

# Cummins/DOE Light Truck Diesel Engine Progress Report



August 2002

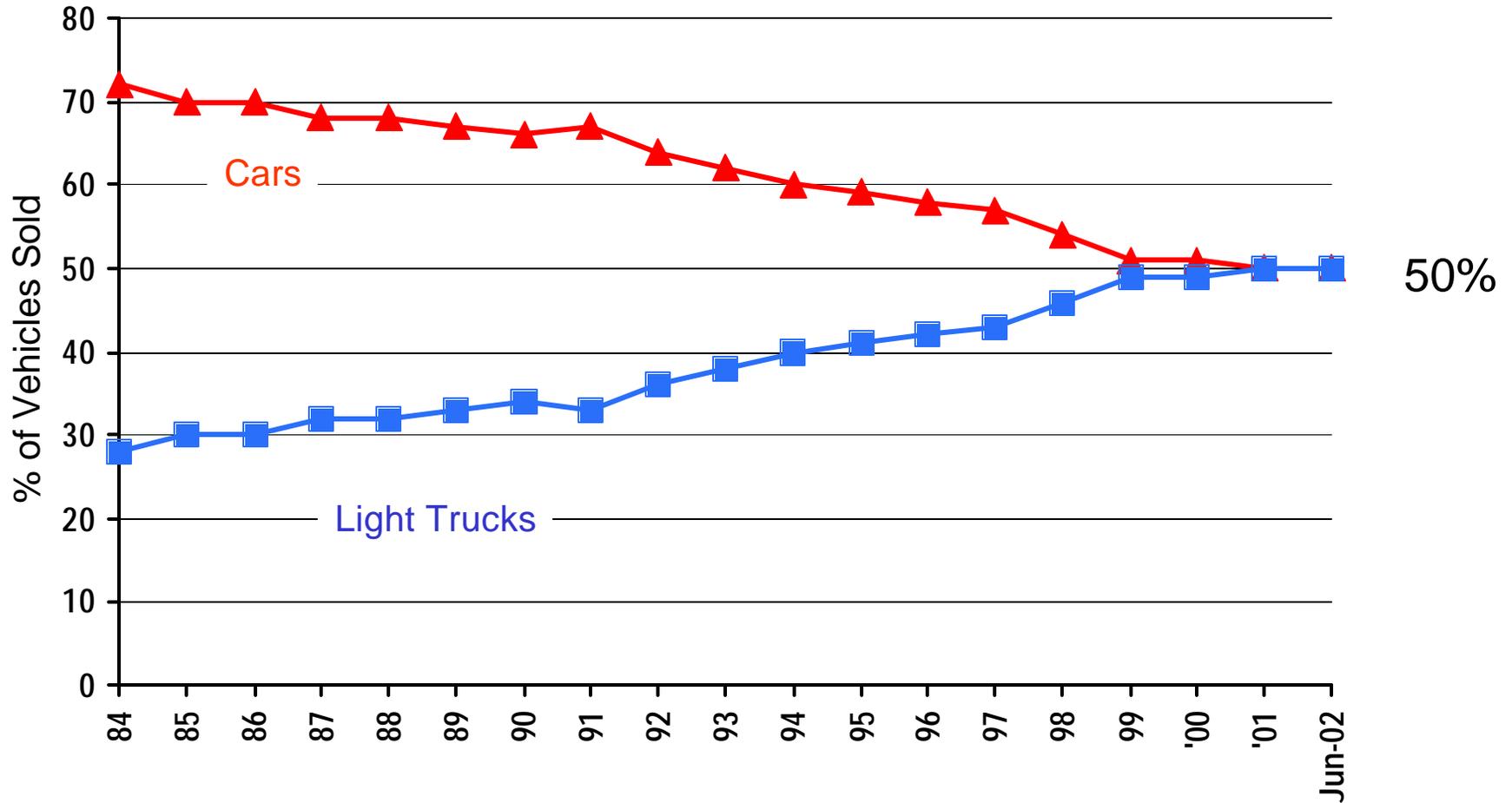
# Technical Program Overview

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- **Partnership, Cummins and U.S. Department of Energy**
- **Focus**
  - **Development of technologies that will result in a product in the near term**
  - **Emissions**
    - ~ **U.S. Tier 2 6000-8500 lb GVW**
    - ~ **NO<sub>x</sub> = 0.07 g/mi; PM = 0.01 g/mi**
  - **Fuel economy - 50 percent MPG improvement over 1997 gasoline powered vehicle it replaces**
- **Acknowledgment**
  - **Contractual funding from DOE**
  - **Vehicle and installation design assistance from Dodge Truck Engineering**
  - **Engine Development Team at Cummins**

