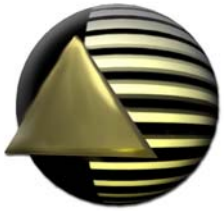
Development of an On-Road Heavy Duty Emissions Research Laboratory



University of California, Riverside

Bourns College of Engineering - Center for Environmental Research and Technology

Presentation

To

Mobile Sources Technical Review Subcommittee

October 23, 2001

Sponsors and Funding Agencies

YEAR ONE

- **Diesel OEMs**
  - **Detroit Diesel, Caterpillar, Cummins, Volvo, International, Mack**
- **USEPA**
- **California Air Resources Board**
- **South Coast Air Quality Management District**

YEAR TWO

- **USEPA**
- **Cummins (3 years), Detroit Diesel (Pending)**
- **California Air Resources Board**
- **California Energy Commission**
- **South Coast Air Quality Management District (Pending)**

CE-CERT PERSONNEL

Faculty: Matt Barth; David Cocker; Wayne Miller; Joe Norbeck

Engineering Staff: Mitch Boretz; Kent Johnson; Dave Pankratz; Chan Seung Park; George Scora; Matt Smith; Bill Welch

Technicians: Don Pachoca; Terry Traver

Graduate Students: Lin Chen; Ben Lin; Yuan Lon

Visiting Professor: Hongchang Zhou

Eight Undergraduate Students

Outline of Presentation

- **Background and Motivation**
- **Design and Technical Approach**
- **Initial Evaluation and Results**
- **Future Research Agenda**

Operational Requirements

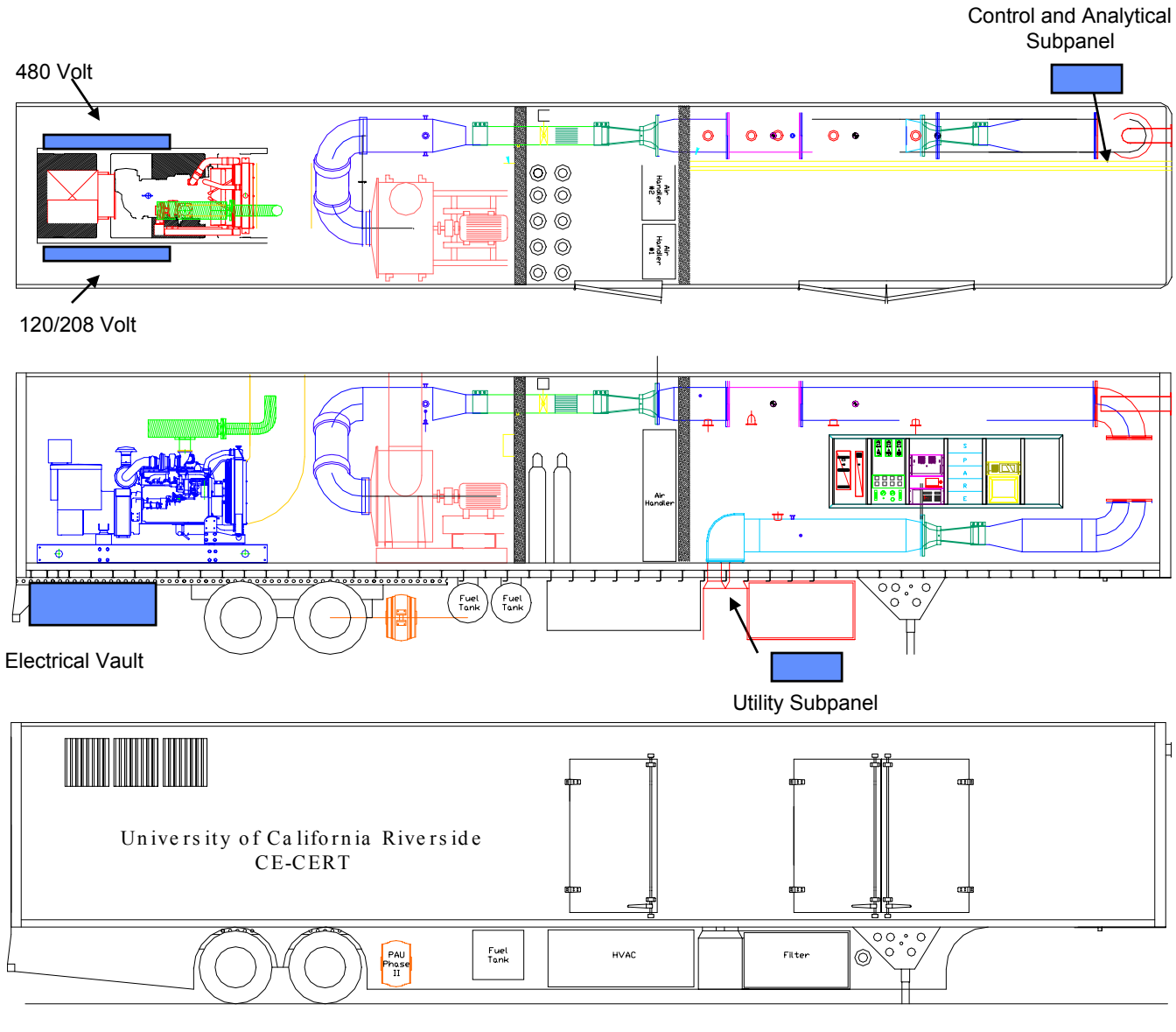
- **CFR requirements**
  - **Real time @1Hz HC and NO_x**
  - **CO and CO_2 either real time or via bag**
  - **Fuel consumption by direct measurement or via CO_2**
  - **1% Calibration standard accuracy**
- **Cycle requirements**
- **Calibration requirements**
- **Size and weight requirements**
- **System data logging and control**

Technical Challenges and System Flexibility

- Need to demonstrate reproducibility and equivalence with engine dyno testing and certification (meet CFR requirements)
- Need to speak several languages in evaluation and use of data
  - Emissions as function of load
  - Emissions as function of distance
  - Comparison with chassis dyno
  - Comparison with engine dyno
- Need modal emissions (real time) for all pollutants Including particulates
  - Organic and elemental carbon
  - Full chemical speciation of semi-volatile and particulate
- Need to be able to test large fleet of vehicles at minimum time and cost

Basic Systems Overview

- 53 ft. refrigerated container trailer with air ride suspension
- Horiba smooth approach orifice CVS/dilution tunnel system
- Gaseous emissions bench with dilution calibration system
- Comprehensive data acquisition/control system on Labview platform
- GPS based driver's aid
- Support equipment (275 kW generator, HVAC)


