

# **Development of Remote Sensing Instrumentation for NO<sub>x</sub> and PM Emissions from Heavy Duty Trucks**

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# **Will discuss progress on development of remote sensing instrumentation for PM and NO<sub>x</sub> from heavy trucks**

- **Internally funded 2-year project, now entering second year**
  - **Developing novel remote-sensing applications**
    - **LIDAR for PM**
    - **UV absorption for NO<sub>x</sub>**
    - **Sound signature analysis for truck operating parameters**
- 
- **Will also briefly discuss site near ORNL that affords great opportunities for truck emissions research**

# **Why in-use emissions data? Because data on in-use truck emissions are needed by EPA, state agencies, DOT, others**

- **For use in models to predict impact of mobile sources on urban air quality**
- **To help characterize “hot spots” of ambient emissions, e.g., truck stops, freeway corridors**
- **To help assess improvements / impacts of emissions control over time**
- **To bolster rule-making process, e.g., anti-idling**

# Approach is to innovate new remote sensing instruments

- Trying to improve upon previous remote sensing developments – not easy
- Emphasis on fast, accurate, and inexpensive measurement technologies
  - Deployable in arrays for multiple data points in exhaust plume



# Developing FM-cw LIDAR to measure density of airborne particles

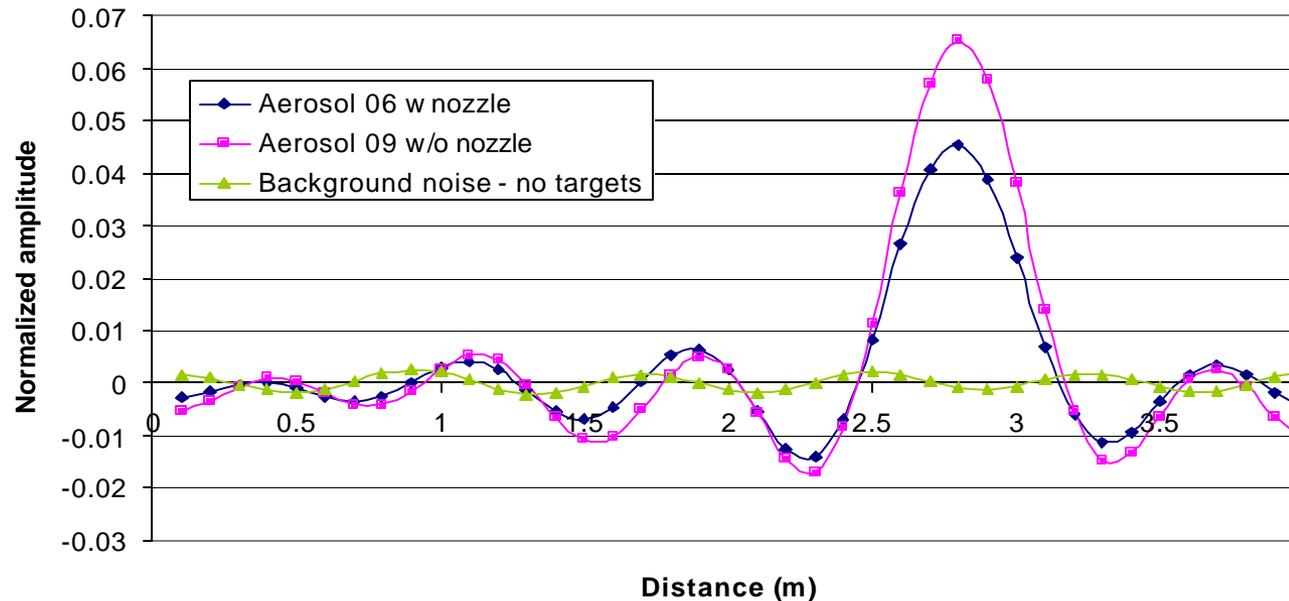
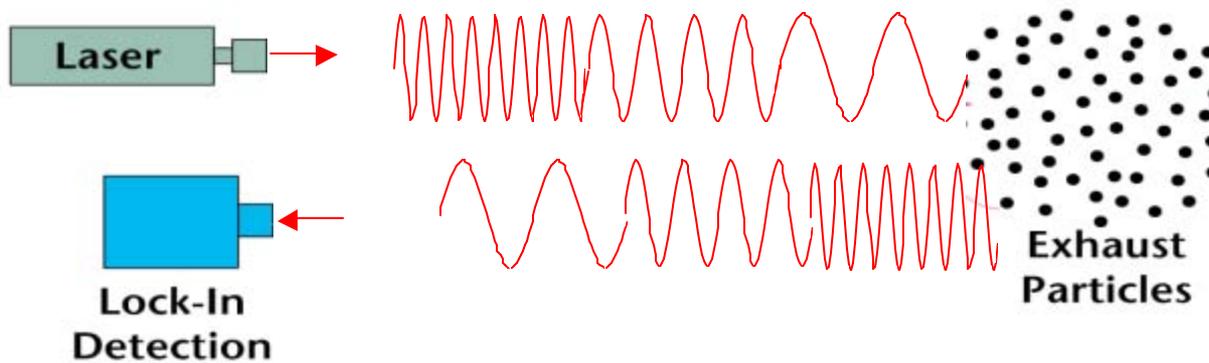
- LIDAR used frequently for atmospheric sciences studies
- Conventional time of flight LIDAR lacks spatial resolution to measure aerosols in diesel exhaust
- We are developing a type of FM-cw LIDAR system
  - modulating amplitude of laser diode using series of stepped frequency waveforms
- We use a unique signal processing and inversion technique
  - potentially reduce package size to a hand-held unit
- **With array detector - Could eventually provide 3D information on exhaust plumes**

