Breakthrough Diesel Engine Technology To Meet Tier-2 and CO_2 Emissions Reduction

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Detroit Diesel Corporation

The Detroit Diesel DELTA engine technology has demonstrated substantial potential to meet future light trucks emissions regulations for personal and commercial transportation. This paper will report on a breakthrough combustion strategy which produces extremely low engine out emissions. In addition, this strategy provides more favorable conditions for effective further reduction of emissions via aftertreatment.

Preliminary engine and vehicle test results will be presented. The effectiveness of the DDC "Wired" approach for engine R&D will be demonstrated. The next generation DELTA brings this advanced technology a step closer to product viability for the 21 Century Truck applications.

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Breakthrough Diesel Engine Technology

to Meet Tier 2 and CO2 Emissions Reduction

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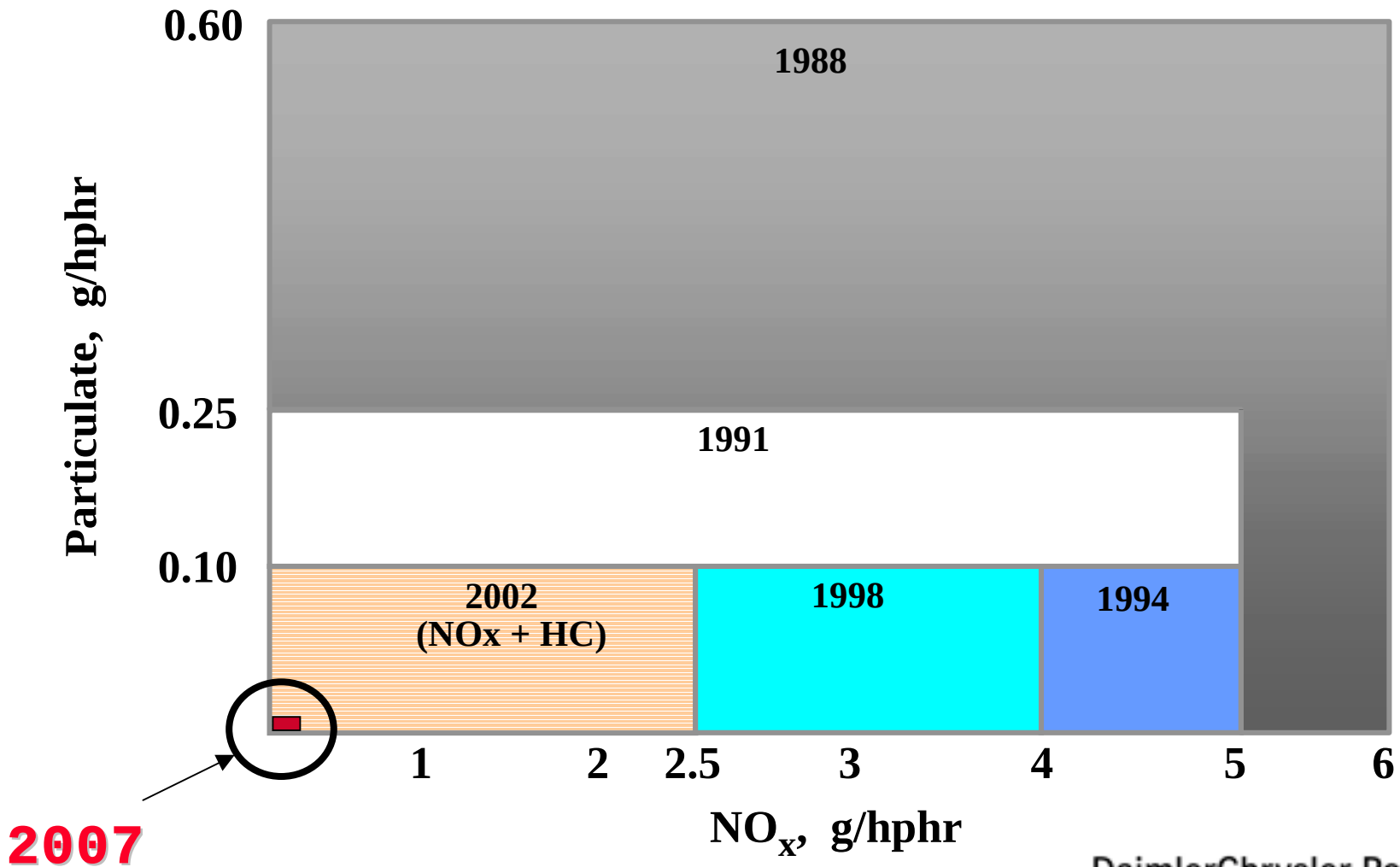
Breakthrough Technology