Control and Analytical Subpanel
480 Volt
120/208 Volt
Air Handler #2
Air Handler #1
Air Handler
Fuel Tank
Fuel Tank
Electrical Vault
Utility Subpanel
University of California Riverside
CE-CERT
PAU Phase II
Fuel Tank
HVAC
Filter


CE-CERT MOBILE ON-ROAD HEAVY DUTY EMISSIONS LABORATORY
IN COOPERATION AND PARTNERSHIP WITH
VOLVO
UCR

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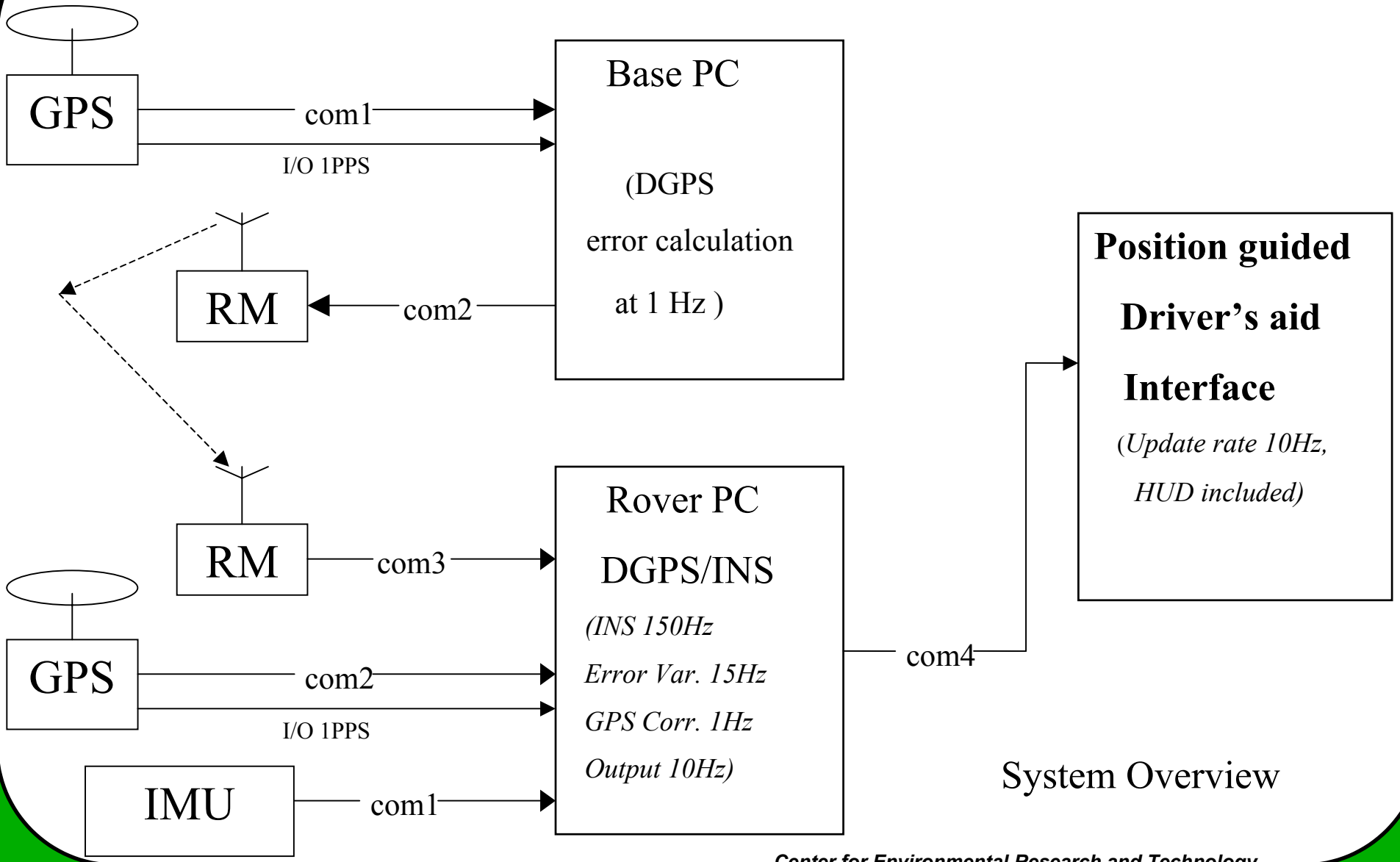
GPS Guided Driving Cycle Aid for HDV