# First year's LIDAR effort devoted to development of concepts, bench-scale, and laboratory experiments

- Nebulizing NaCl aerosols
- Imaging number-density of particles in back-scatter mode
- Using diode lasers – very inexpensive - < 5 mW power (eye-safe)
- Hardware cost for one beam ~ \$5,000

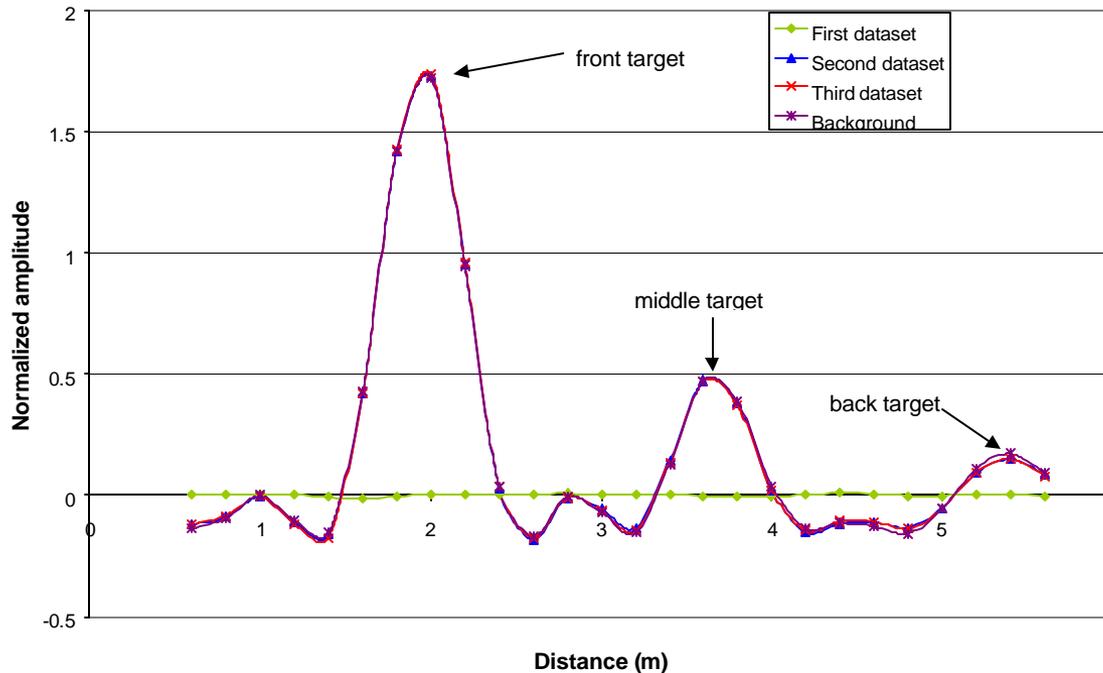


# Initial laboratory experiments with aerosols were successful



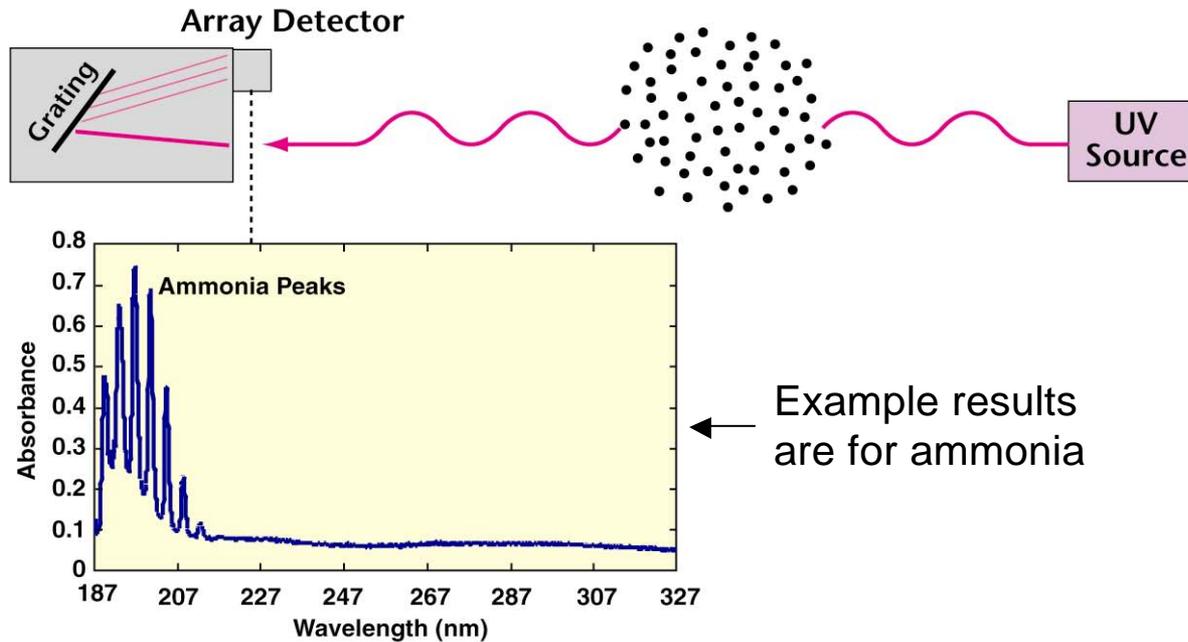
# Distance measurements with LIDAR also promising

