Portable **E**missions **M**easurement **S**trategy

On-Vehicle Measurement Strategy

U.S. EPA
Office of Transportation Air Quality
October 21, 2002

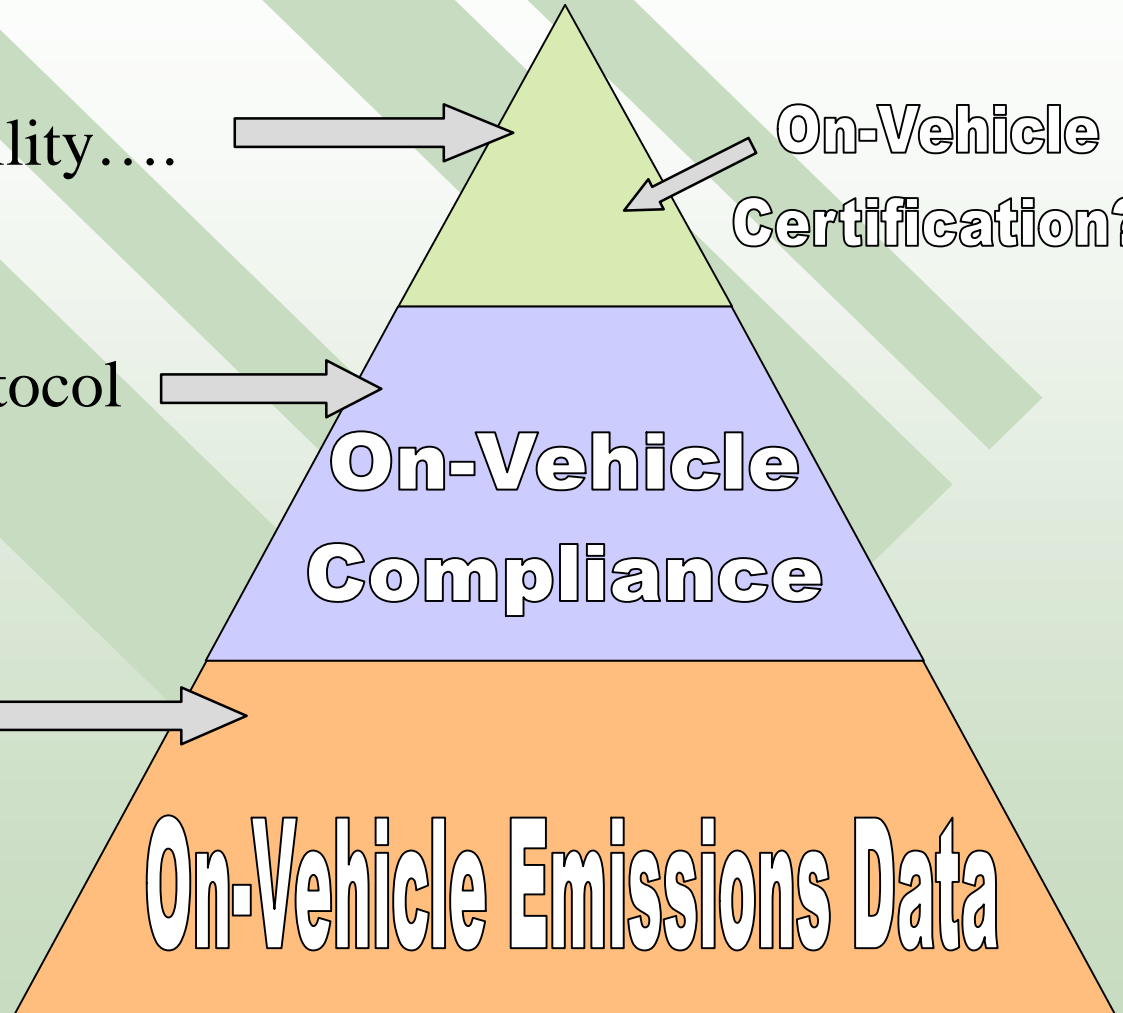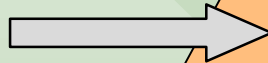# PEMS

■Investigate Feasibility…. → On-Vehicle Certification?

