

# MOVES

## Heavy Duty HC/CO/NOx

Connie Hart

James Warila, George Hoffman, Bob  
Giannelli, Ed Nam, David Brzezinski

FACA MOVES Meeting  
August 8, 2006

The word "MOVES" is displayed in a bold, metallic, three-dimensional font with a brushed metal texture and a slight shadow effect, set against a dark grey rectangular background.

## MOVES Heavy Duty HC/CO/NO<sub>x</sub>

- What will be different in MOVES?
- Definitions
- Test Programs
- Running
- Hole Filling
- Cold Start
- Extended Idle
- Next Steps

# Definitions

- Light Duty (LDV – not included)
  - Light Duty (< 8500 lbs) & Light Heavy Duty
- Heavy Duty Gasoline Truck (HDGT)
- Heavy Duty Diesel Truck (HDDT)
- Weight Ratings:
  - Based on Gross Vehicle Weight Rating (GVWR) – Rated weight of fully loaded vehicle
  - Light Heavy Duty (LHDT: 8500 – 19500 lbs)
  - Medium Heavy Duty (MHDT: 19501 – 33000 lbs)
  - Heavy Heavy Duty (HHDT: >33,000 lbs)
- Test Weight
  - Weight at which vehicle is tested

## What Will Be Different in MOVES?

- Modal VSP rates vs. Speed Correction Factors
  - VSP directly proportional to bhp-hr units
- Looking into weight correction for higher weights of HHDVs in fleet
- HD idle will be explicitly accounted for in MOVES
- HDD Cold start included in MOVES

## Data

- MOBILE6 is based on engine certification data
- Gathered as much in-use continuous data as we could find
- Real-time data collected on chassis dynamometer by West Virginia University
  - CRC E-55/59
  - WVU
  - Grant '97, NY
- Some on-road data collected (UC Riverside trailer), though not in model yet.

## New Heavy Heavy Duty Diesel Test Data

- Model years 1969 – 2005
- Tests on several driving cycles for each truck

<b>Test Programs</b>	<b>Test Yr</b>	<b>Trucks</b>
CRC_E55/59	2001-2005	66
GRANT97_NY	1999	22
WVU	1998-2002	12
<b>Total</b>		<b>100</b>