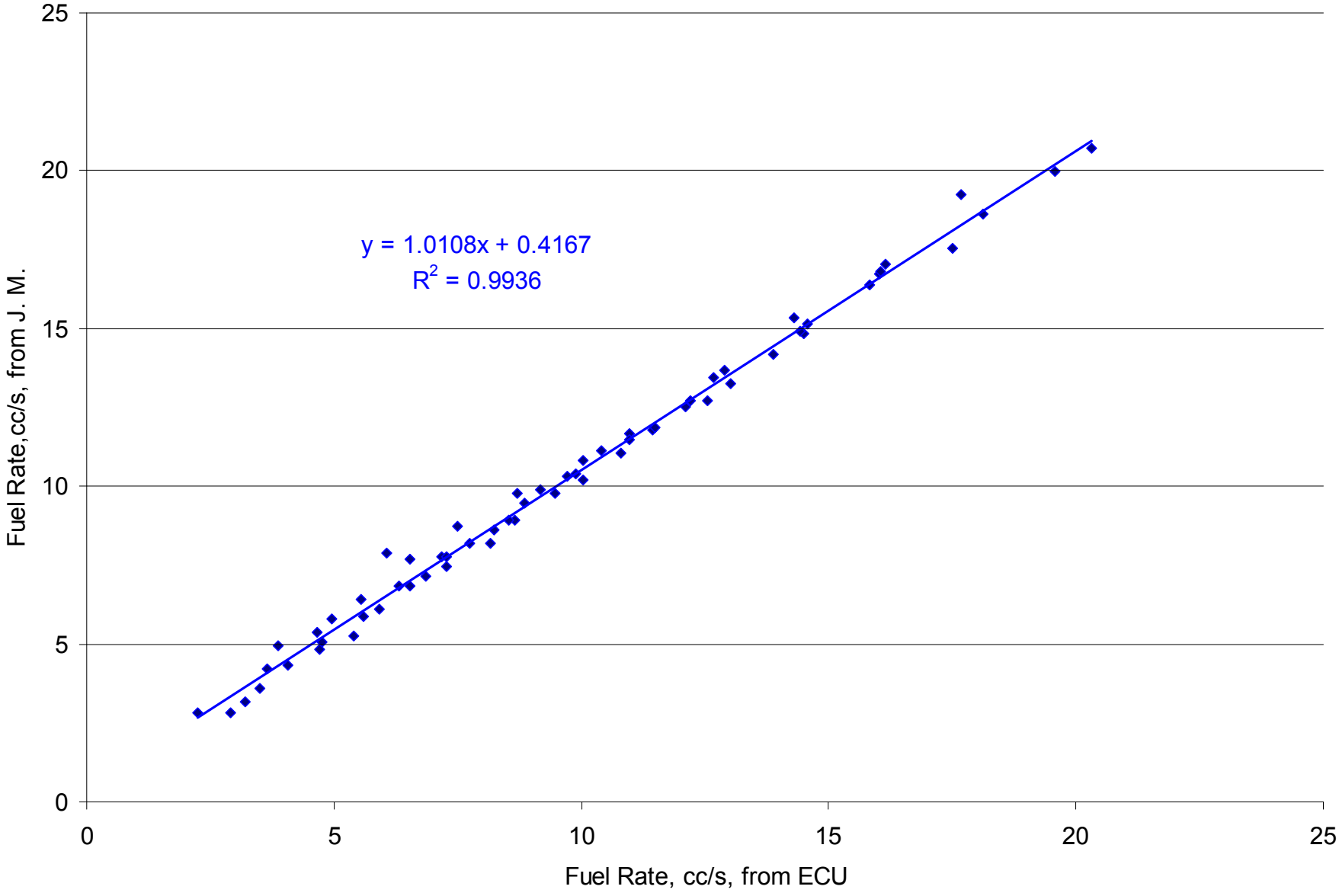
System Overview

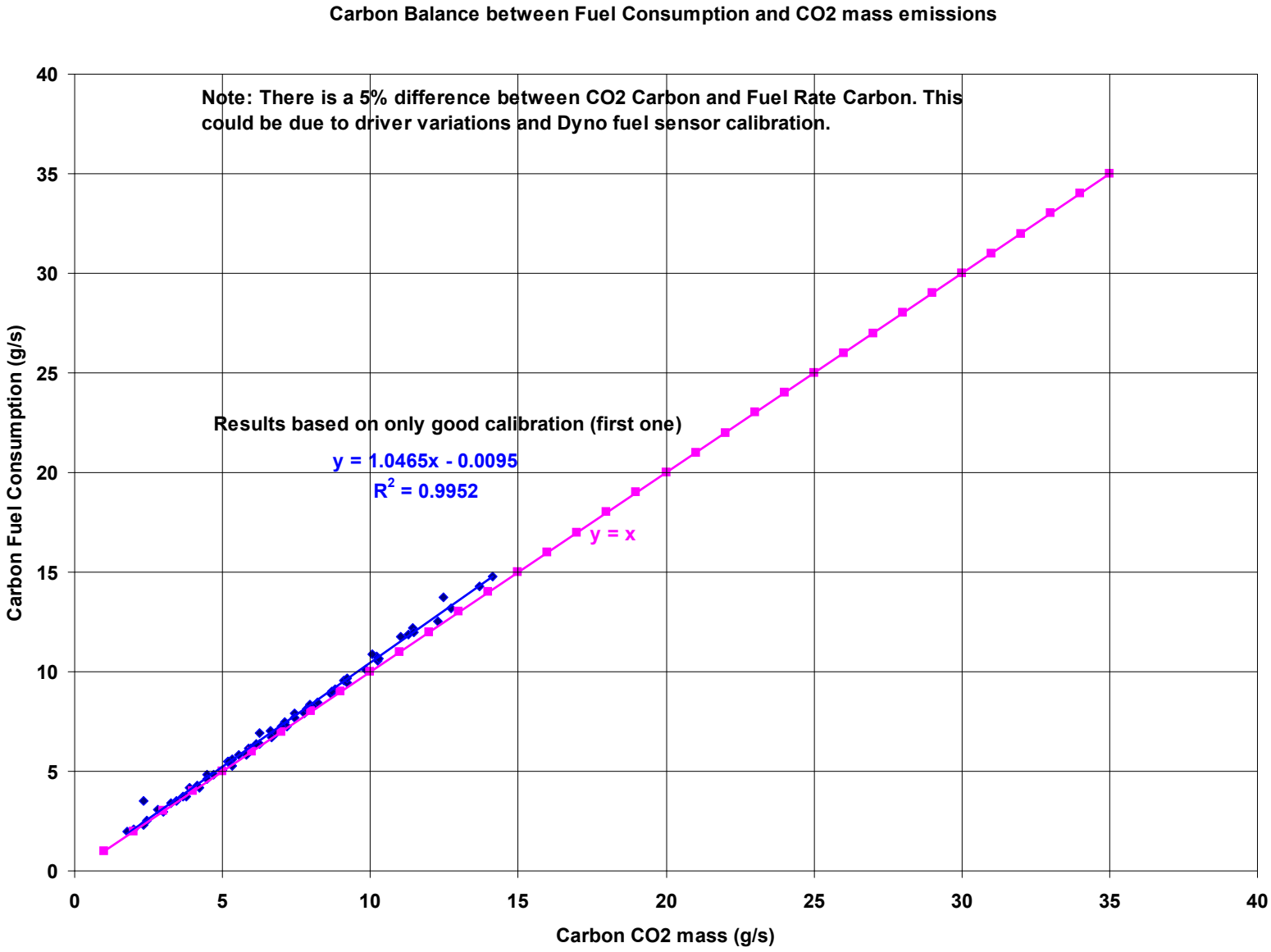
Verify the Analytical Systems

- **Propane material balance @ 98+%**
- **Independent measurements of:**
  - **Fuel flow**
  - **Load (torque)**
  - **NOx (3 analyzers)**
- **Mobile and stationary calibrations**