■Establish Test Protocol → On-Vehicle Compliance

■Model Inventory →
-Duty Cycles
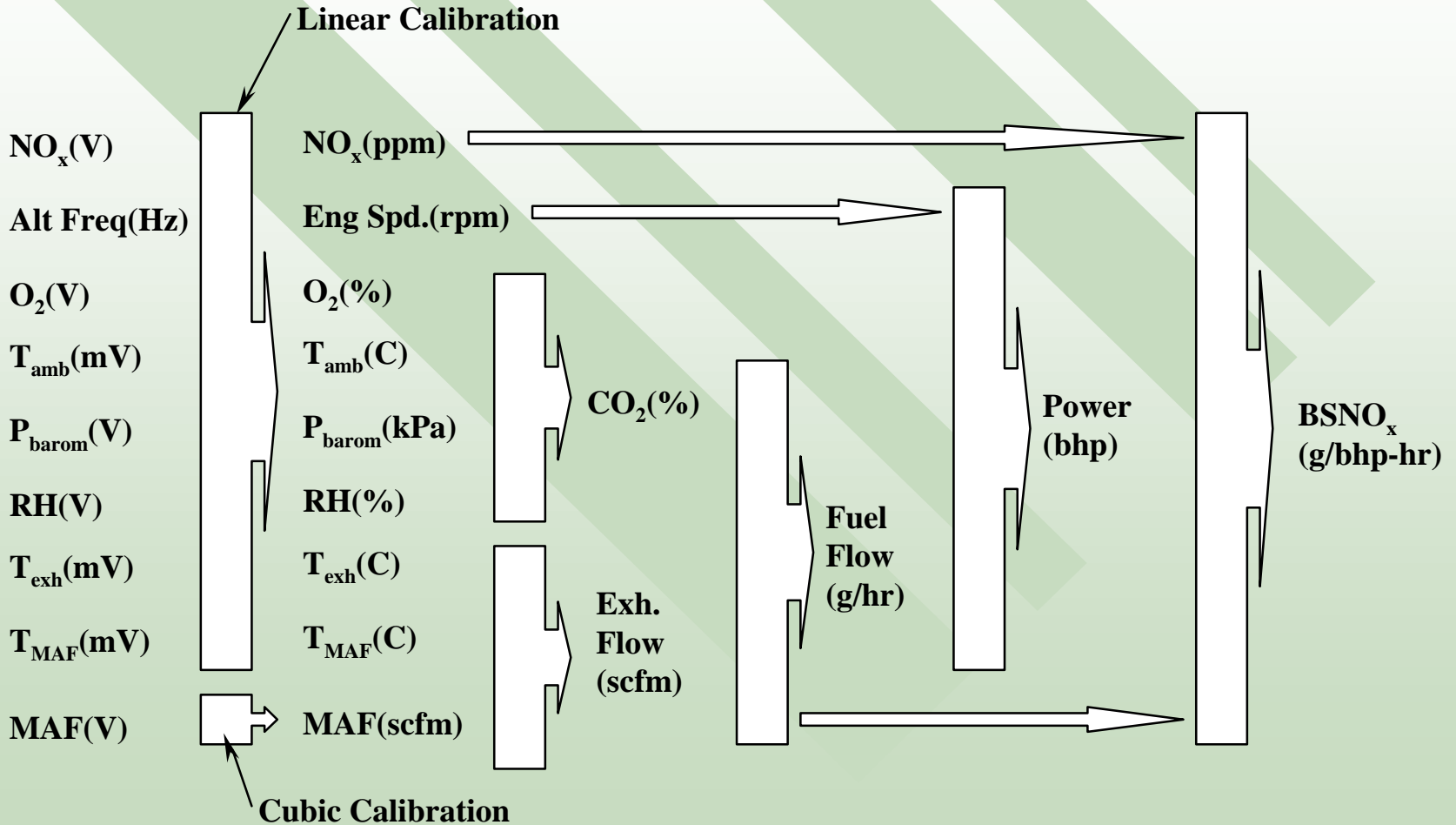-Emissions
-Activity
-Population

On-Vehicle Emissions Data

PEMS Foundation:
Significant Data Collection

- **Design Requirements**
  - Simple installation
    - » Wide variety of vehicles
  - Unattended operation
    - » Weather & tamper-proof
    - » Low power consumption
    - » Remote communication
  - Proportional emissions data
    - » Fast-response sensors
    - » Stand-alone flow measurement
    - » Ambient conditions
    - » Engine speed, temperatures, etc.

