On-Board **S**ensing, **A**nalysis, and **R**eporting **(OSAR)** Development and Application

PEMS 2021

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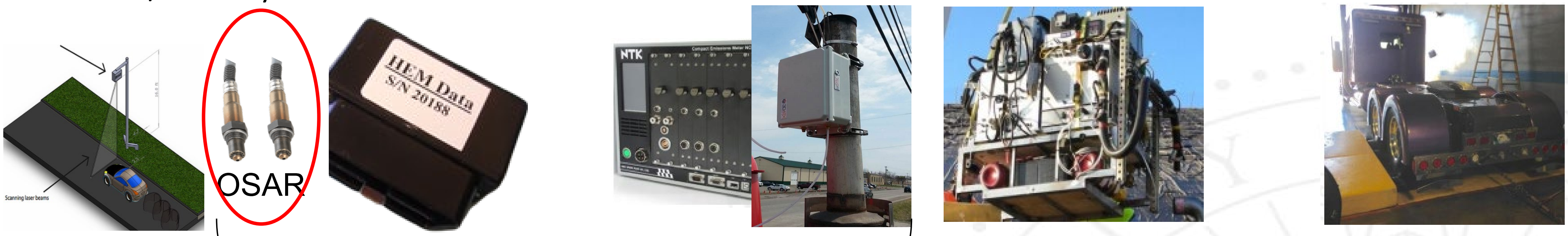
From The Laboratory to the Real World: A Vision of Data, Measurements, and Modeling with uPEMs – OSAR

Low cost/accuracy

Moderate cost/accuracy

High cost/accuracy



Remote Sensing

uPEMS

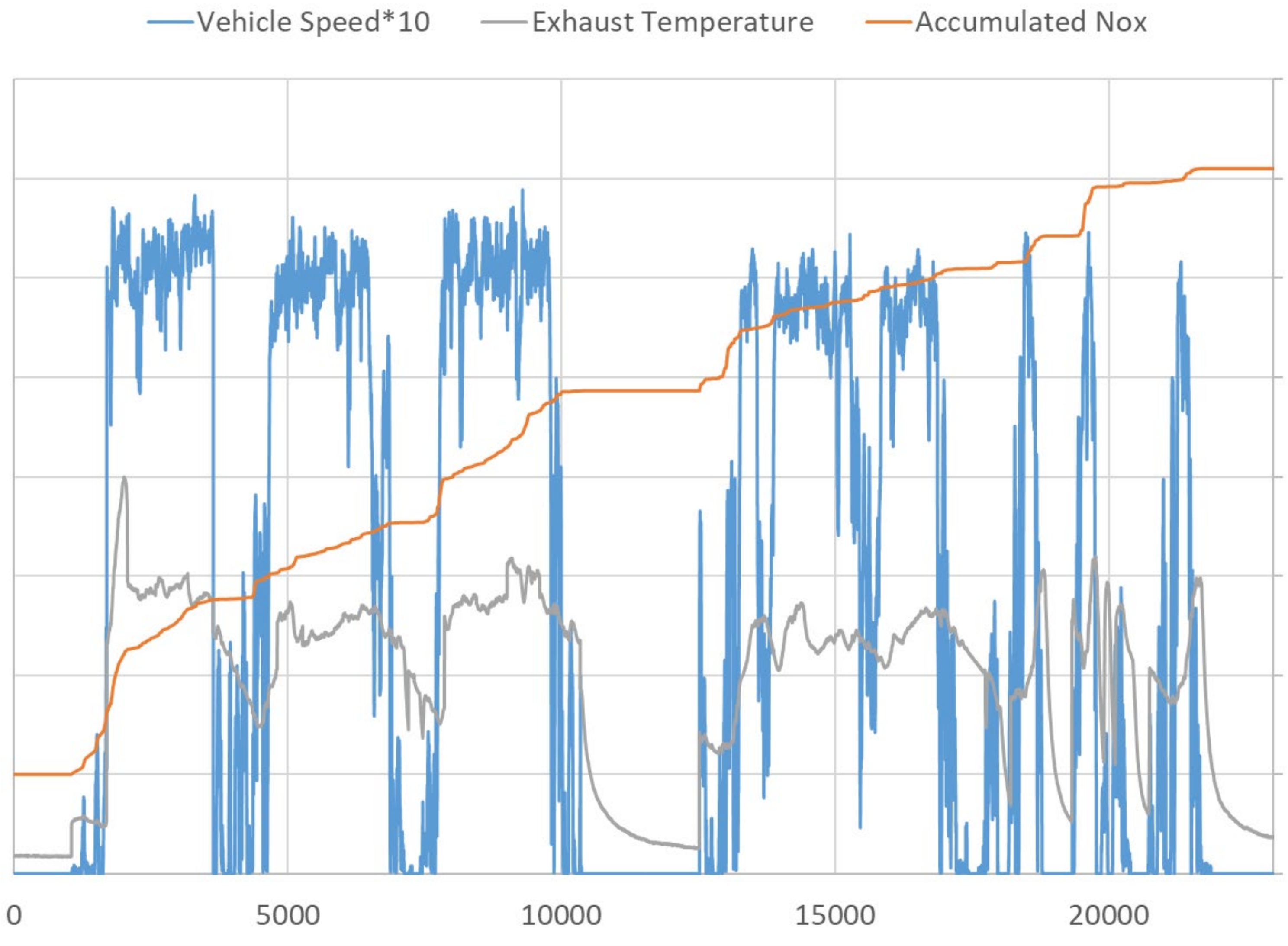
1065 Compliant PEMS

Chassis Testing

NEW METHODS OF EVALUATION

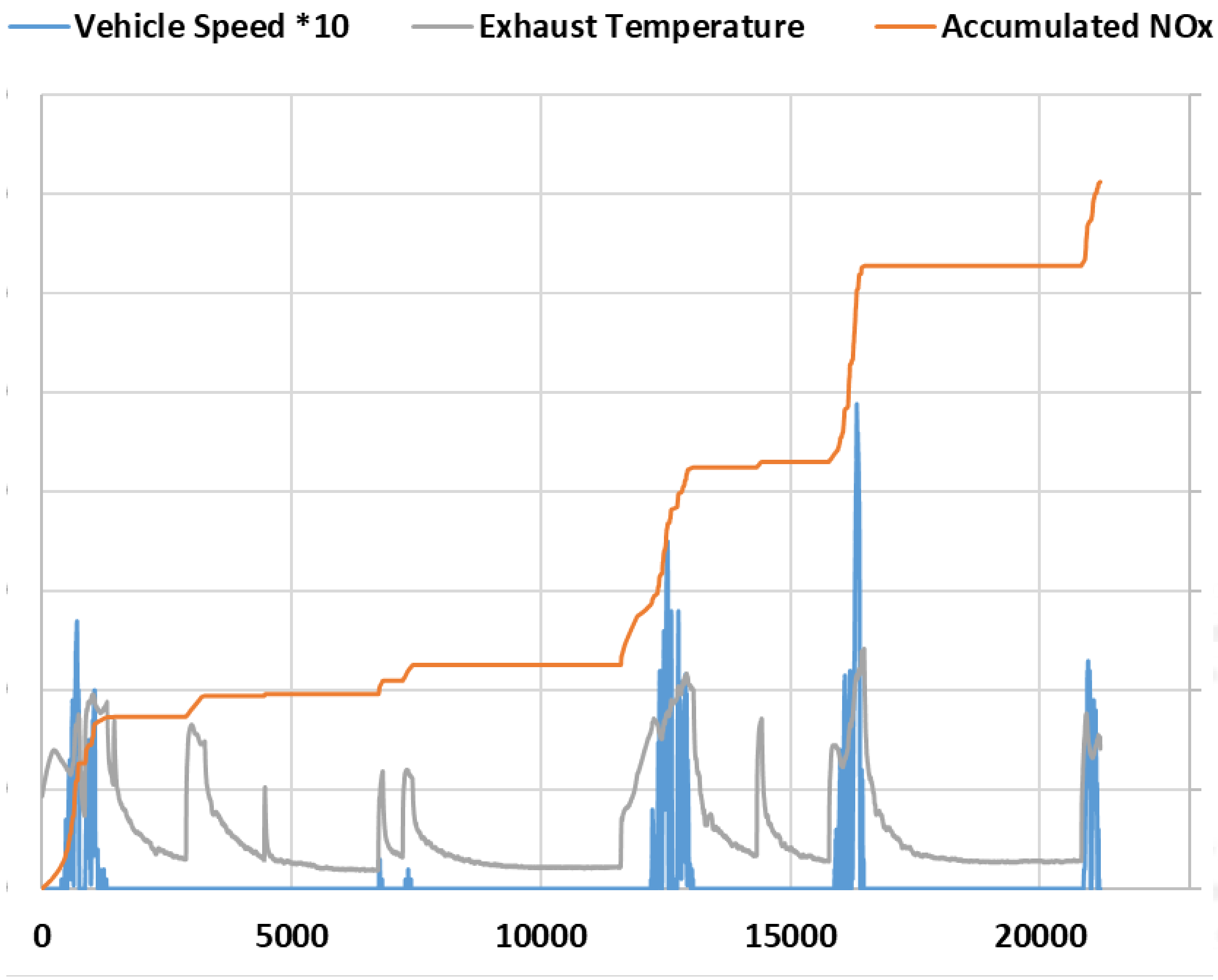
- Understand Inventory
- Take Advantage of Connected and Automated (Electric and Shared)
- Evaluate Conformity, Magnitude, and Suggest Change
- Consider new Drivetrains: Battery Electric, Hybrid Electric, and Fuel Cell

