

Development of Remote Sensing Instrumentation for NO_x and PM Emissions from Heavy Duty Trucks

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Will discuss progress on development of remote sensing instrumentation for PM and NO_x from heavy trucks

- Internally funded 2-year project, now entering second year
 - Developing novel remote-sensing applications
 - LIDAR for PM
 - UV absorption for NO_x
 - Sound signature analysis for truck operating parameters
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- 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

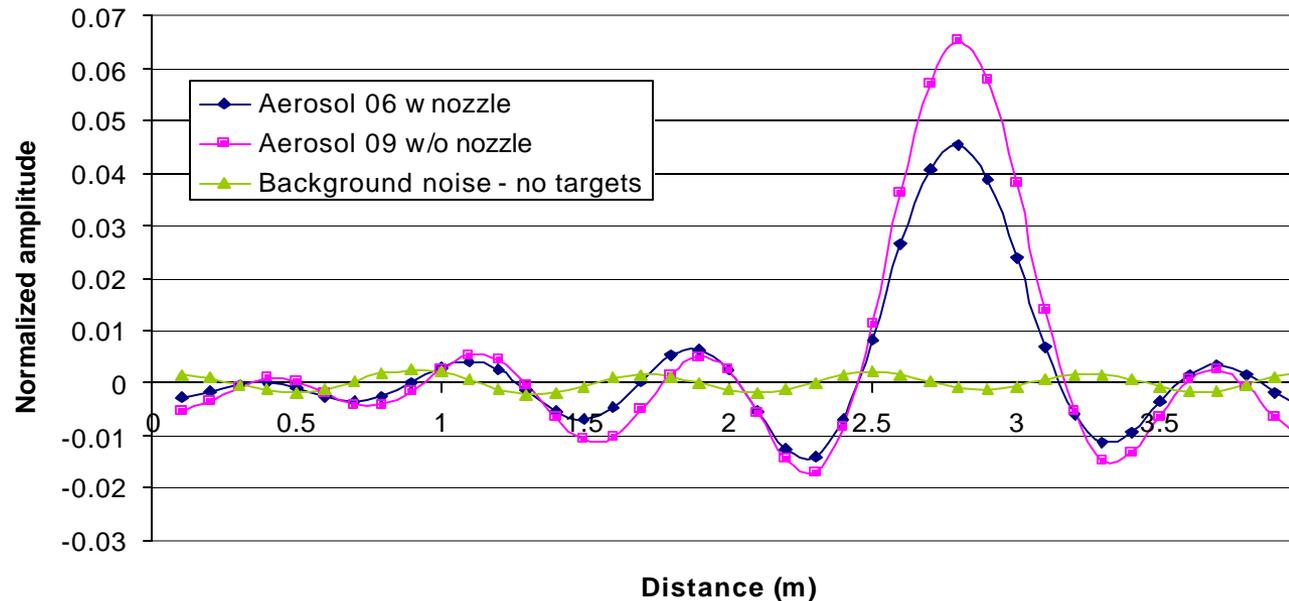
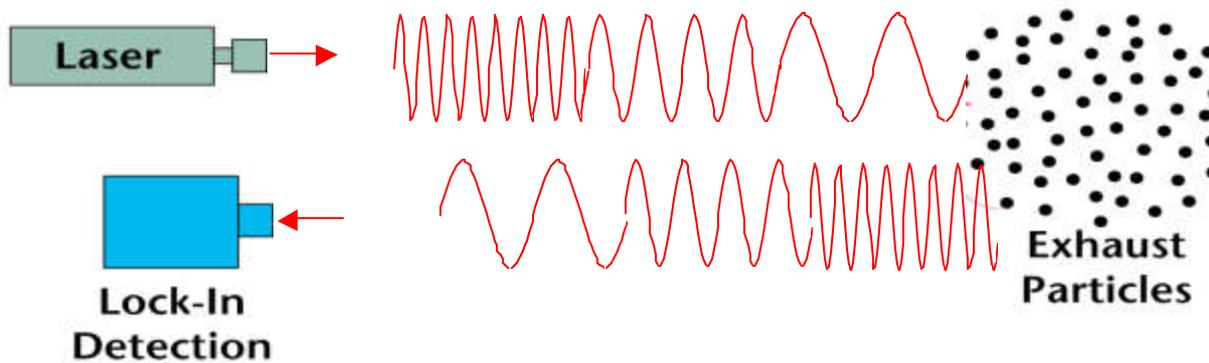
- LIDAR used frequently for atmospheric sciences studies
- Conventional time of flight LIDAR lacks spatial resolution to measure aerosols in diesel exhaust
- We are developing a type of FM-cw LIDAR system
 - modulating amplitude of laser diode using series of stepped frequency waveforms
- We use a unique 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