Introduction

US Class 8 Emissions Regulation



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"21st Century Truck IWG" Perspective

2007 Emissions Impact

- Fundamental technology not invented yet
- Estimated fuel economy penalty 5-10%
- Estimated annual operating cost impact 10-15%
- Huge technical challenge to deliver customer-worthy product to meet 2007 regulation

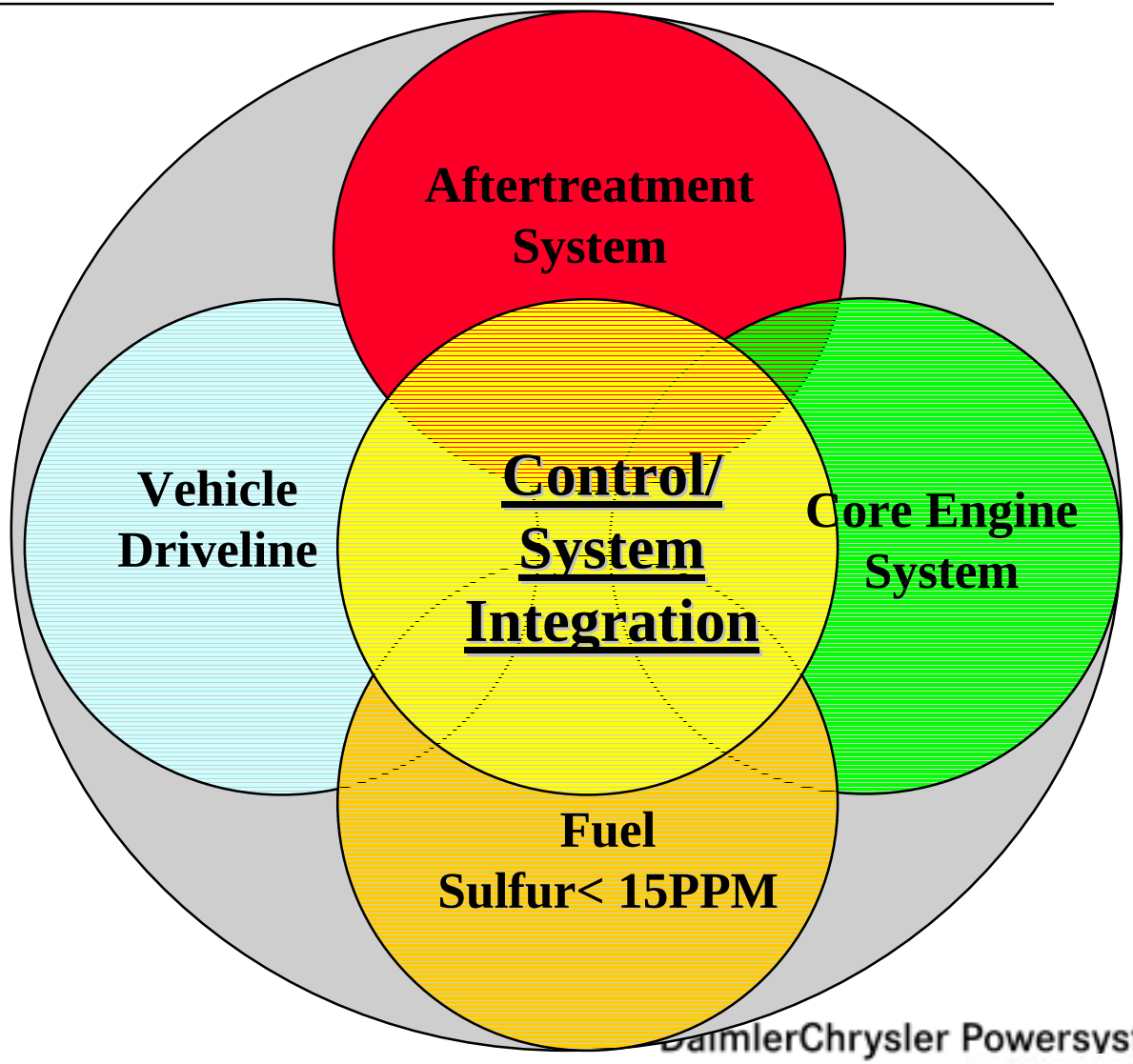
HD & LD 2007+ Standards

- **Technically Daunting**
  - **Leap Frog Technologies Required**
    - » **Integrated Controls (AT - Engine - Transmission - Vehicle)**
    - » **Advanced Combustion ➔ Very Clean Engine Out Emissions**
    - » **Durable, Low Cost, Highly Effective AT**

- **Requires Unprecedented AT/Engine/Vehicle Integration**
  - **This Toolbox is Not Readily Available Today**

Control & System Integration

This presentation addresses advanced combustion and its integration into aftertreatment and vehicle systems



Breakthrough Technology

DDC's CLEAN Combustion©

Advanced Combustion

- Advanced Combustion Is a Critical DDC Core Competency
- The Next Segment Provides Early Results from Many DDC Programs
- Technology Demonstrated in Multiple Engines

DDC Advanced Combustion

Demonstrated Results

- **Controlled Combustion**
  - **Stable HC and CO**
- **Low Emission**
  - **Simultaneous NOx and PM Reduction**
- **Aftertreatment Nurturing**
  - **Integration with Passive and Active Aftertreatment**

