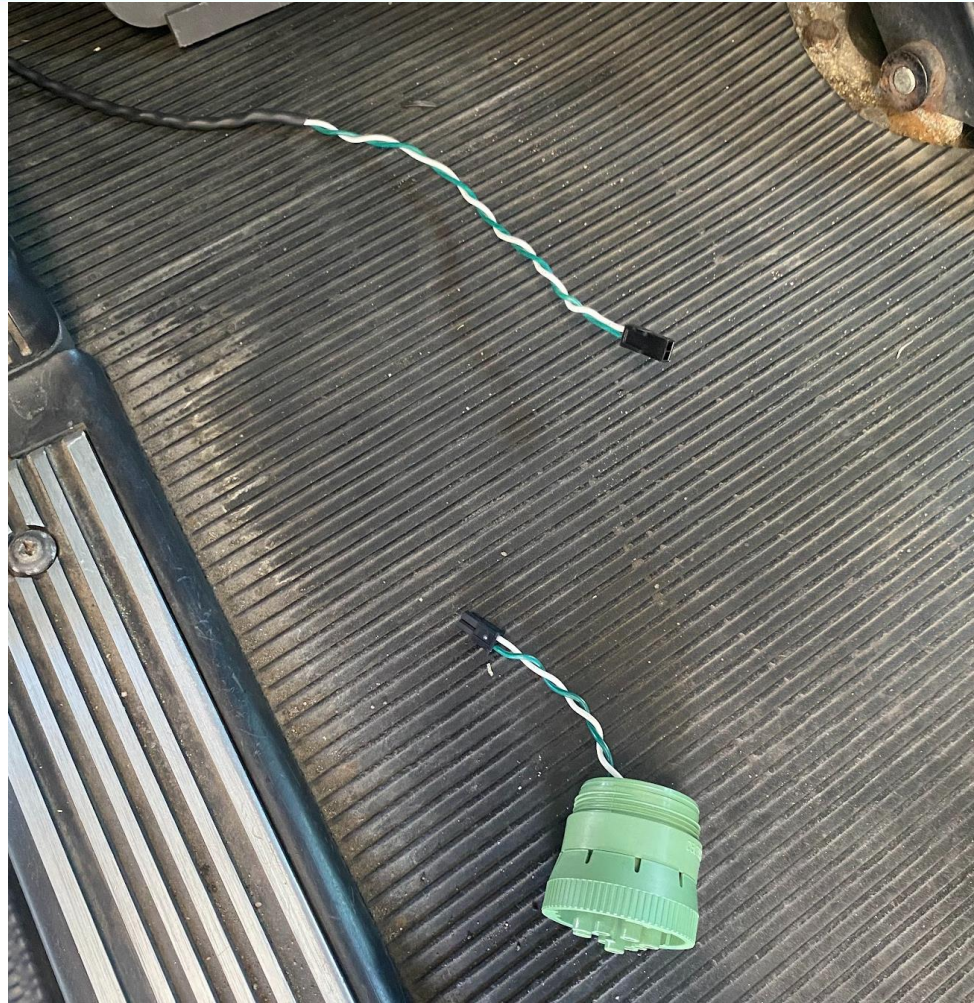


# Installation of OBD Jack





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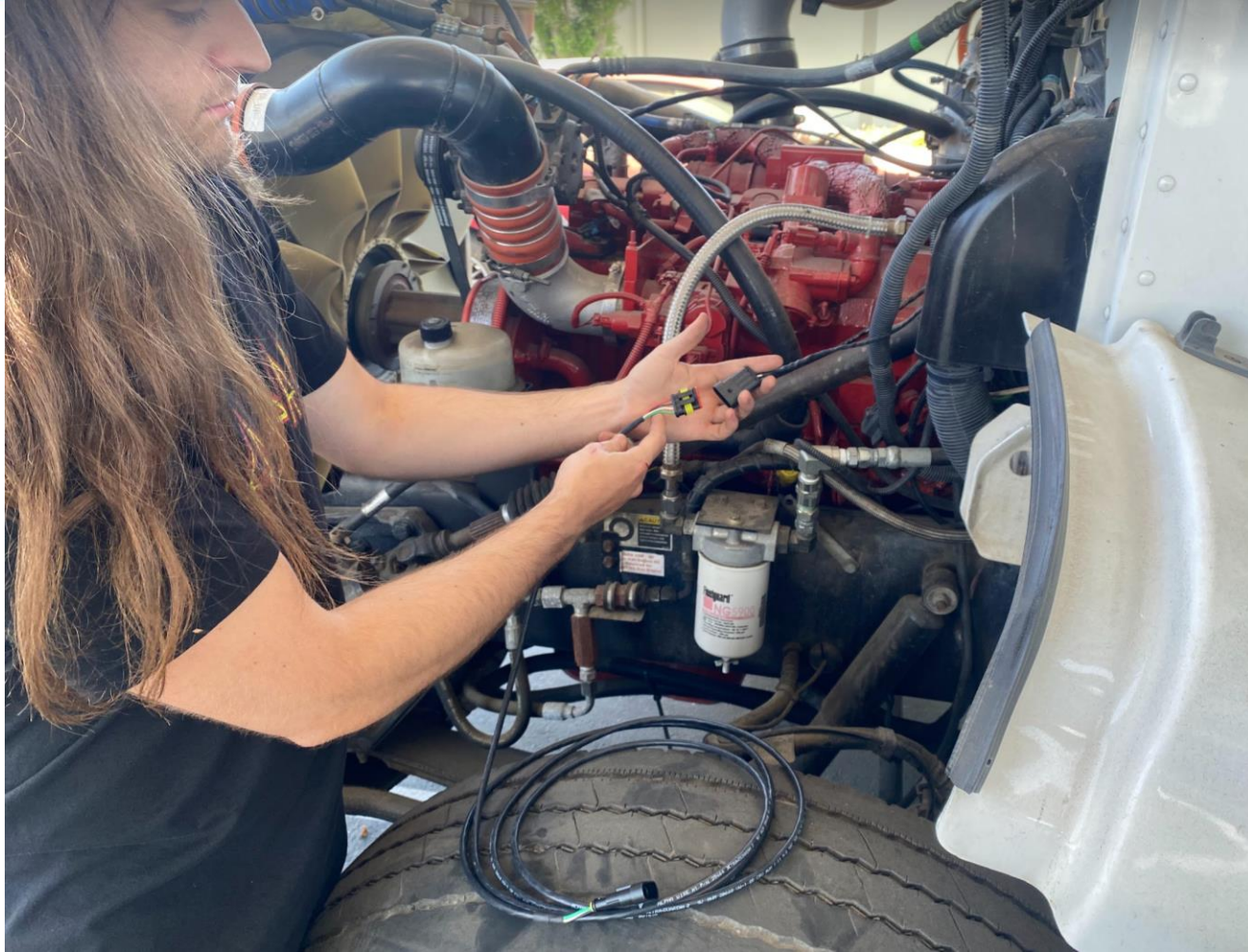


# Installation of OBD Jack





# Installation of OBD Jack Extension Cable





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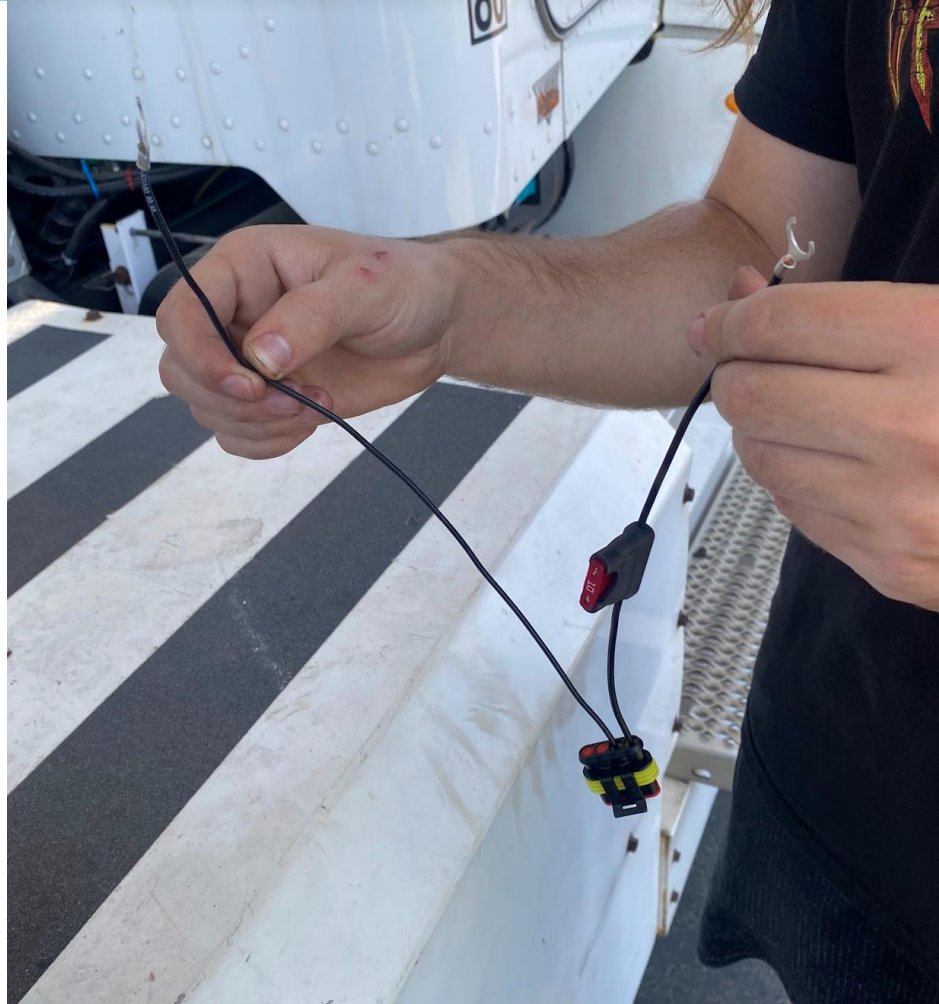