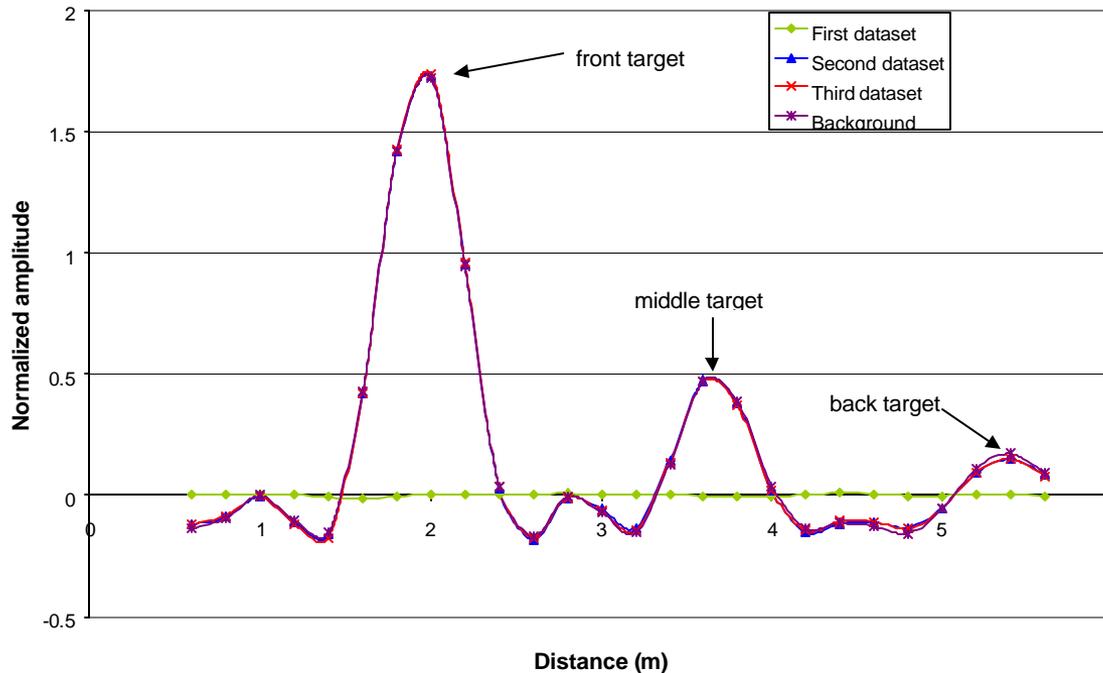


Initial laboratory experiments with aerosols were successful



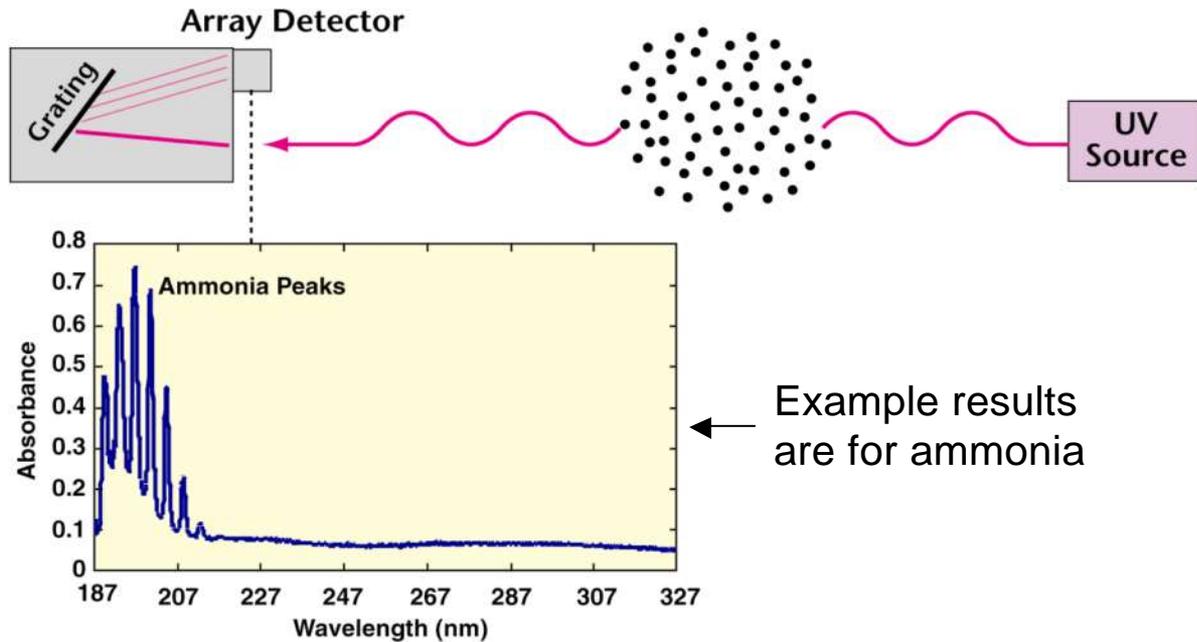
Distance measurements with LIDAR also promising