Local Goods Movement Vehicles Have Moderate Duty Cycles



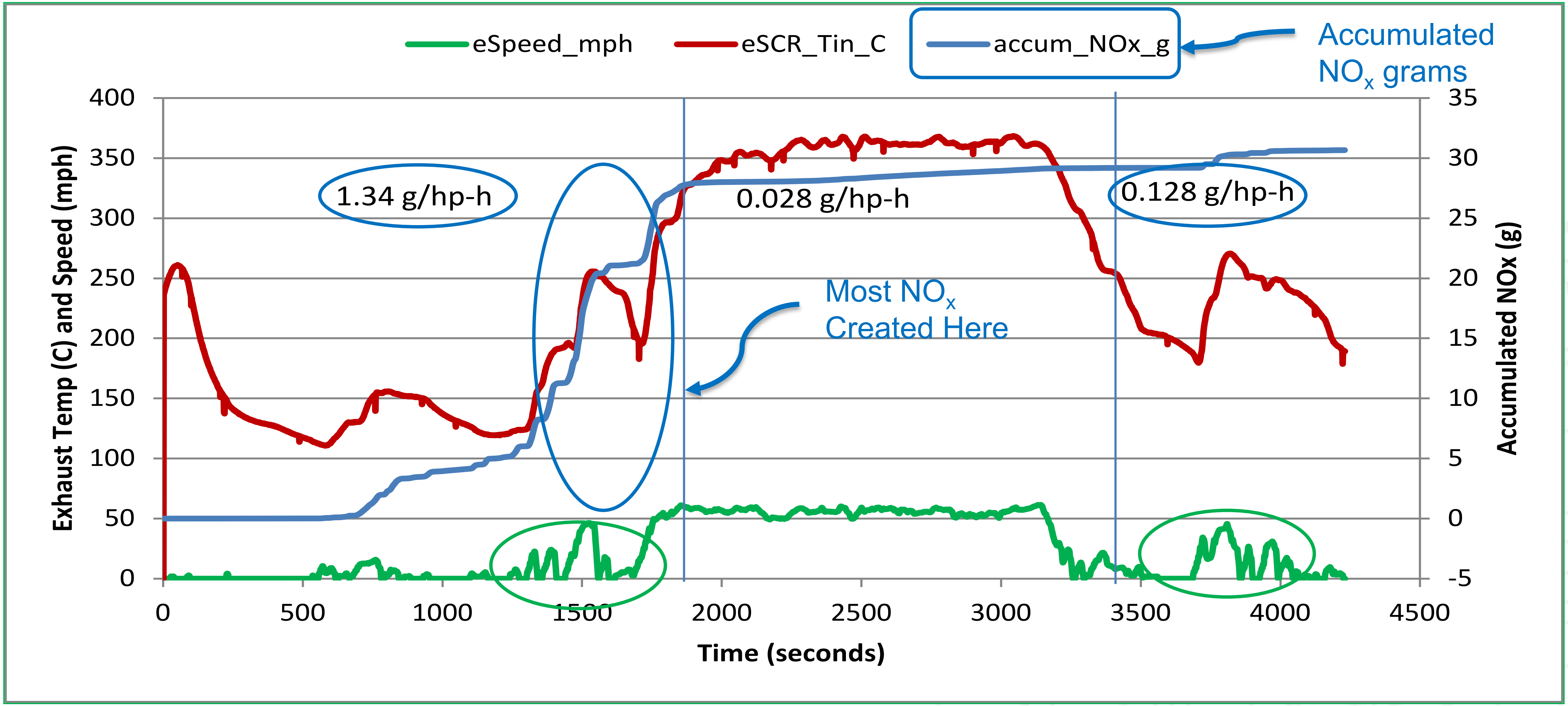
- Representative of HDIUT, may be slightly low since NTEs count are low.
- Binning methods may look reasonable.
- How significant is this data to the inventory?