Emissions Calculations

Linear Calibration

$NO_x(V)$

$NO_x(ppm)$

Alt Freq(Hz)

Eng Spd.(rpm)

$O_2(V)$

$O_2(\%)$

$T_{amb}(mV)$

$T_{amb}(C)$

$CO_2(\%)$

$P_{barom}(V)$

$P_{barom}(kPa)$

Power
(bhp)

$BSNO_x$
(g/bhp-hr)

$RH(V)$

$RH(\%)$

$T_{exh}(mV)$

$T_{exh}(C)$

Exh.
Flow
(scfm)

Fuel
Flow
(g/hr)

$T_{MAF}(mV)$

$T_{MAF}(C)$

MAF(V)

MAF(scfm)

Cubic Calibration

PEMS Uses:

- **On-Highway Sources**
  - Emission factor / source apportionment
  - HD in-use compliance
- **Nonroad Sources**
  - Most engines/vehicles (> 25 Hp)
  - Activity information as well as in-use compliance

EPA's History on Developing On-Vehicle Systems

- EPA investigated and developed on-highway applications (i.e. ROVER)

- Continued development for on-highway heavy-duty applications through the HD Consent Decree (i.e. work done by WVU on MEMS)

- EPA continued development work for non-road applications (i.e. SPOT)

Technology Development

- Goals
  - Bring technology to market
  - Make accurate, accepted equipment readily available
  - Specify EPA needs so manufacturers can respond
- Approach
  - Cooperative Research and Development Agreements
    - Measure gasoline and diesel emissions
    - Operate unattended for extended periods of time
    - Accuracy requirements approach lab measurement
    - Goal is to have commercially available products in ~6 months
  - OTAQ lab and contractor development
    - PM and toxics measurement capability
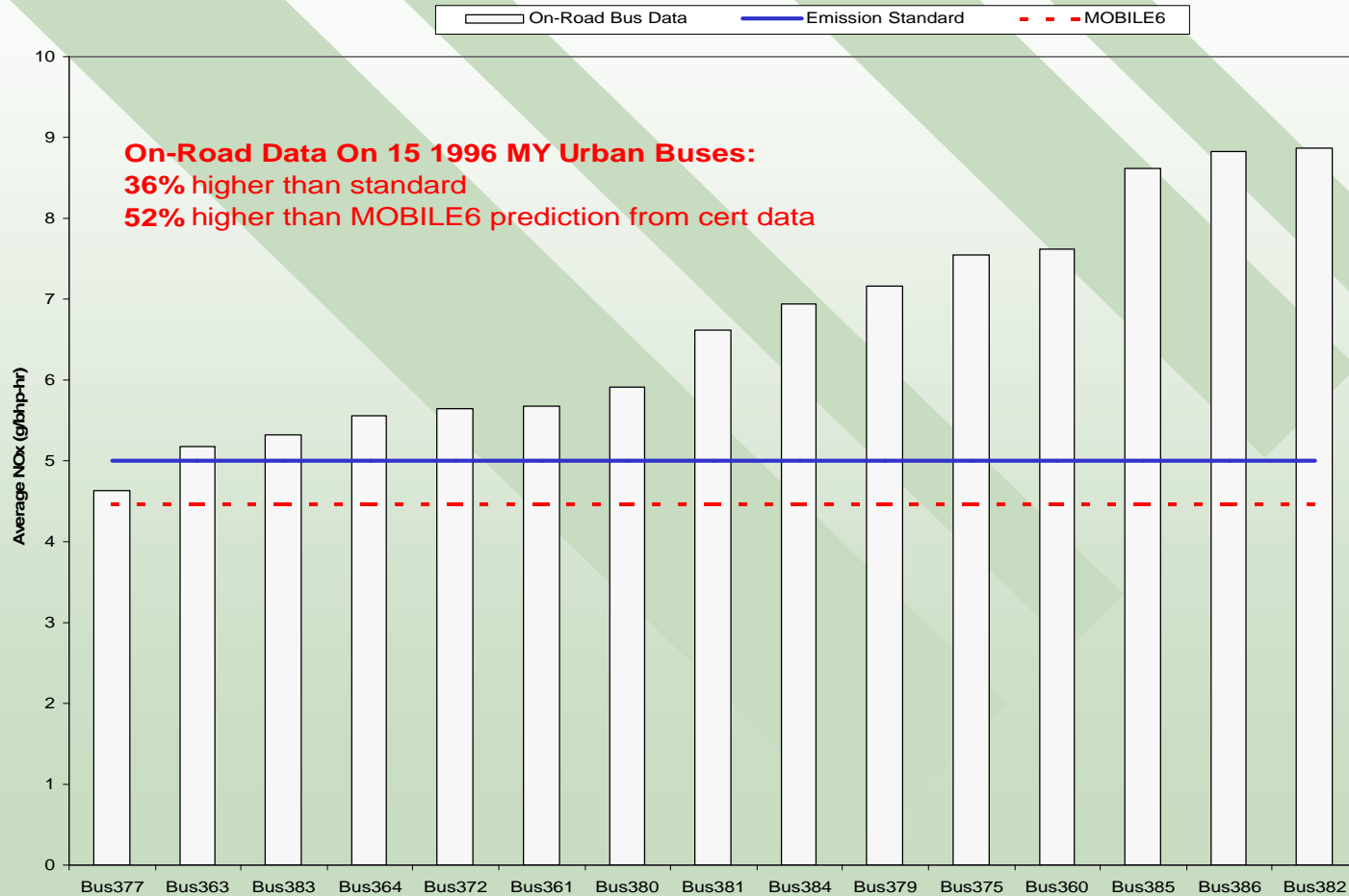   - Measurement strategy development