- Using similar setup for ranging experiments with transparent plastic pieces



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

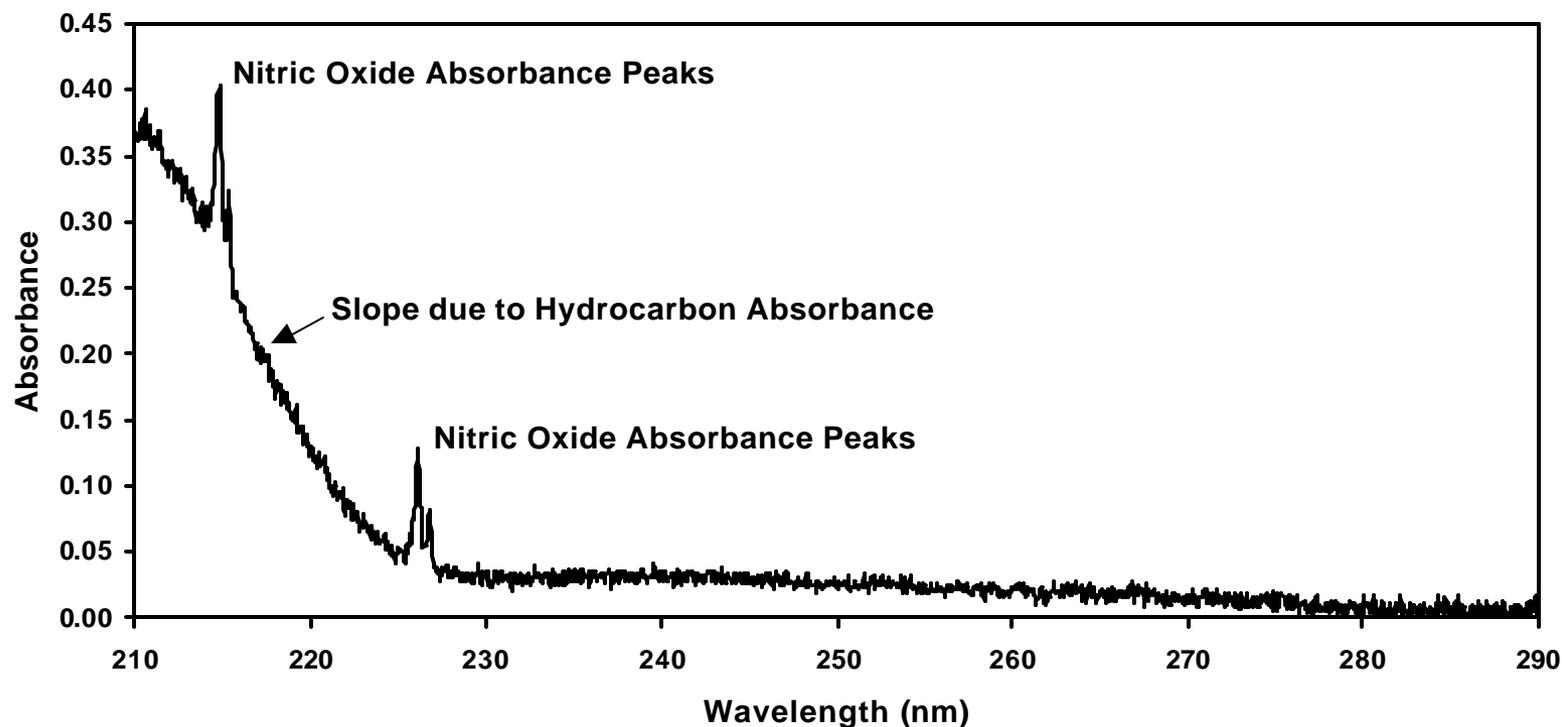
UV absorption spectroscopy used for NO_x concentration



