

# MOVES Heavy Duty PM

**Connie Hart**

**Edward Nam, George Hoffman**

FACA Meeting  
August 8, 2006

EPA Office of Transportation & Air Quality

**MOVES**



# MOVES Heavy Duty PM

- What will be different in MOVES?
- Data from CRC E-55/59
- EPA contract with WVU:
  - Processing of TEOM data
  - Expand database with predictive model
- EC/OC split
- Hole Filling
- Next Steps

## What Will Be Different in MOVES?

- VSP vs. Speed
- Looking into weight correction for higher weights of HHDVs in fleet
- HD idle will be explicitly accounted for in MOVES
- PM2.5 (PM10 coming in MOVES2007)
- Given as EC or OC

## CRC E-55/59 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
- TEOM SBS PM for subset of vehicles (167 tests)

## New Heavy Heavy Duty Diesel Test Data

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

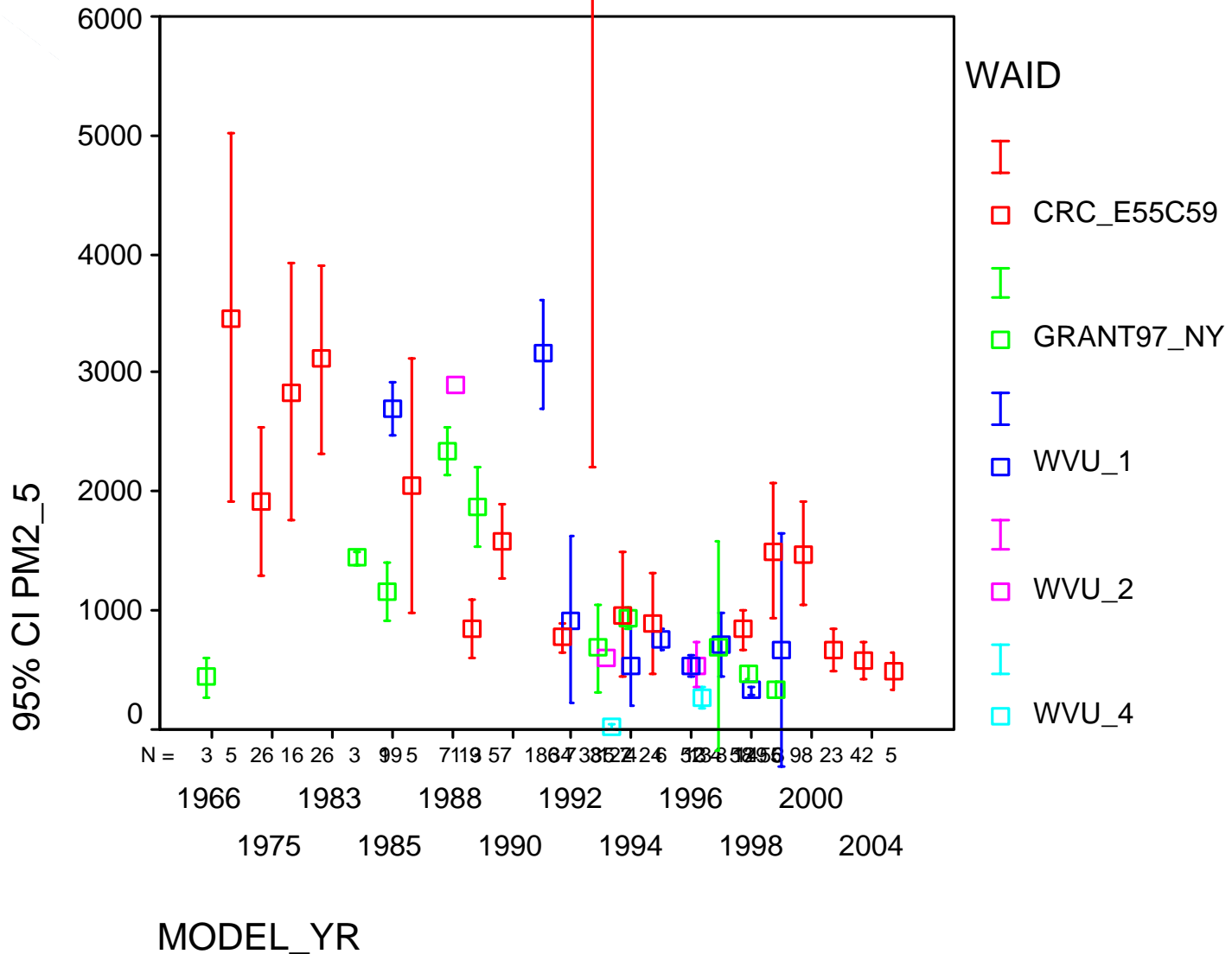
<b>Test Programs</b>	<b>Test Yr</b>	<b>Trucks</b>
CRC_E55/59	2001-2005	66
GRANT97_NY	1999	22
WVU	1998-2002	12
<b>Total</b>		<b>100</b>