# US Passenger-Car & Light-Truck Market



# Light Truck Major Segments

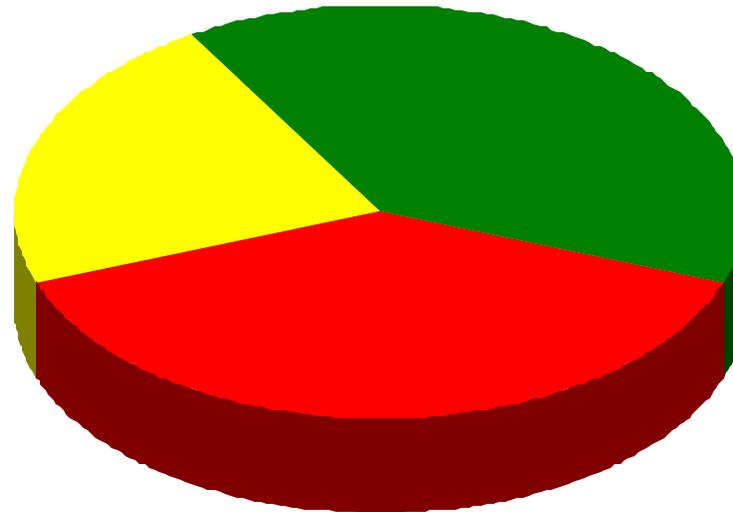


## 8.4M Vehicles

Vans 22%



Sport Utility Vehicles 39%



Pickup Trucks 39%



2001 Sales

# V Family Goals and Status

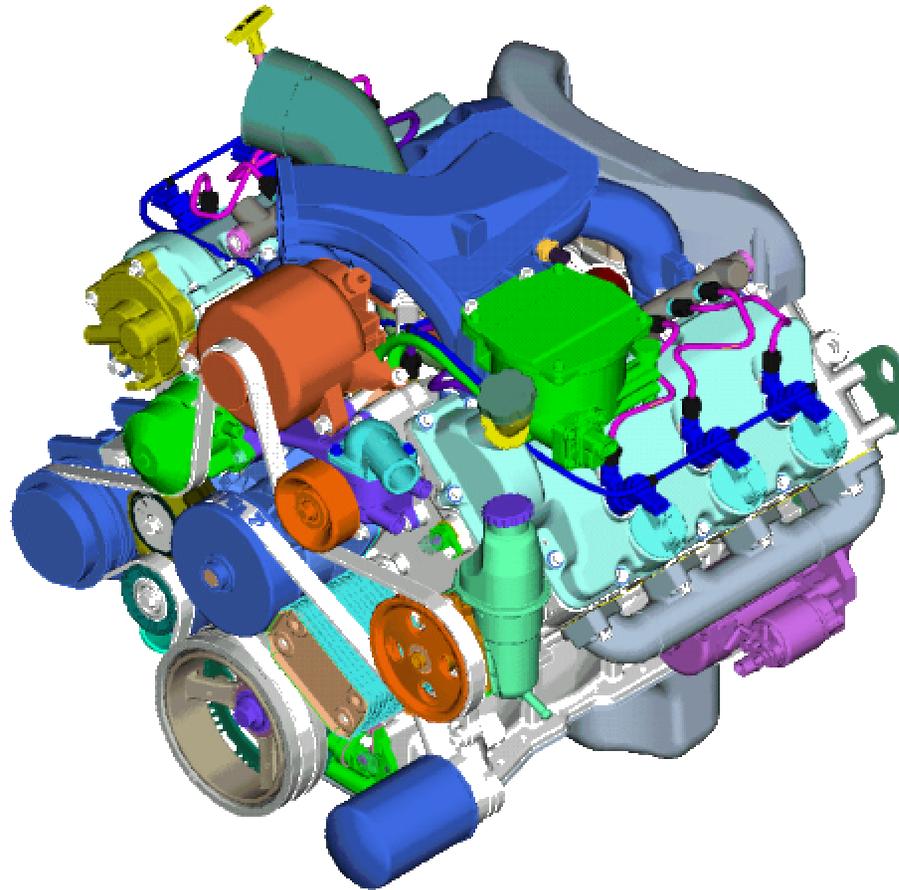


Description	Actual (status)	
	V6	V8
Emissions	Tier 2 Interim demonstrated, Tier 2 final, met on laboratory basis.	
Noise, dBa	68.7 Interior, Cruise @ 65 mph, Durango	65.0 Interior, Cruise @ 65 mph, BR 1500
Fuel Economy, MPG	22.1 Combined, Durango (+60%)	21.7 Combined, BR1500 (+60%)
Quality/Reliability	Not yet evaluated.	
Rated Speed	4000 rpm (5000 max.)	
Useful Life km(mi)	4000 hr Total Development Testing (equivalent usage >965,000(600,000))	
Performance	11.9 sec, 0-60 mph, Durango	9.95 sec, 0-60 mph, BR1500 4x4
Displacement, liter	4.2	5.6
Power, kW(hp) @ rpm	177(237) @ 3600	224(300) @ 4000 Interim target met.
Torque Peak, Nm(ft-lb)	475(350)	623(460)
Warm-Up	Not yet evaluated.	
Serviceability	No Adjustments Diesel fuel filter added.	
Cold Start	Not yet evaluated.	
Weight, kg(lb)	301(663)	379(835)

- Meets Goal
- Partially Meets Goal;  
Plan in Place

# Light Duty Automotive Engine - V6

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DEERE0802(V)

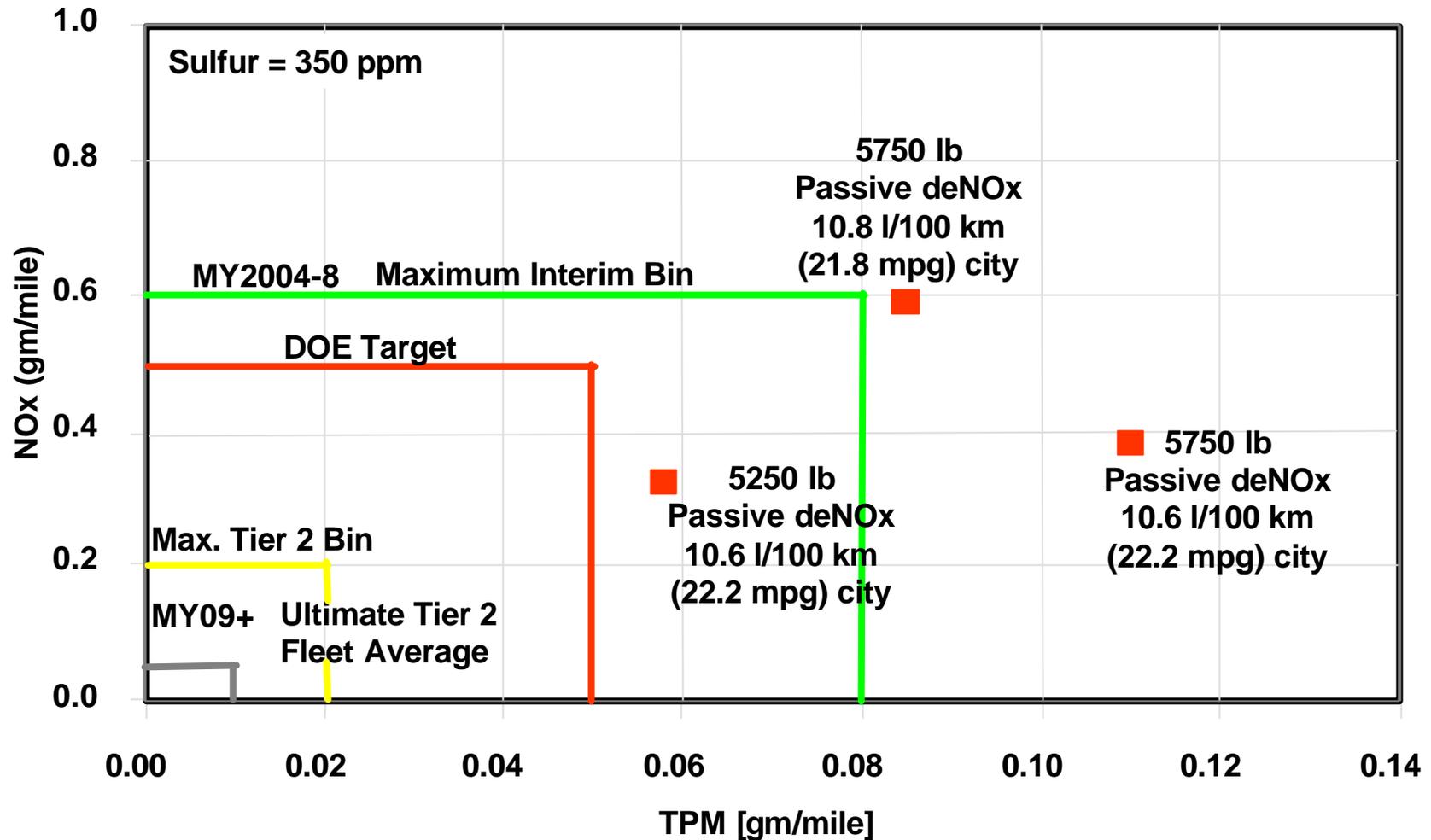
# Light Truck Diesel Subsystem Description