- 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

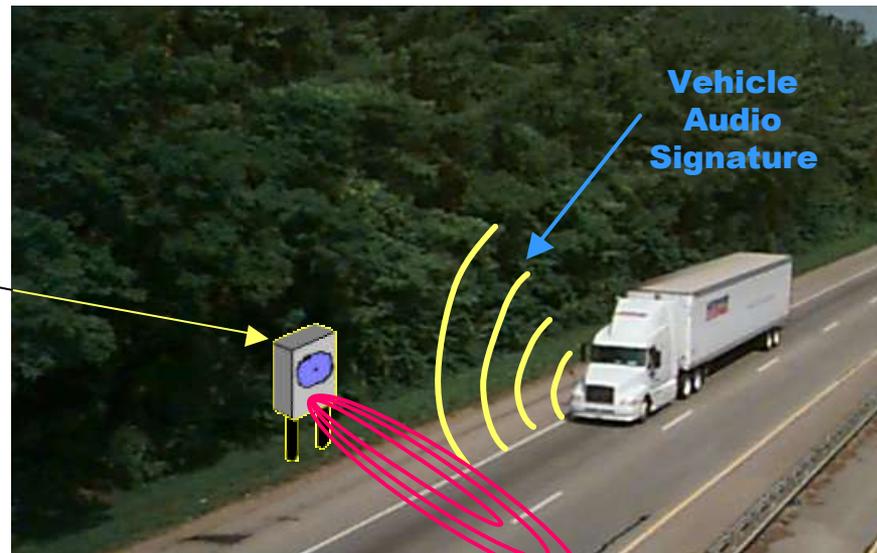
Open-Path Cold Start Absorption Spectrum for Honda Civic