- Using similar setup for ranging experiments with transparent plastic pieces



- Can locate 3 diffuse targets (clear plastic) accurately and repeatably

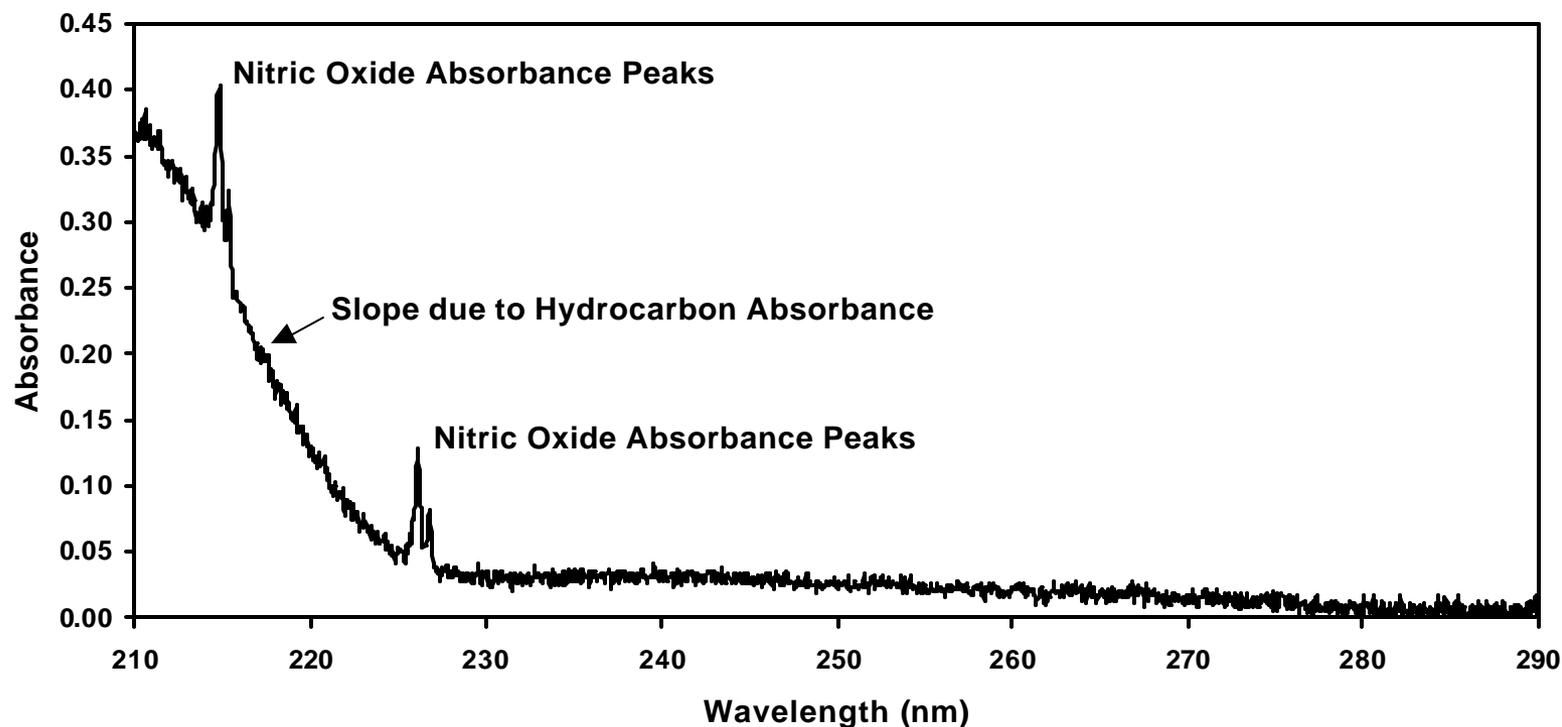
# UV absorption spectroscopy used for NO<sub>x</sub> concentration



- Hardware assembled