DDC Advanced Combustion

Demonstrated Results

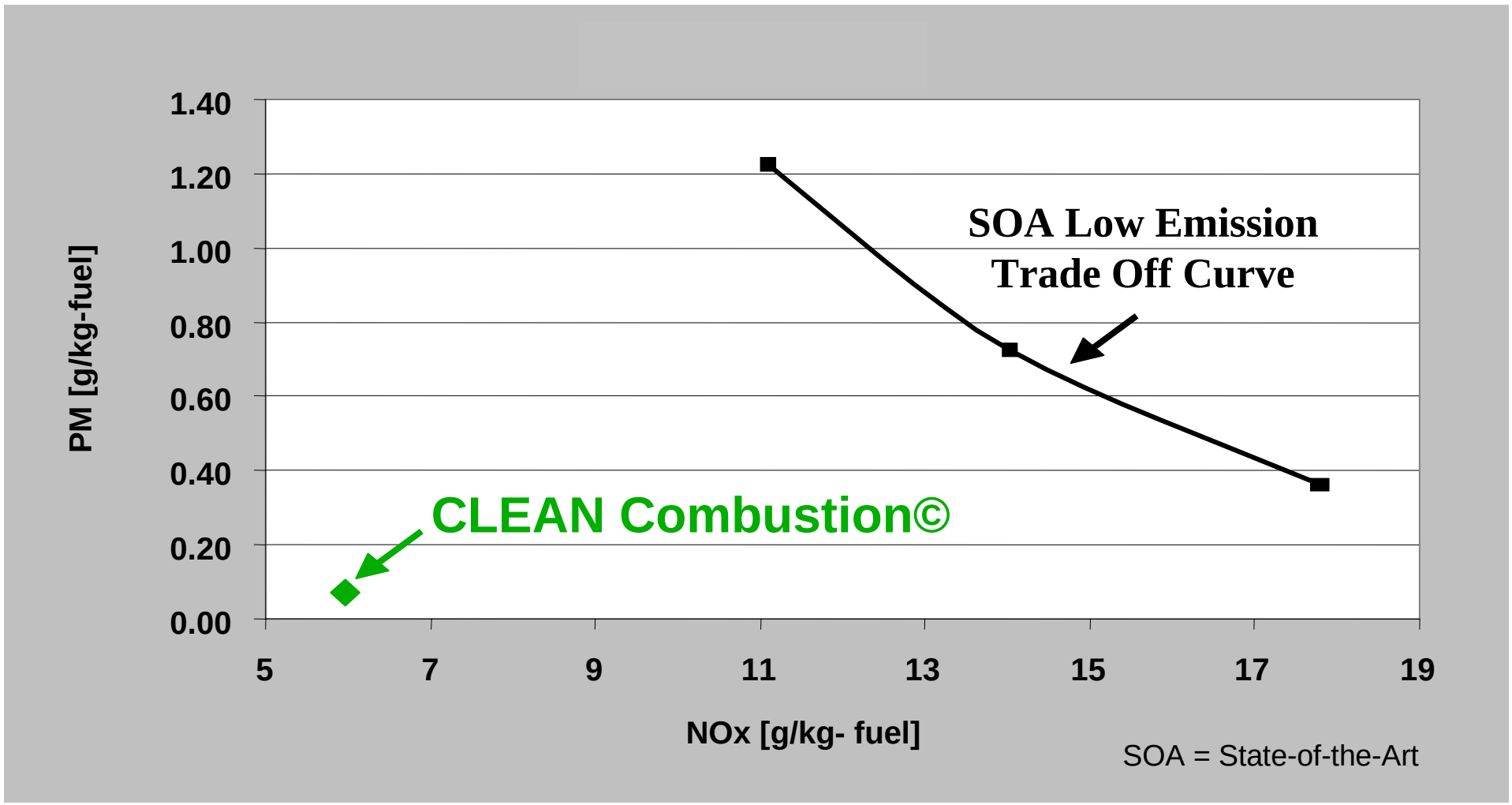
- **C**ontrolled Combustion
  - » Stable HC and CO
- **L**ow **E**mission
  - » Simultaneous NOx and PM Reduction
- **A**ftertreatment **N**urturing
  - » Integration with Passive and Active Aftertreatment

→ **CLEAN Combustion©**

Breakthrough Technology

Steady State Results

DDC's CLEAN Combustion©



DDC's CLEAN Combustion©

Demonstrated Steady State Advantages

- 66% Reduction in NOx
- 80% Reduction in Soot
- Robust NO/soot ratios
- Exhaust Temperature Increase

Simulation – A Closer Look at CLEAN Combustion©

Combustion Simulation - (KIVA)