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

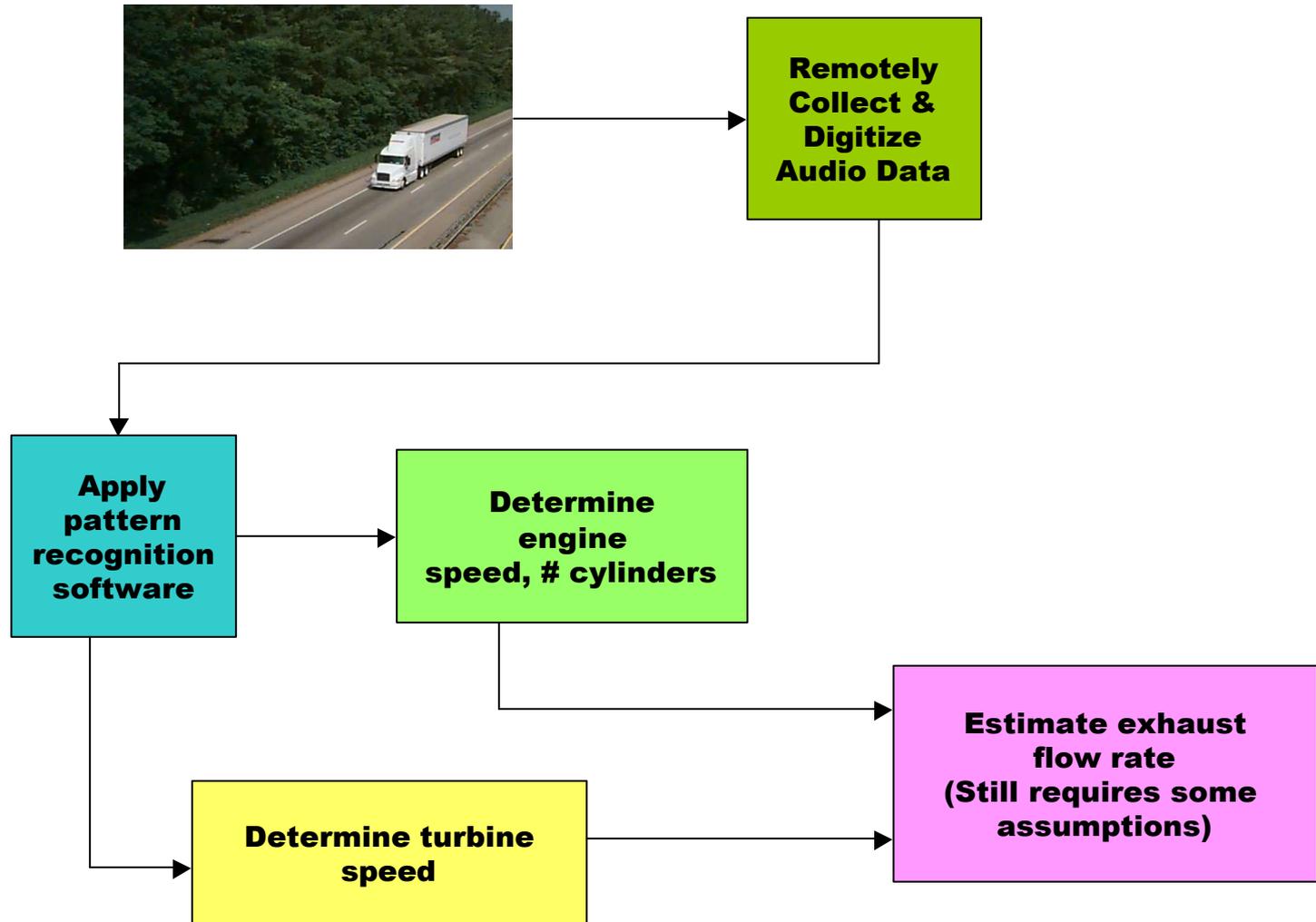
- Engine produces a characteristic audio/ultrasound signature
- Deconvoluting, interpreting signals can yield engine speed, # of cylinders, turbine speed [®] can calculate exhaust flow (assumptions are required)