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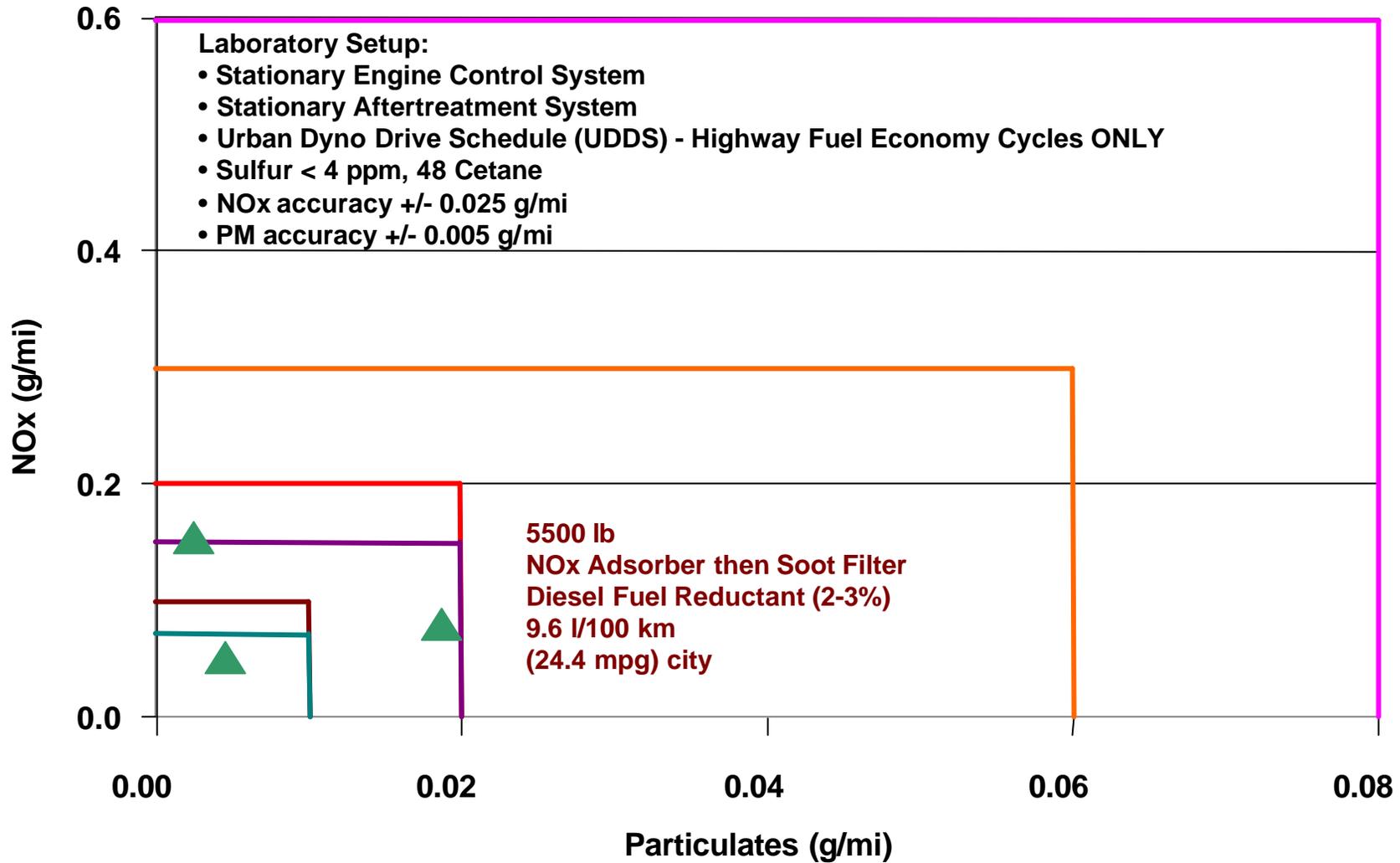


<b><u>Subsystem</u></b>	<b><u>Description</u></b>
<b>Configuration</b>	<b>90° V</b>
<b>Displacement</b>	<b>4.2 L V6 5.6 L V8</b>
<b>Bore and Stroke</b>	<b>94 X 100 mm</b>
<b>Valvetrain and Drive</b>	<b>Single overhead cam, chain-driven</b>
<b>Valve System</b>	<b>Four valves per cylinder with hydraulic lash adjustment</b>
<b>Fuel System</b>	<b>High-pressure common rail (HPCR)</b>
<b>Control System</b>	<b>Full electronic</b>
<b>Emissions Control</b>	<b>Modulated-cooled EGR plus deNOx catalyst (Interim) 4-Way Catalyst (Tier 2, Bin 5)</b>
<b>Aspiration</b>	<b>Wastegated turbocharged</b>
<b>Intercooling</b>	<b>Vehicle mounted air-to-air</b>
<b>Block</b>	<b>Cast iron, thin-walled</b>
<b>Head</b>	<b>High temperature alloy aluminum</b>
<b>NVH Control</b>	<b>Deep skirted block, with bedplate</b>
<b>Accessories</b>	<b>Common automotive V-8 gasoline</b>
<b>Accessory Drive</b>	<b>Single serpentine belt, self-adjusted</b>