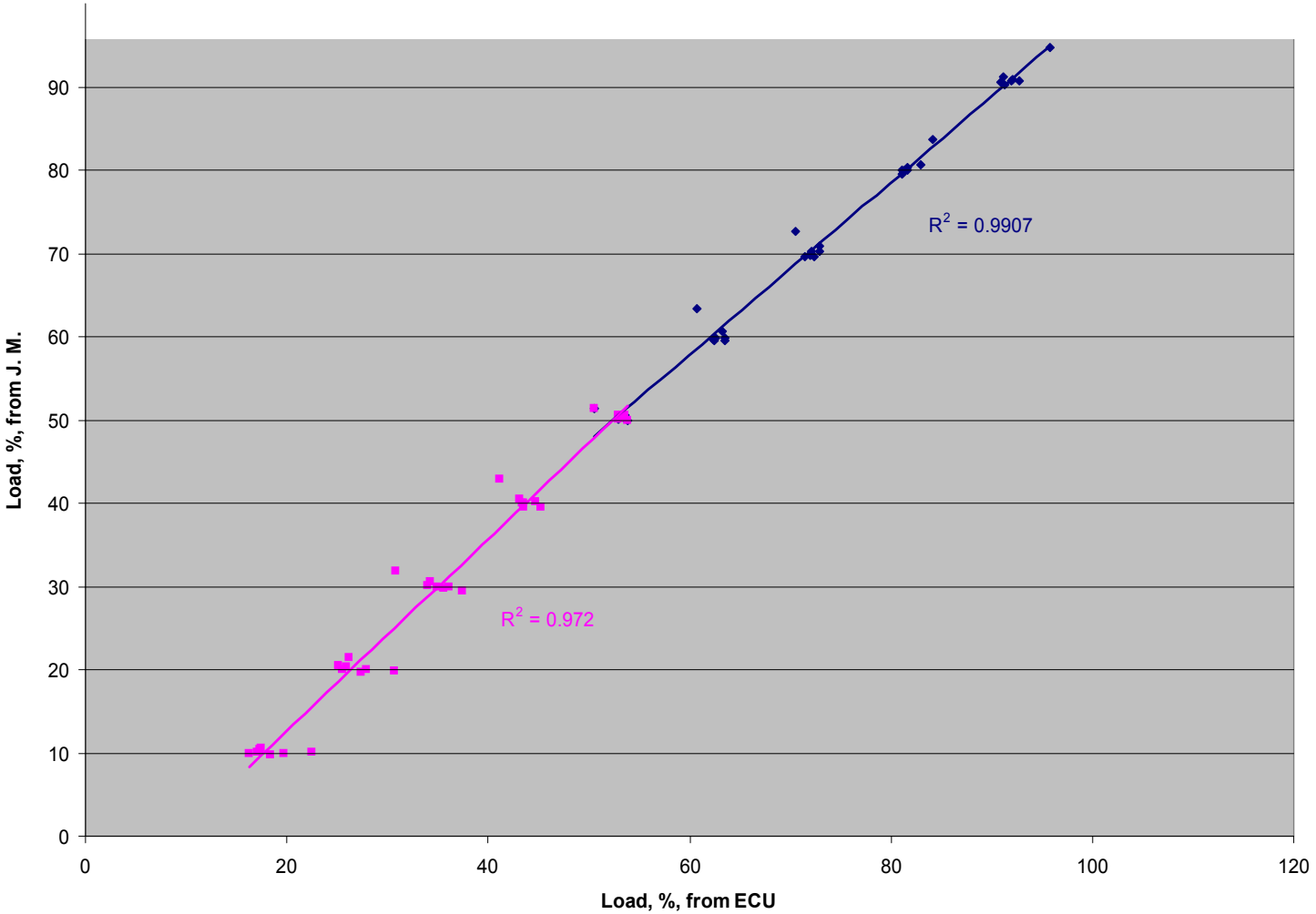
Propane Injection Mass Recovery

Test ID #	CVS flow scfm	Concentration THC ppm C1	Mass Inject g	Mass Recovered g	Recovery %
200107180940	2500	85.9	29.77	29.68	100.3%
200107190901	2501	84.5	29.13	28.86	100.9%
200107191032	2500	83.6	29.17	28.89	101.0%
200107261315	2500	83.9	29.11	28.92	100.7%
200107261359	2500	83.2	28.93	28.69	100.8%
200108061239	2500	82.8	28.56	28.42	99.5%
200108061326	2499	82.4	28.67	28.51	99.4%
200108061412	2499	83.9	29.11	28.94	99.4%
200108061456	2500	83.3	28.98	28.76	99.2%
200108131002	2500	82.1	29.36	29.62	100.9%
200108131428	2500	80.1	29.02	29.04	100.1%
200108140843	2500	81.4	29.27	29.13	99.5%
200108140928	2500	80.4	29.00	28.67	98.8%
200108141015	2500	80.2	28.84	28.55	99.0%
200109061103	2499	82.8	29.40	29.19	99.3%
200109061103	2499	82.8	29.40	29.21	99.4%
200110010901	2500	84.2	29.27	29.13	99.5%
				Average	99.9%
				95% Conf	1.47%


y = 1.0108x + 0.4167
R2 = 0.9936
Fuel Rate,cc/s, from J. M.
Fuel Rate, cc/s, from ECU
0
5
10
15
20
25


Carbon Balance between Fuel Consumption and CO2 mass emissions
Note: There is a 5% difference between CO2 Carbon and Fuel Rate Carbon. This could be due to driver variations and Dyno fuel sensor calibration.
Results based on only good calibration (first one)
y = 1.0465x - 0.0095
R2 = 0.9952
y = x
Carbon Fuel Consumption (g/s)
Carbon CO2 mass (g/s)
0
5
10
15
20
25
30
35
40