# Installation of OBD Jack Extension Cable

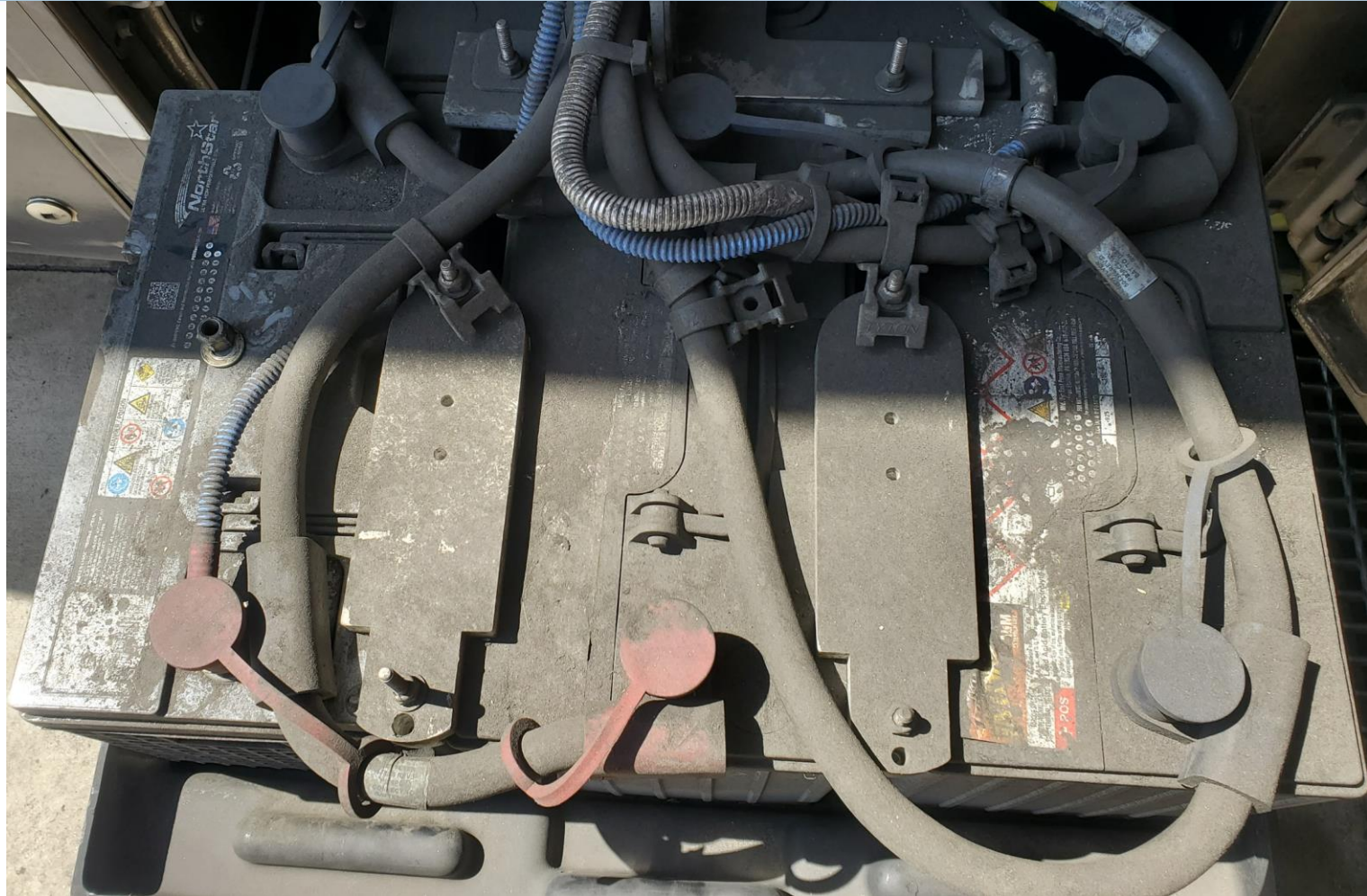


# Installation of Power Tail



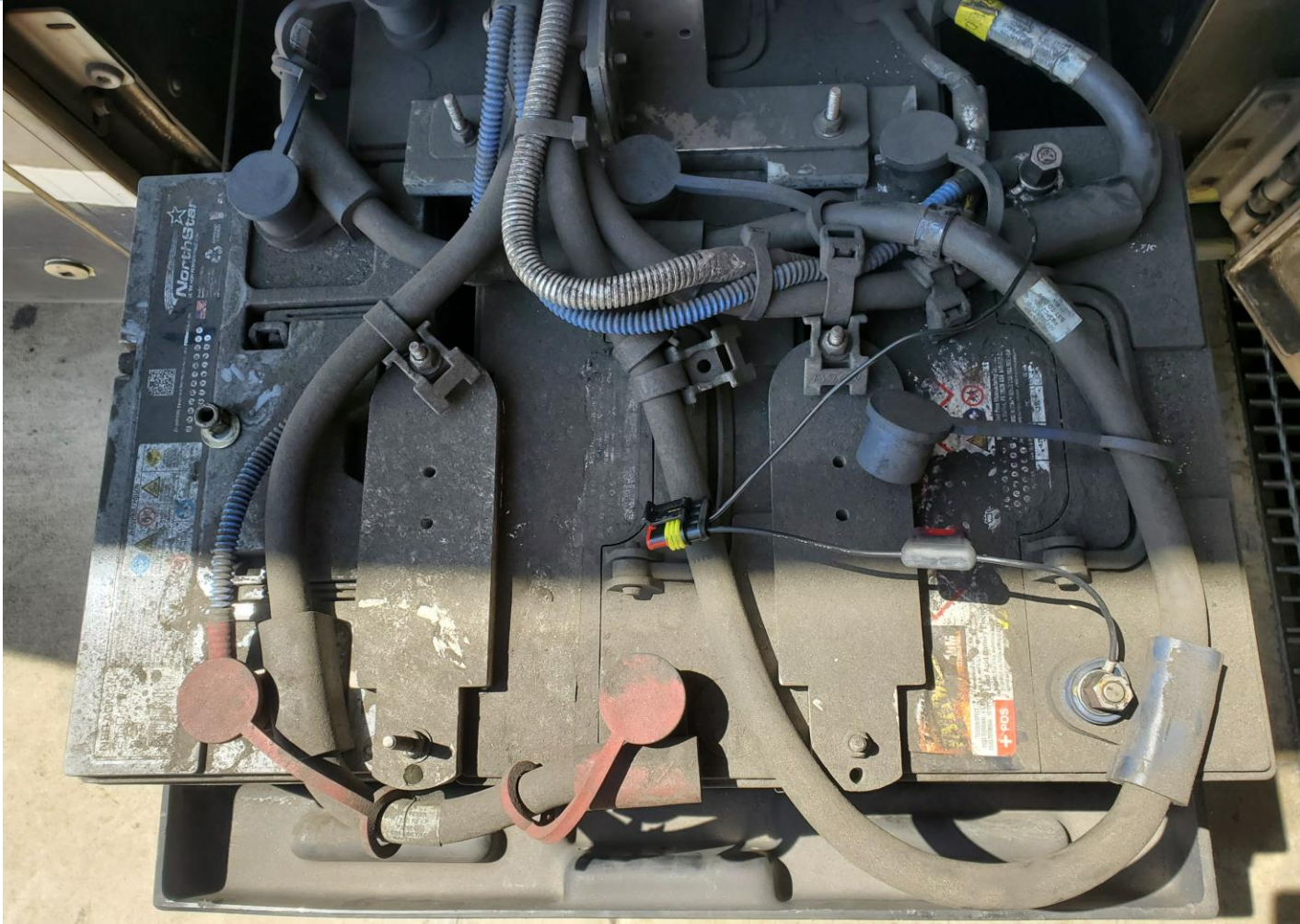


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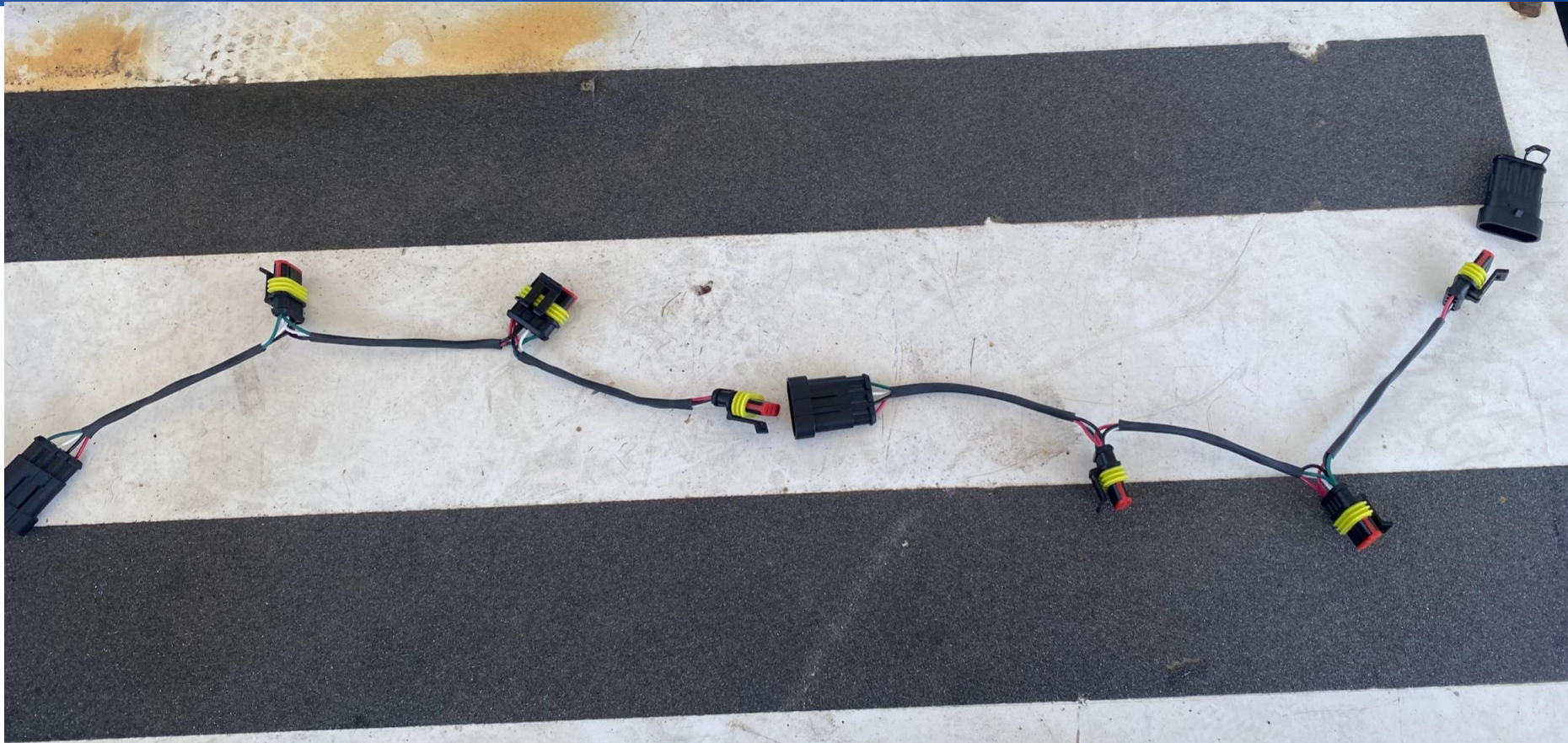