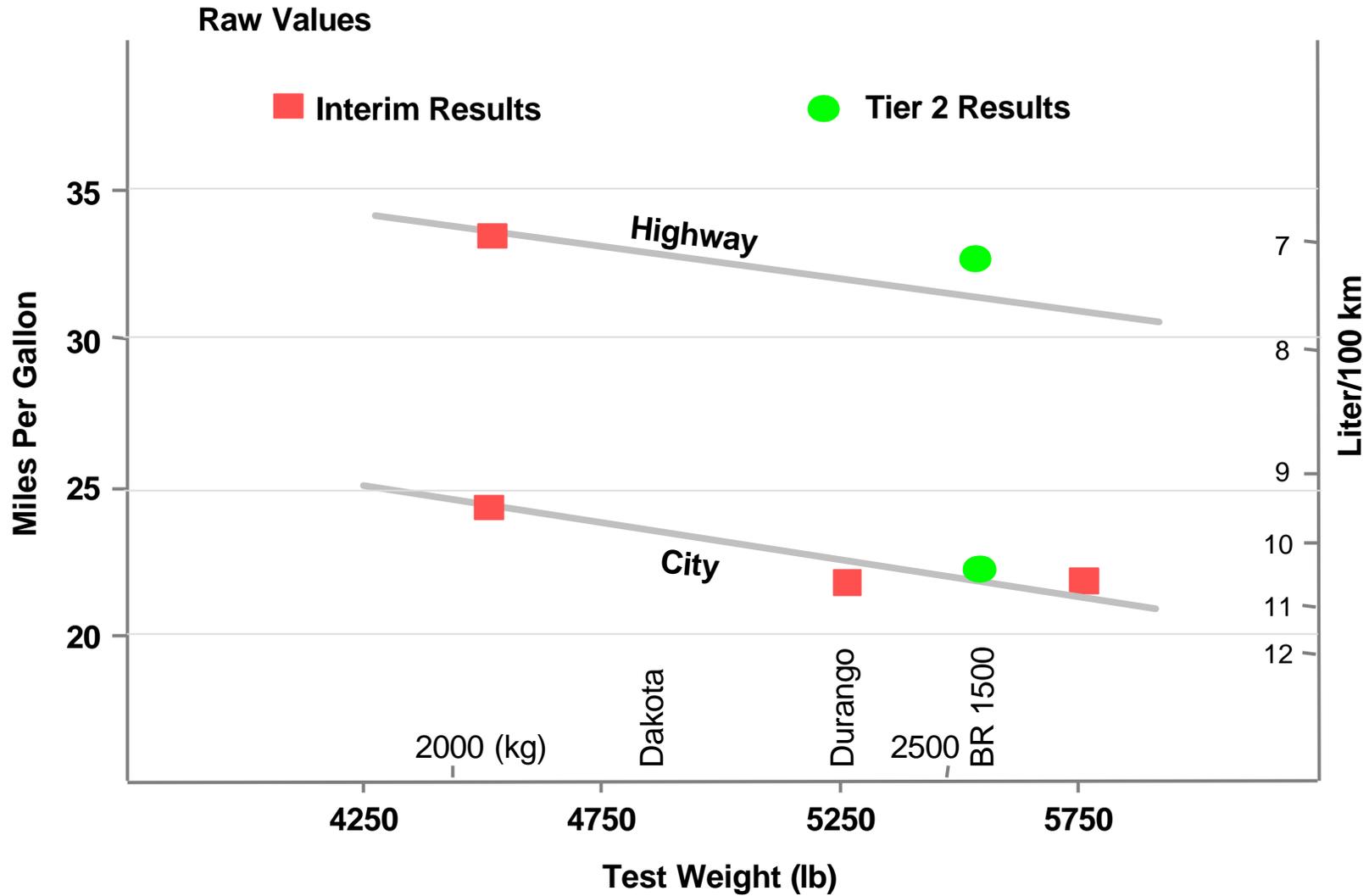
# Demonstrated Emissions Interim Results