Note: After all filters applied, numbers not final

## CRC-E55/59 HDDV Vehicle Information

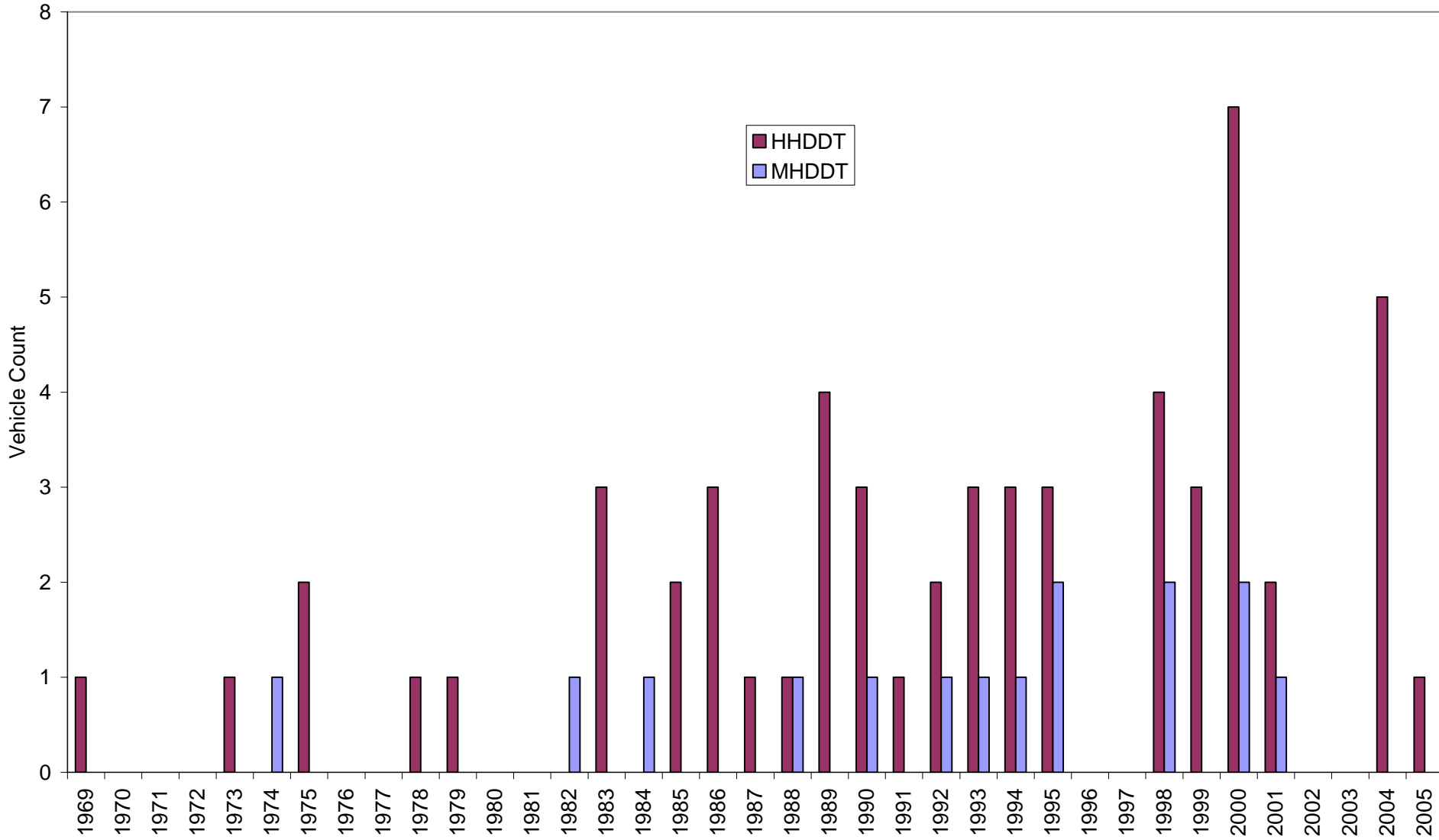
- 78 vehicles:
  - 40 HHDV
  - 36 MHDV
  - 2 MHGV
- 1277 tests, on new CARB truck cycles
- Largest program for HDDVs to date
- SBS for all criteria pollutants

# New Data Strengths & Weaknesses

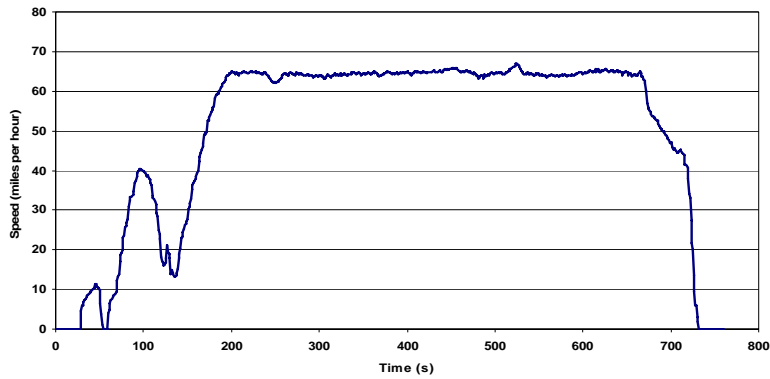
- Strengths
  - Based on in-use trucks
  - Chassis driving cycles based on real-world driving over wide range of operating conditions
  - Reflects real world deterioration & maintenance
- Weaknesses
  - Not randomly sampled
  - Biased to older, potentially dirty trucks
  - Unknown maintenance history or degree of tampering
  - Although biggest dataset yet, only 100 trucks covering 30 model years
  - Outliers driving results