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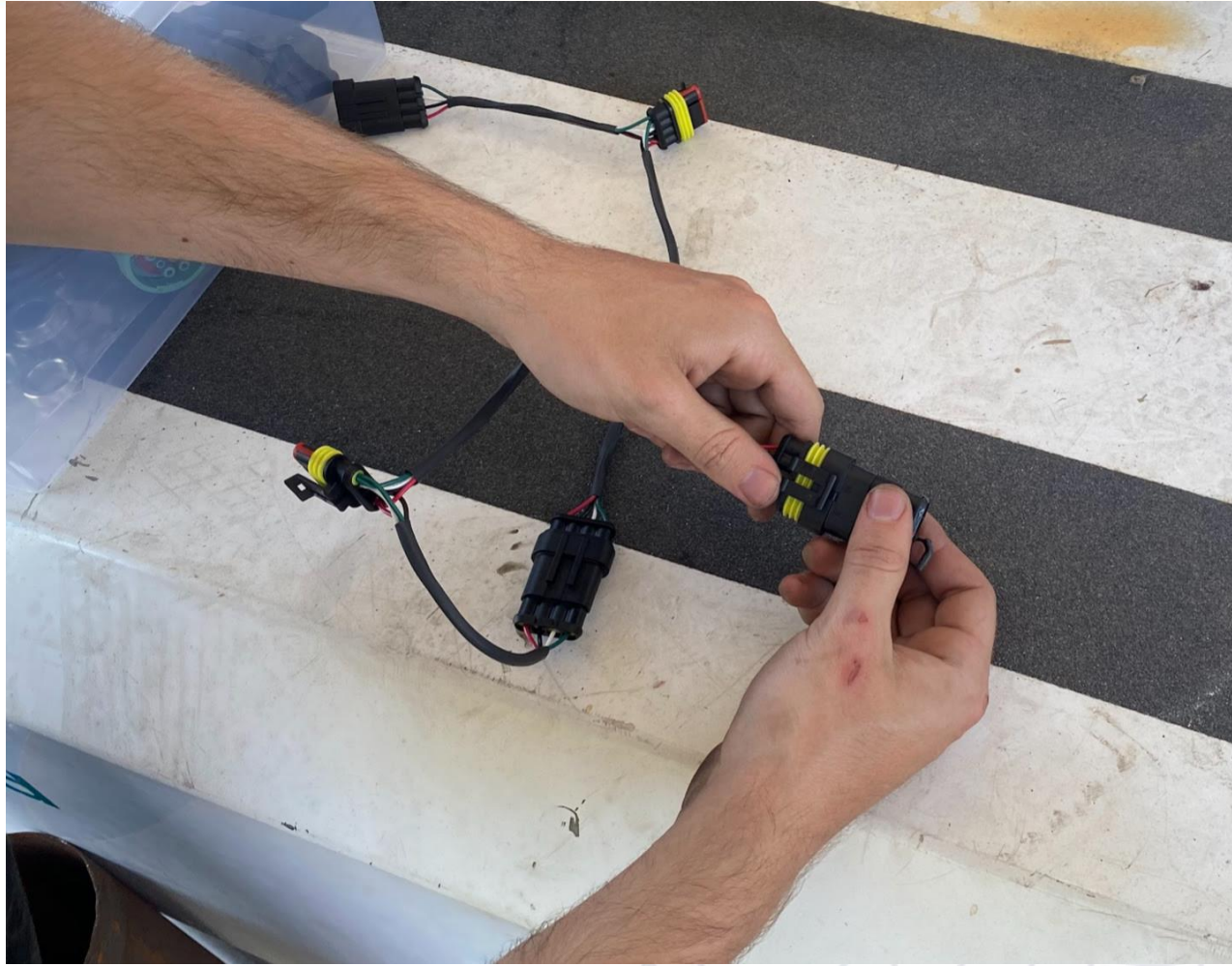