Local Delivery Vehicles Have Very Low Duty Cycles



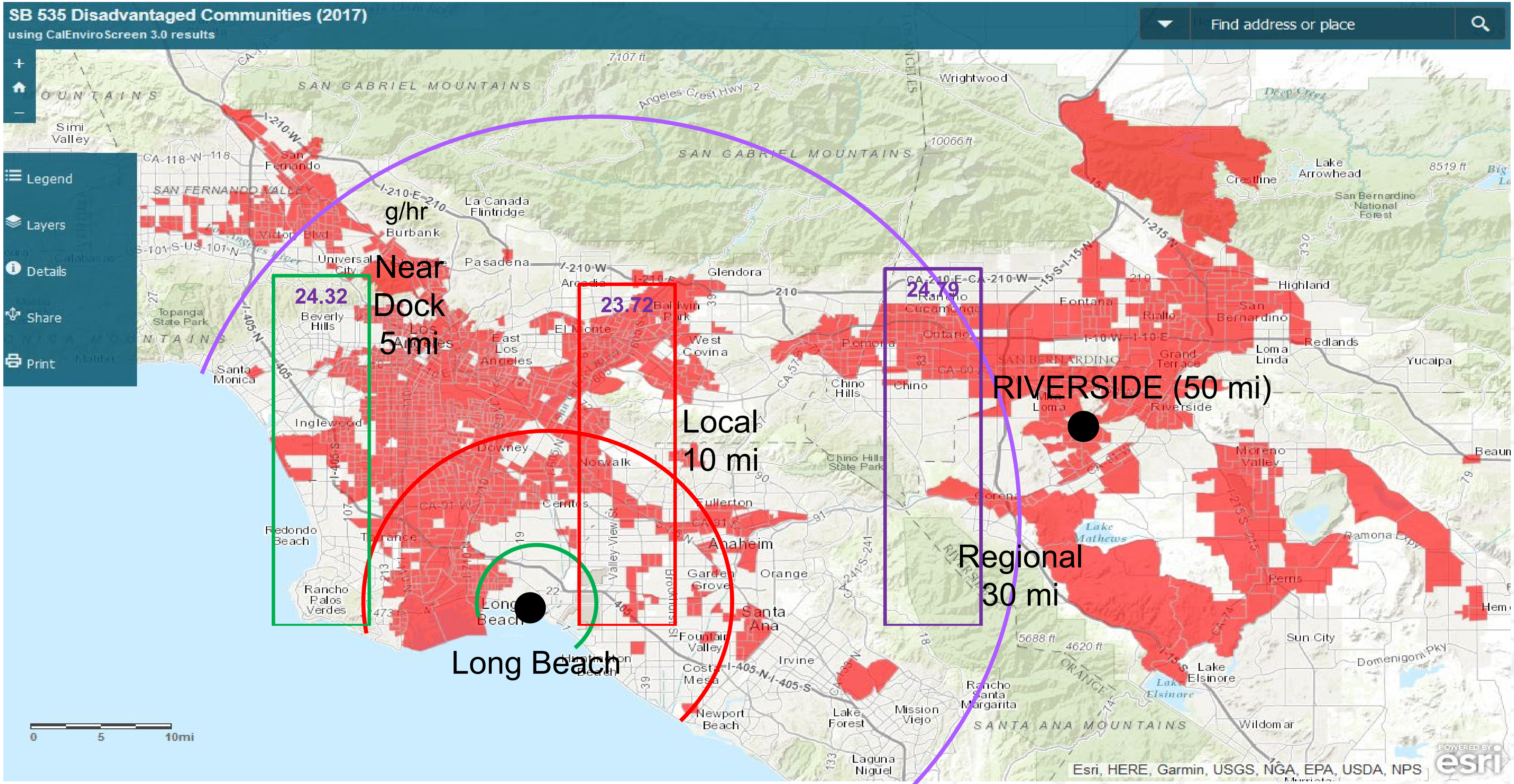
- Not found in the HDIUT program (No NTEs)
- What binning will represent this real data?
- How significant is this data to the inventory?

Higher Emissions Result from Real Operation



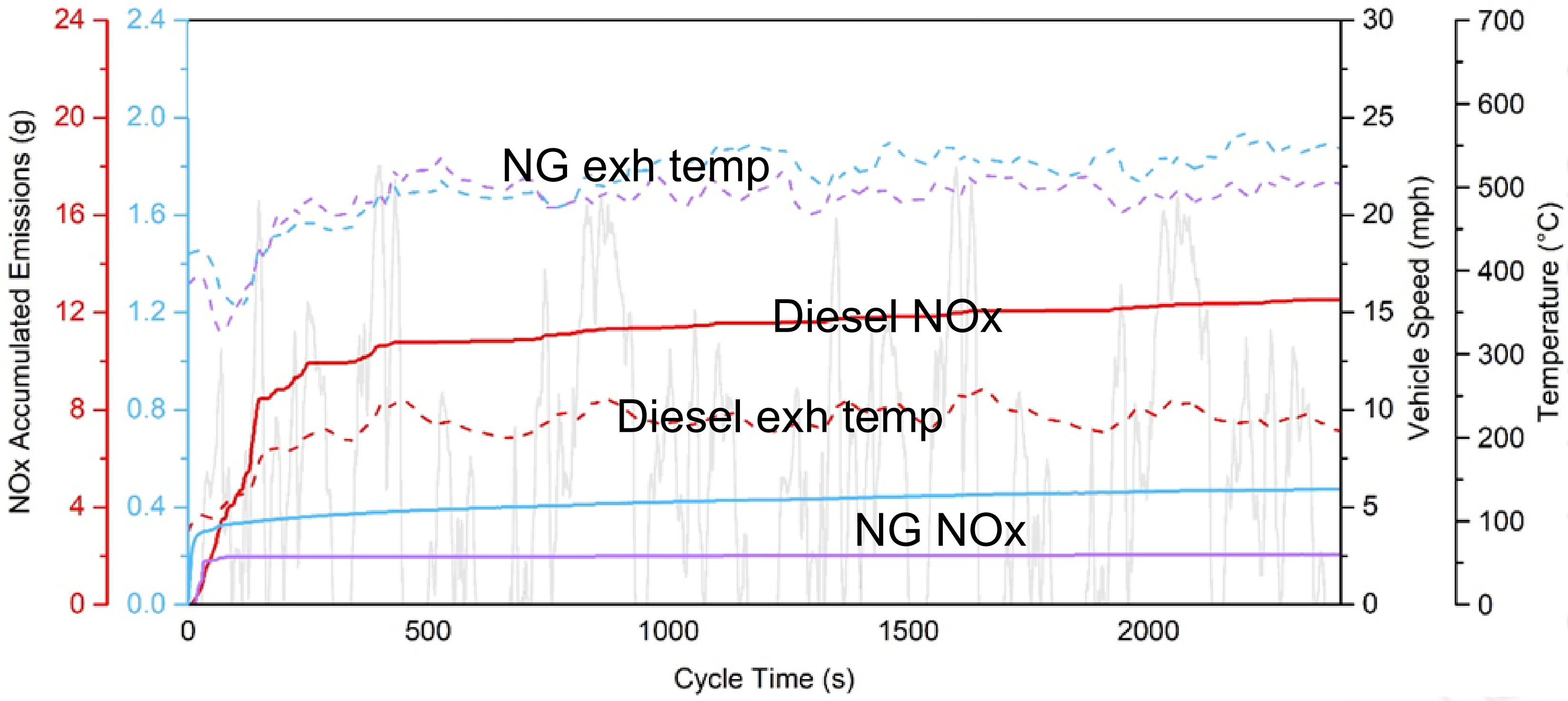
Source: UCR Miller et al (2013), Final report to SC-AQMD and CWI “In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy Duty Engines”, Sep 2013

Real Emissions Impact Real Communities: Location Is Important



Chassis Cycles Can Really Impact the EF Reported

- More than 90% of the NOx emissions for a 0.02 NG vehicle were in the first 50 seconds
- The Diesel took about 5 min to accumulate to 90% of the total mass and continued to accumulate over the test cycle and would be even higher if there were long periods of idle (as found with many real in-use test programs)