# Demonstrated Emissions Tier 2 Results



# Demonstrated Fuel Economy



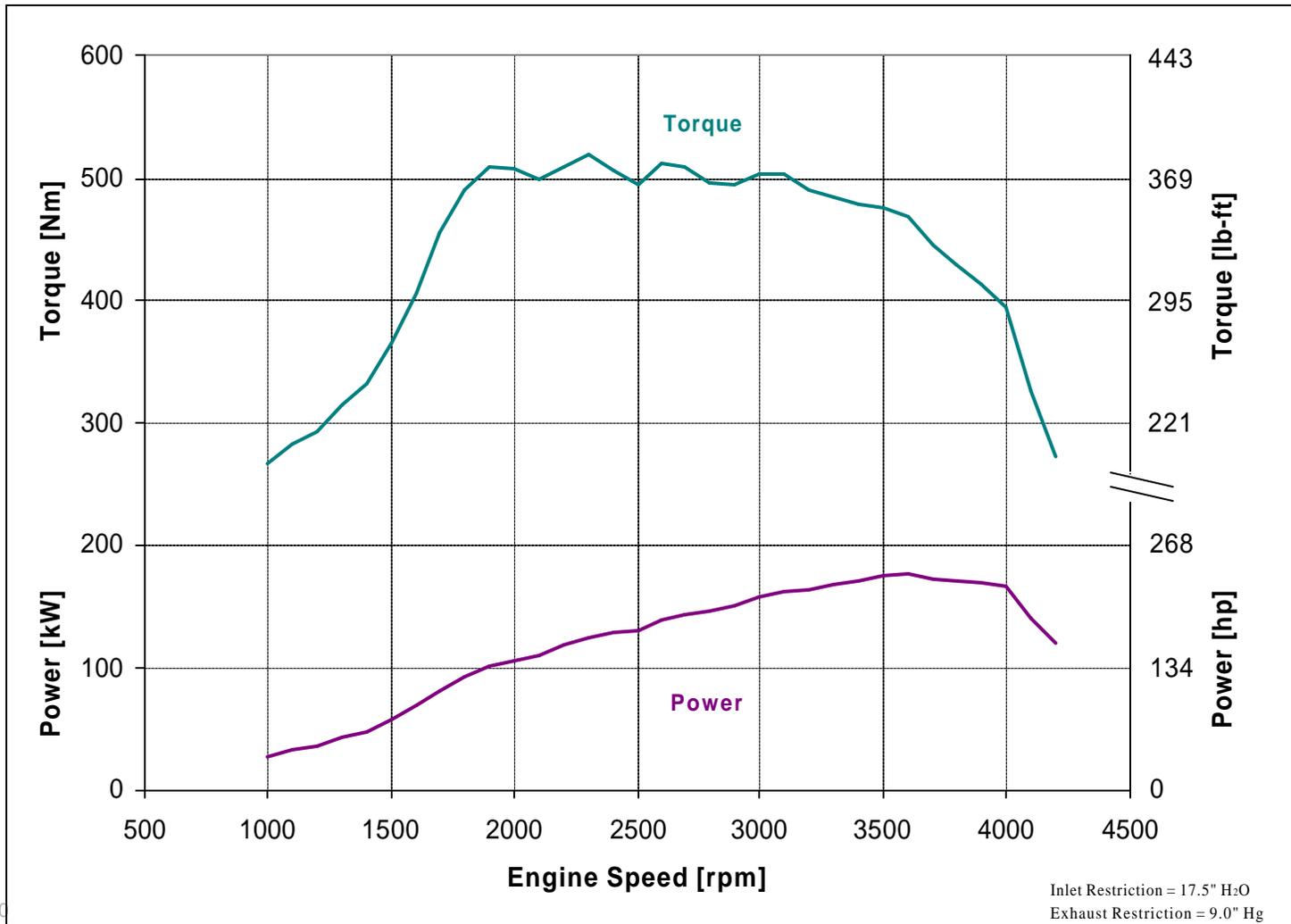


# Typical Results

	<u>City,</u> <u>mpg*</u>	<u>Highway,</u> <u>mpg*</u>	<u>Combined,</u> <u>mpg*</u>	<u>Combined</u> <u>gal/mi</u>	<u>CO<sub>2</sub></u>
<b><u>Dodge Durango</u></b>					
- Gasoline	12	17	13.8	0.072	
- Diesel	20.3	25.0	22.1	0.045	
			+60% Improve	37% Reduction	27% Reduction
<b><u>Dodge Ram 1500</u></b>					
- Gasoline	12	16	13.5	0.074	
- Diesel	19.8	24.6	21.7	0.046	
			+61% Improve	38% Reduction	