Note: After all filters applied, numbers not final

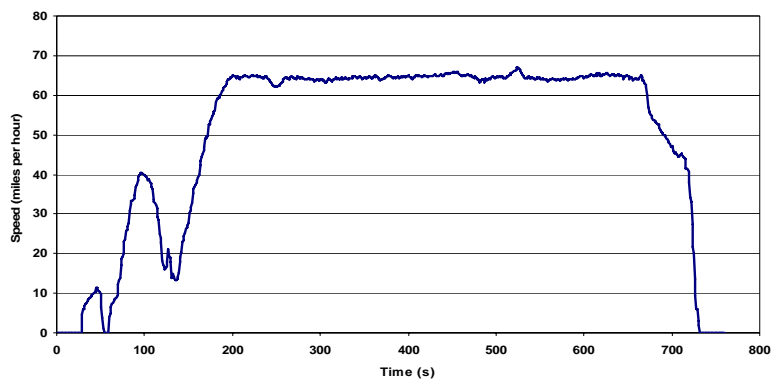
# New Data Strengths & Weaknesses

- 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

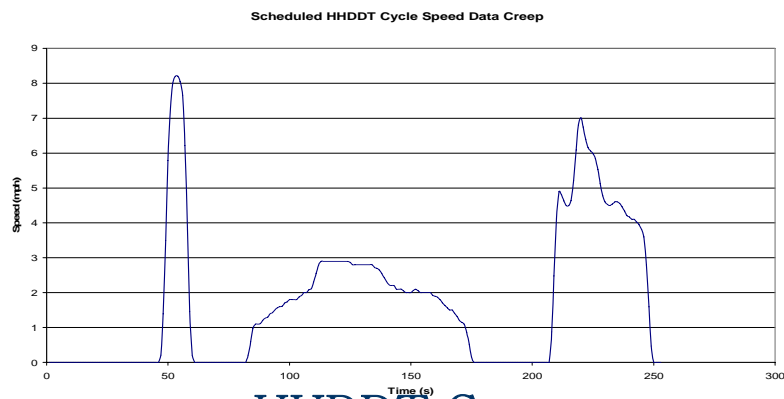
- Emissions higher for older technologies, but steady after 1993
- Hi-Emitters can lead to odd trends
- Test programs consistent with each other