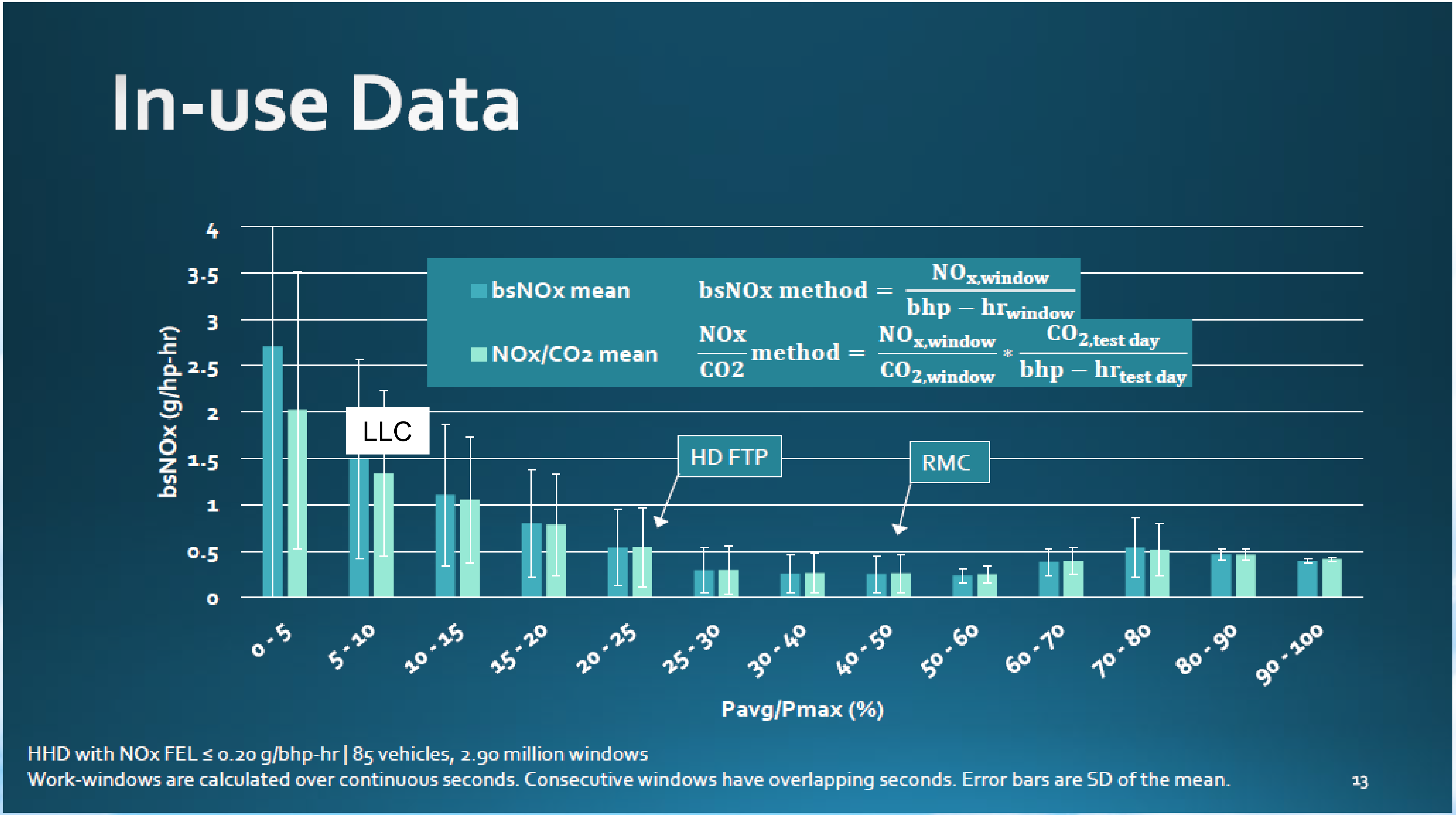


- If the test cycle were 4 hrs long (typical for a fleet), the emissions for the NG vehicle would **decreased** by a **factor of 6** where for the diesel it would only reduce by a factor of 2
- So what is important accuracy or continuous in-use measurements.

What Questions Are we Trying to Answer

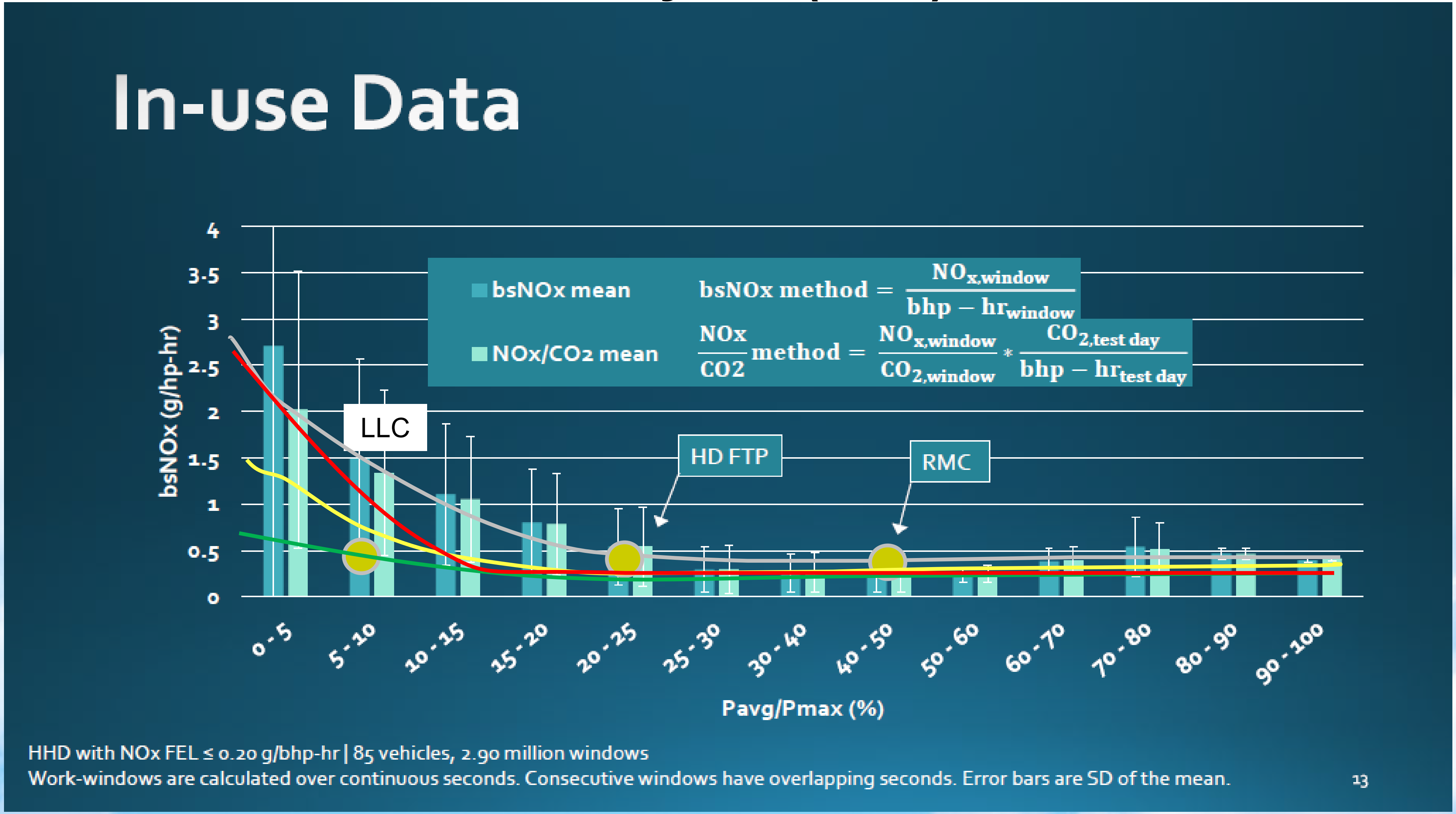
- Conformity Factor
  - How well does the vehicle meet our expectation
  - Our expectation is the certification cycle (hot, low load, cold)
  - Exclusions of in-use conditions to avoid issues
- Full Useful Life: Do the emissions remain low over full useful life (and for the life of the vehicle)
- Inventory
  - How do we evaluate a fleets or a basin's emissions from emission factors and fleet specifics (age, distribution…)
  - I measure a truck under its in-service actual operation and sometimes I find the emissions are higher than the conformity factor and I report that they are in excess.
  - At one of my conferences we had the discussion. "We built the vehicles following a set of rules, but we get tested under other rule." Even with the evolution of the not to exceed, work base window and proposed sum/sum binning methods, I suspect we are going to still be talking about conforming issues.
- In the end what is the air quality and is it getting better and is the exposure lower