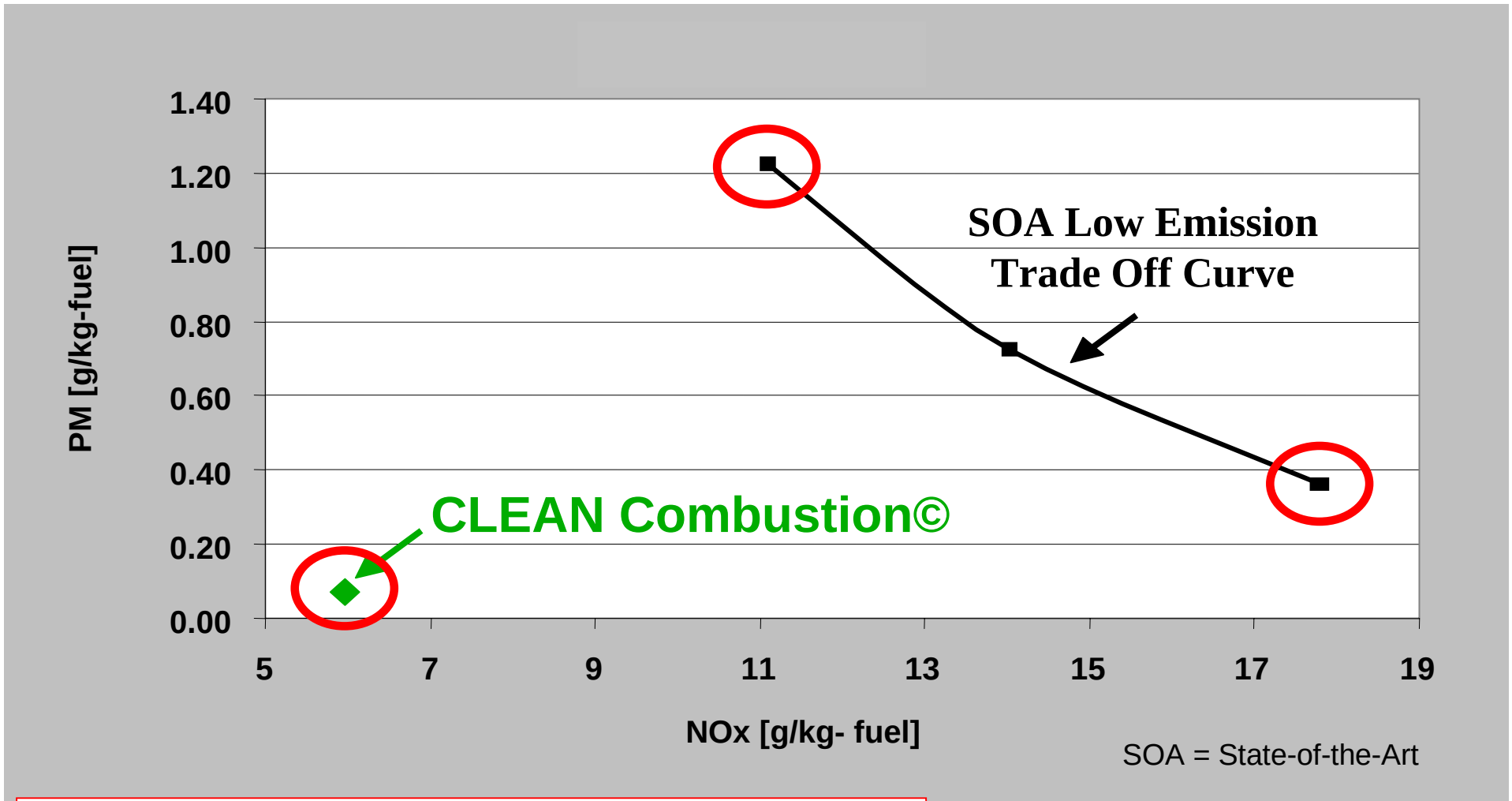
- **Diesel Combustion Complexity and Modeling Assumptions**
- **Model Accuracy and Sensitivity Factors**
  - **Physical sub-models**
  - **Boundary Conditions**
  - **Numerics**

Validated Simulation Allows Insight into Combustion, Emission Formation Mechanisms & Interactions