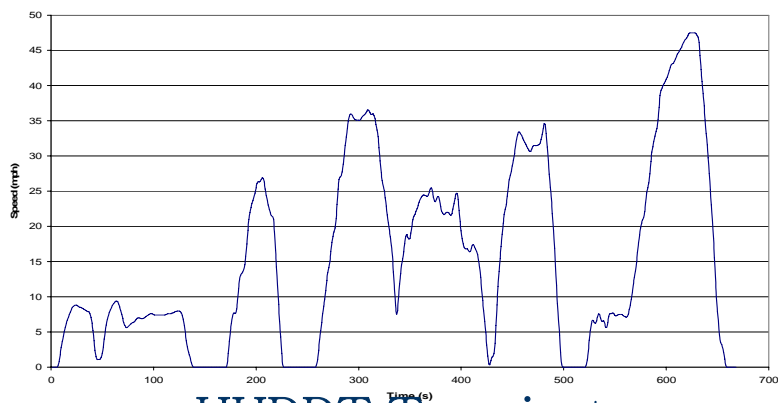
## HHDDT Cycles



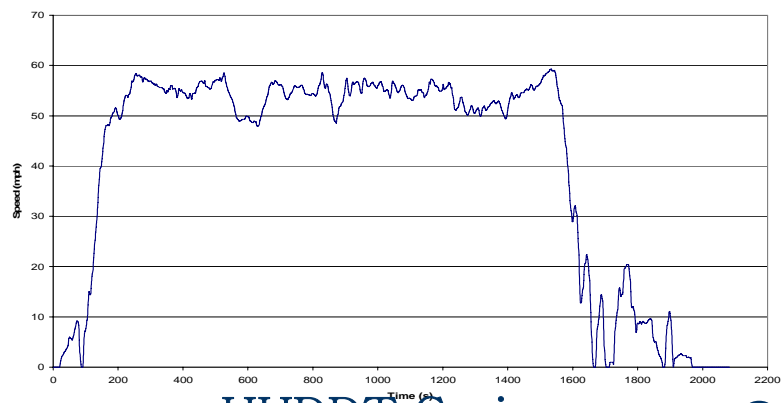
HHDDT Short



HHDDT Creep



HHDDT Transient

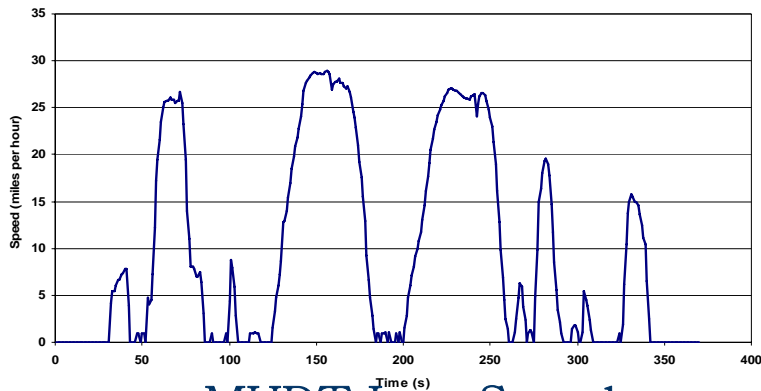


HHDDT Cruise

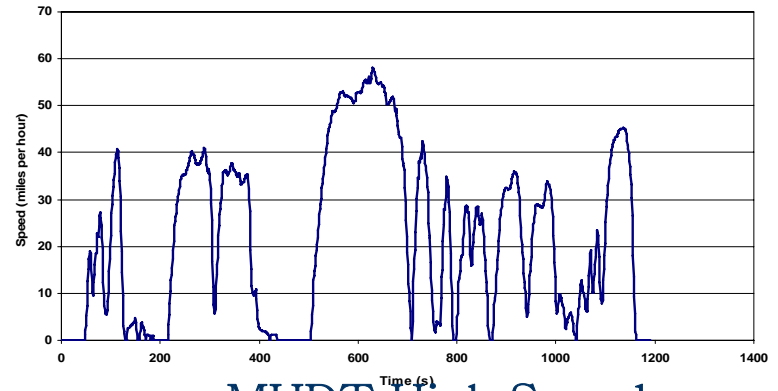




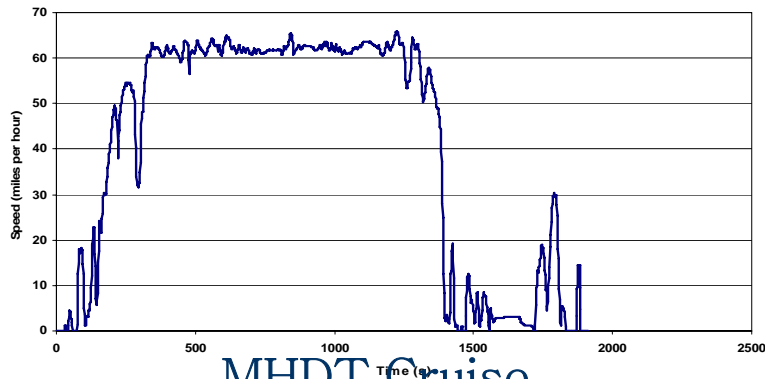
## MHDDT Cycles



MHDT Low Speed