2001-2002 Modeling Approach
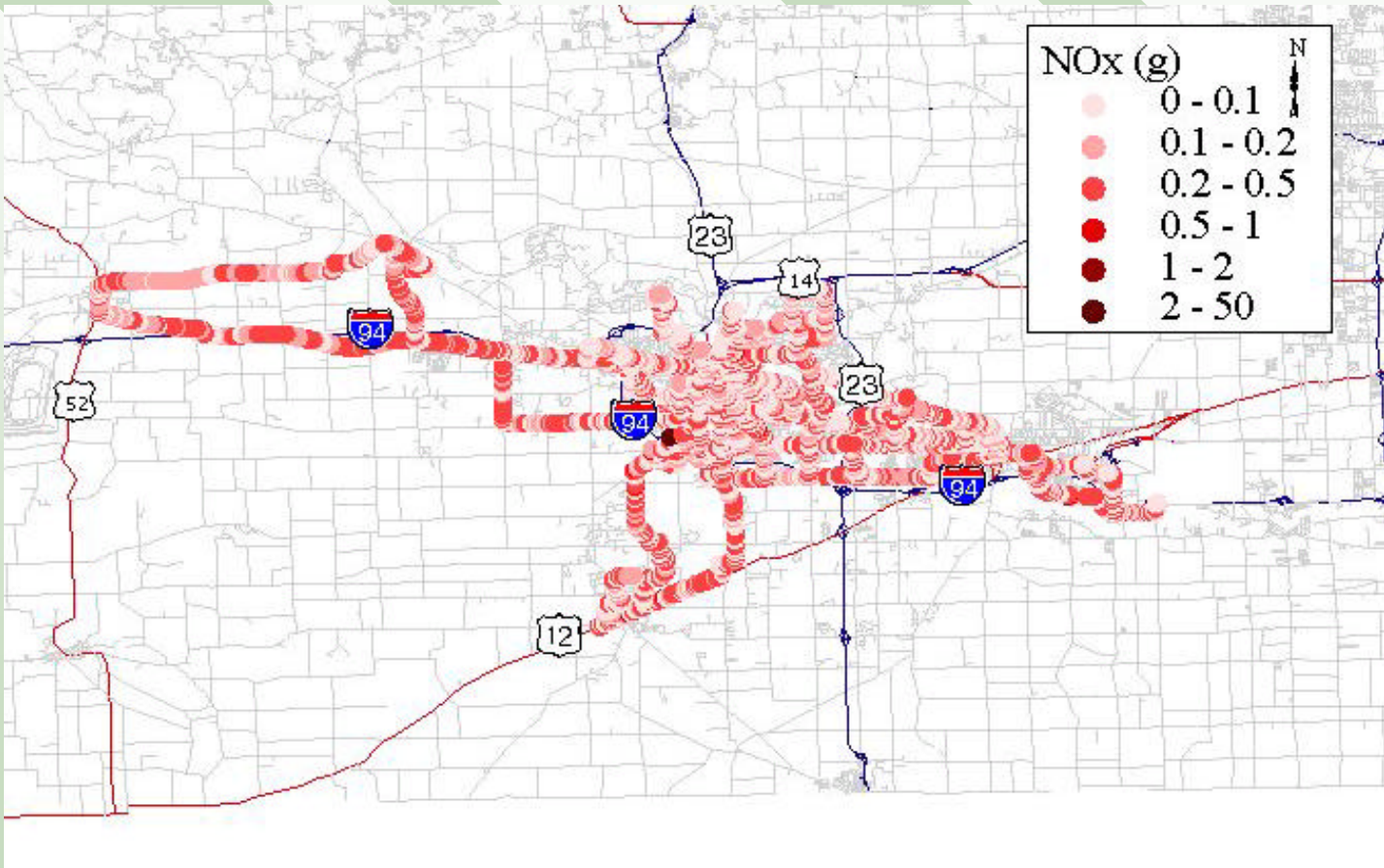
■ **Modeling Sec-by-Sec Proof-in-Concept Tests**