- Tested with a stationary car exhaust
  - 10 ms temporal resolution
  - Detection limit of 100 ppb NO

# NOx absorption spectrum clearly seen in test of idling car at rest

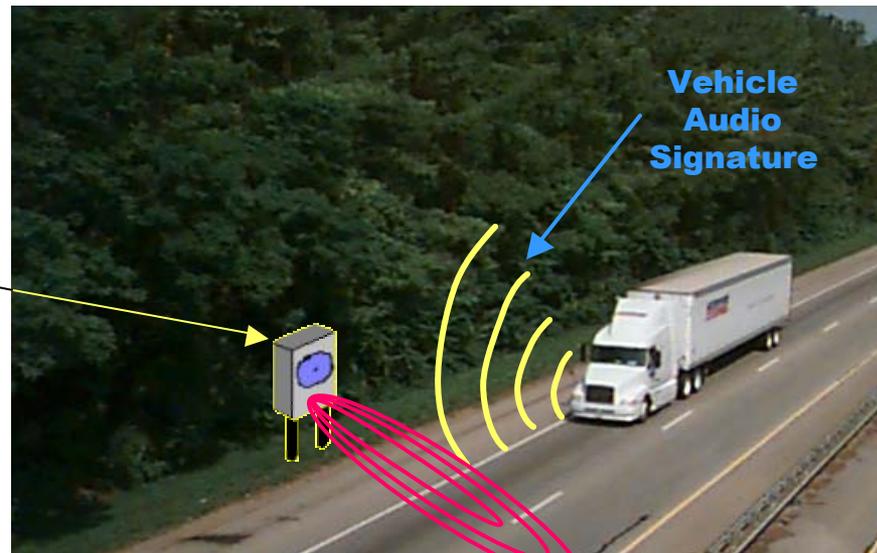
Open-Path Cold Start Absorption Spectrum for Honda Civic