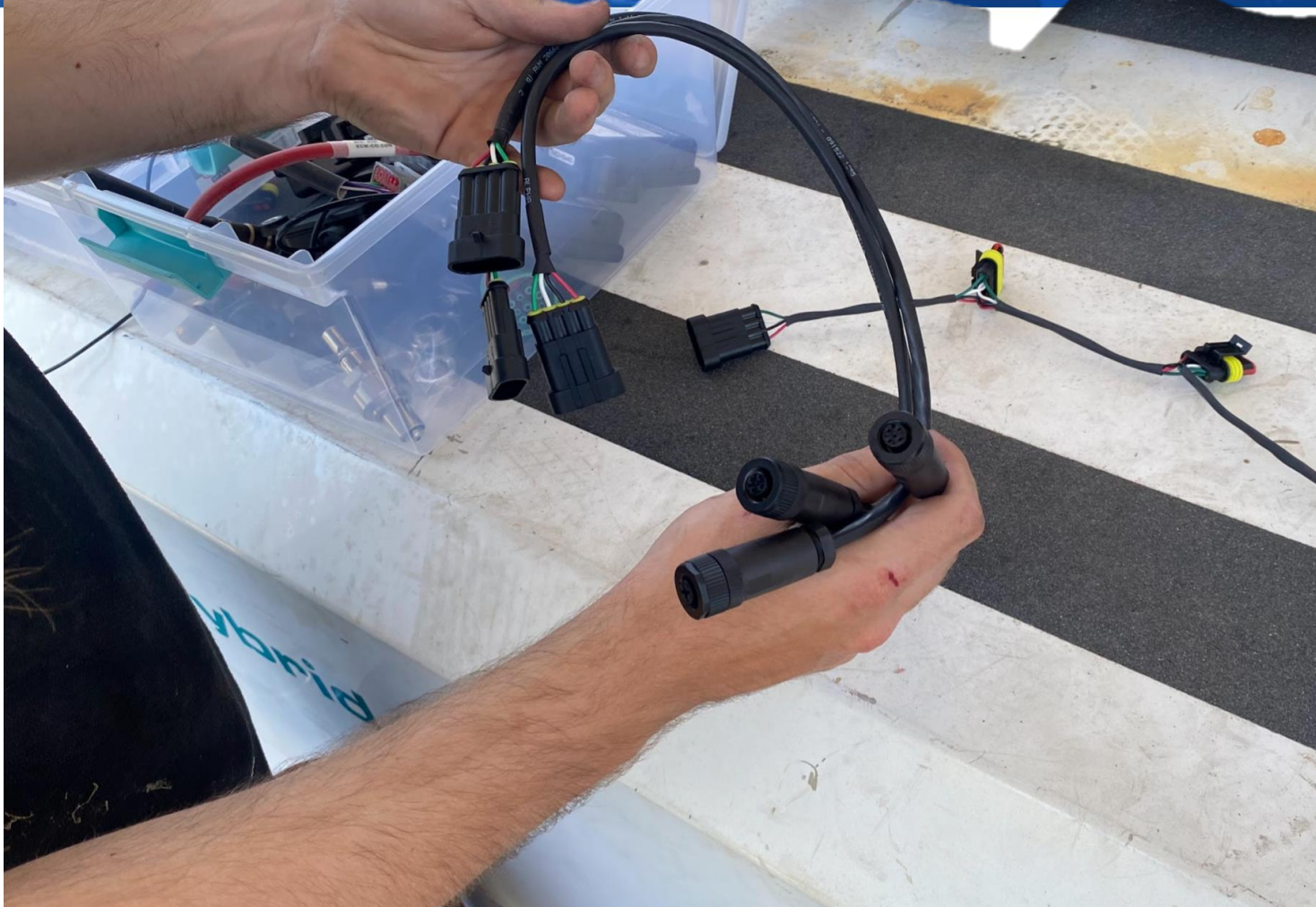






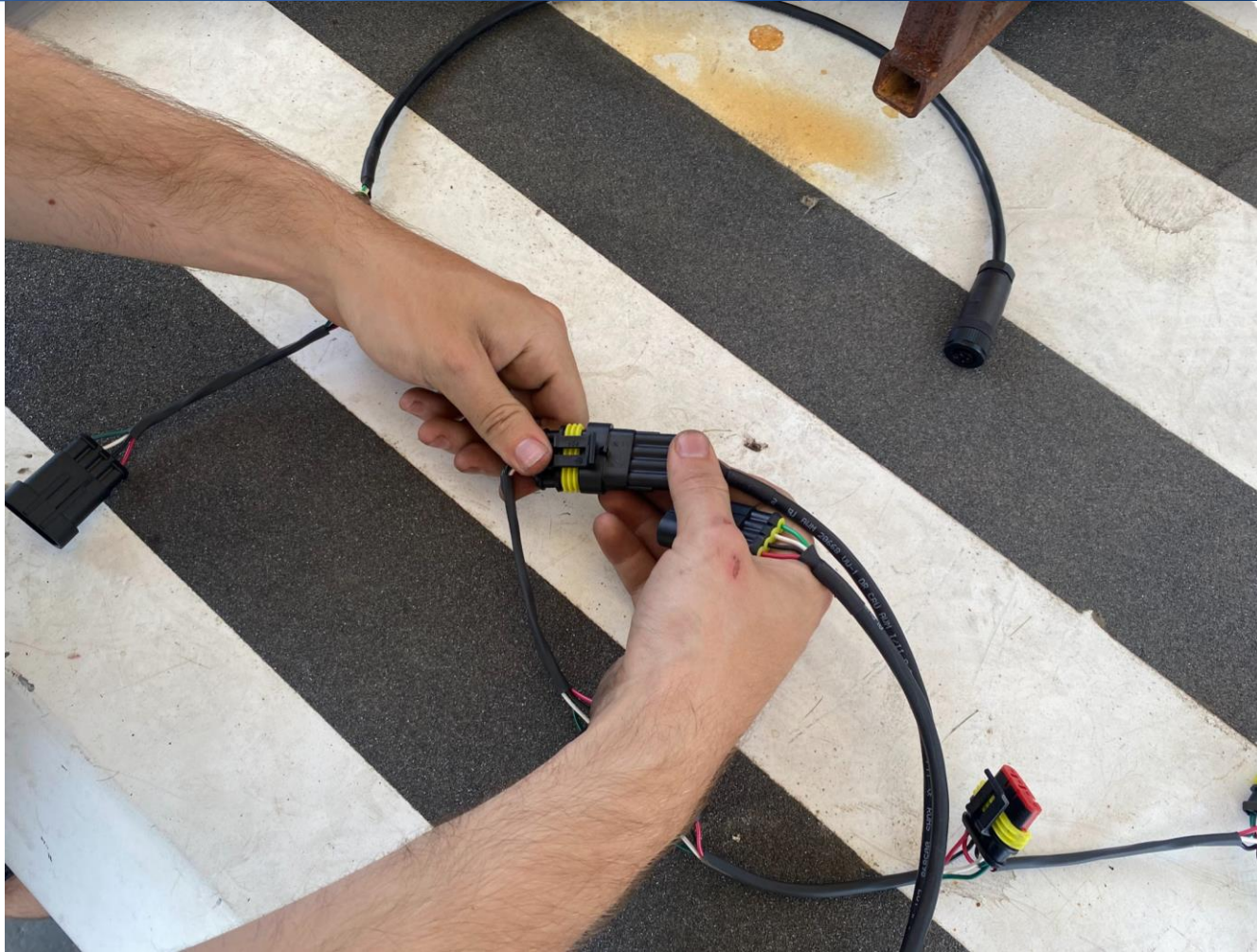
































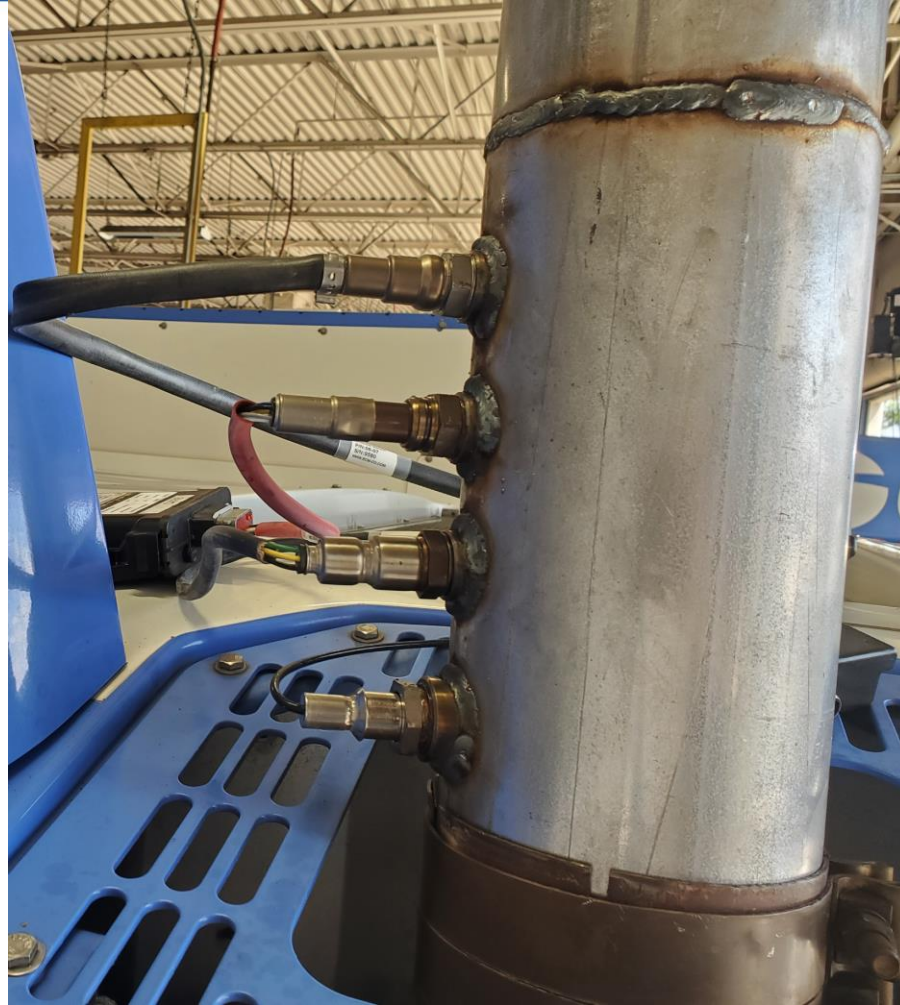








# Installation of Sensors

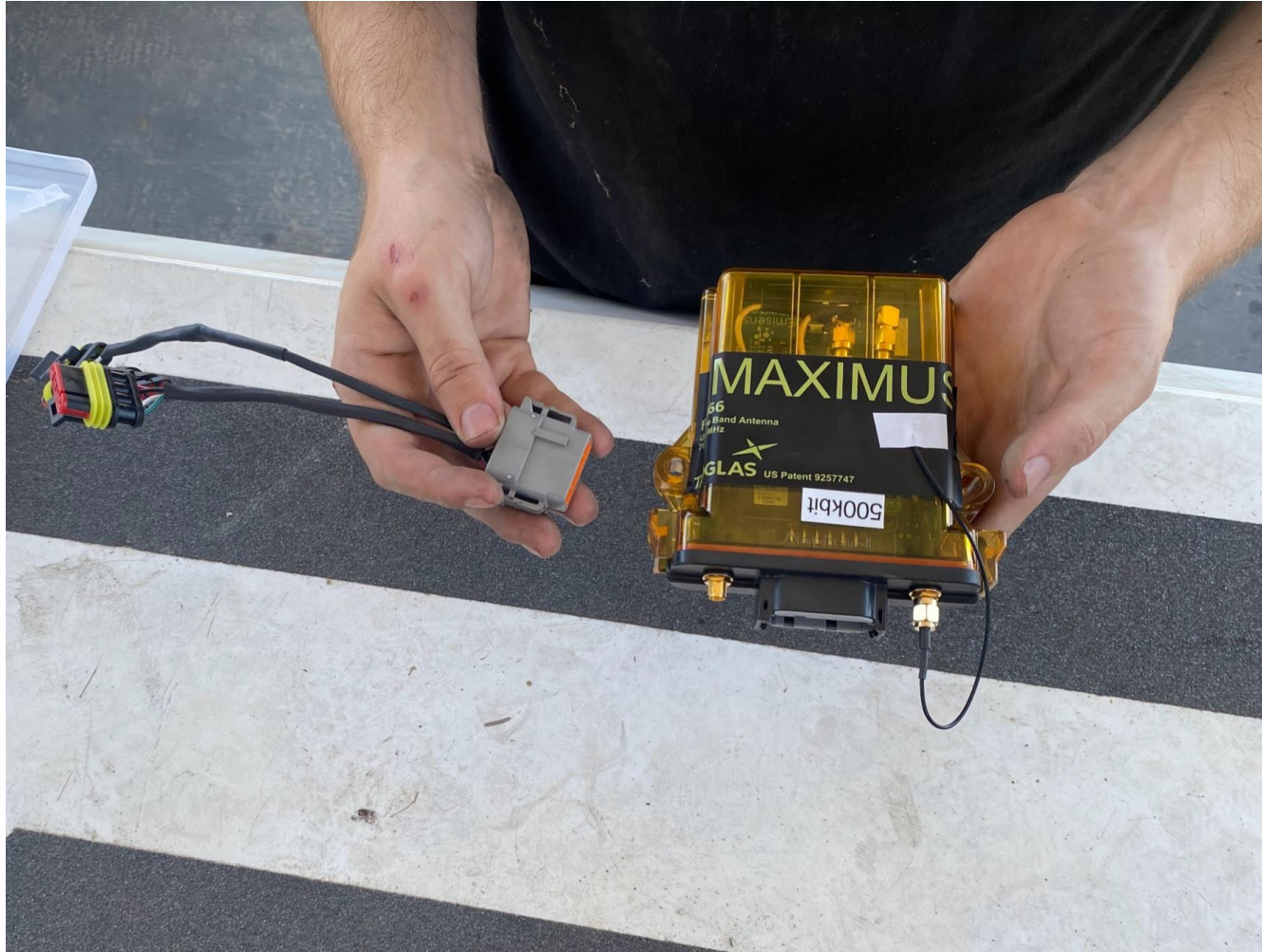








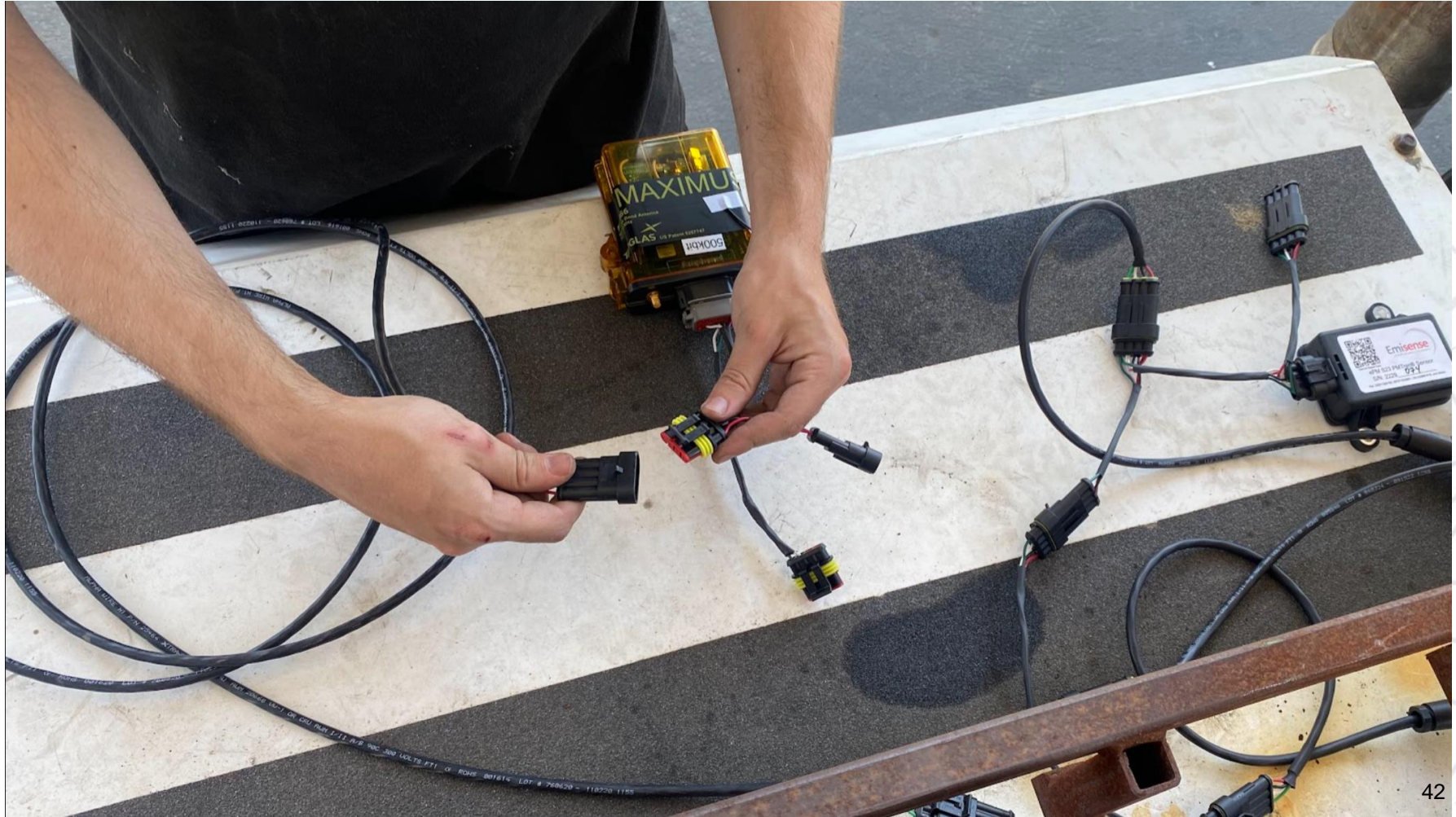








# Connection of Sensors to OSAR Unit





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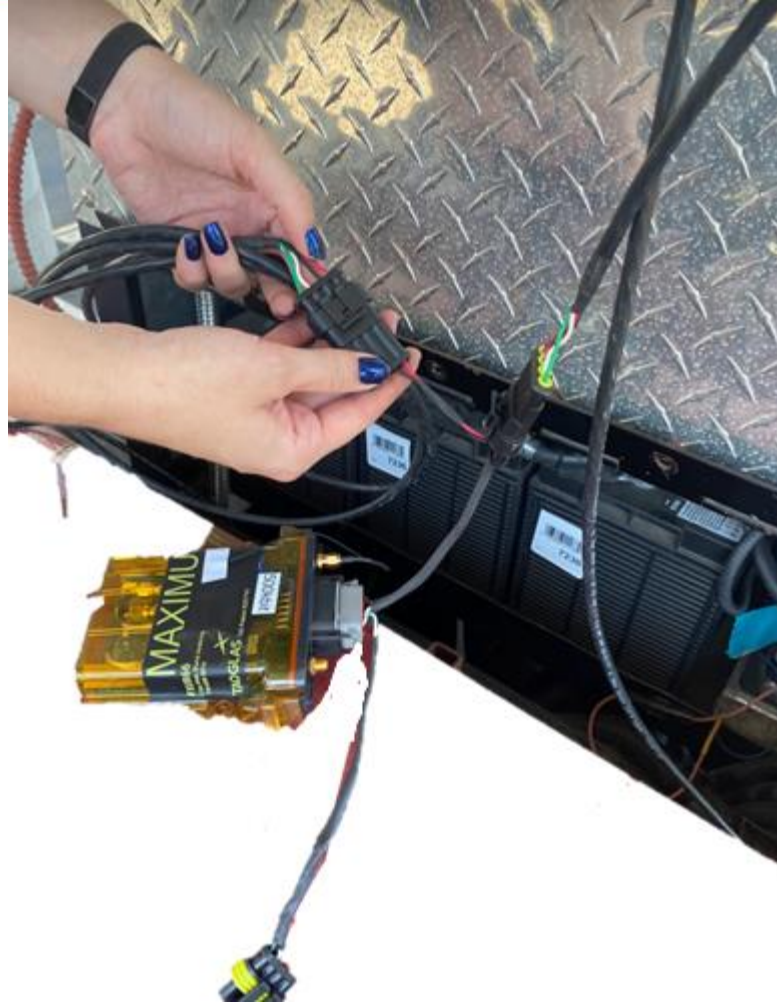