MHDT High Speed

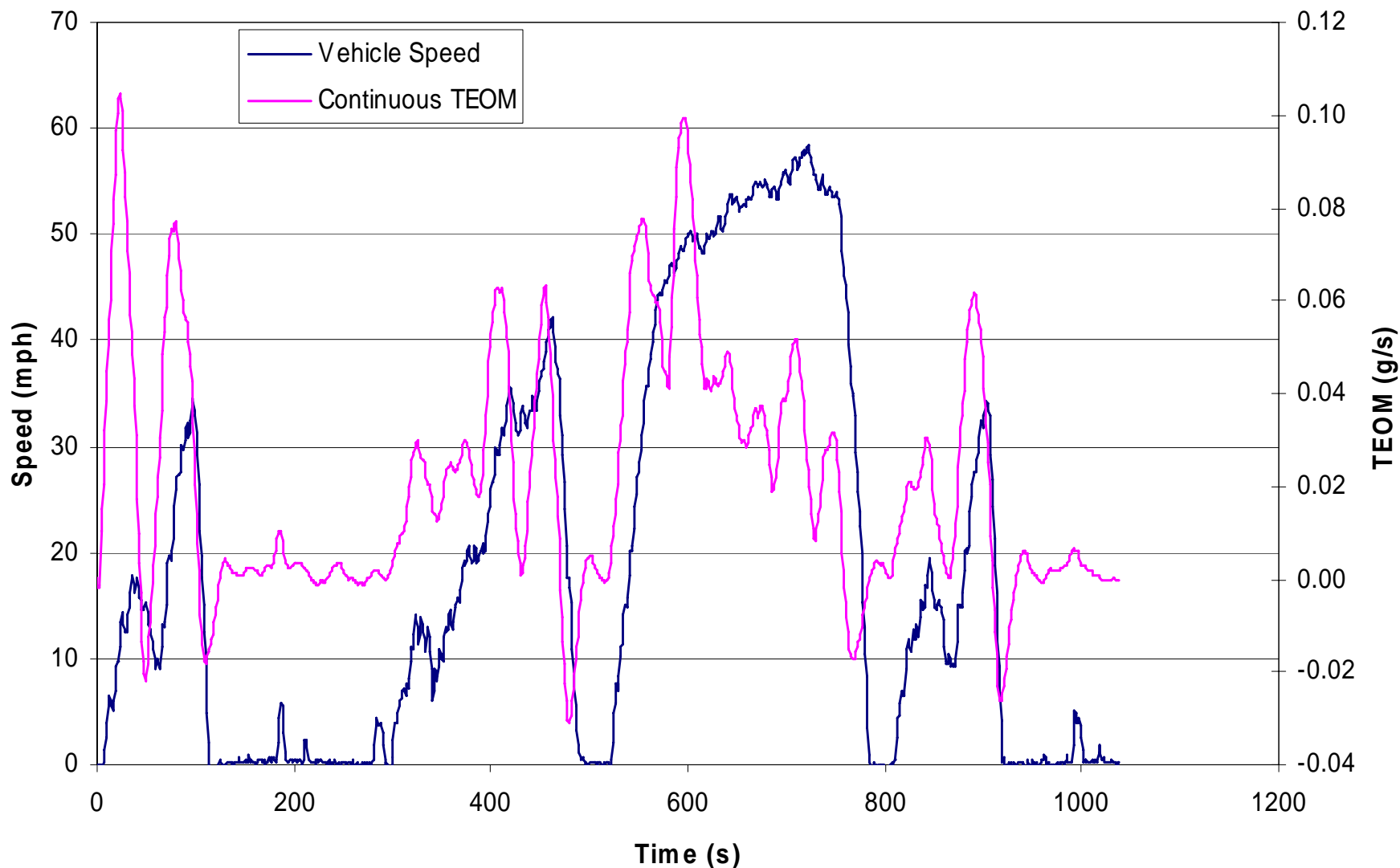


MHDT Cruise

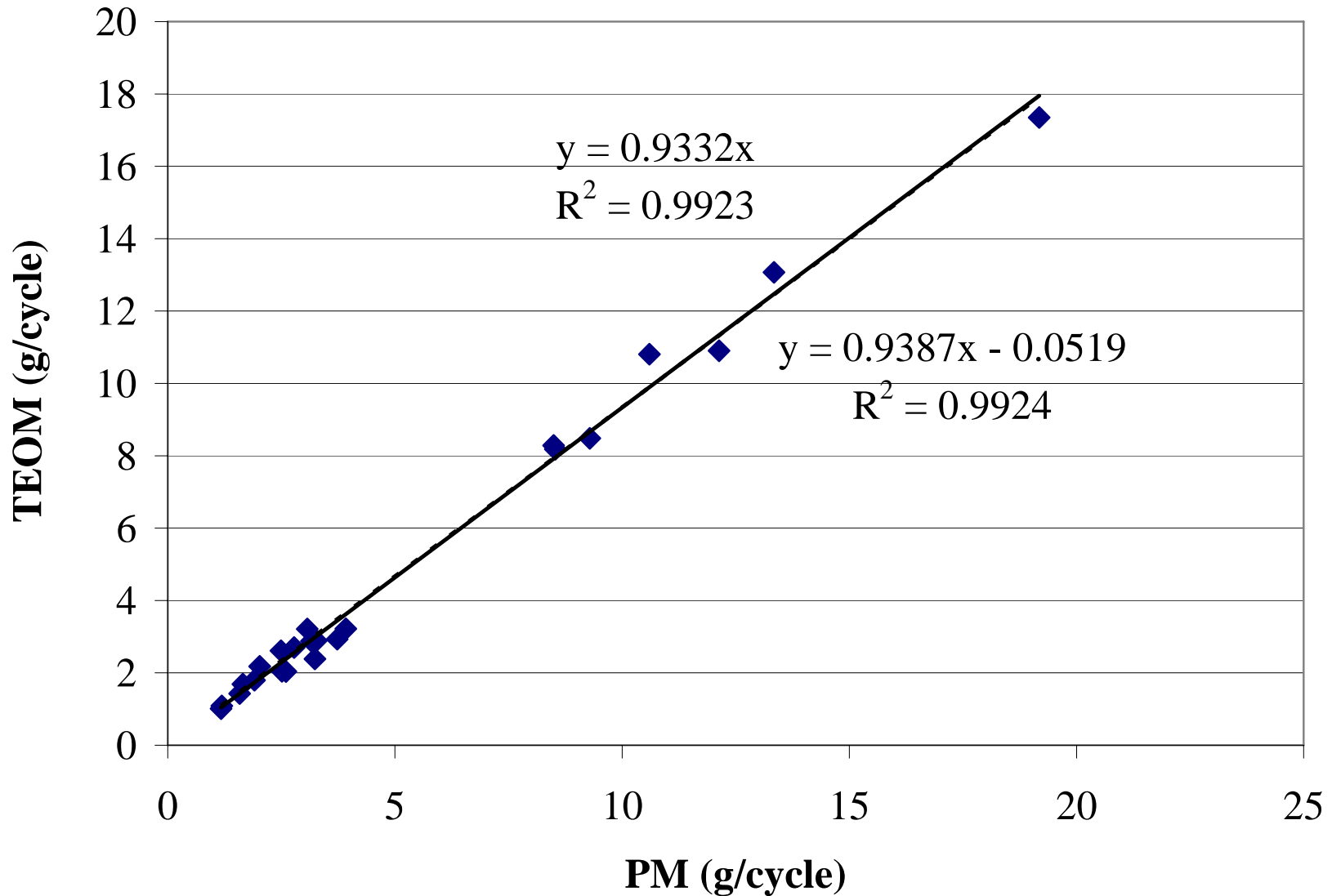
## EPA Contract with WVU

- Create TEOM, DMS500, CO, CO2 dataset
- Water correct TEOM data using Jarrett method
- Apportion corrected TEOM data to gravimetric PM
- Apportion DMS500 continuous data to gravimetric data