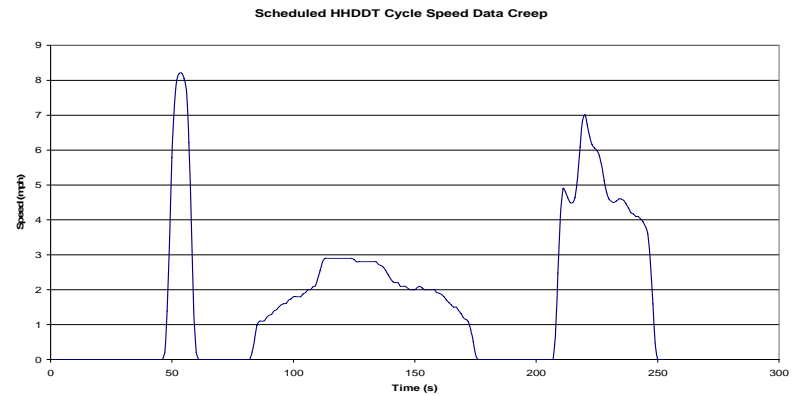
# Coordinating Research Council E-55/59 Heavy Duty Test Program



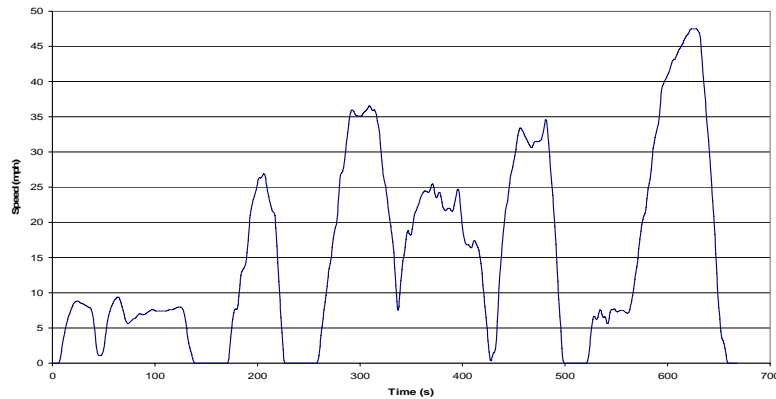
## HHDDT Cycles



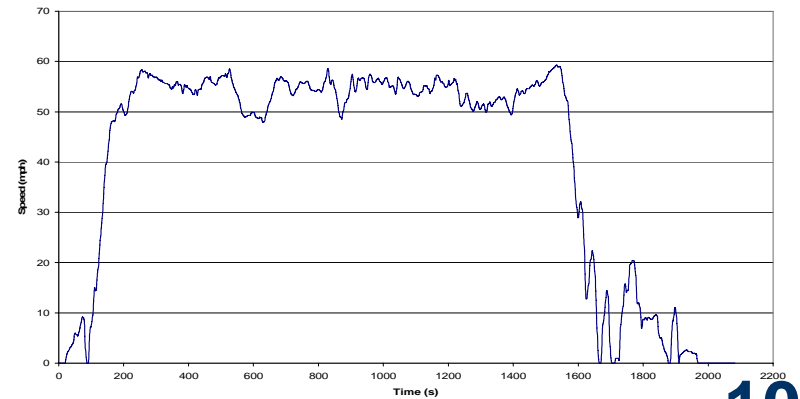
HHDDT Short



HHDDT Creep



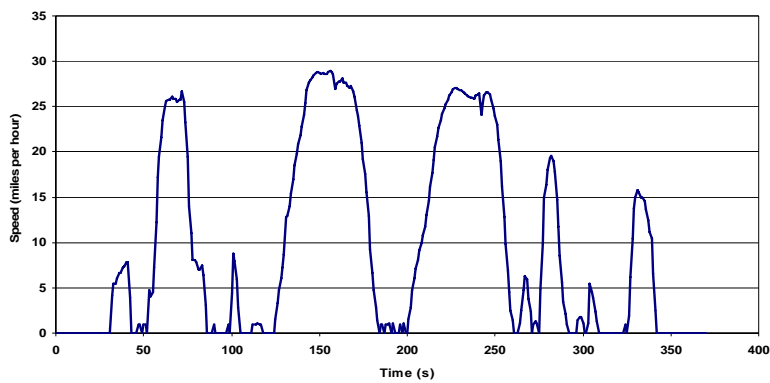
HHDDT Transient



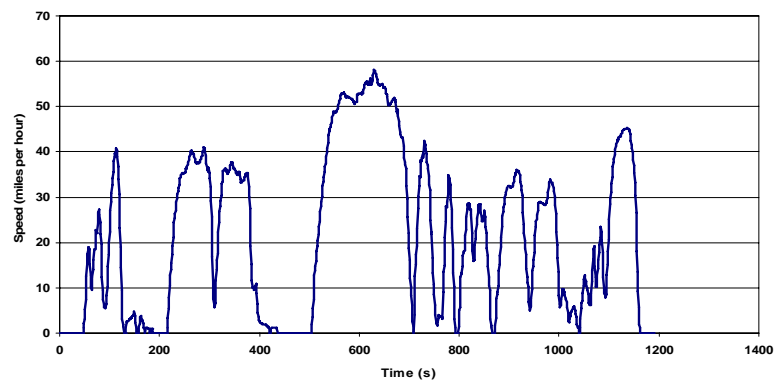
HHDDT Cruise



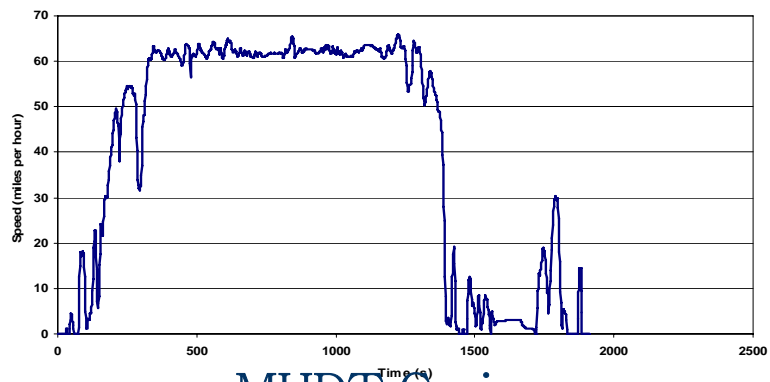
## MHDDT Cycles



MHDT Low Speed



MHDT High Speed



MHDT Cruise

# Running Emissions Analysis

- Time Alignment
- Data Coverage
- Data vs. Holes
- Hole Filling

# Time Alignment

- Similar to Light Duty
- Aligned to Vehicle Specific Power
- NO<sub>x</sub>, CO<sub>2</sub>, and CO aligned independently
- HC and PM aligned with CO

## Data Coverage

- MOVES source bins
  - Regulatory Class
  - Model year
  - Age
- Data represents small proportion of combinations

## Data vs Holes

- Each “bin” represents number of trucks
- Contains many more tests
- Require age depth to model deterioration

Mod Yr	Age of Truck (years old)						
	0-3	4-5	6-7	8-9	10-14	15-19	20+
pre85						3	2
85-87					4		
88-89				1	3		
1990					2		
1991-1993			6	6	1		
1994-1997	13	13	7				
1998-2004	46	4					