# Connection of Power Tail to OSAR Unit

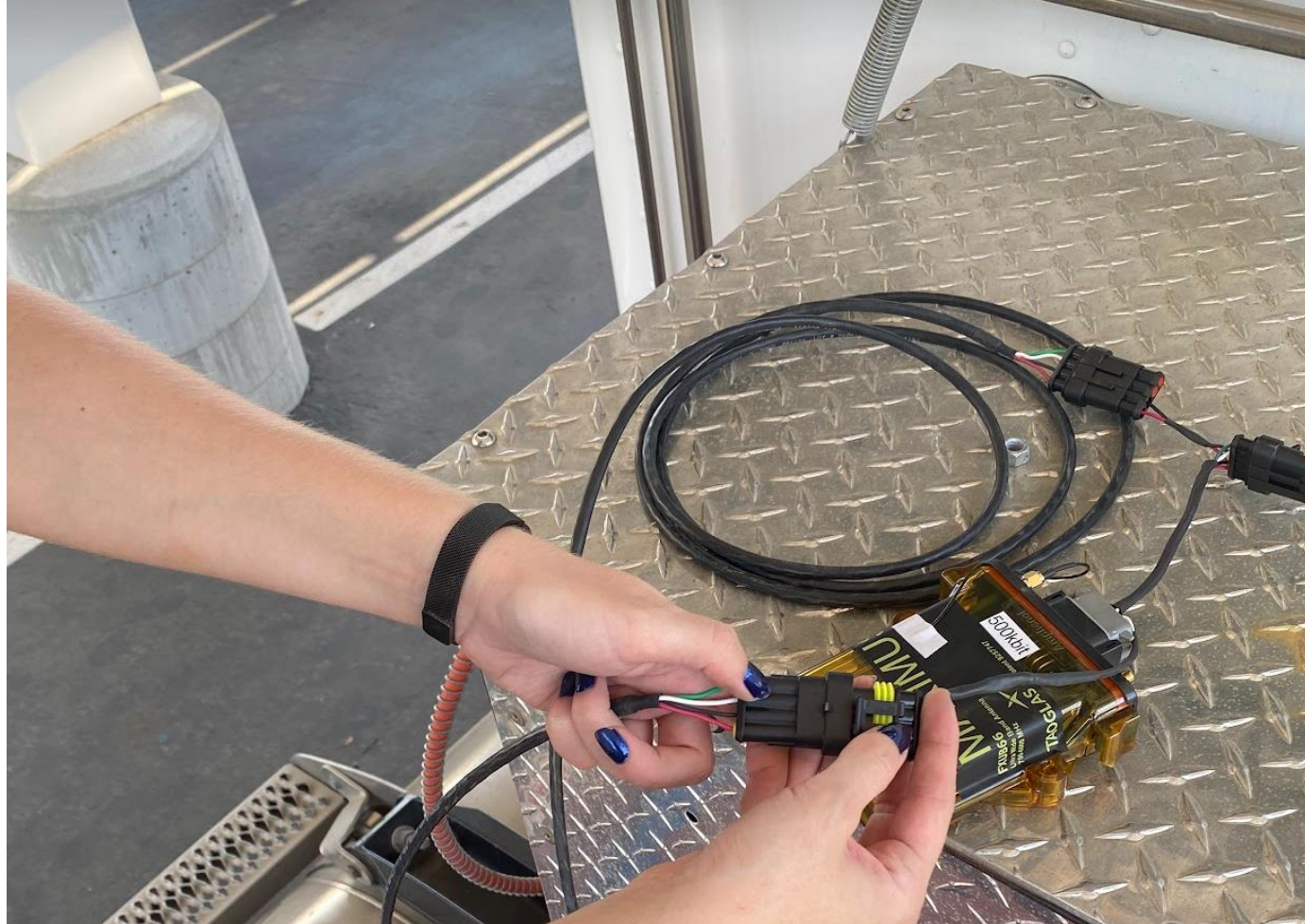




# Connection of Power Tail to OSAR Unit

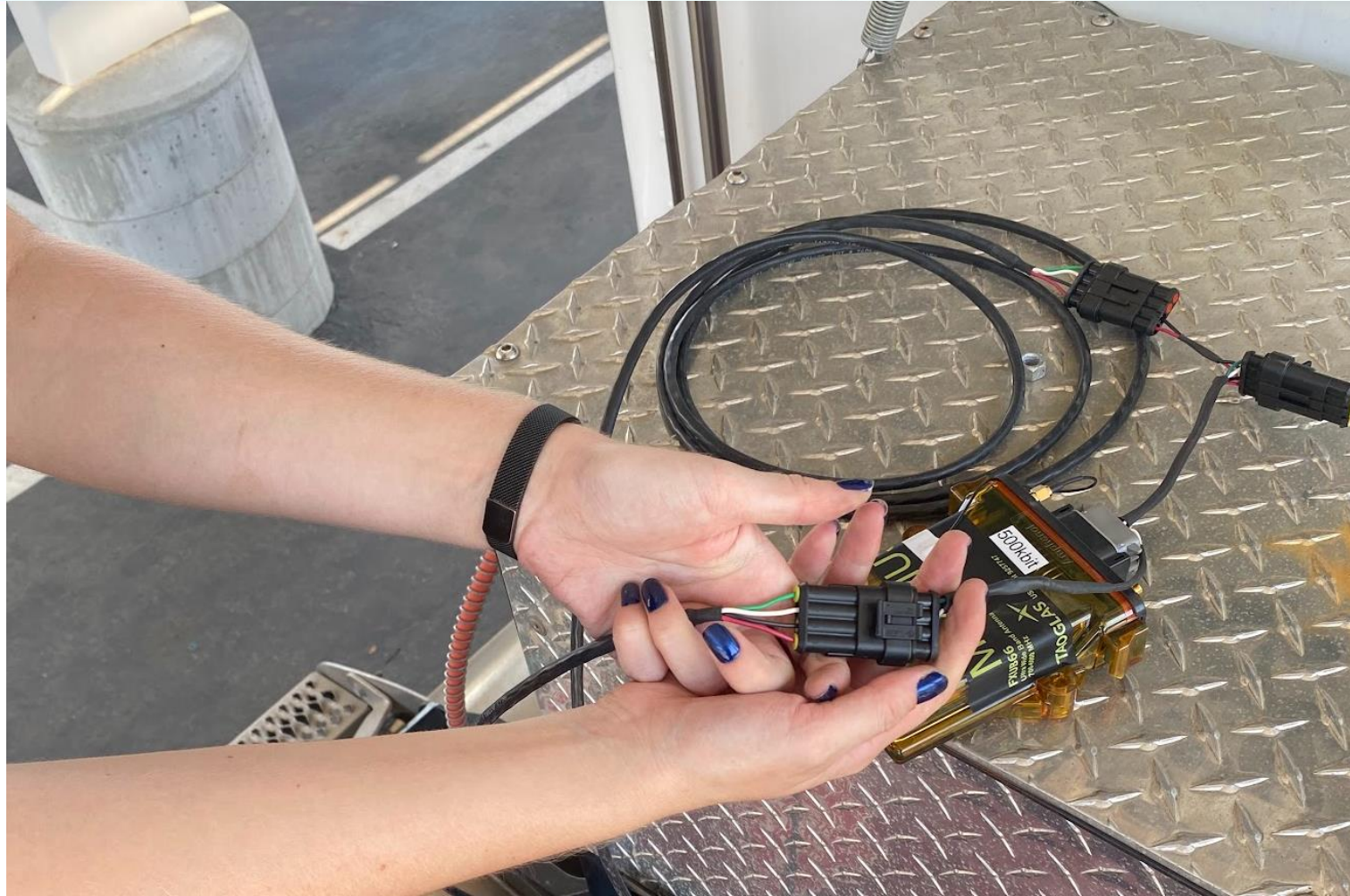


# Connection of OBD Jack to OSAR Unit



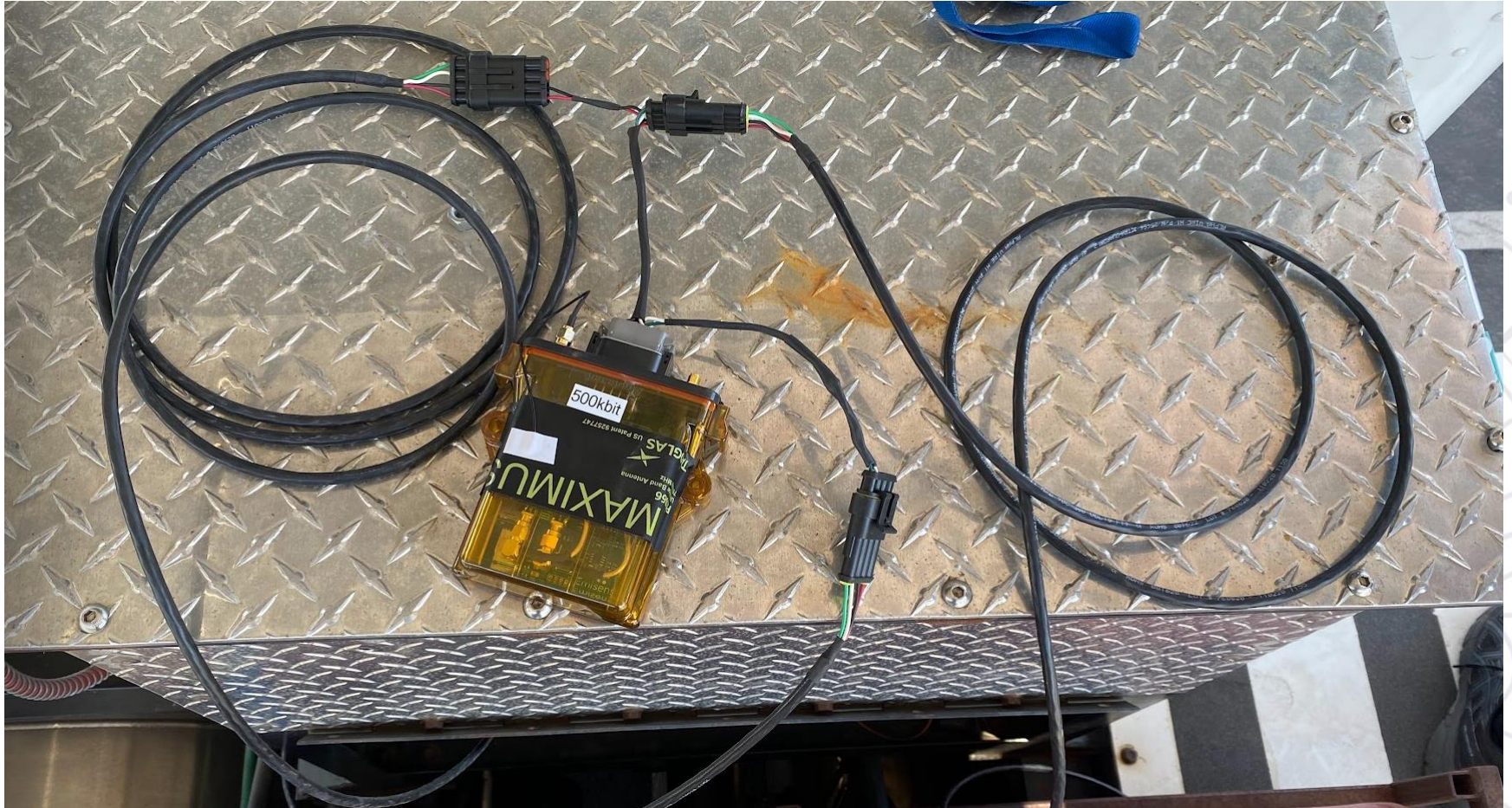


# Connection of OBD Jack to OSAR Unit



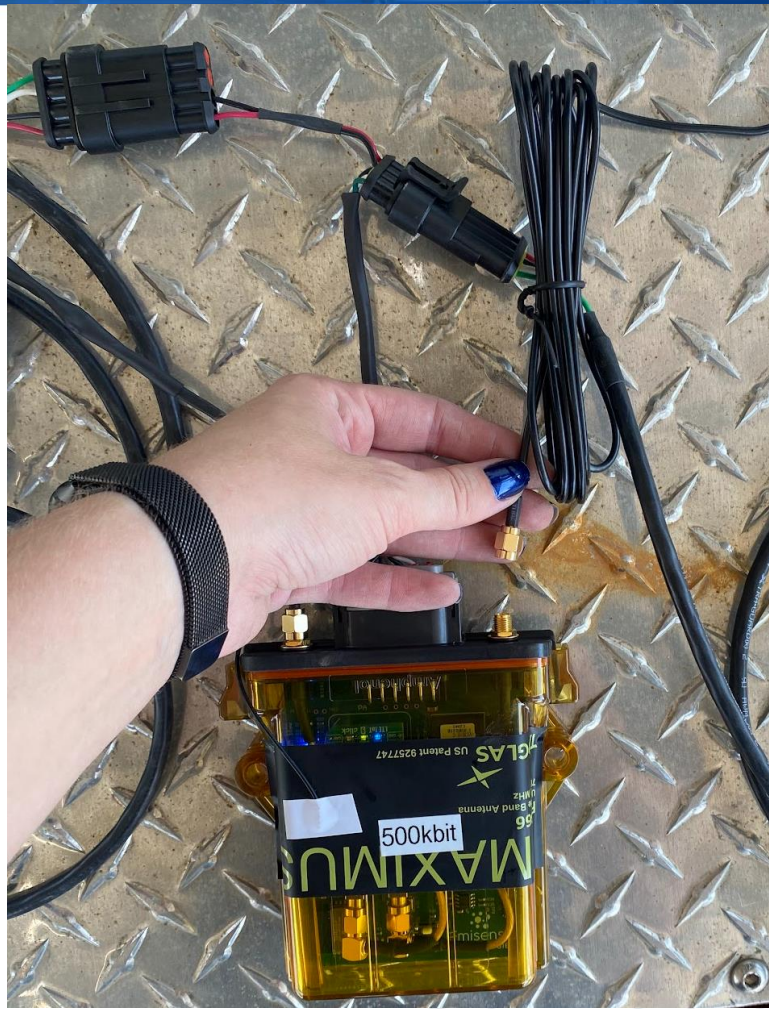