KIVA Boundary and Initial Conditions

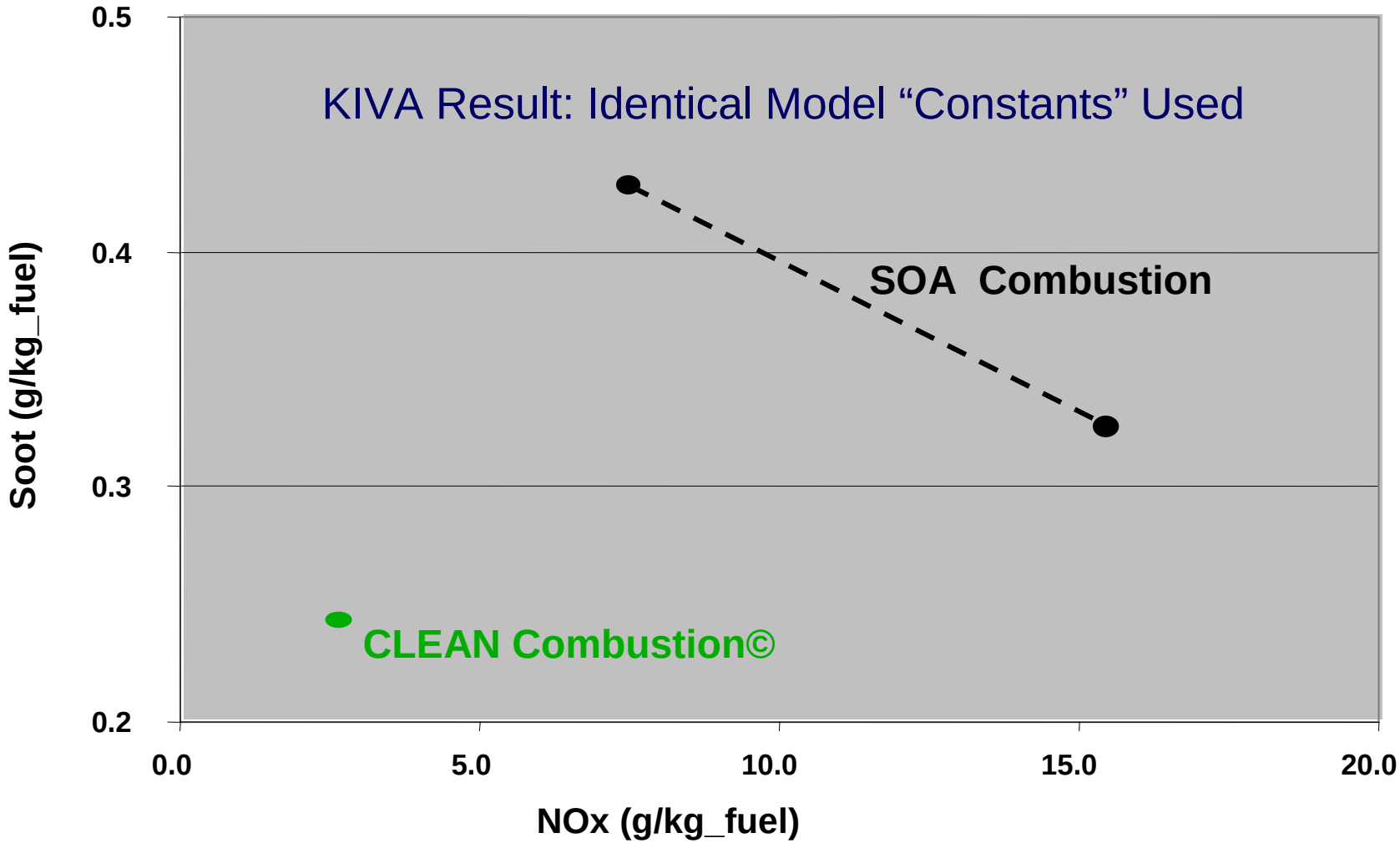
- In-cylinder Swirl, Air Flow, Species Fractions
- Injection Rate and Conditions
- Wall Temperature
- Fuel Definition

KIVA Explains CLEAN Combustion© Mechanisms



KIVA Simulation of Circled Points

KIVA Predicts Trends and Appropriate Emissions Formation



DDC's CLEAN Combustion©

Transient Developments

Demonstrated Salient Features

- Broader Operating Range
- Transient Capability
- Hot/Cold Cycle Sensitivity Investigated
- Drivability/NVH Considerations

CLEAN Combustion© - Transient Emissions

Example

- **Applied CLEAN Combustion© into Engine Design and Calibration**
- **Evaluated on Hot 505 and Full FTP75 Transient Emission Tests.**