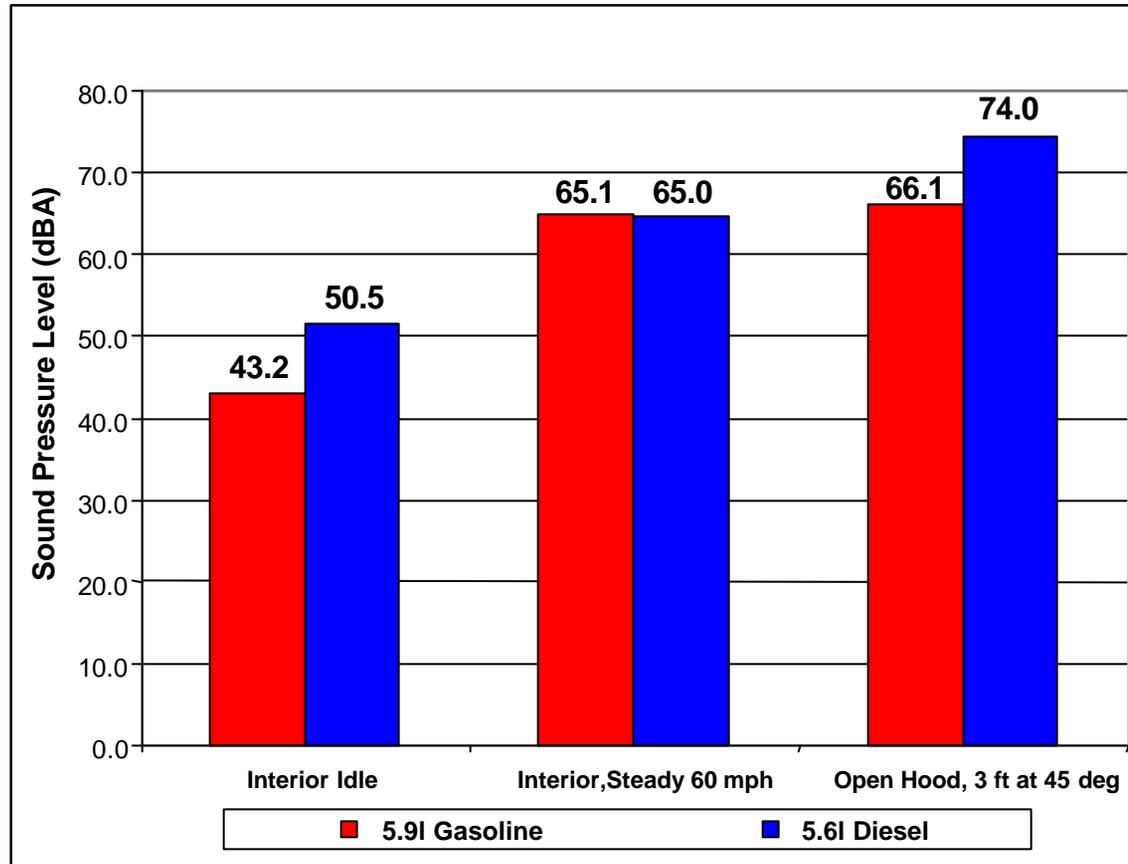
\*Adjusted values for vehicle labeling

# V6 Performance Results

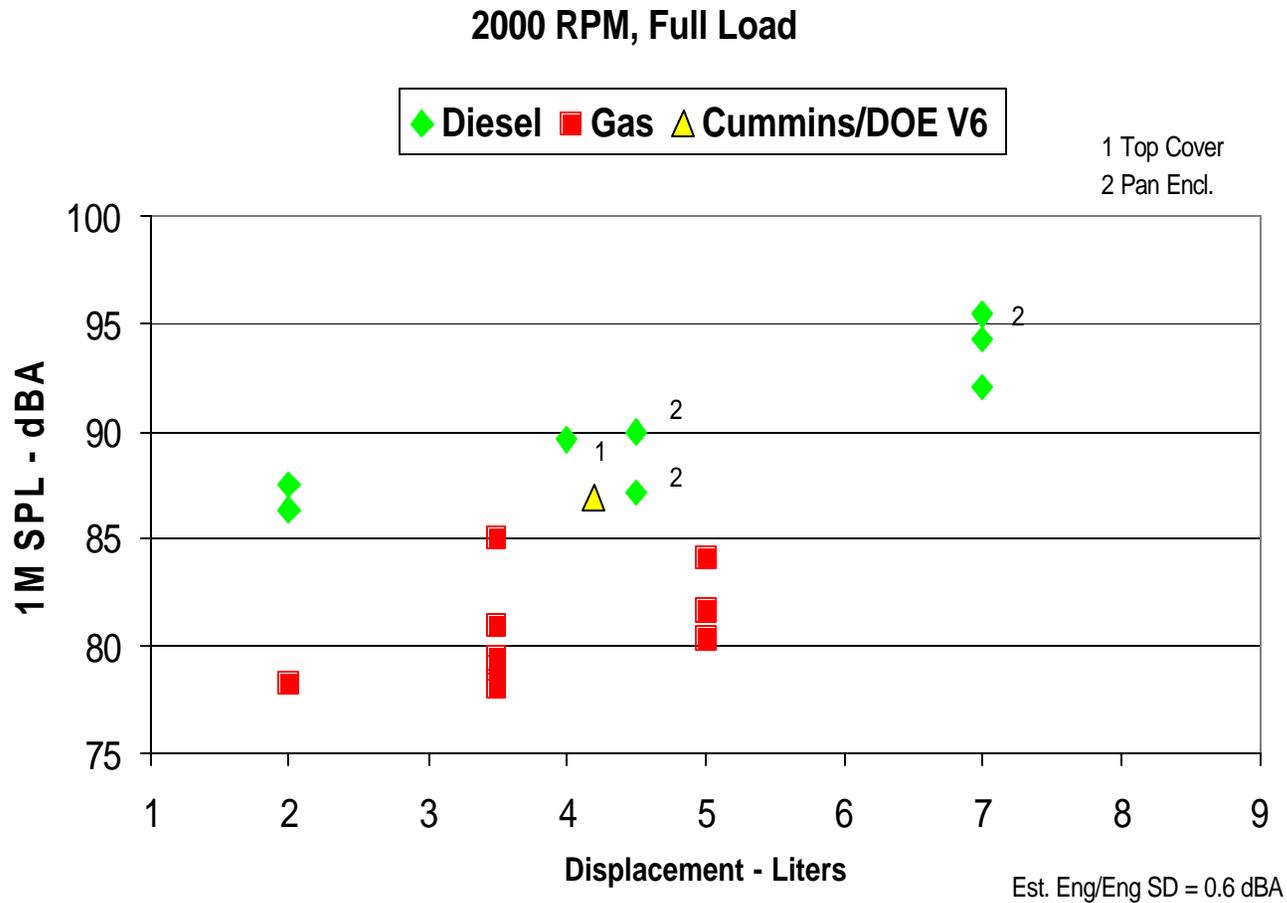


# Noise Test Results

## V8 in Ram 1500

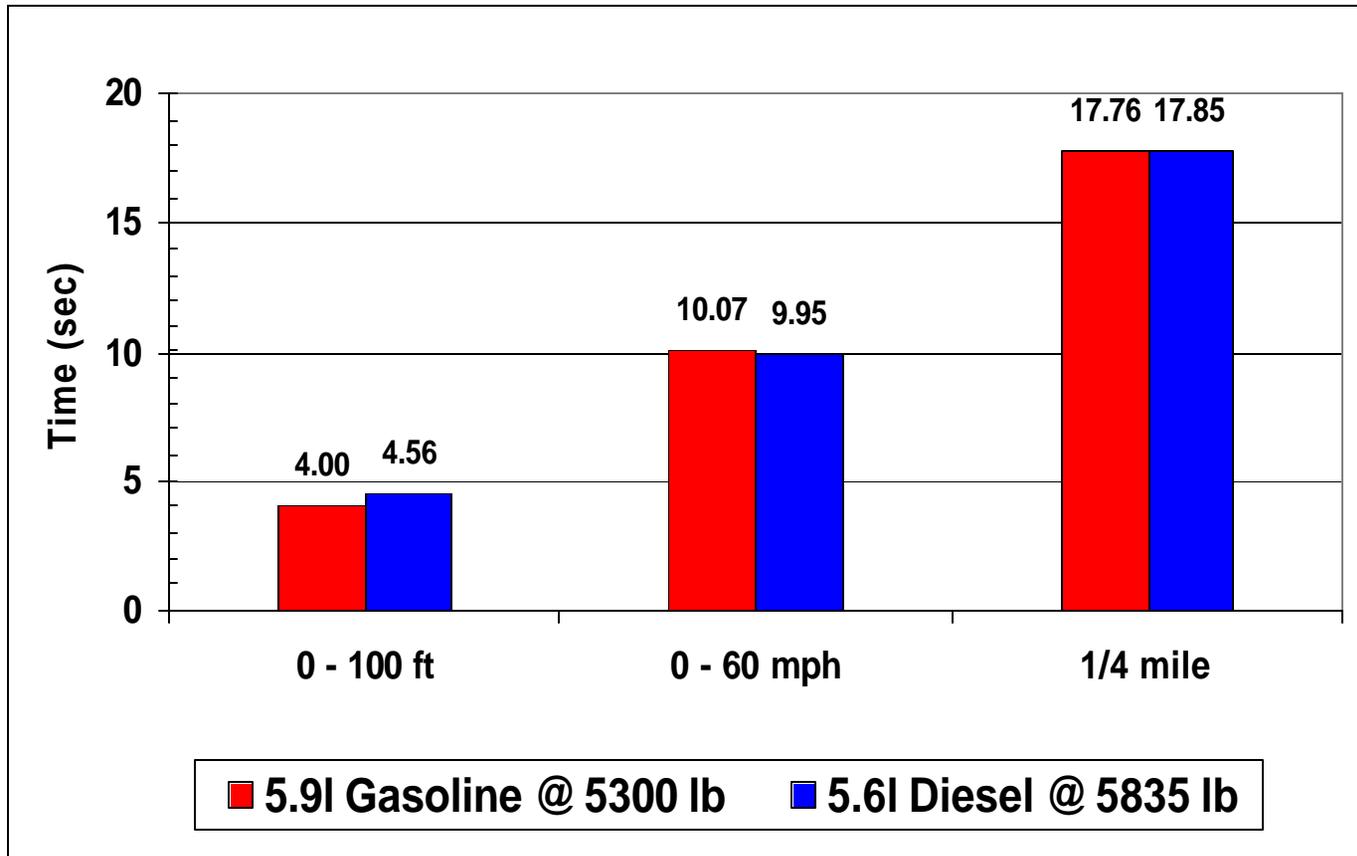


# Competitive Noise Comparison



# Acceleration Test Results

## V8 in Ram 1500



# Current Focus

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- **What needs improvement in this picture**

- **Emission System**

- ~ **Lower Cost, Simpler**
    - ~ **More Robust**
    - ~ **Compact**
    - ~ **Reliability**
    - ~ **Fuel Variability Tolerance**