CRC E55 data counts not included



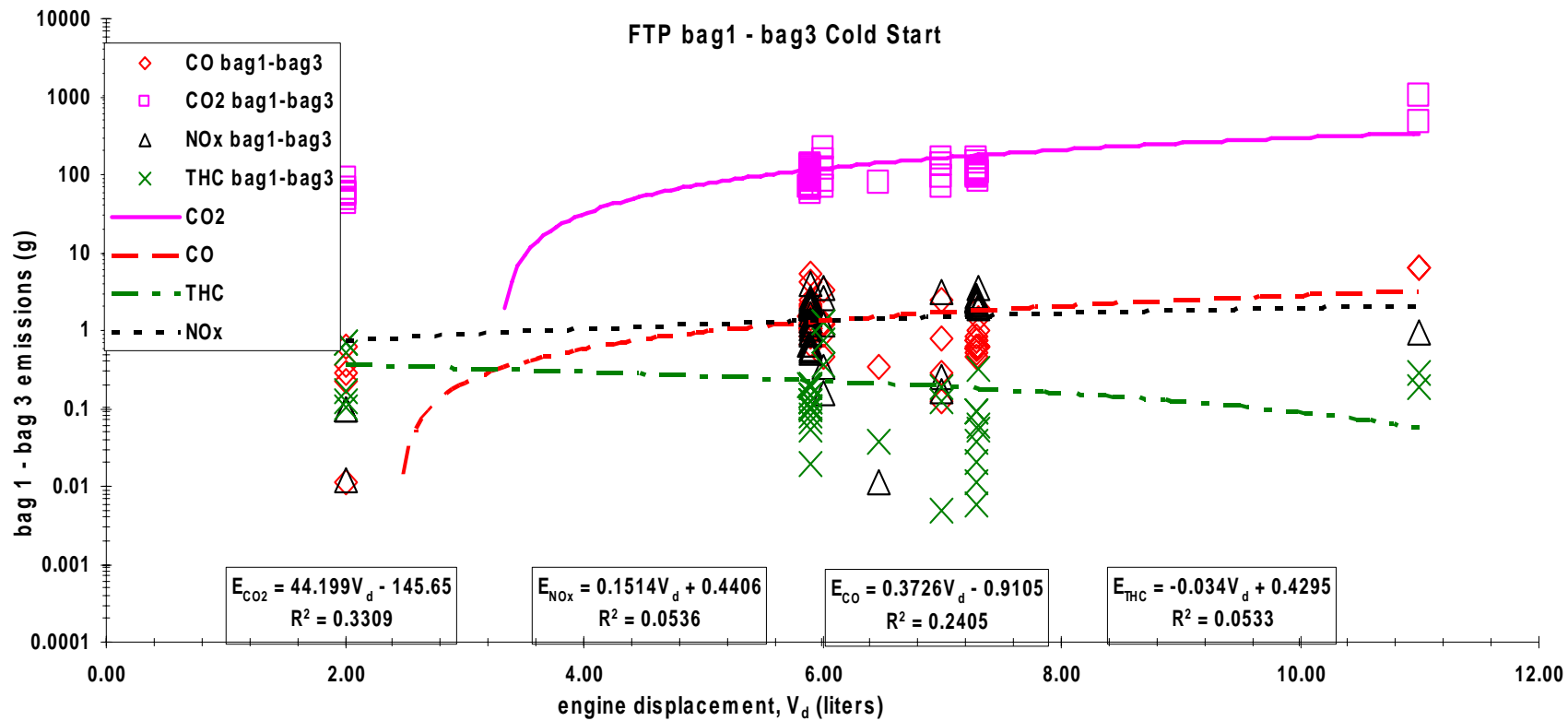
## Hole Filling

- Used mixed model to estimate missing values in VSP/operating mode cells
- Due to the sparseness of the data, and the uniformity of emissions by model year, no deterioration was assumed
- Refining the process