- Increase PM database: Apportion continuous CO data to filter-based PM data for each test
- Compare methods, recommend best set of continuous PM data from E-55/59

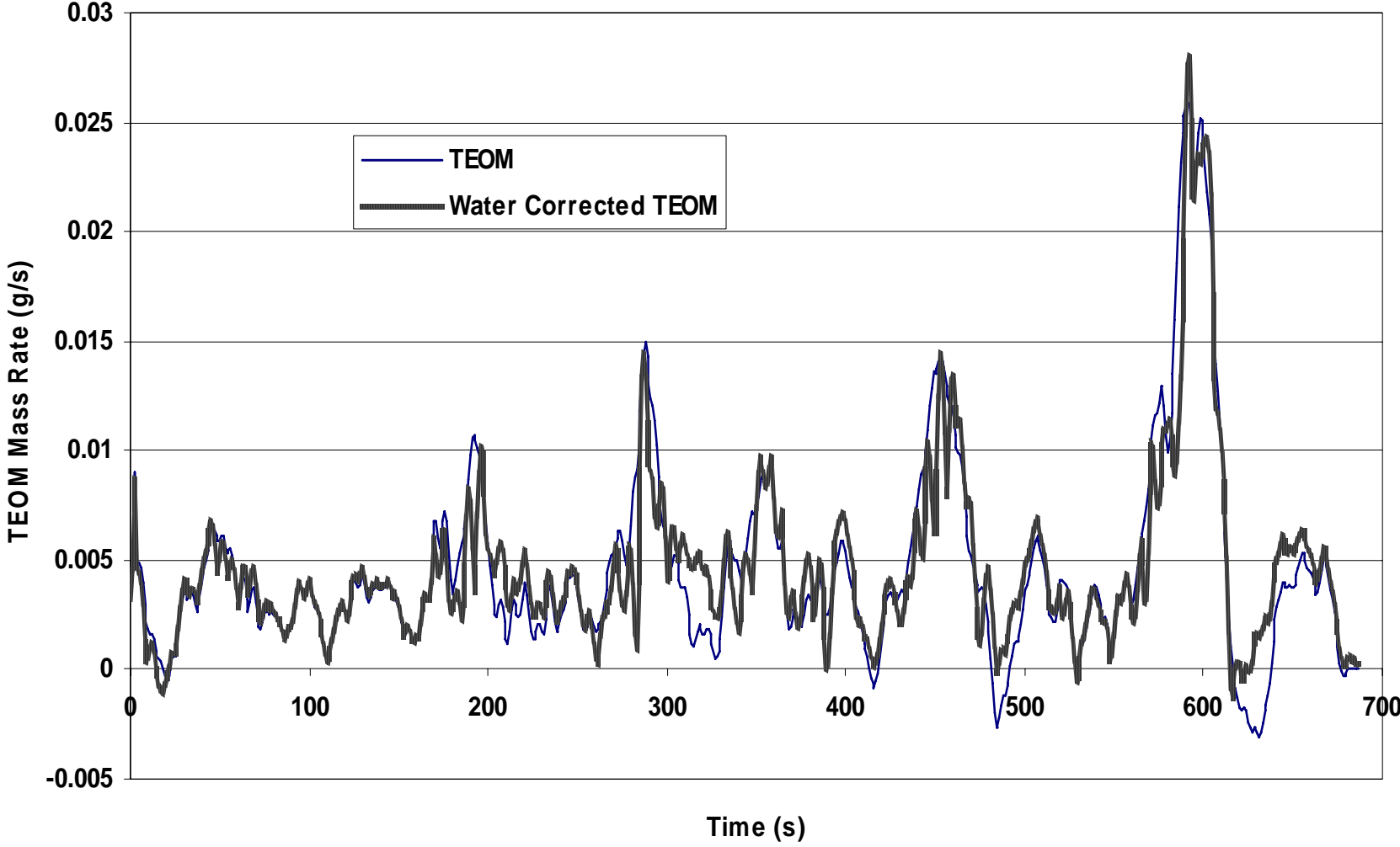
# Continuous TEOM mass rate data from a 1983 truck over the Transient mode of the HHDDT:



# TEOM versus PM Based on 22 Trucks HHDDT Transient Cycle



# TEOM vs. Water Corrected TEOM, CRC26 HHDDT Transient Cycle



# Predictive Model Formulation

- CO not complete picture: varies from engine to engine with  $R^2$  ranging from .06 to .83
- CO correlates well with EC, both from rich zones in cylinder
- HC correlates well with OC
- Idle isolated for better correlation

## Predictive Models

- Equation 4a: 
$$PM_i = PM_{total} \left( \frac{CO_i}{CO_{total}} \right)$$

- Equation 4b: 
$$PM_i = \left[ \frac{PM_{total}}{n} - (PM_{idle})_i \right] n \left[ \frac{CO_i}{CO_{total}} \right] + (PM_{idle})_i$$

- Equation 4c: 
$$PM_i = PM_{total} \left[ \frac{aCO_i + bHC_i}{aCO_{total} + bHC_{total}} \right] + (PM_{idle})_i$$

where 
$$\frac{aCO_{total}}{bHC_{total}} = \frac{EC}{OC}$$

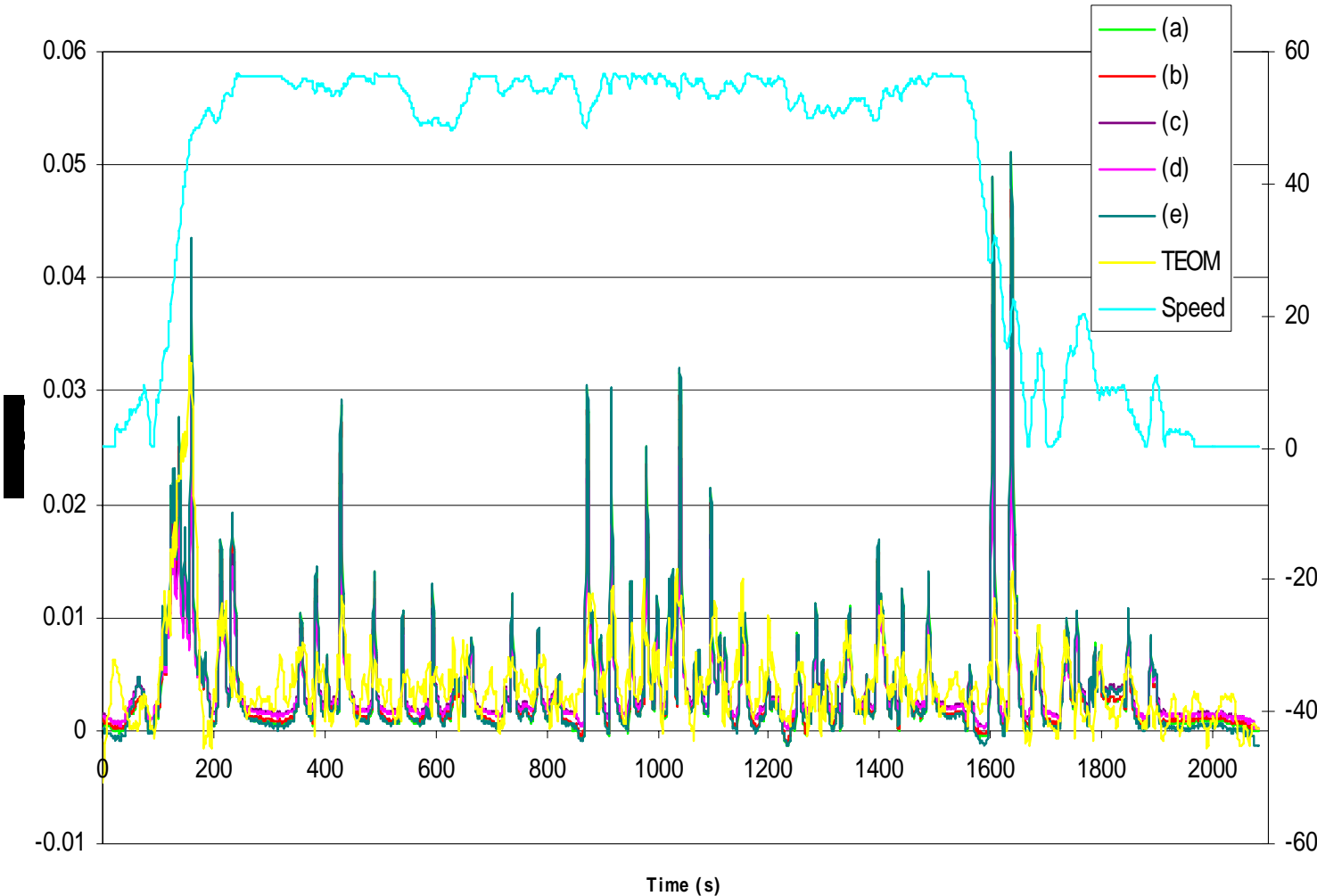
- ★● Equation 4d: 
$$PM_i = \left[ \frac{PM_{total}}{n} - (PM_{idle})_i \right] n \left[ \frac{aCO_i + bHC_i}{aCO_{total} + bHC_{total}} \right] + (PM_{idle})_i$$

where 
$$\frac{aCO_{total}}{bHC_{total}} = \frac{EC}{OC}$$

- Equation 4e: 
$$PM_i = \left[ \frac{PM_{total}}{n} - (PM_{idle})_i \right] n \left[ \frac{a(CO - CO_{idle})_i + b(HC - HC_{idle})_i}{a(CO_{total} - CO_{idle}) + b(HC_{total} - HC_{idle})} \right] + (PM_{idle})_i$$