# Connection of GPS Antenna to OSAR Unit

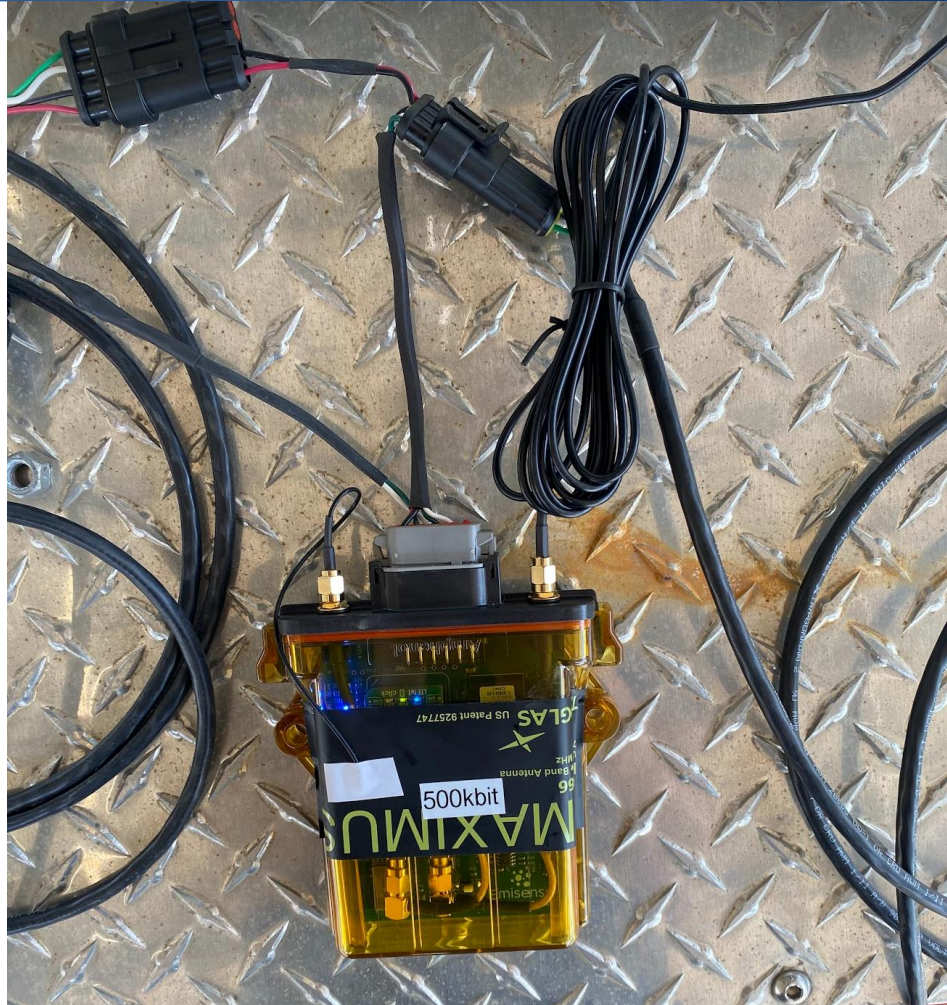




# Connection of GPS Antenna to OSAR Unit



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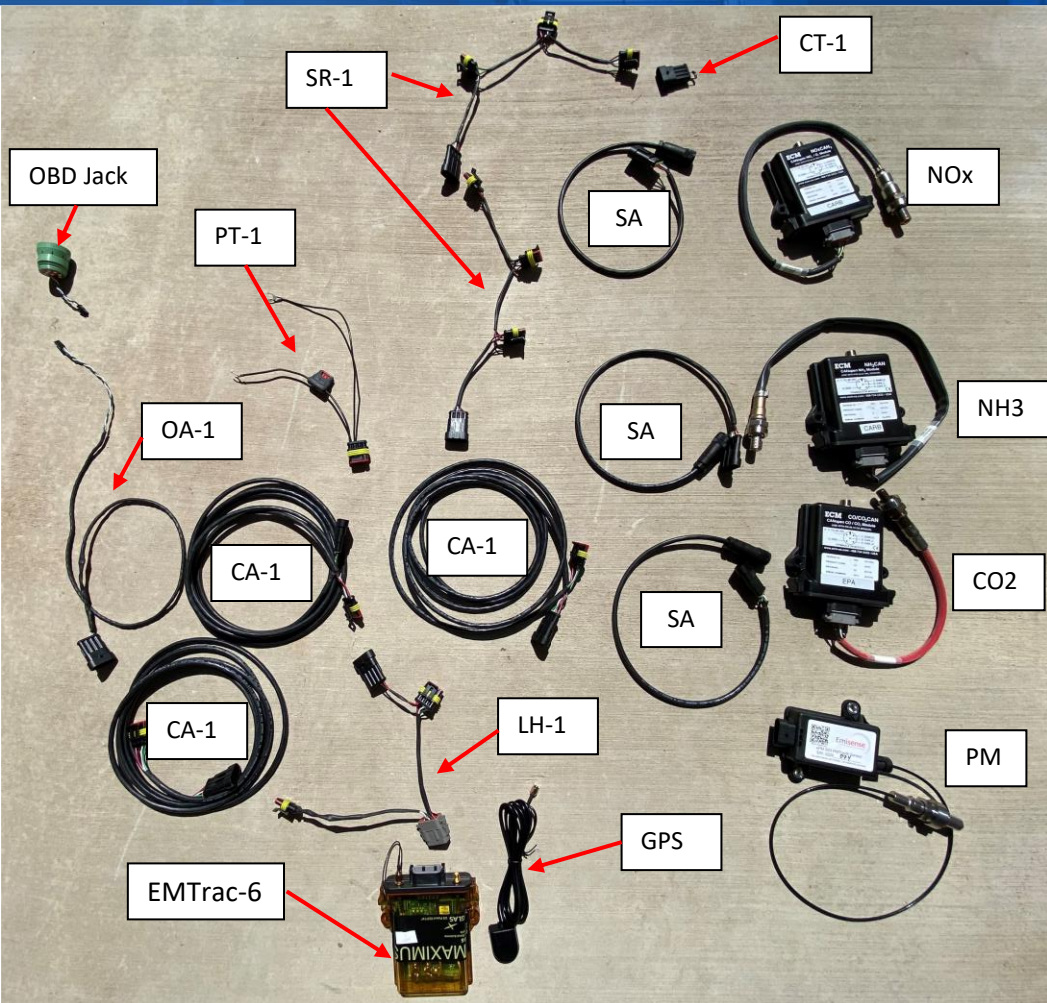
# Connection of GPS Antenna to OSAR Unit













## 4 Heavy-Duty Natural Gas Fleets Utilized (MYs 2016-2022)

- Refuse Hauler Fleet (x1)
- Goods Movement Fleet (x1)
- Transit Bus Fleet (x2)