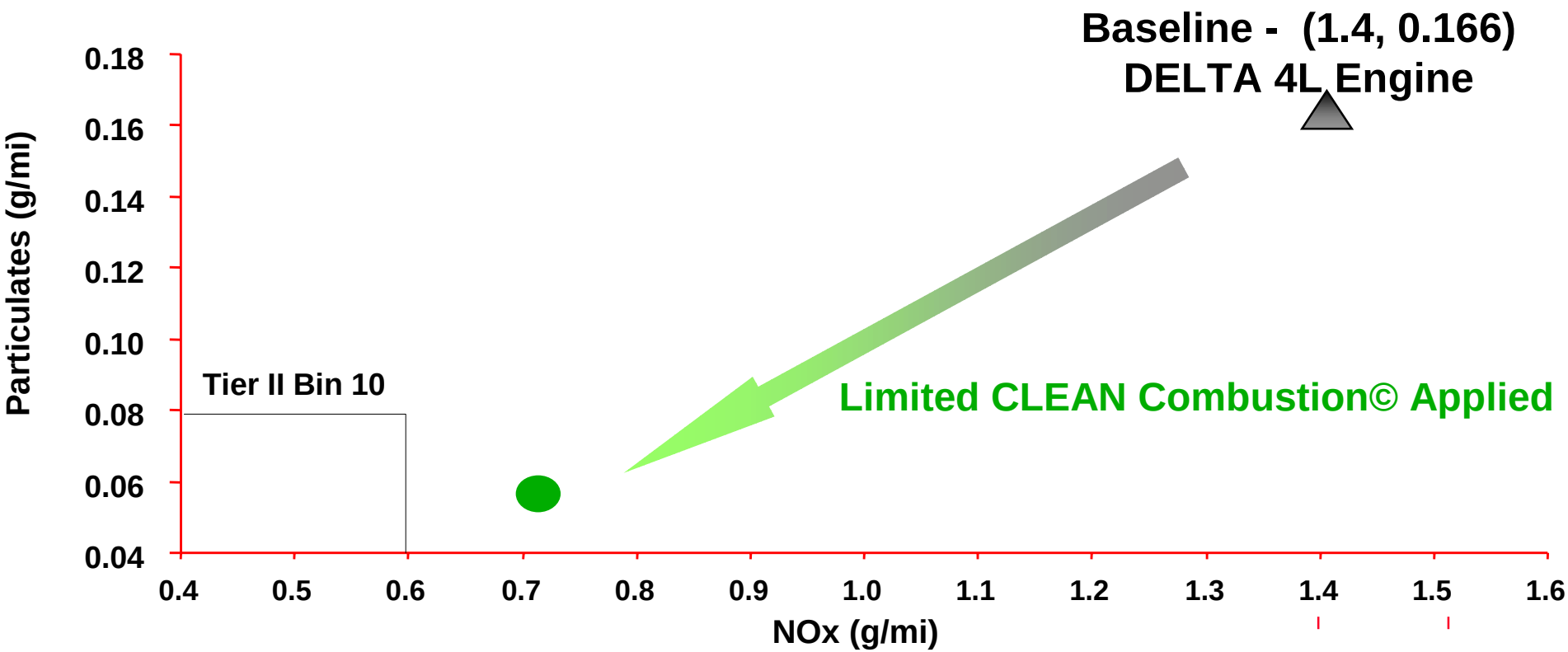
CLEAN Combustion© - Transient Emissions

Hot 505 Results

- Simultaneous ~33% Reduction in NOx and PM
- No Impact on HC, CO Emissions and MPG
  - Differences within Experimental Variation