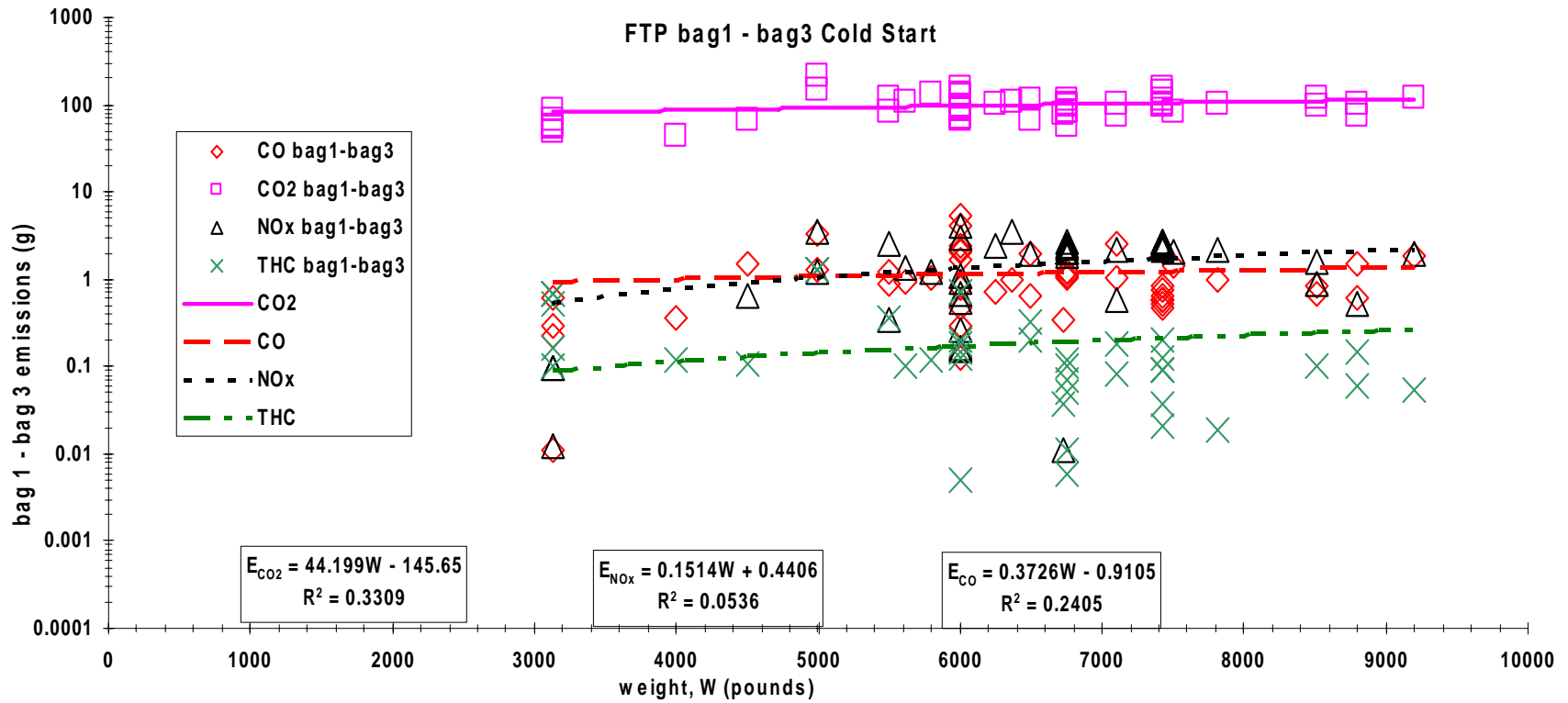


# Cold Start Emissions

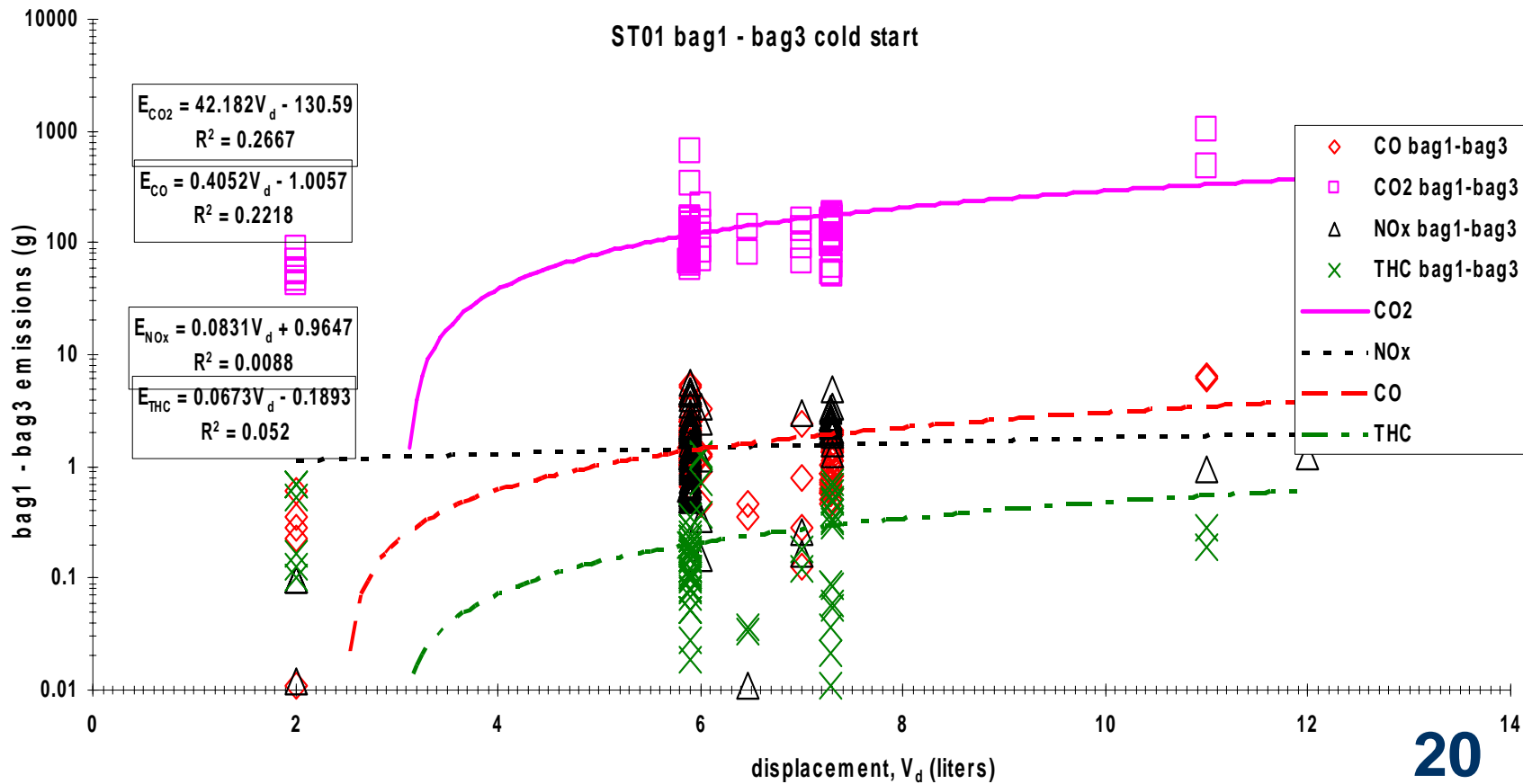
- Cold start data only for LHDD
- Applied to all HDDV
- Explored relationships with engine displacement and weight
- Data led us to take averages