~10 Vehicles per Natural Gas Fleet

- OSAR recorded data for approximately 2 months per vehicle

Filtered out SAE Max and Min ECU and Sensor Values

- Avoiding Sensor Drop Out

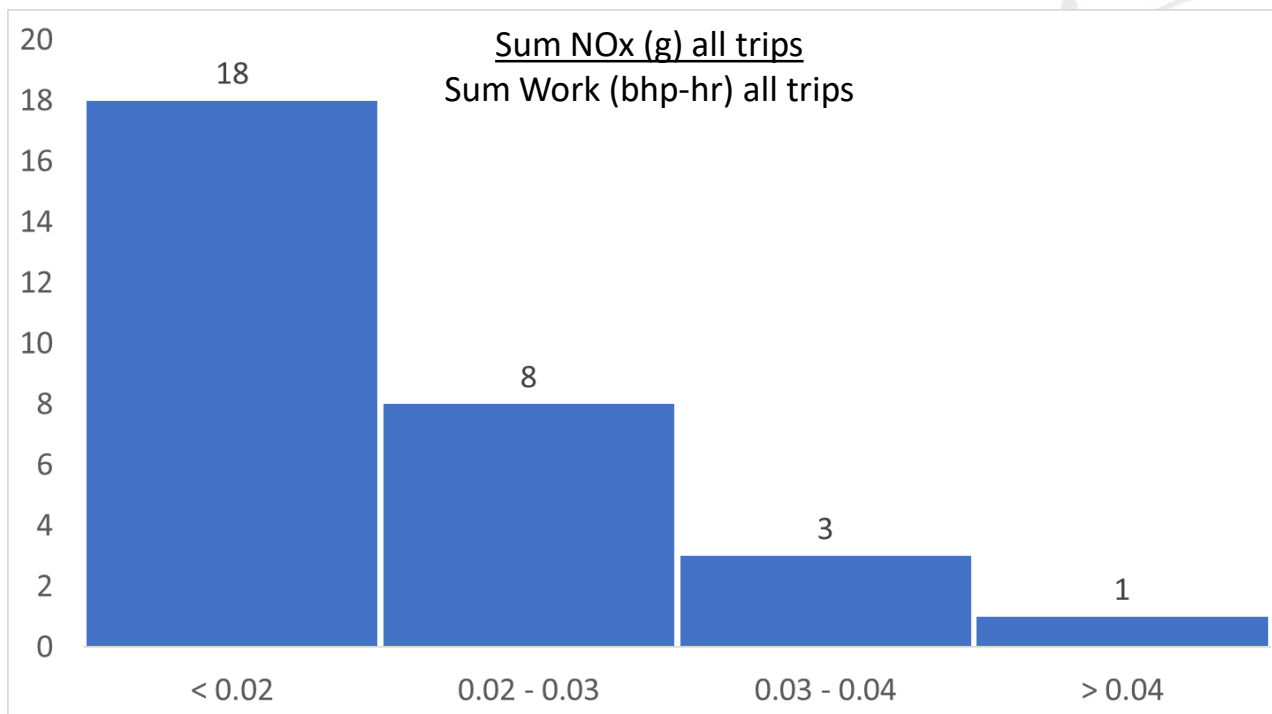
All figures show data that meets specified criteria

- 20 min < and 23 bhp-hr <

# Vehicle Emissions Factor Histogram

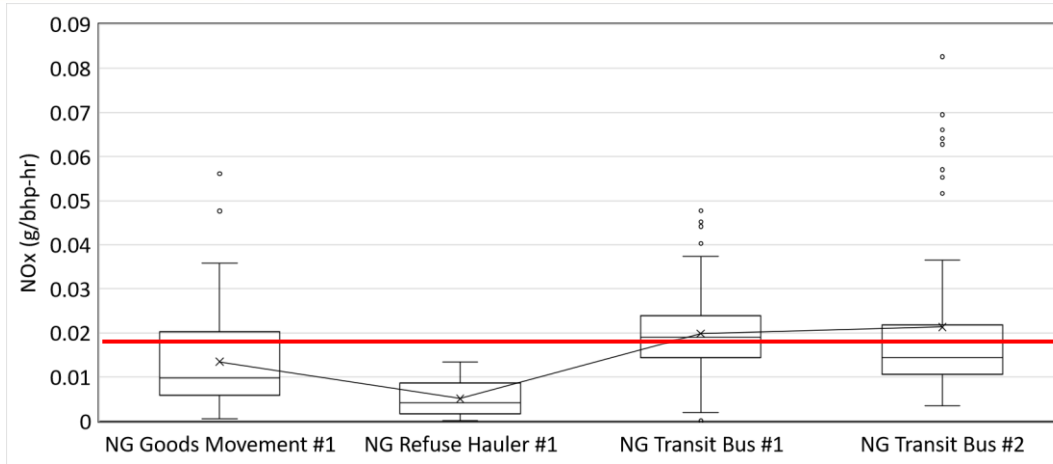
Total Vehicles: 30			
< 0.02	0.02 – 0.03	0.03 – 0.04	0.04 <
18	8	3	1

Criteria filter not applied data

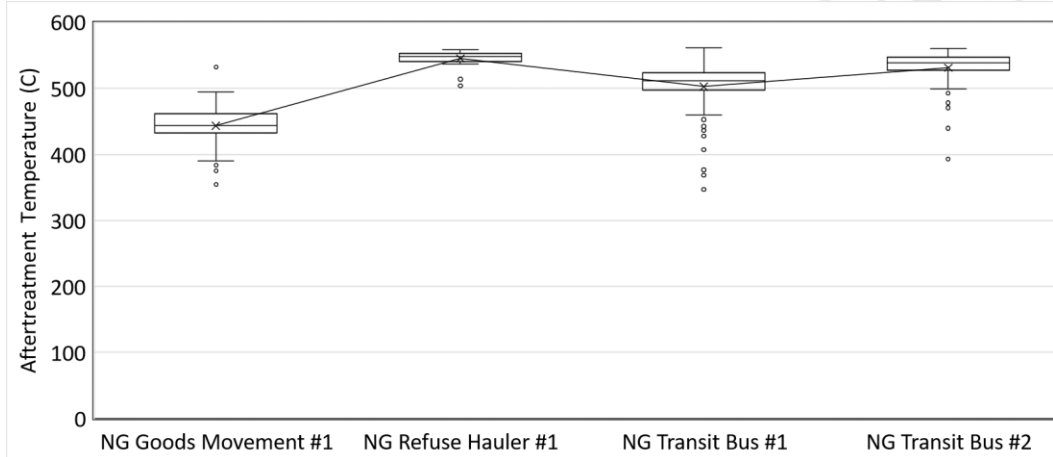




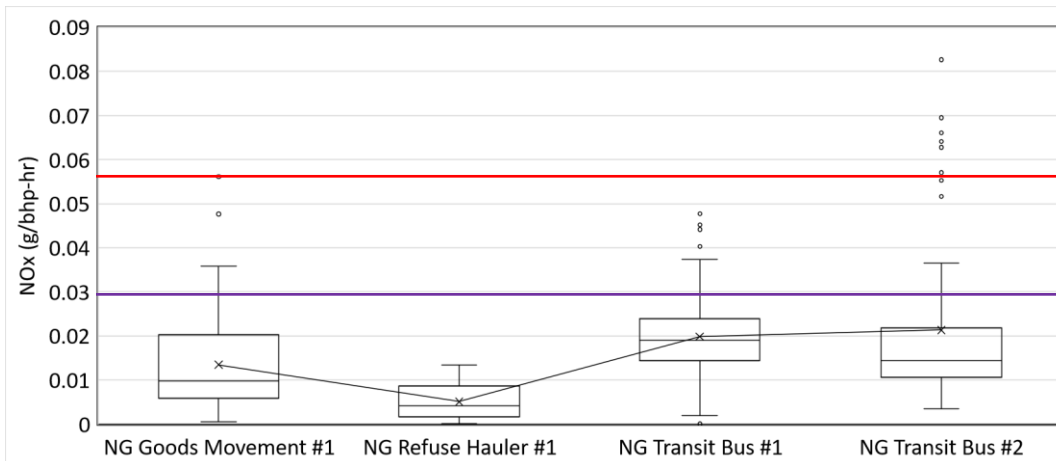
# Fleet Comparison – NOx Emissions



- These four fleets showed an average of 0.019 g/bhp-hr with the sum over sum calculation
- Close to the average seen in these whisker plots comparing all fleet data on a daily basis

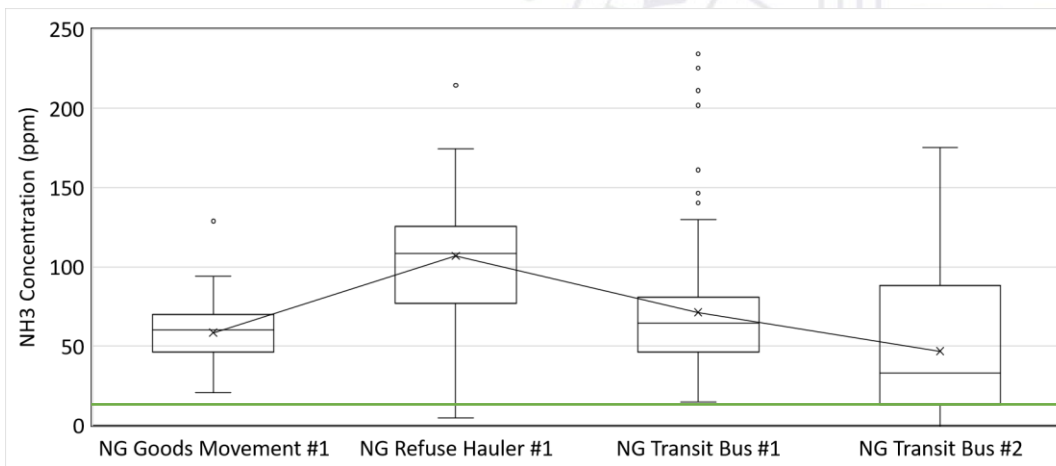


# Fleet Comparison – NH3 Concentration



0.058 g/bhp-hr Bin 2  
 Federal Off-Cycle  
 Standard (2035)