– Tested 15 Diesel Buses from AATA w/ Sensor's SEMTECH-D (older version)

– Tested 15 LDVs and LDTs w/ Sensor's SEMTECH-G (older version)

– Modelers using data to develop a model based on sec-by-sec in-use data.
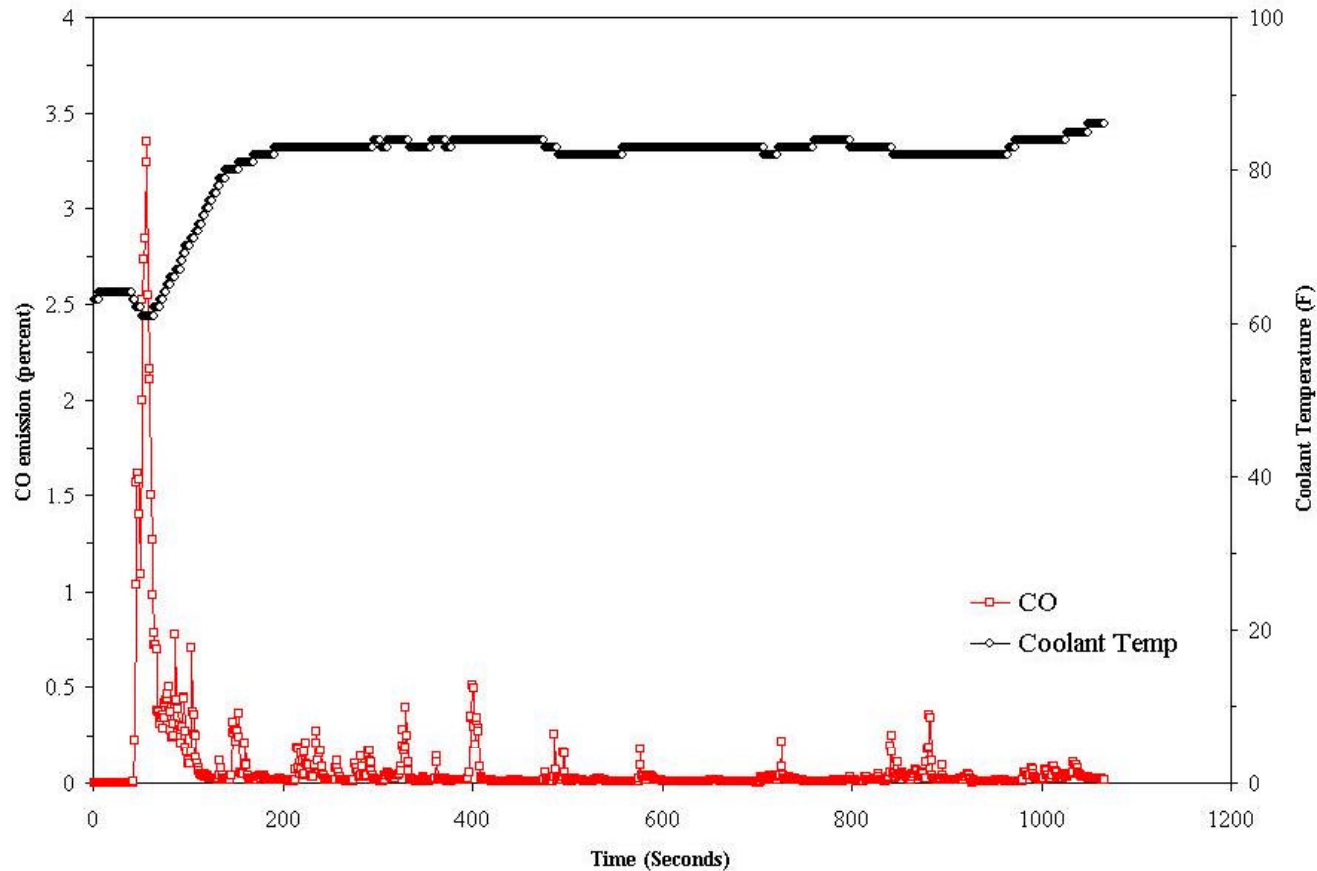
– Gathering sec-by-sec data from other test programs.