MOVES and EMFAC Models View SCR Diesels Like This



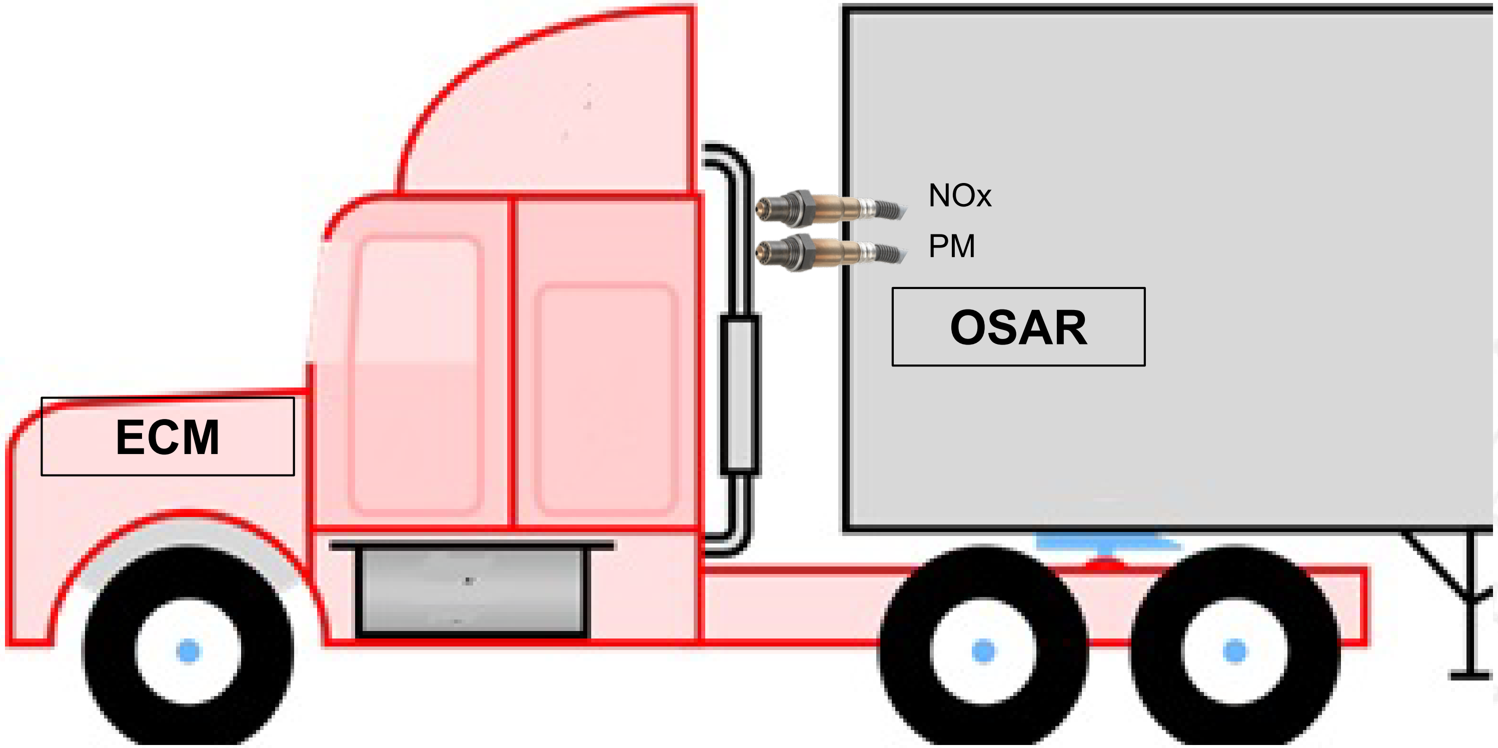
Source: James Sanchez EPA’s Cleaner Trucks Initiative ERC 2019 Symposium

What Will the New Low Load Cycle (LLC) do to In-Use Binning



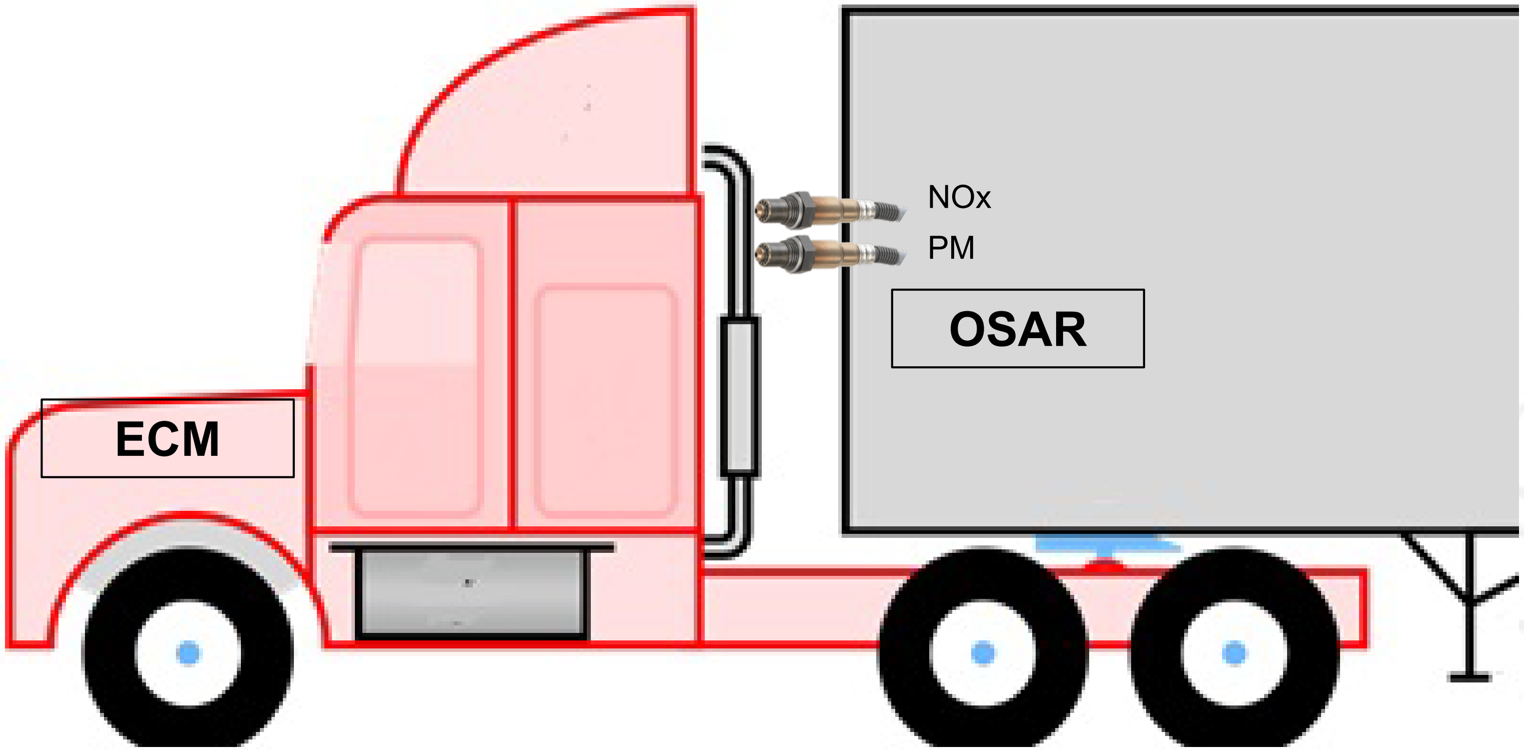
Source: Modified by UCR from James Sanchez EPA's Cleaner Trucks Initiative ERC 2019 Symposium