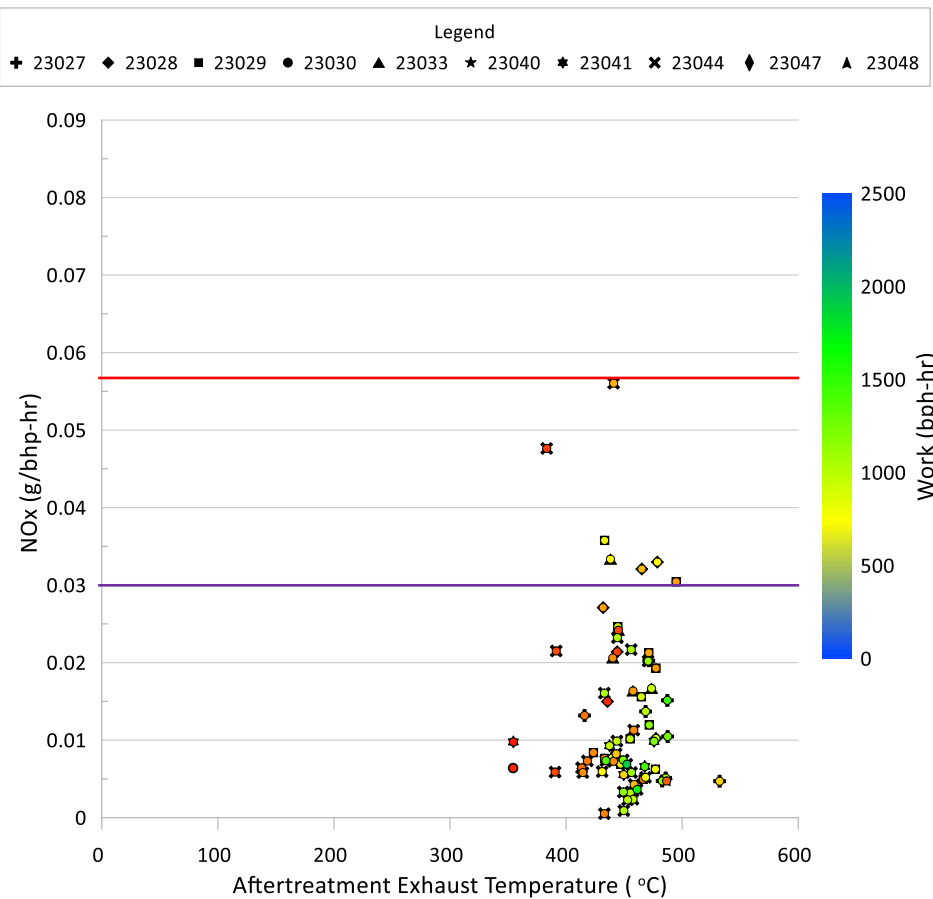
1.5x 0.02 g/bhp-hr  
 Optional Low NOx  
 Standard (0.03 g/bhp-hr)  
 (2018)



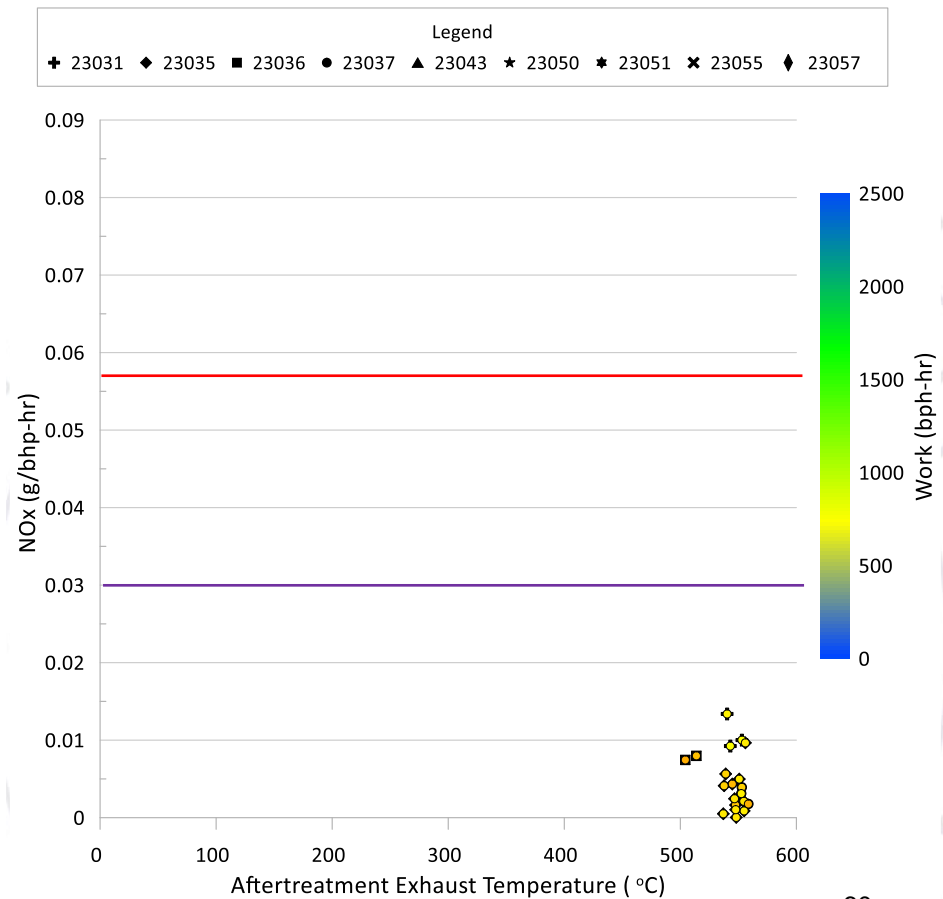


- Each datapoint represents a day of data
- NOx in g/bhp-hr on Y-Axis
- Aftertreatment Temperature in °C on X-Axis
- Work (bhp-hr) gradient applied
  - **Blue** indicates highest work values across all fleets
  - **Green** indicates more frequent work values across all fleets
  - **Yellow** indicates lower but not uncommon work values across all fleets
  - **Red** indicates significantly low work values across all fleets

## NG Goods Movement #1

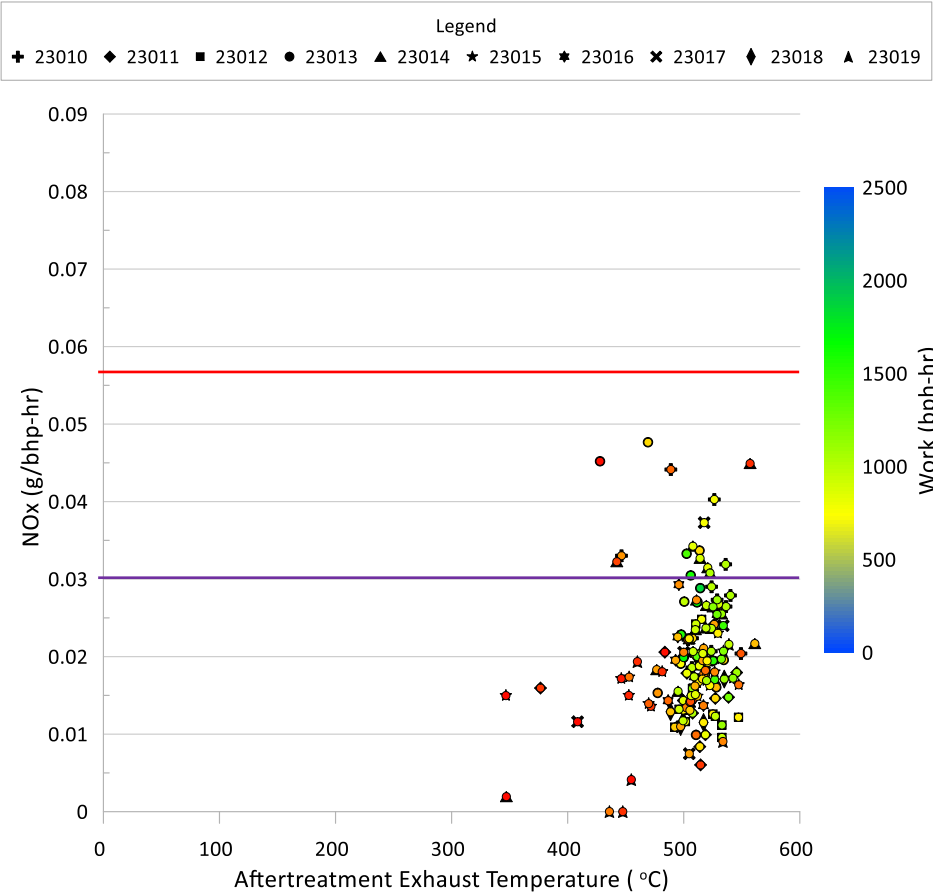


## NG Refuse Hauler #1

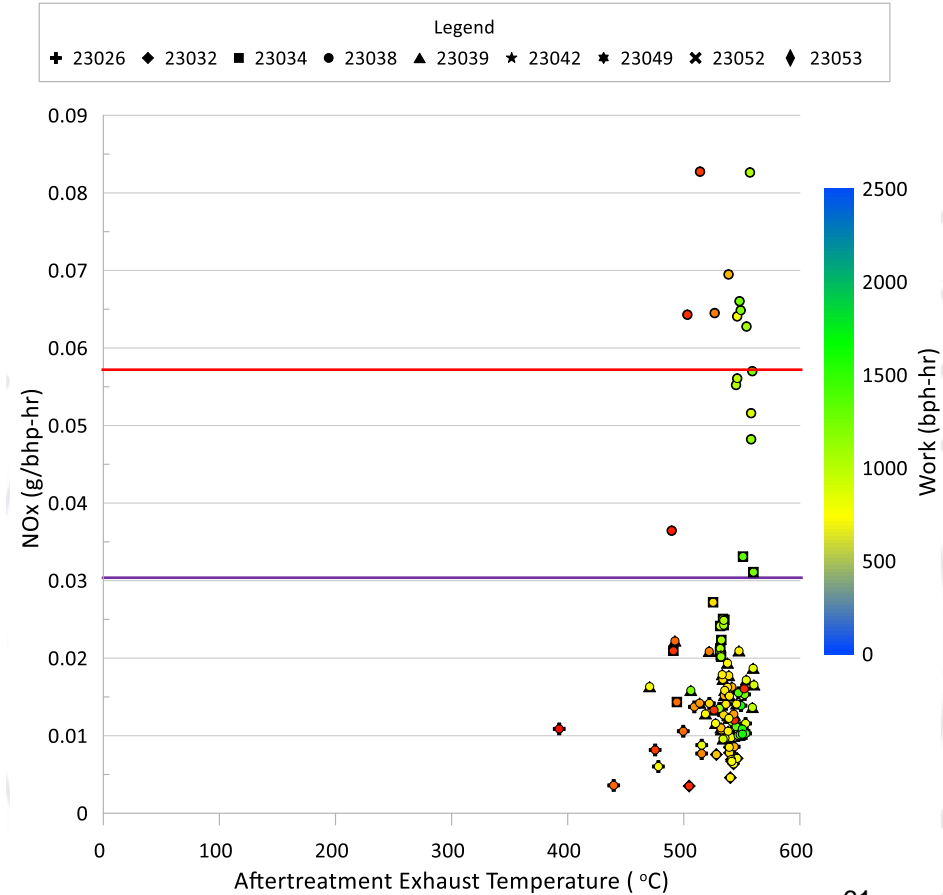




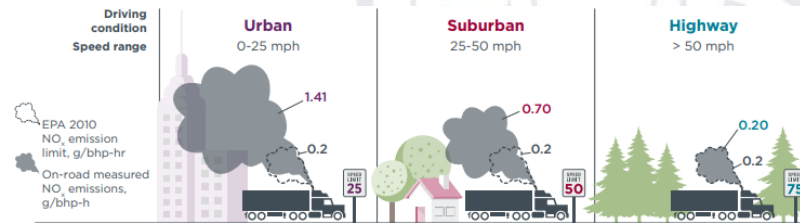
NG Transit Bus #1



NG Transit Bus #2



- Natural gas engines can reduce NOx ozone inventory today
- Natural gas engines do emit ammonia which through secondary formations can form ammonia nitrate particles which could affect particulate matter output
- In-use conditions have large variability in loads, distances, and other conditions that can significantly affect emissions control systems with multiple types of variable control
- Even with the in-use conditions, the natural gas vehicles we tested fall on average under the current 1.5x 0.02 g/bhp-hr Optional Low NOx Standard and the to-be-implemented 0.058 g/bhp-hr Bin 2 Federal Off-Cycle Standard





Questions?