# Non-contacting and non-intrusive acquisition of certain vehicle operating parameter data IS possible !!

- Engine produces a characteristic audio/ultrasound signature
- Deconvoluting, interpreting signals can yield engine speed, # of cylinders, turbine speed <sup>®</sup> can calculate exhaust flow (assumptions are required)

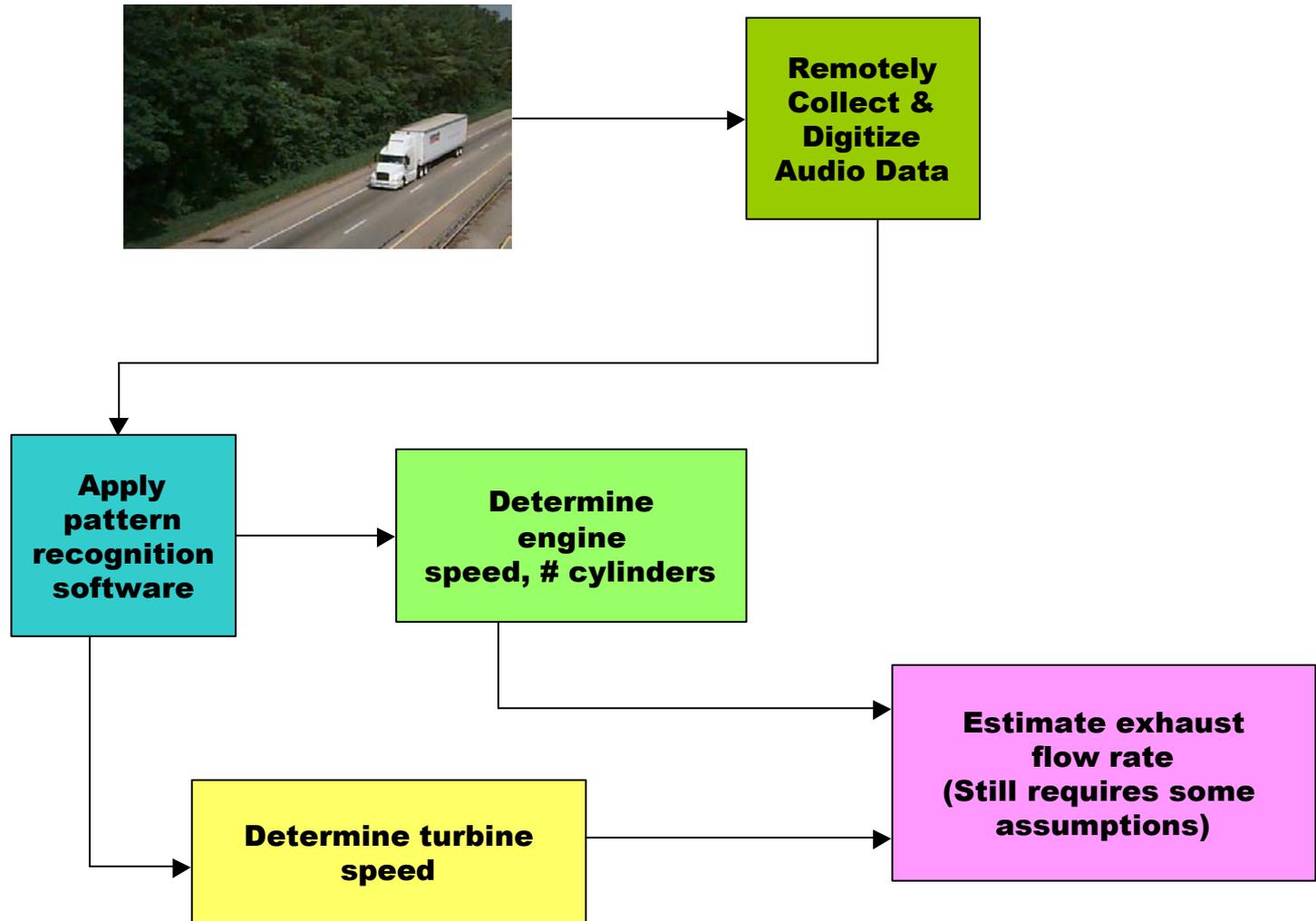
Sensor and Data  
Collection Enclosure



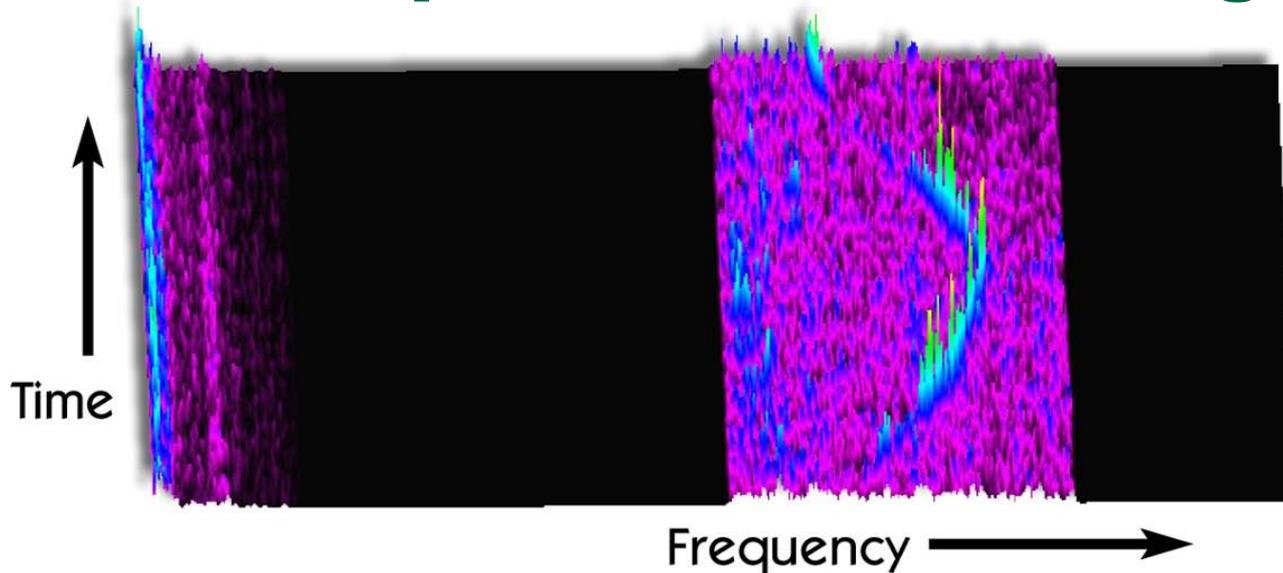
Vehicle  
Audio  
Signature

Probing / sensing field used  
for triggering data acquisition

# Analysis, interpretation of audio signal is key to extraction of meaningful data



# “Waterfall” plot reveals both engine and turbine speeds from audio signal



- **Signature from Cat C-12 engine in truck traveling up a grade. Vehicle speed held constant**
- **Engine speed (to the left) is relatively constant, turbo speed (to the right) varies greatly with engine load as the vehicle travels up grade**
- **Advanced analysis applied here to detect turbo speed**

# **Next year's instrument development will move to increasingly complex experiments**

- **Engine laboratory tests**
  - Engines of different sizes, # cylinders
  - Working with raw and dilute exhaust
- **Stationary trucks**
  - Comparing remote sensing instruments with more conventional
- **Drive-by trucks in controlled environment**

# Ideal spot for truck emissions studies exists not far from ORNL



major  
mile  
day  
at site  
per  
one

- Terrain conducive to sequestering emissions
- Promoting this site as field laboratory

# **Site offers many opportunities for real-world truck emissions studies**

- **Develop large database of in-use emissions of heavy trucks**
- **Validate improvements in emissions, air quality over time with newer trucks**
- **Benefits of overnight idling reduction**
- **Impacts of truck traffic on localized air quality**

**Meteorology towers are in place now**

**Multiple ambient air quality towers are envisioned**



# Acknowledgements

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