Verification of Load

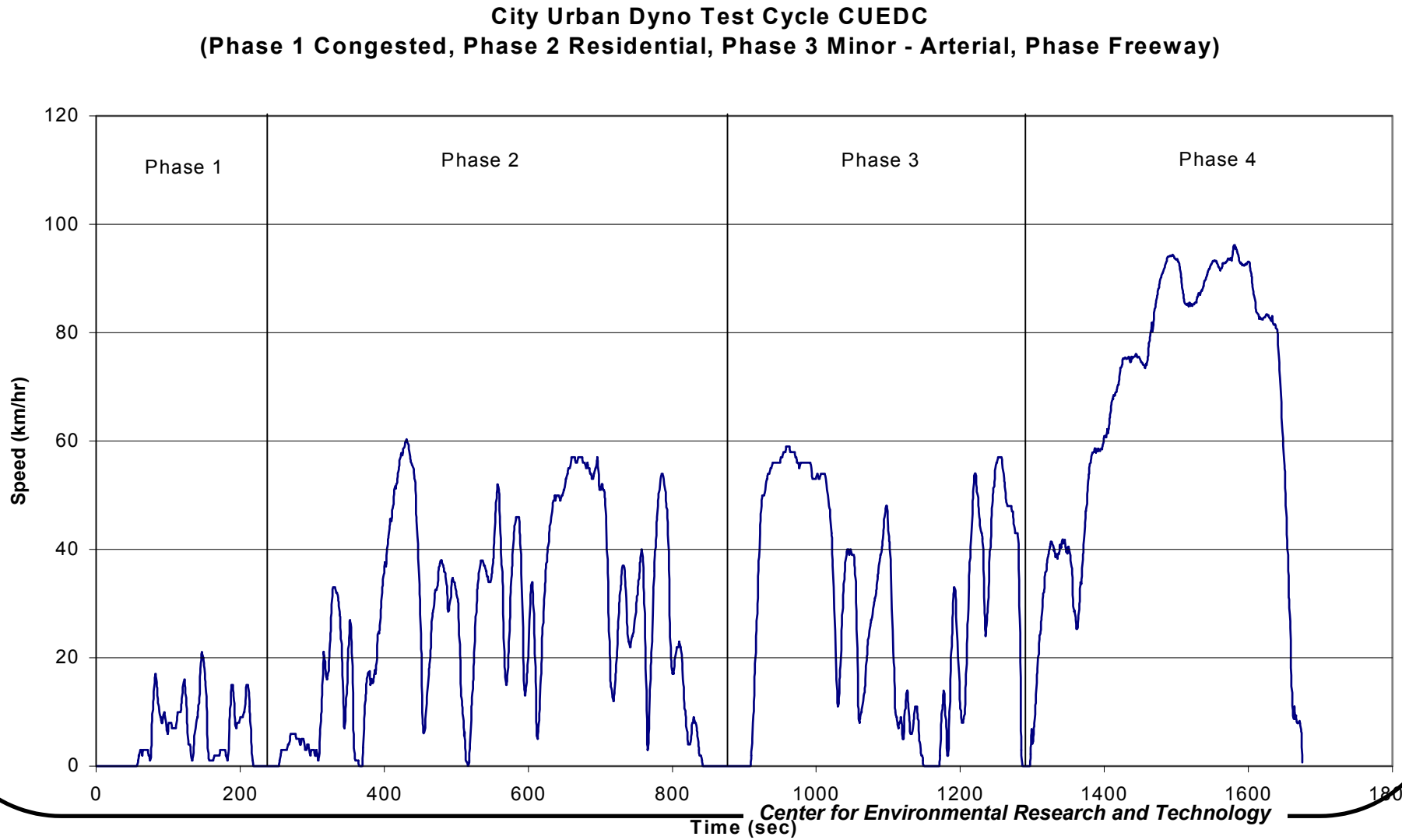


On-Road Repeatability of WVU 5-Cycle is Good

- **Example of relative error at 95% confidence limits after eight runs:**
  - **Fuel used - 0.98%**
  - **Engine power - 1.25%**
  - **Tractor work - 1.19%**
  - **Driver deviations – 5.88%**