- **Overall System**

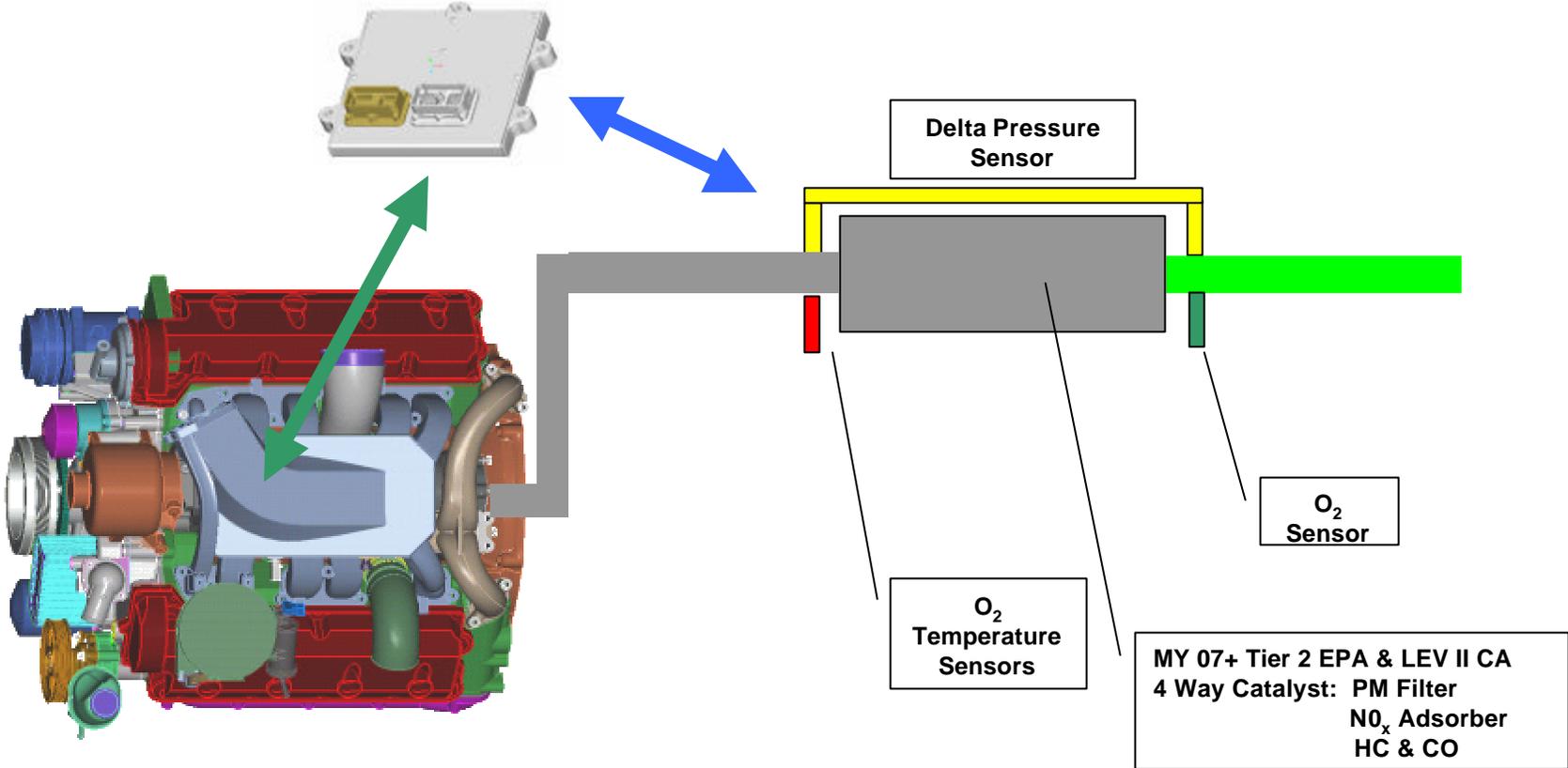
- ~ **Improved Control of Variability**
    - ~ **Very Low (Precise) Emissions**
    - ~ **Sensor Technology Applied to Diesels**

**Cost/Robustness**

**+**

**Variability**

# Prime Path System with 4-Way Catalyst



# Regeneration Strategy

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<u>Condition</u>	<u>Engine Out</u>	<u>Combustion Condition</u>
NO <sub>x</sub> Regen	Rich	Thermal Management + { Pilot + Main Injection Pilot + Main + Post Pilot + Main + Post
Soot Regen	Lean	
Sulfur Regen	Rich	



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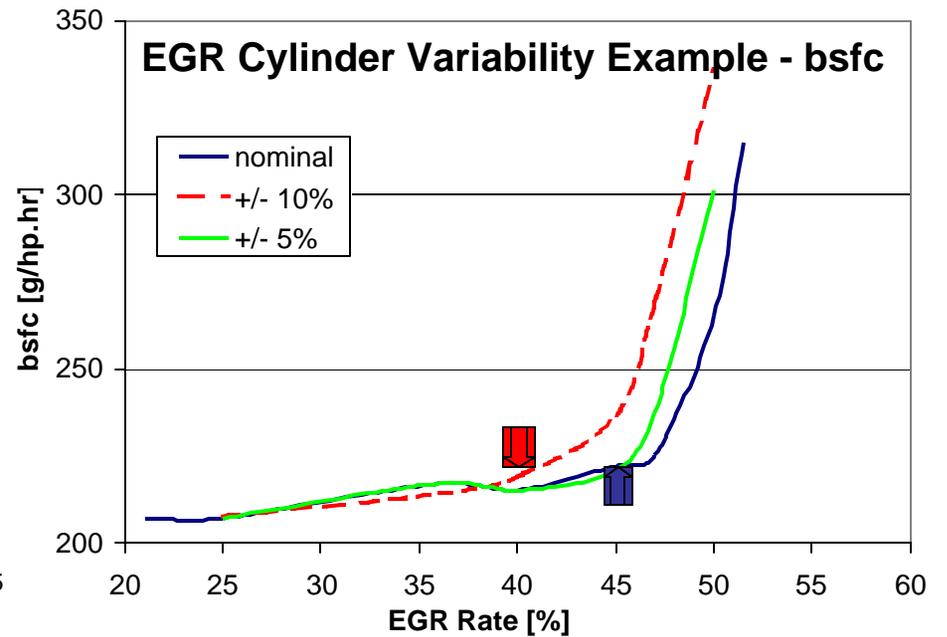
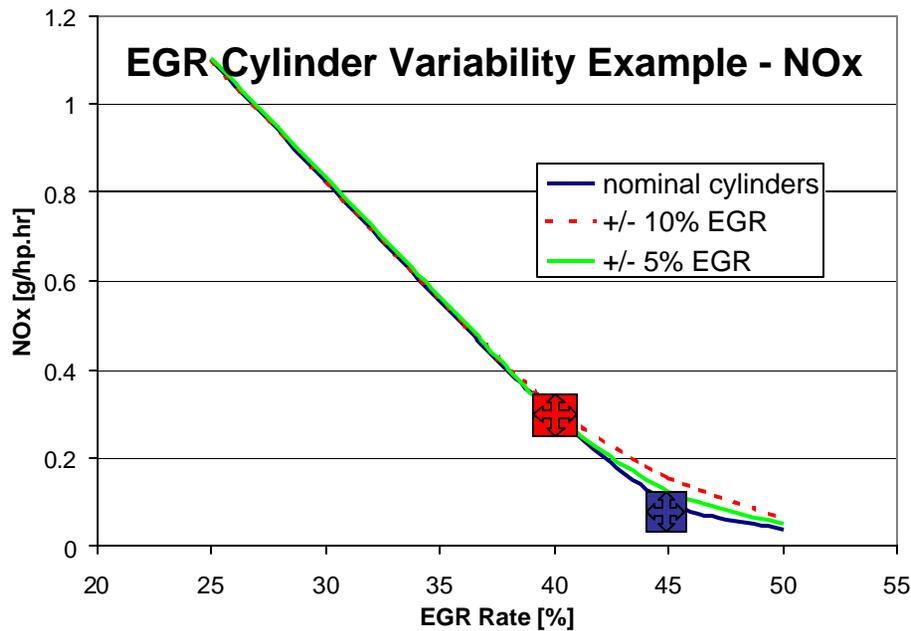
# Variability