Real World Bus Emissions

On-Road Data On 15 1996 MY Urban Buses:
36% higher than standard
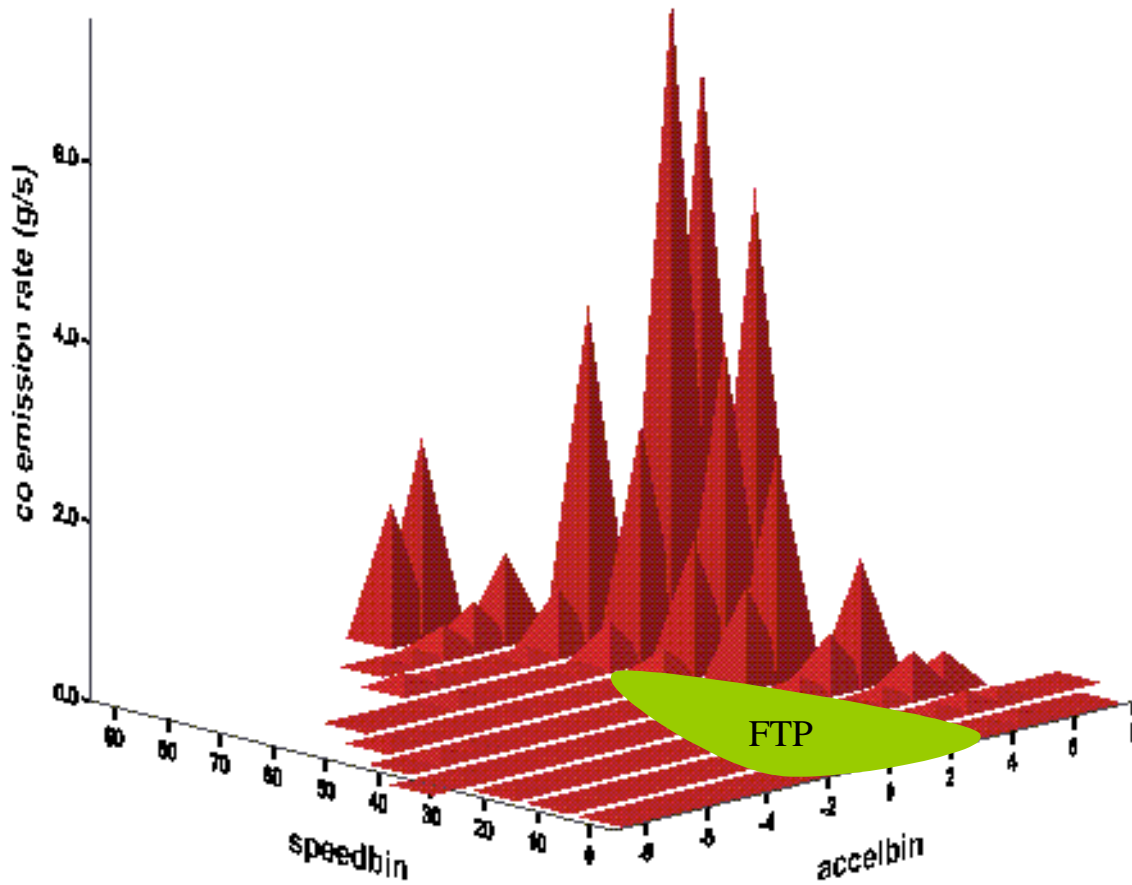**52%** higher than MOBILE6 prediction from cert data