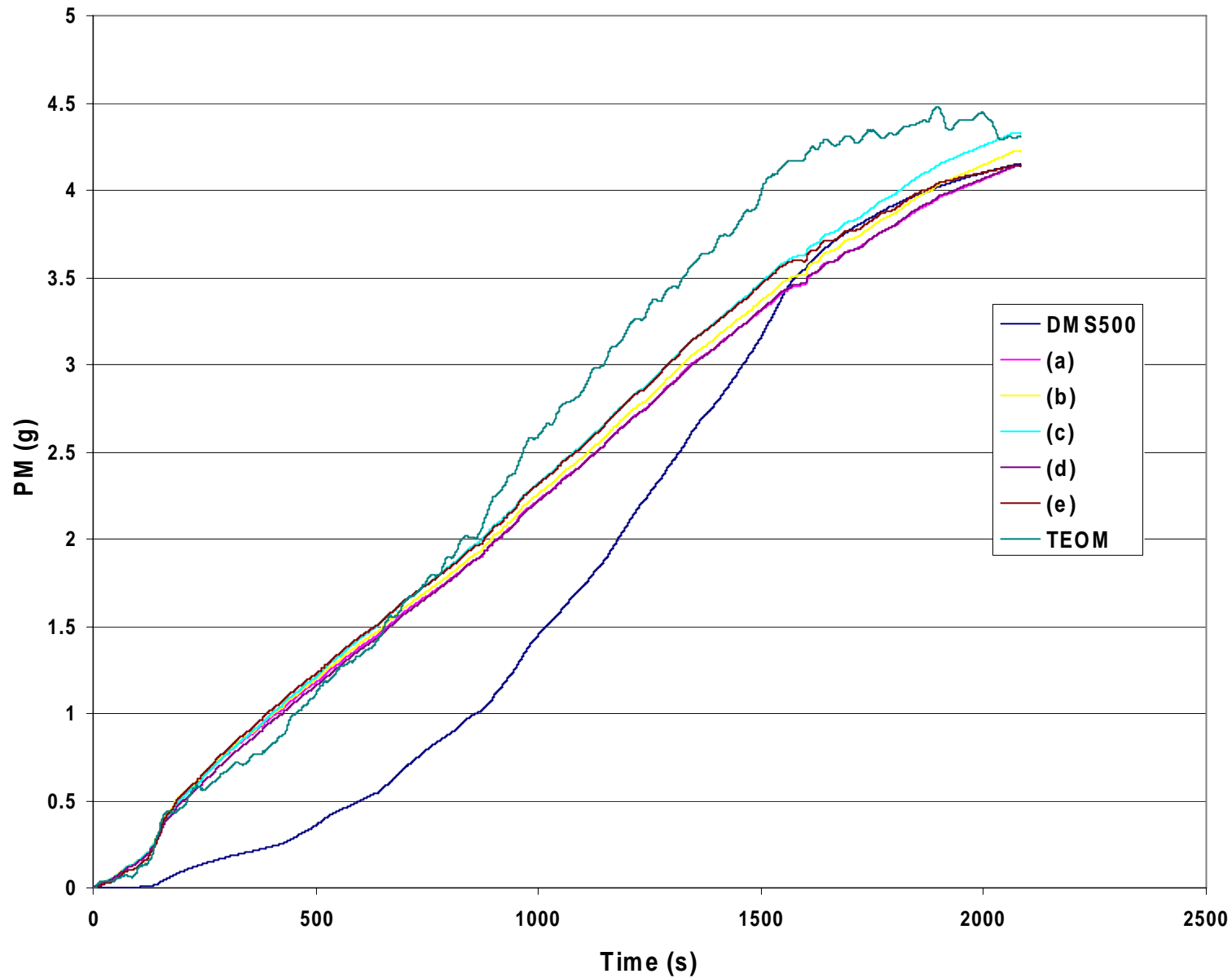
where 
$$\frac{aCO_{total}}{bHC_{total}} = \frac{EC}{OC}$$