CLEAN Combustion© - Transient Emissions

Initial Vehicle Emissions Improvement – Light Truck



Measured FTP-75 Tail Pipe Emissions <u>Without Aftertreatment</u>

Hitting Emissions Targets

CLEAN Combustion©
+ AT Integration

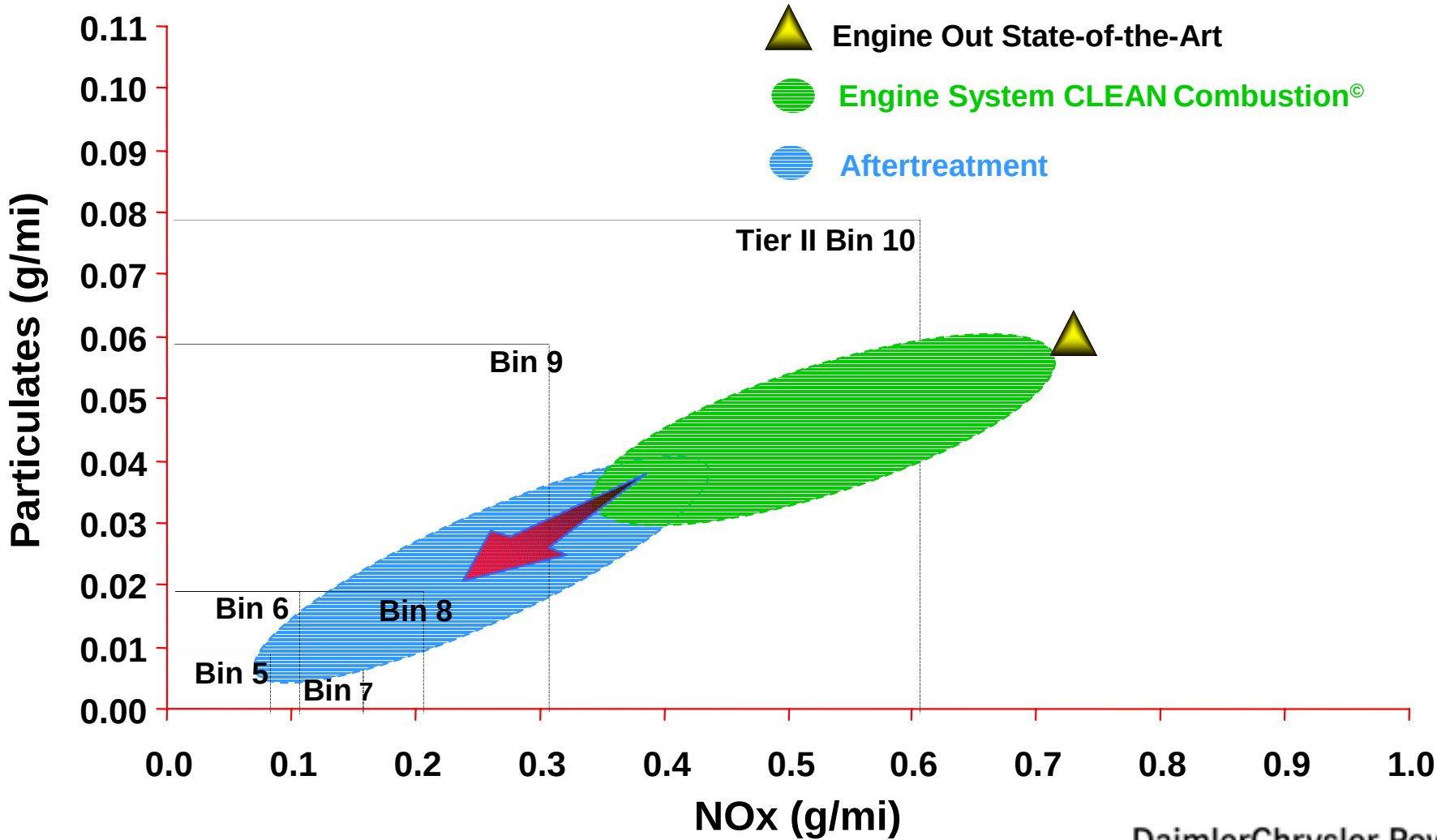
CLEAN Combustion© Plus Passive AT

CLEAN Combustion© Has Been Combined with Passive AT on an Advanced Passenger Car Vehicle:

- **Hot 505 Results:**
  - » 0.16 g/mi NOx and 0.02 g/mi PM W/ Low S Fuel.
  - » These Figures are Tier 2 - Bin 7* Values
- **Shows Potential but Many Challenges Remain**

* Tier 2 - Bin 7 Figures Pertains to Full FTP75 Composite Test

New Integrated Emissions Reduction Path – Light Duty



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Concluding Remarks

- **Breakthrough CLEAN Combustion© Concept Demonstrated.**
- **Integrated with Advanced AT Technologies, Extremely Low Diesel Engine Emissions Are Technically Feasible**