Sensor and Data
Collection Enclosure

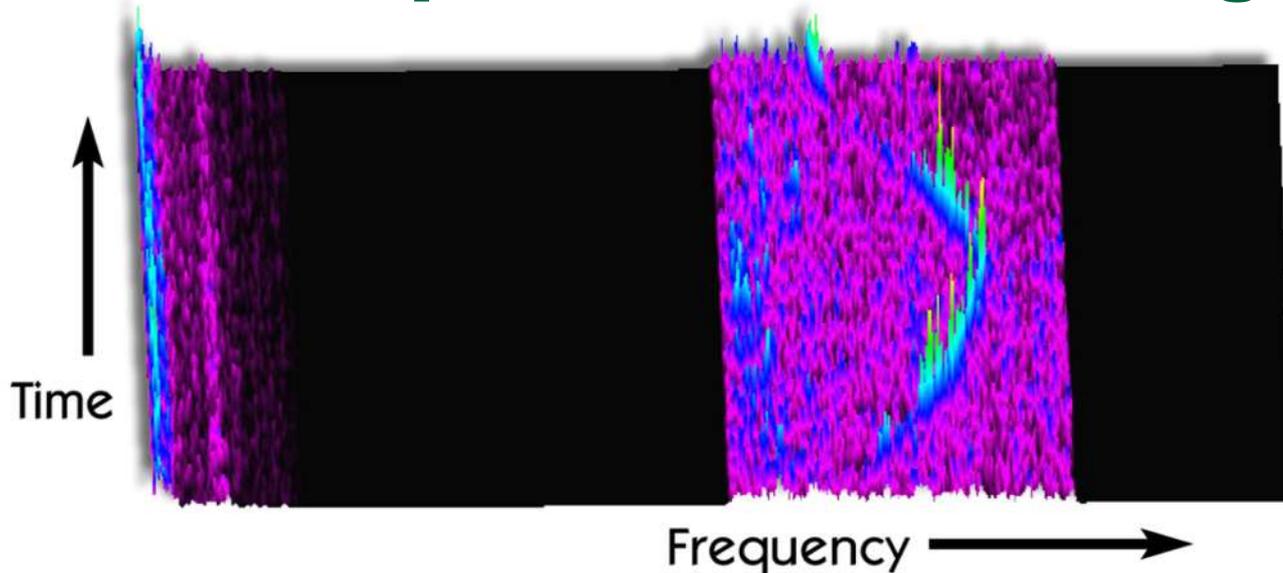


Probing / sensing field used
for triggering data acquisition

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



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

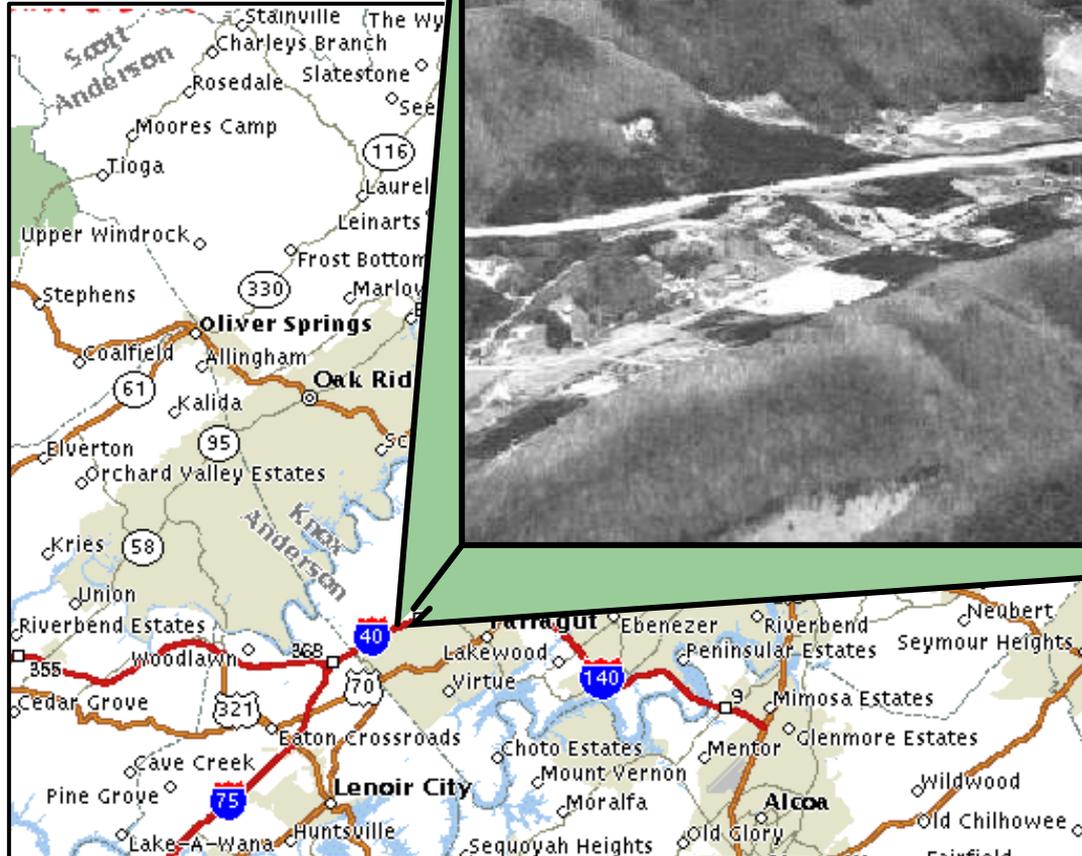


- Signature from Cat C-12 engine in truck traveling up a grade. Vehicle speed held constant
- Engine speed (to the left) is relatively constant, turbo speed (to the right) varies greatly with engine load as the vehicle travels up grade
- Advanced analysis applied here to detect turbo speed