# 5 Predictive Equations and TEOM data HHDDT Cruise Cycle



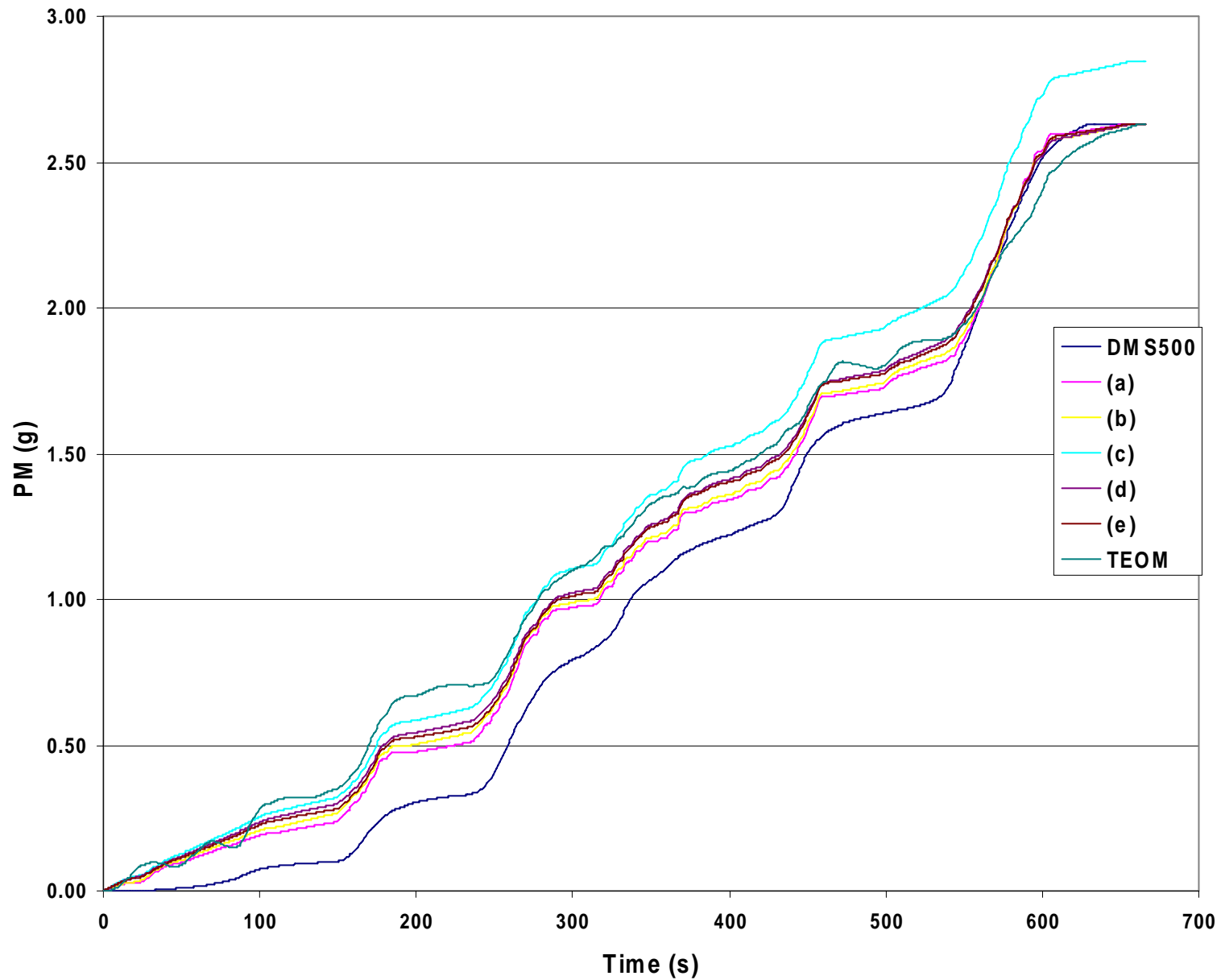


# Cumulative PM Over the HHDDT Cruise Cycle





# Cumulative PM Over the HHDDT Transient Cycle



# MHDDT

- No idle PM data
- Equation 5.

$$PM_i = PM_{total} \left[ \frac{aCO_i + bHC_i}{aCO_{total} + bHC_{total}} \right]$$

## EC/OC Split

- 6 Tests in E-55/59
- 3 usable HHDDT (CRC39, CRC42, CRC43)
- Split into Transient, Cruise and Idle
- Will revisit before Draft MOVES version is released, looking at all possible data sources

## EC and OC Fractions of Total PM

	Idle		Combined Transient and Cruise	
	ECfraction	OCfraction	ECfraction	OCfraction
HHDDT	0.34	0.59	0.64	0.32

## Hole Filling

- Model year age source bins are sparse
- No deterioration in current model
- Used mixed models to estimate missing values in VSP/operating mode cells
- Refining the process

## Time Alignment

- Alignment procedure similar to Light Duty
- NO<sub>x</sub>, CO<sub>2</sub>, and CO aligned independently.
- HC and PM aligned with CO.



## 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
- Revisit EC/OC split utilizing all available data
- Continue refining hole filling process

# Acknowledgments

- **West Virginia University:** Nigel Clarke, David McKain, Mrudal Gautam
- **EPA:** Carl Scarbro