On-Board Sensing, Analysis, and Reporting (OSAR)
System Design



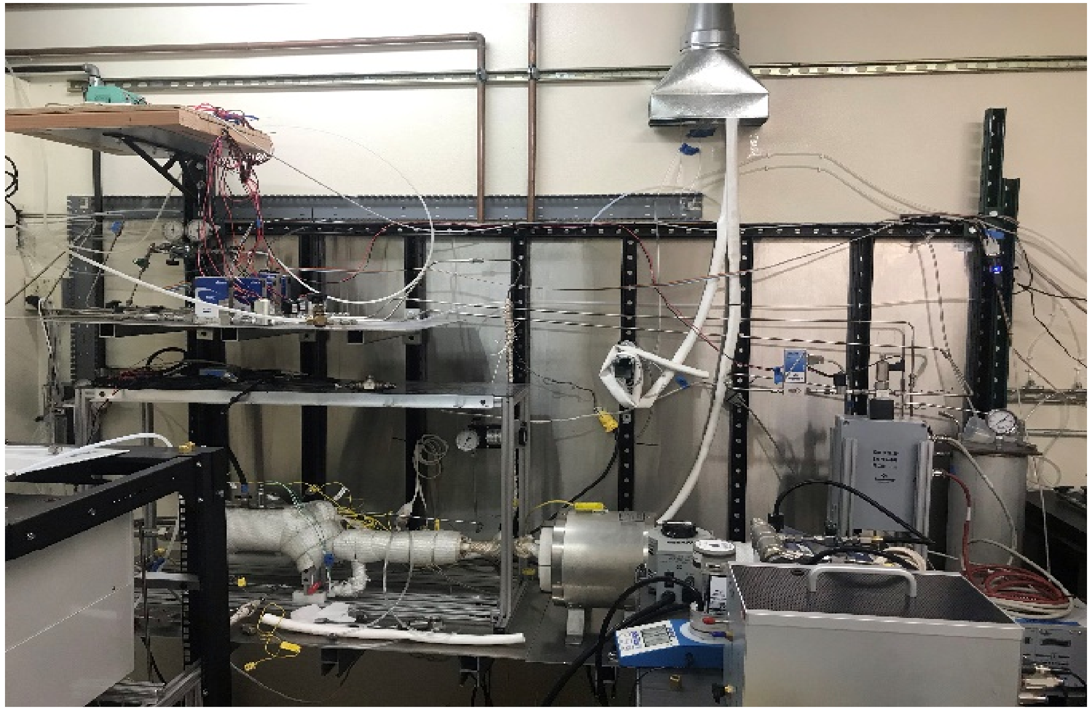
- Low cost system designed by a sensor integrated for high volume low cost applications
- Designed to measure
  - Existing NOx sensors
  - Modern low temperature sensors
  - Future sensors
  - Other analog signals
- No ECU interface (independent)
- Designed for pre-use wake up
  - Scheduled wake up to capture cold start conditions
  - Cellular to update schedules
- Goal is to install and leave installed for years to investigate degradation

On-Board **S**ensing, **A**nalysis, and **R**eporting **(OSAR)** System Design



- Working with sensor suppliers for
  - Samples from suppliers
  - Collaboration
  - Innovations
  - Future sensors
- Working with other sensing methods (Lasers, and other ideas) for comparison and alternate methods and approaches
- Evaluate accuracy in OSAR laboratory
- Discussing collaboration with telematic companies for large scale deployment

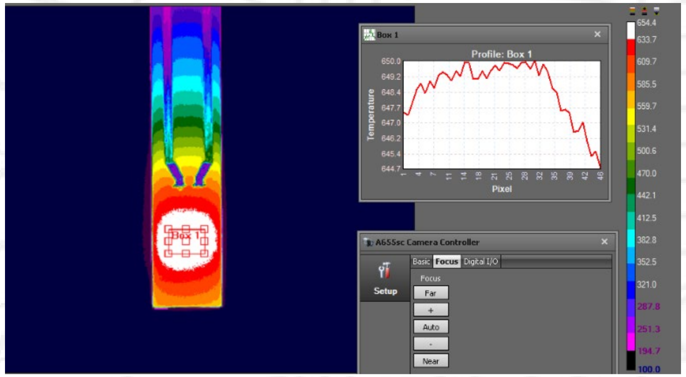
OSAR Evaluation and Calibration Laboratory at UCR



High flow bench to simulate exhaust conditions while calibrating and comparing with an FTIR and PM (miniCAST)

- NO 0-200ppm
- NO2 0-200ppm
- NH3 0-200ppm
- **H2O 0-8%**
- O2 3%-18%

Durability system for getting new sensors to a aged starting point of interest



IR Camera and Solartorn Impedance analyzer to investigate the surface

In Partnership with EmisSense

OSAR Strategic Roadmap & Regulatory Timeline

OSAR Launch

- Lit Review and OEM data mine
- Evaluate Data metrics with existing data sets (EMA, UCR, WVU, others)
- Evaluate Bin Methods
- AQMD/EPA/ARB Study

2020

OEM Early Adoption

- Estimate baseline emissions (OEM deploy with support)
- Define accuracy
- Evaluate data metrics
- Exhaust flow OBD signal

2021

Laboratory Evaluation & Improvements

- Development test plan for sensor evaluations and metrics
- Propose recommendation for sensor improvements

2022

Sensor Innovations

- Evaluate sensor improvements in beta programs

2023

Final Sensor Evaluation

- Evaluate new sensor; cold operation, high accuracy telematics 1000+ trucks
- Consider retrofits
- Discuss compliance evaluation with I/M
- PM Sensing Maybe Consider

2024

Ongoing Truck and Bus Fleet Turnover (by 2023)

2018 2019 2020 2021 2022 2023 2024 2025 2026 2027

REAL Proposed 2020

Regulatory Development

2022

2024

2027

Engine and Vehicle CO_2 Standards (Step 1)

NOx Rule

EPA HD NOx NPRM

- Modified NTE
- Euro -VI(d) reporting
- Longer warranty (step 1)
- Warranty reporting and corrective action changes
- OBD REAL (NOx, CO_2)

Engine and Vehicle CO_2 Standards (Step 2)

- NOx:
  - 0.05 g/hp-hr FTP/SET
  - 0.2 g/hp-hr LLC
  - 10 g/hr idle
- PM: 0.005 g/hp-hr
- Pre-conditioning, break-in, FUL aging
- Euro VI(d) compliance
- OBD Changes, Separate CA AB&T
- REAL in-use pilots
- ZEV truck requirement

Engine and Vehicle CO_2 Standards (Step 3)

- NOx:
  - 0.02 g/hp-hr FTP/SET
  - 0.05 g/hp-hr LLC
  - 5 Idle g/hr
- Longer useful life
- Alt durability life (DF) program
- Euro VI(e) with cold start, down to idle
- REAL in-use compliance option
- Longer warranty