# Variability Example

- Engine condition 1500 rpm, 2.6 bar BMEP (~18 hp for V6-4.2)
- Consider a nominal target of 45% EGR

	<u>EGR,%</u>	<u>NO<sub>x</sub>,g/hp-hr</u>
- All cylinders nominal	45	0.1
- +/- 10% EGR target	40	0.30
- +/- 5% EGR target	43	0.18

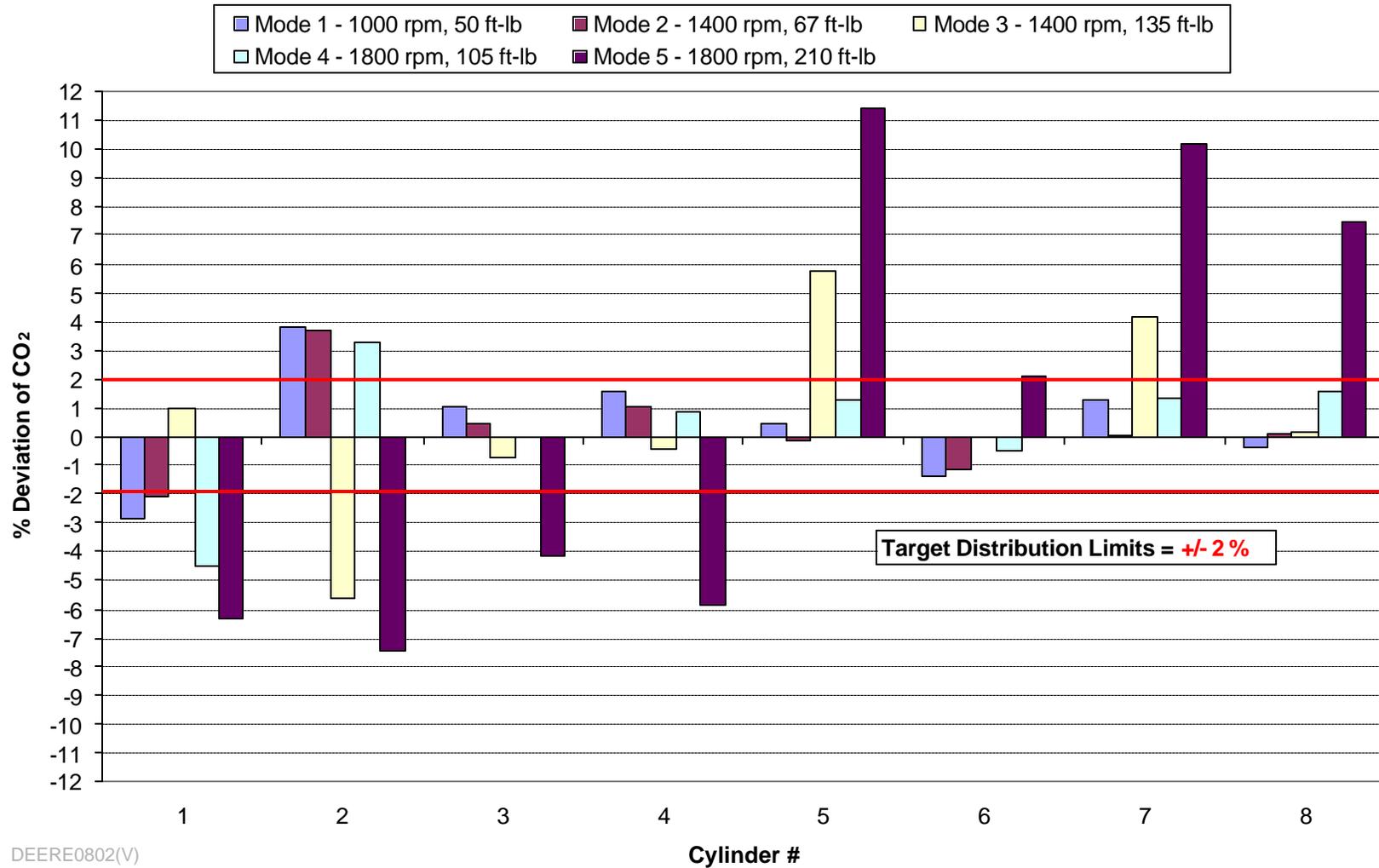


# EGR Measurements



## V8 EGR Port-to-Port Distribution

Measured by CO<sub>2</sub>



# Sources of Variability

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- **EGR Distribution**
- **Swirl Port-to-Port**
- **Piston Bowls**
- **Spray Angle**
- **Spray Hole Size**
- **Shot-to-Shot Fueling & Timing**
- **Cylinder-to-Cylinder Air Flow**
- **Fuel**
- **Etc.**

# Conclusions

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- **Light Truck Diesel Family continues to show promise**
- **Fuel economy advantage is clear, approaching 60 percent**
- **Performance and sociability are gasoline-like**
- **Interim Tier 2 emissions, met using known technology**
- **Final Tier 2 emissions, demonstrated using advanced aftertreatment devices**
- **There is a path to market for the Light Truck Diesel**
  - **Cost/Robustness issues resolved**
  - **Variability issues minimized**