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

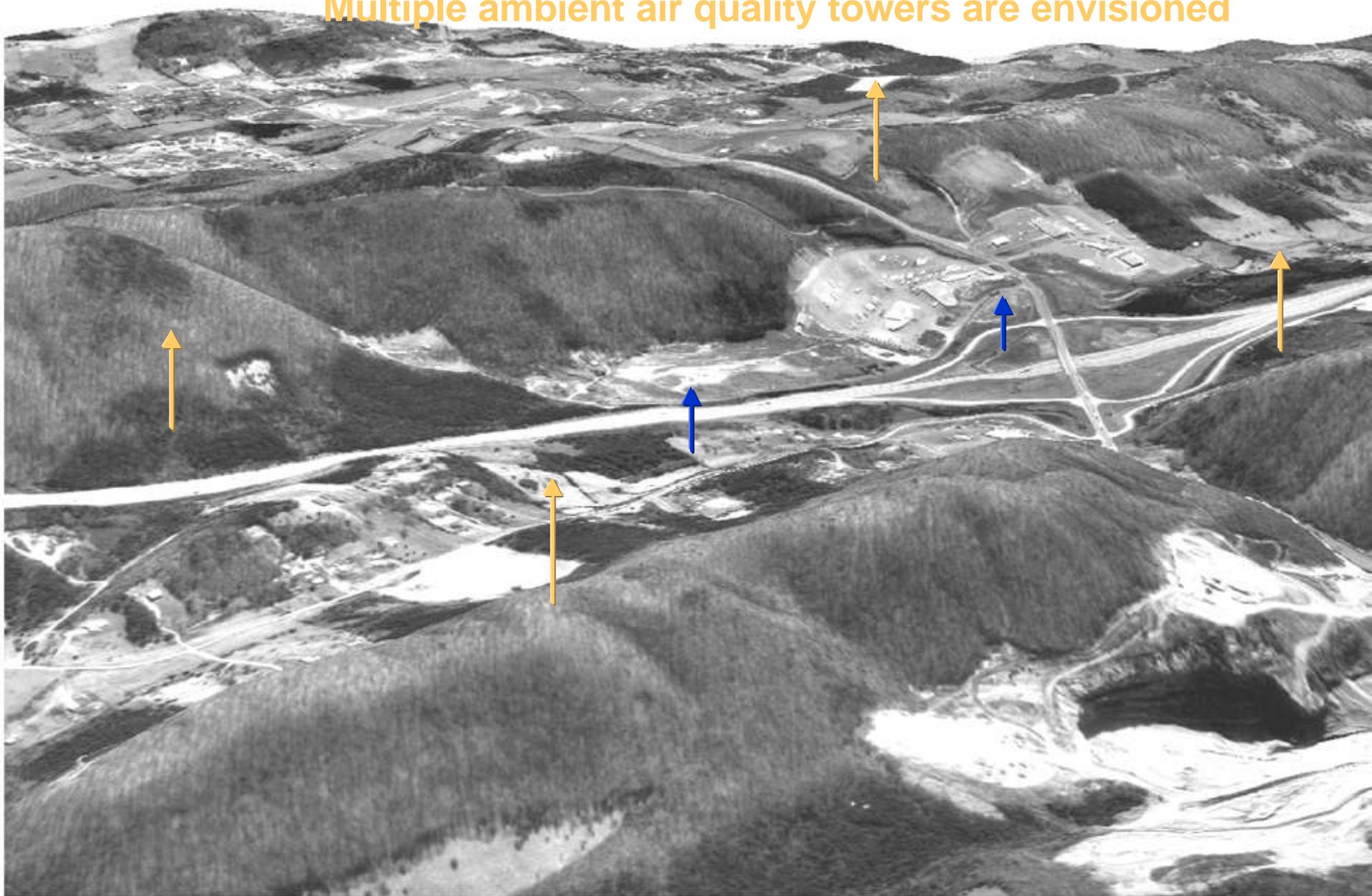
- Terrain conducive to sequestering emissions
- Promoting this site as field laboratory

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



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