Emissions Where They Occur

Second-by-Second LDVs
Cold Start Data

Real World vs. Lab

Real World vs Lab
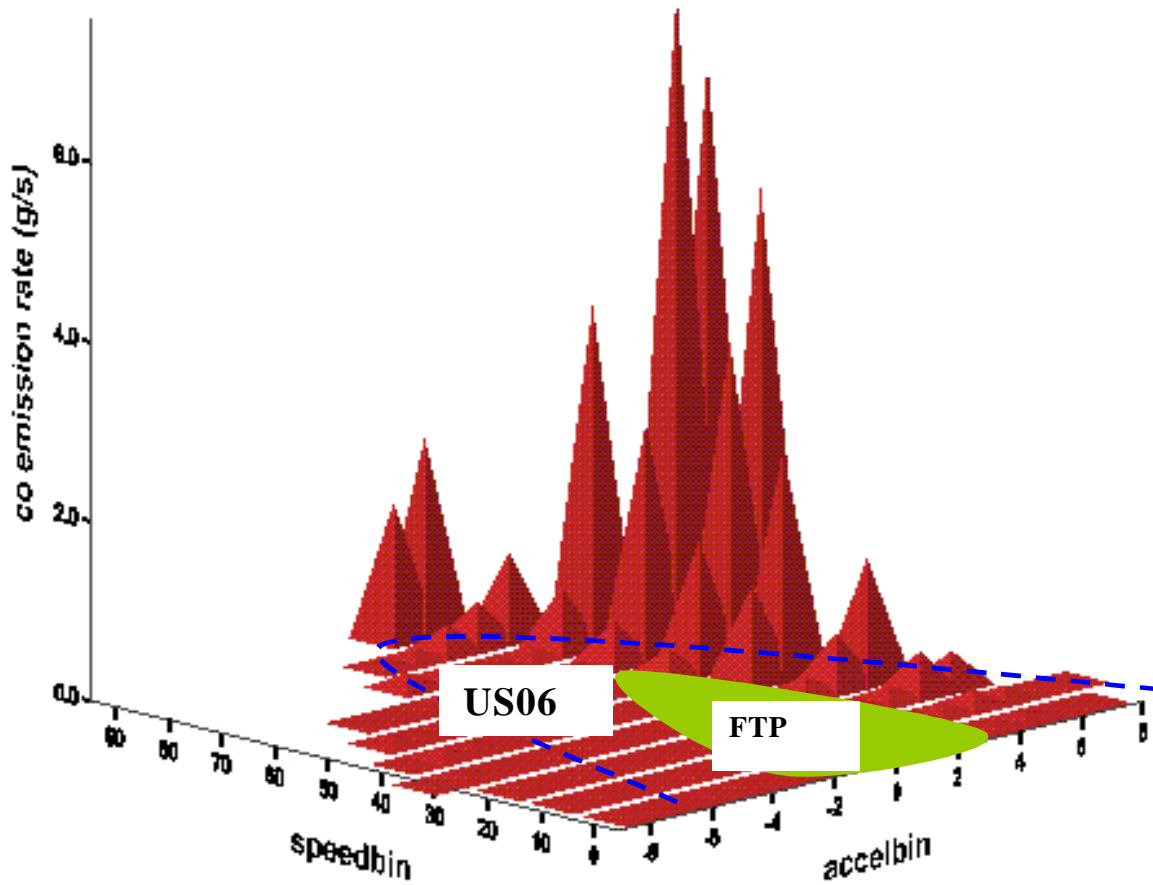
2001-2002 Non-road Progress

- Constructed seven SPOT systems
  - $\underline{S}$imple $\underline{P}$ortable $\underline{O}$n-vehicle $\underline{T}$est system
  - NO_x, O_2, Exhaust Flow, temperatures, pressures, humidity, engine speed
  - 1Hz data collection; 1-week unattended
- Initiated fifty 1-week non-road vehicle tests:
  - Primary purpose to challenge SPOT & develop procedures for non-road data collection
  - 100% complete
  - ~50% of collected data has been processed (QA/QC)