WVU 5 Mode Cycle at Cabazon Up Hiil 1.5% Grade and a Head Wind

. Four-Phase HDD Cycle



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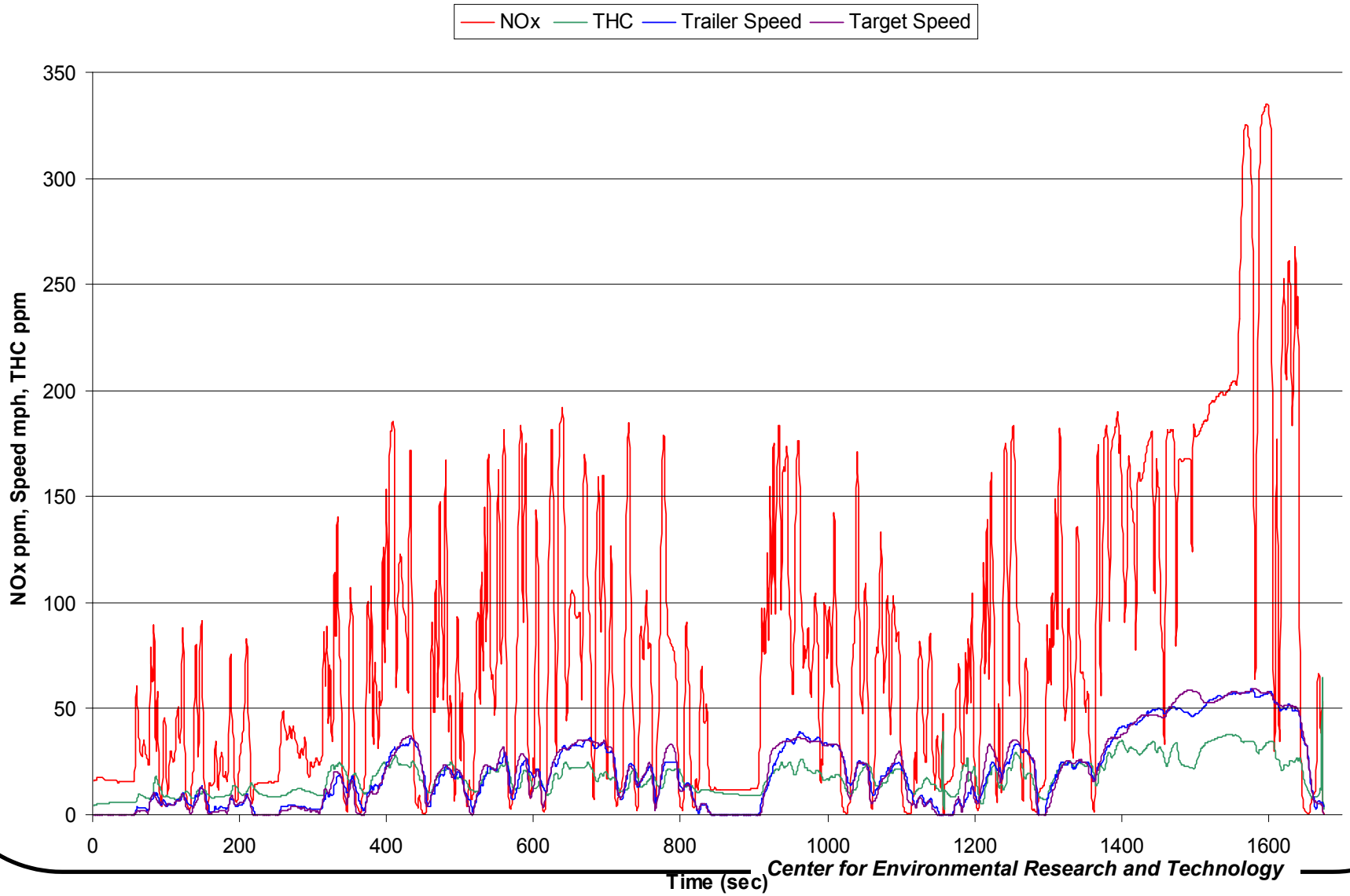
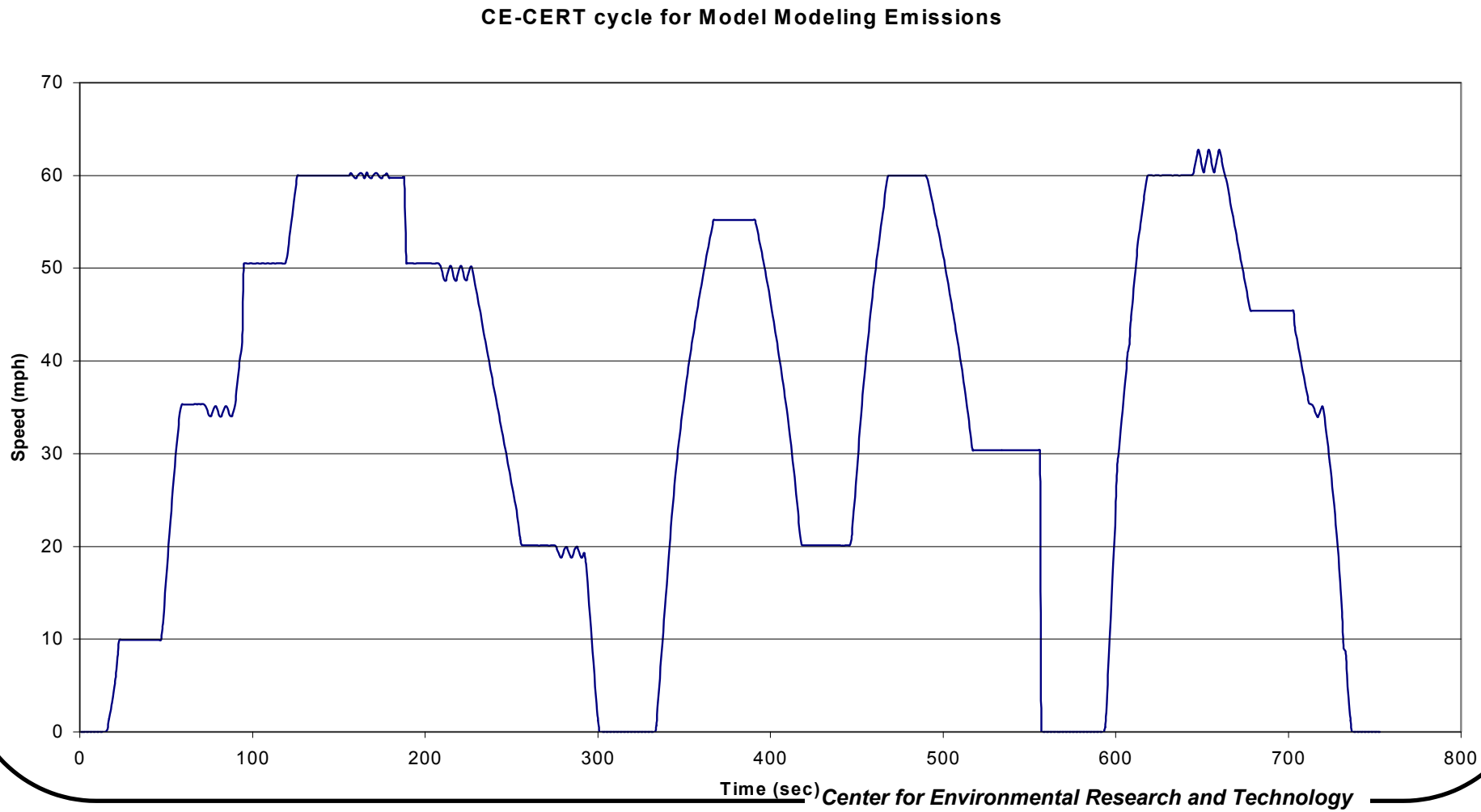
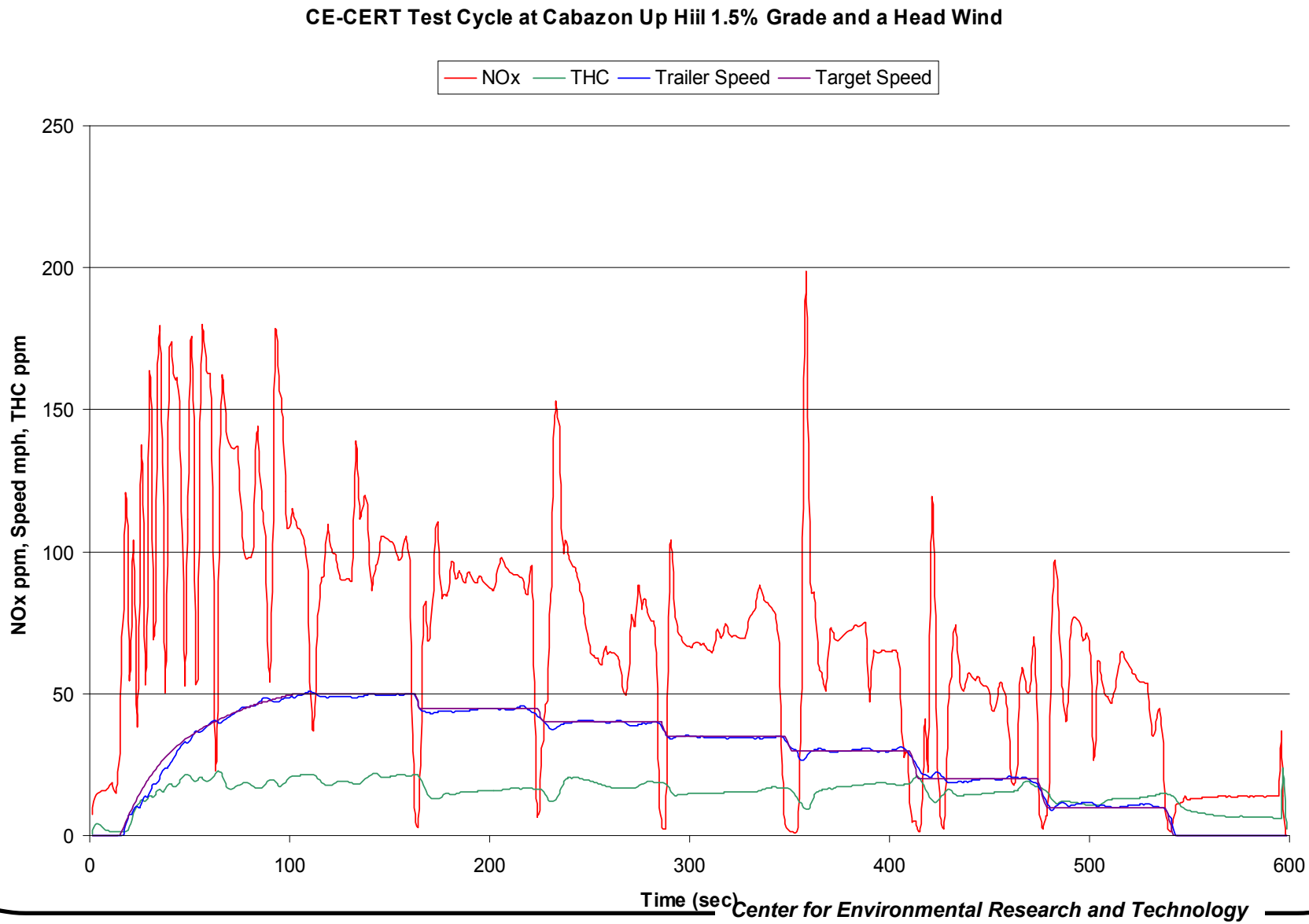
On-Road CEUDC Test