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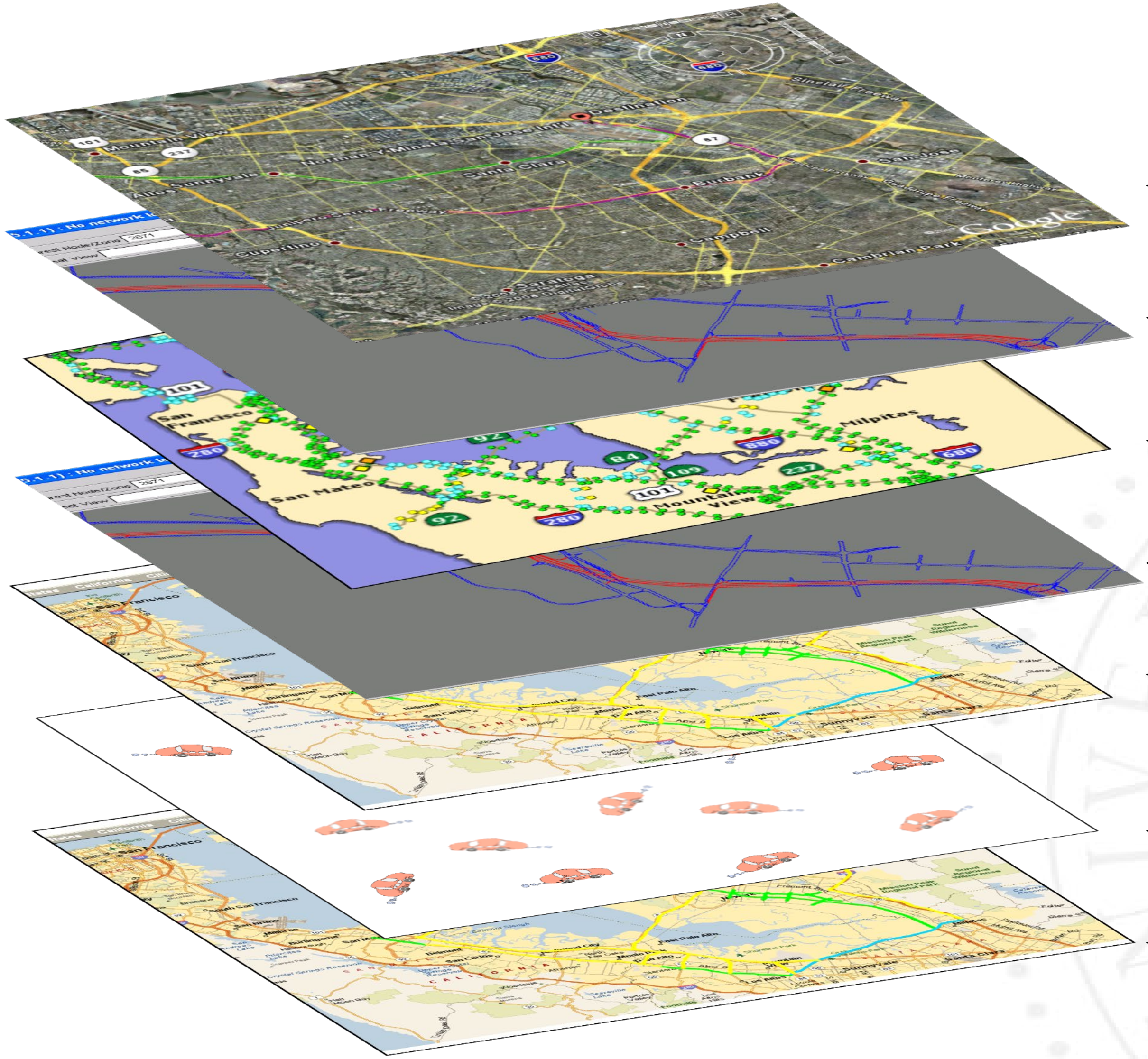
Data Integration for A Complete Picture of Emissions Impact



Google Earth or Google Maps Interface

Traffic simulation result for arterials

Population & Health info

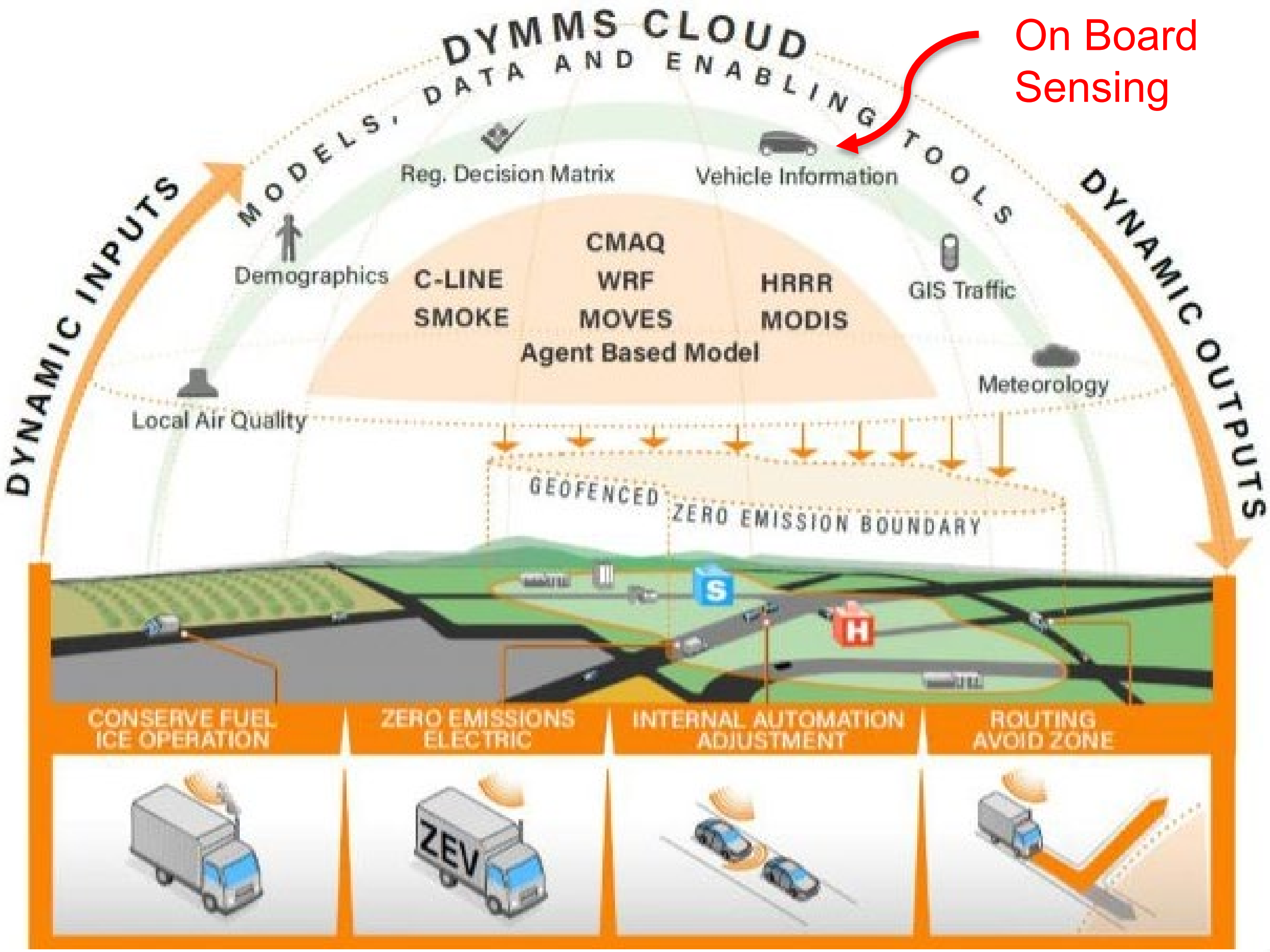
Traffic signal/detector info

Air quality sensor data

In-use vehicle data (OSAR)