Measuring Emissions in the Field
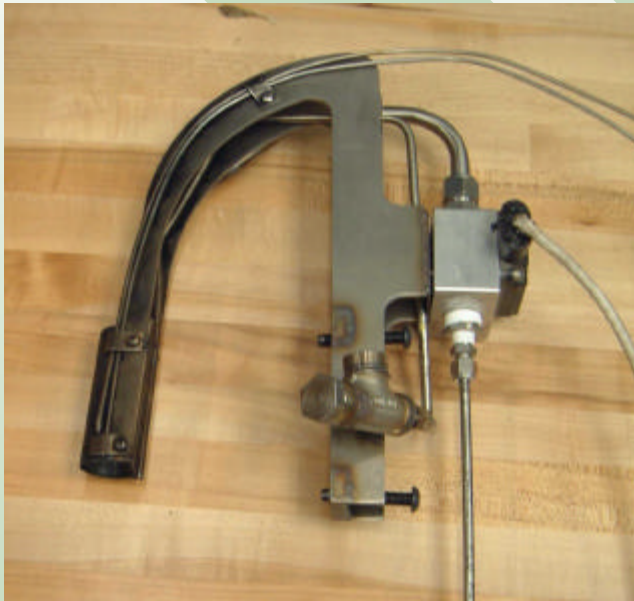
- CAT Dozer D8R
- CAT Scrapper 627B

Non-road Exhaust Flow Device

Flow Device Version 3

Experience Executing Test Plan

- Unexpectedly positive level of volunteerism from owners
  - Data will help EPA set reality-based regulations
  - Testing would never impede productivity
- Logistics challenges
  - Who to contact: start at the top
  - Locating vehicles & tracking vehicle movement
- Field installation challenges
  - Environment: snow, rain, frost, darkness
 - Safety: lifting 80-lb SPOT, speed sensor calibration with tachometer

Conclusions (so far…)

- Non-road effort is already yielding very valuable information
  - Equipment evaluation & test execution
- Results might support a simple, effective compliance protocol for non-road

2002-2003 PEMS Plans

- Acquire four commercially available systems to measure all gaseous regulated pollutants
  - CO, CO_2, NO_x, HC
  - For gasoline and diesel (2 each)
- Develop on-vehicle PM _mass_ measurement instruments
  - EPA lab research with TEOM, PDM, & QCM
    » Includes proportional, partial-flow sampling research
  - SwRI investigation of TEOM and QCM
    » sampling from CVS
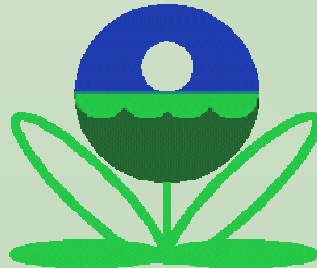
# ON-ROAD, IN-USE DIESEL VEHICLE EMISSIONS ANALYZER

SEMTECH-D

SEMTECH-D
(DIESEL VEHICLE ANALYZER)

Technologies employed:

- **HC:** Heated FID (200^oC)
- **CO:** NDIR (35^oC)
- **CO_2:** NDIR (35^oC)
- **NO:** NDUV (60^oC)
- **NO_2:** NDUV (60^oC)
- **CPU:** Pentium MMX
- **Vehicle ECM Interface(s)**
- **Wireless Communications**
- **GPS**

2002-2003 PEMS Plans

- Evaluate systems against engine dyno, chassis dyno and in-use operations (gasoline & diesel)
  - Accuracy
  - Durability
  - Sensivities/Interferences
- Develop procedures and methodologies including QA/QC for PEMS use.
  - EPA funded test programs
  - Work w/ PEMS manufacturers
  - Work w/ industry (vehicle & engine)
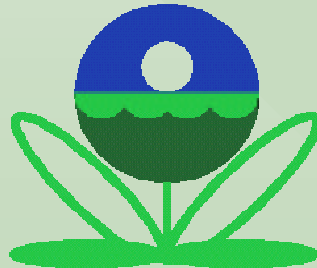
2003-2004 PEMS Plans

- Kansas City PM Test Program
  - To determine the % of the LDV population that are high emitters.
  - Use PEMS/PAMS to gather in-use information.
  - Use continuous mass PM measurements based on tests conducted in Winter '02/Spring '03
- Develop methodologies and sampling procedures to get accurate nonroad population and activity data.
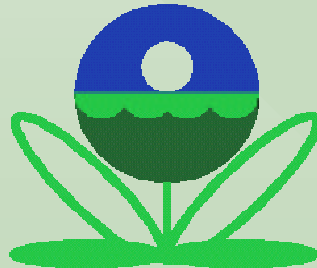
Desired Results from On-Vehicle Measurements

- Robust emissions inventory
- Effective compliance protocol
- Investigate feasibility of on-vehicle certification