CEUDC 4 Phase Test Cycle at Cabazon Up Hiil 1.5% Grade and a Head Wind



CE-CERT Modal Emissions Testing Cycle for HDD




CE-CERT Test Cycle at Cabazon Up Hiil 1.5% Grade and a Head Wind
NOx
THC
Trailer Speed
Target Speed
NOx ppm, Speed mph, THC ppm
250
200
150
100
50
0
0
100
200
300
400
500
600
Time (sec)

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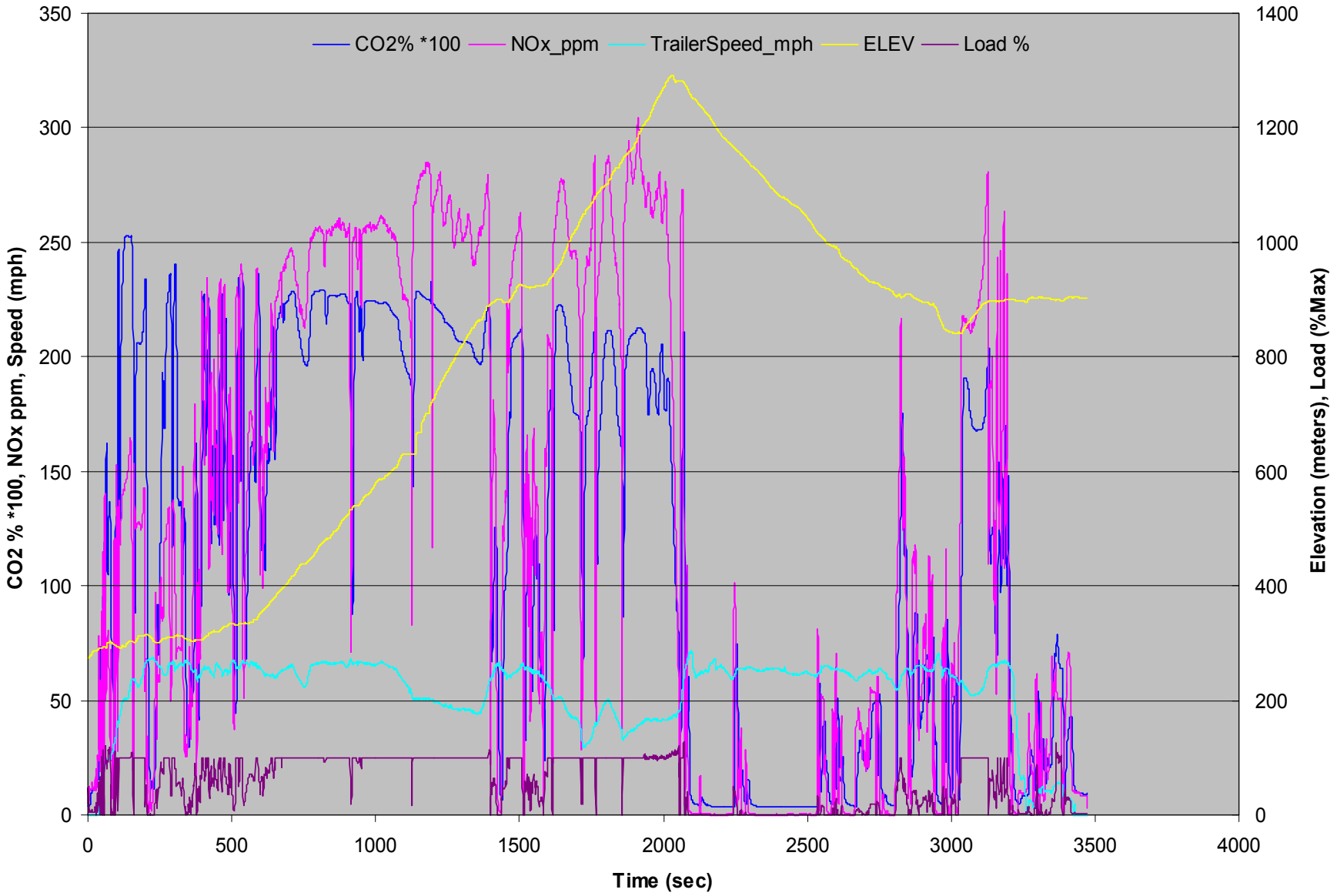
On Road Emissions on Route from Riverside to Victorvill