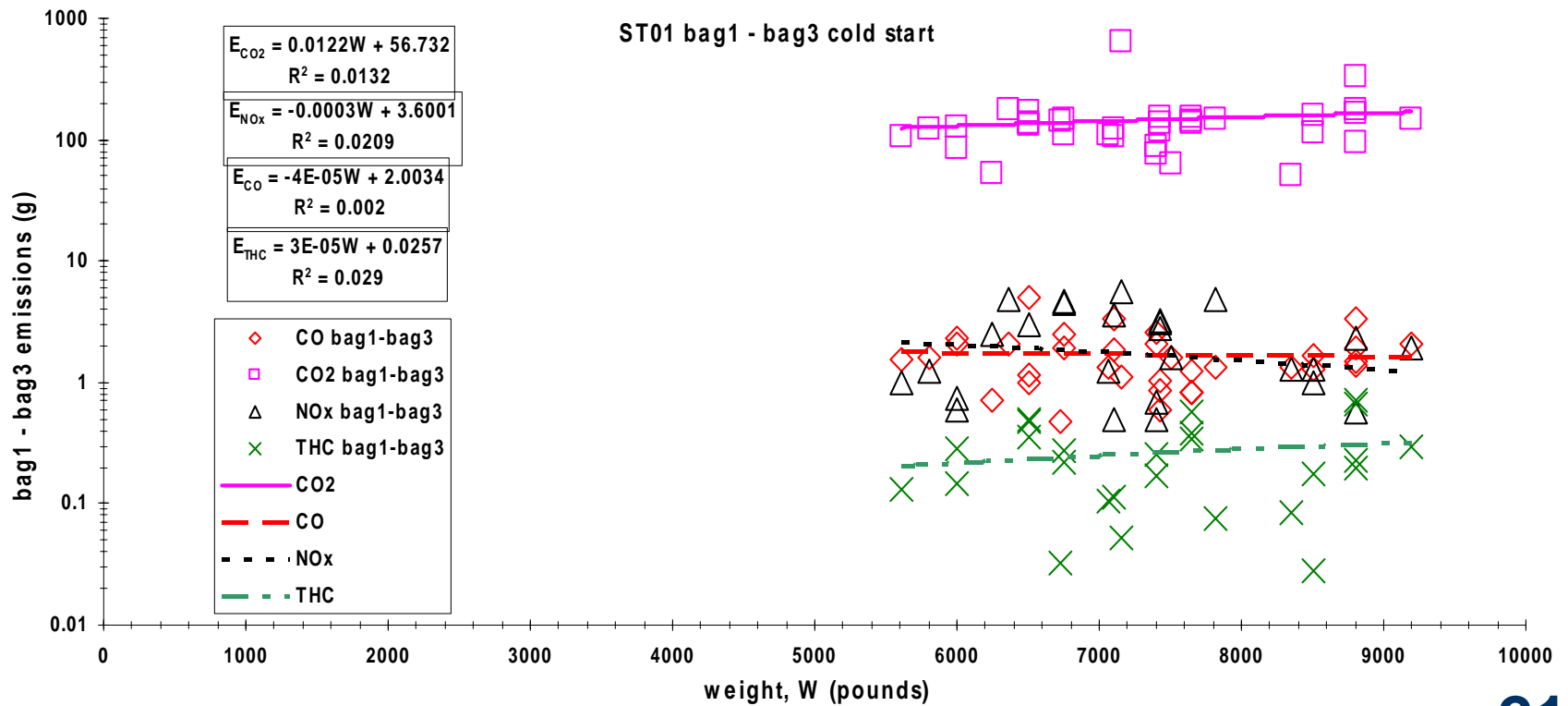
# MOVES



# MOVES



# MOVES



# Extended Idle Operating Mode

- Extended idle is treated as a separate operating mode.
- Extended idle emissions represent engine operation during long periods of “hoteling” or rest periods by long distance truck drivers.
- Activity is defined by federal law that requires 10 hours of rest for every 14 hours of driving.
- Only long haul combination trucks have extended idle emission rates.

# Extended Idle Emission Data

- Pre-1988 model year rates are taken from EPA guidance regarding idling control: <http://www.epa.gov/smartway/idle-guid.htm> .
- 1988 and newer model year rates taken from “Evaluation of Heavy-Duty Diesel Vehicle Emissions During Cold-Start and Steady-State Idling Conditions and Reduction of Emissions from a Truck-Stop Electrification Program,” Dissertation Presented for the Doctor of Philosophy Degree, University of Tennessee, Knoxville, James A. Calcagno, III (December 2005).
- Effects of 2007 standards taken from “Draft Analysis of Heavy-Duty Diesel Vehicle Idle Emission Rates,” (EPA420-D-03-001, November 2003).



## Extended Idle Emissions

- Assume major effects of the new 2007 standards on idling PM emissions, but very small effects on HC, CO and NO<sub>x</sub> emissions.
- Reflect the use of accessories (A/C, heaters, televisions, etc.) and engine manufacturer recommendations to increase idle speed during long duration idle periods.
- Extended idling measurements have large variability due to low engine loads.



## Next steps

- Evaluate the representativeness of the data to reflect the in-use fleet.
- Address age effects vs. model year
- Look into weight correction factor
- Continue refining hole filling process

# Acknowledgments

- **West Virginia University:** Nigel Clarke, David McKain, Mrudal Gautam
- **MOVES Emissions Analysis Team:** David Brzezinski, Bob Giannelli, Ed Glover, Connie Hart, John Koupal, Larry Landman, Edward Nam, Erika Roesler, George Scora, Sujan Srivastava, James Warila
- **Data Acquisition Team:** Carl Fulper, Carl Scarbro, Bob Short