Underlying network data

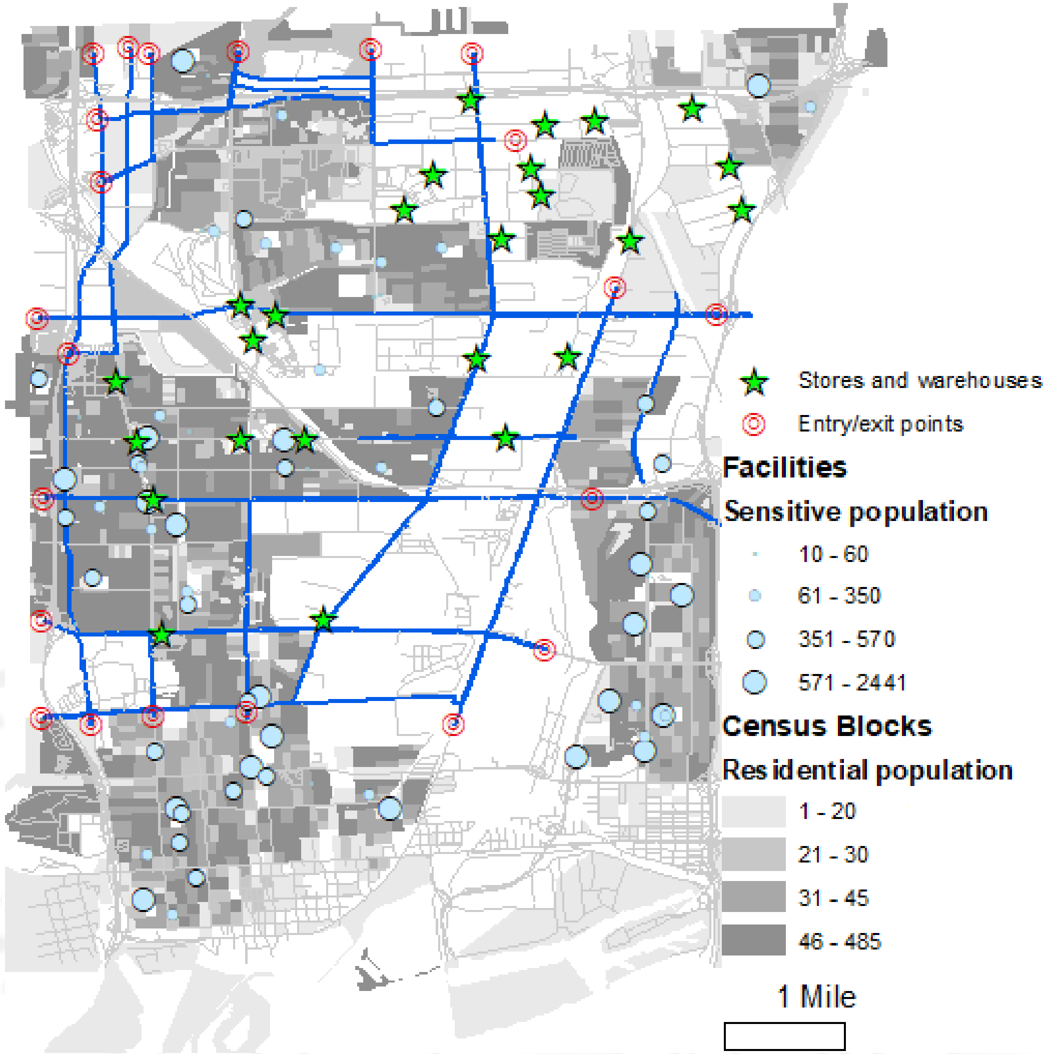
Ultimate Vision: Self Reporting and Dynamic Mobility Control



- The **Dynamic Mobility Management System** will collect data from vehicles, the transportation system, and the atmosphere and use these inputs to implement real-time decisions on vehicle behavior and energy management.

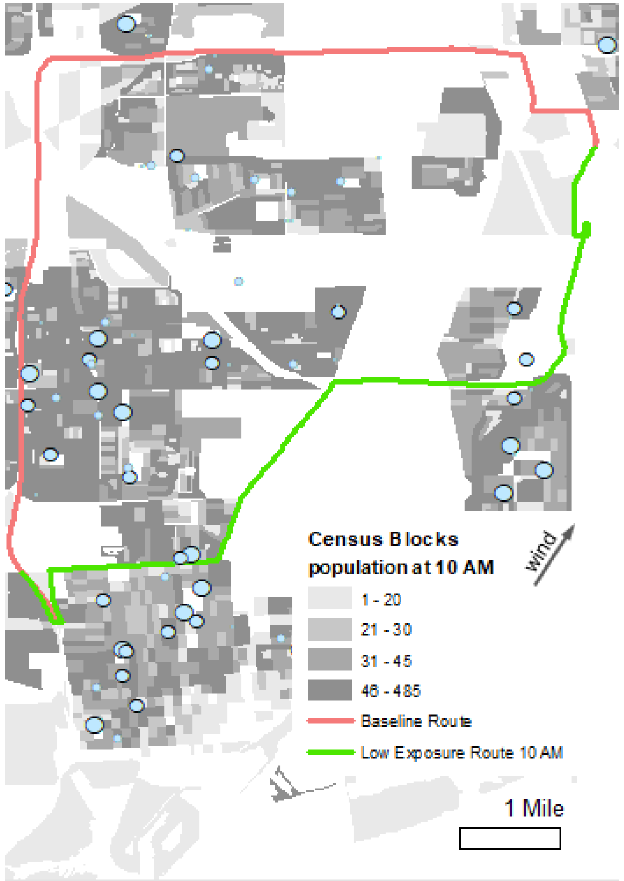
Example of a CARB Funded Program on Geofencing: Exposure

- Truck trip origins/destinations
  - 22 entry/exit points to/from the city
  - 25 truck trip attractions (e.g., large retail stores, logistic centers, and warehouses) inside the city
  - 22 x 25 x 2 = 1,100 trips
- For each trip, calculate multiple routes for comparison:
  - Low exposure route (LER)
  - Baseline route (BR)

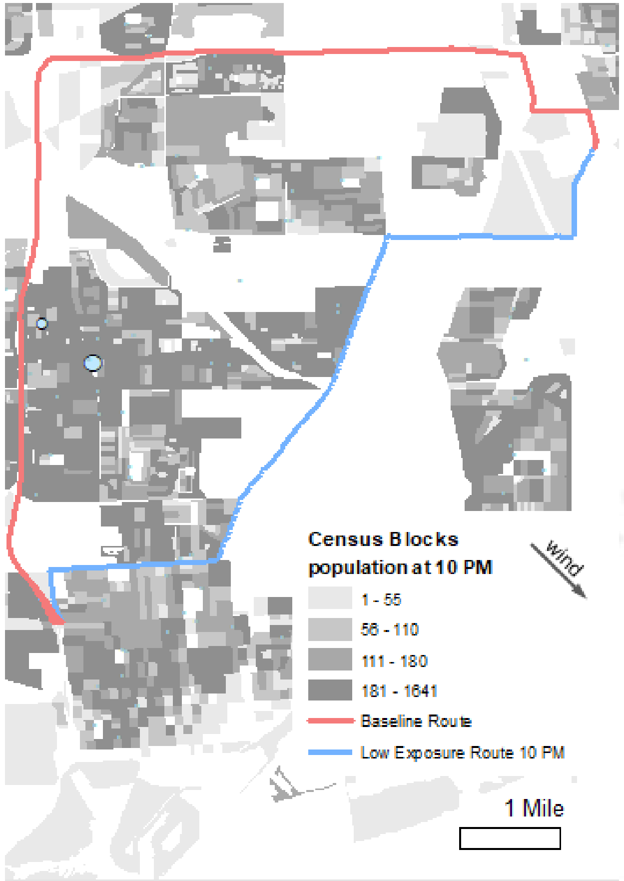


Low Exposure Route (LER) Much Less than Baseline (BR)

10 A.M.



10 P.M.



	10 A.M.		
	BR	LER	% Diff.
Trip Distance (miles)	11.9	9.3	-22%
Trip Time (minutes)	16.4	17.0	4%
Inhaled Mass of PM2.5 (µg)	0.3	0.1	-73%
Inhaled Mass of NOx (µg)	29.9	20.6	-31%
Tailpipe emission of CO2 (kg)	17.6	15.9	-9%

	10 P.M.		
	BR	LER	% Diff.
Trip Distance (miles)	11.9	8.7	-27%
Trip Time (minutes)	15.9	17.6	11%
Inhaled Mass of PM2.5 (µg)	3.7	0.9	-77%
Inhaled Mass of NOx (µg)	369.0	205.7	-44%
Tailpipe emission of CO2 (kg)	17.4	15.5	-11%