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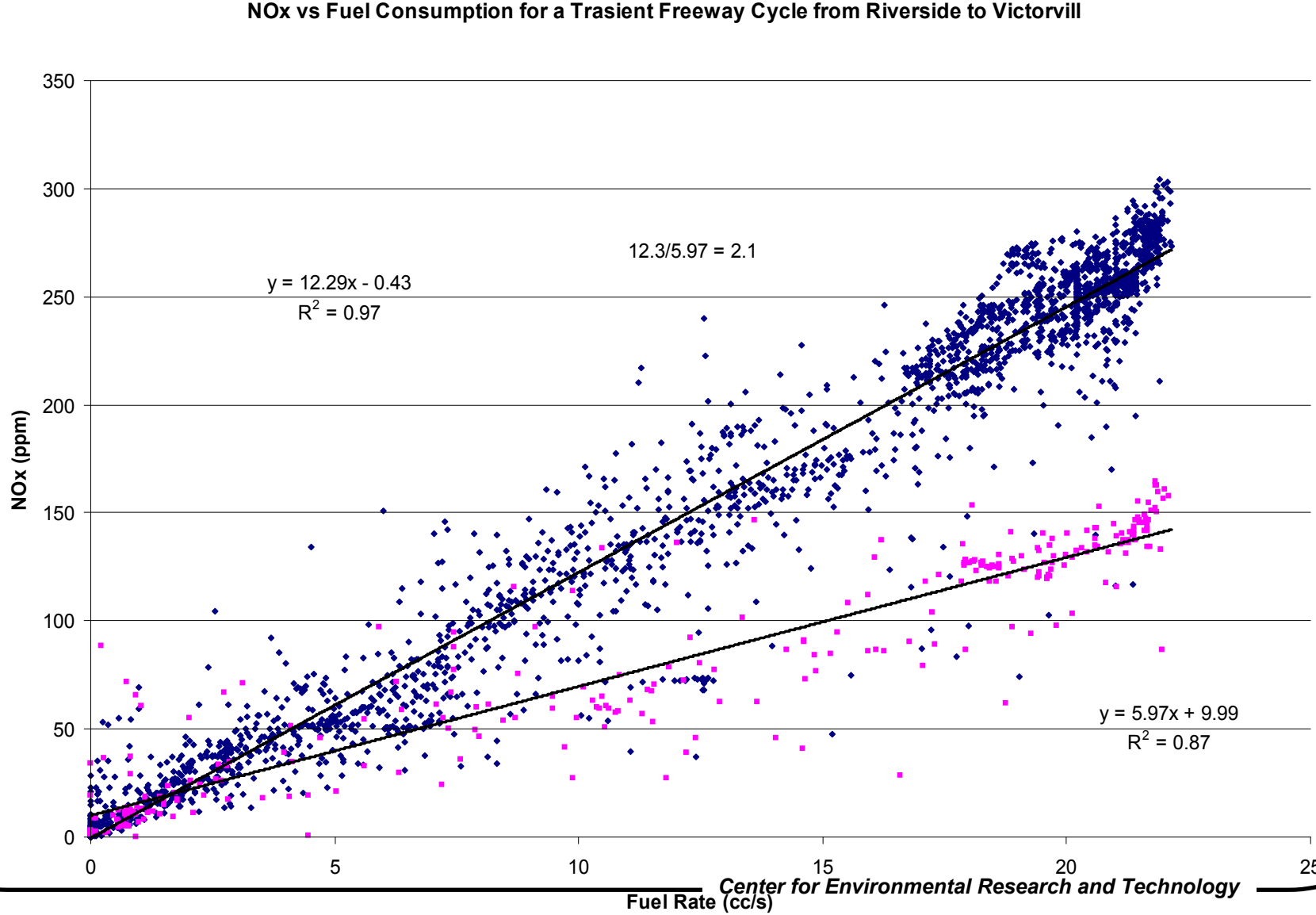
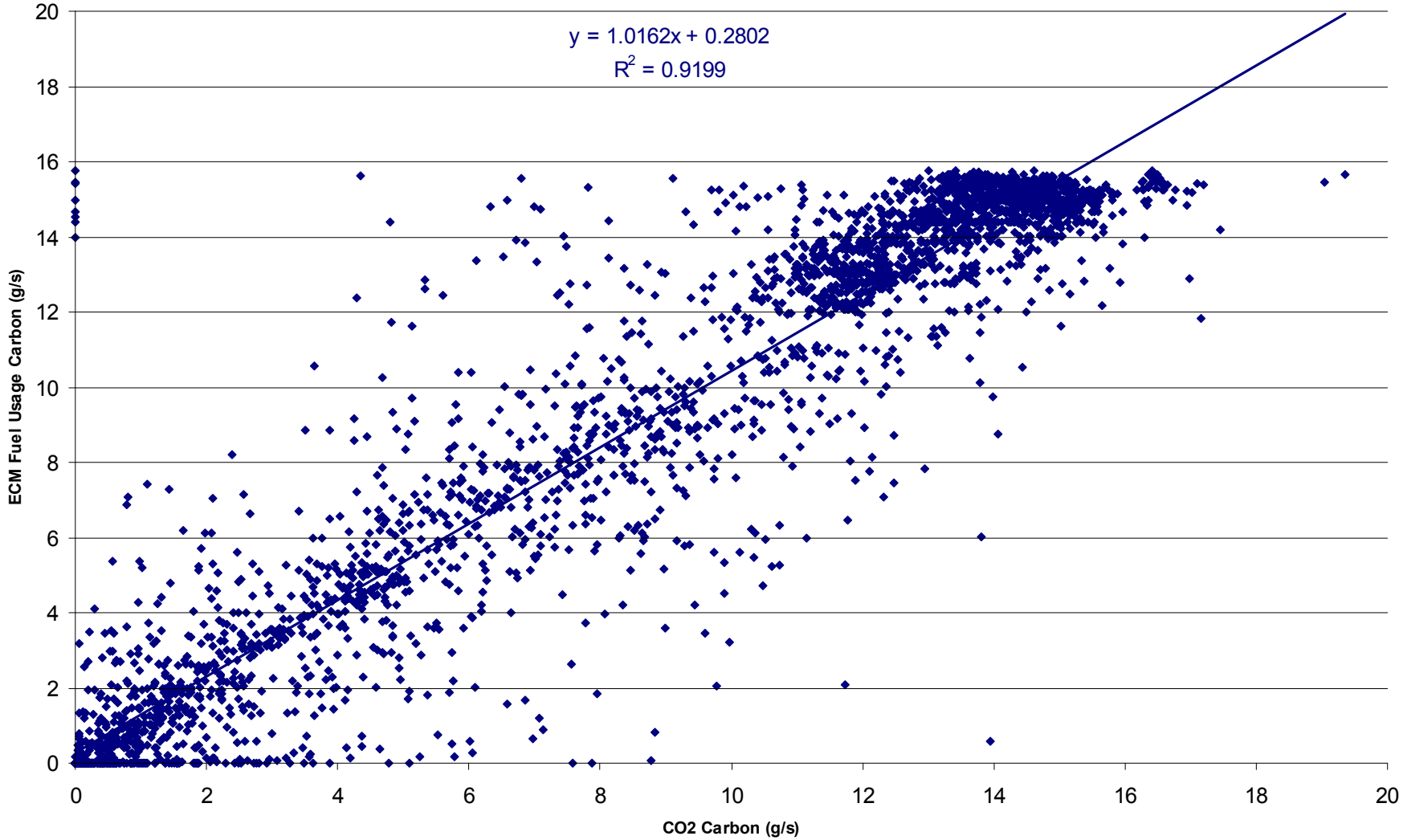
NOx vs. Fuel Consumption



Carbon Balance from CO2 and ECM Fuel Usage for a transient test cycle I-15/215 from Riverside to Victorville



Future Research Direction

- Continue to develop several on-road driving cycles
- Evaluate HDV activity with respect to driving cycle
- Assess on-road repeatability of emission measurements
- Develop empirical emission adjustment factors (speed, grade, altitude, wind, temp.)
- Correlate emission measurements with activity data and dynamic modal measurements
- Initiate emission program with 25 vehicle fleet
- Develop real-time particulate measurement system
- Improve analytical capability for organic species
- Evaluate effectiveness of emission control devices and alternative fuels