# Model−Based Diesel Engine Control With On−Board Fuel Efficiency Optimization

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DIRECTIONS IN ENGINE-EFFICIENCY AND EMISSIONS RESEARCH CONFERENCE

## Outline

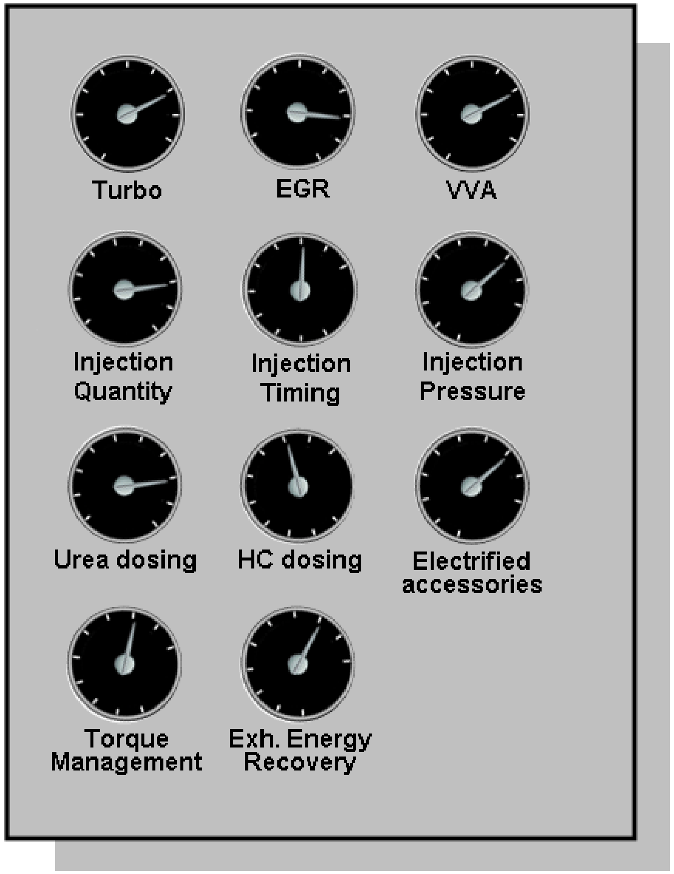
- Objectives
- Technical Approach
- Experimental Set-up
- Experimental Results
- Summary & Next Steps

## Objectives

- Develop a map-less, predictive, empirical engine controller
- Reduce calibration and controller complexity
- Include an on-board fuel efficiency optimizer

**Calibration Constraints**

- Drivability
- Durability
- Fuel economy
- Life-cycle cost
- NOx / PM / NMHC / $CO_2$
- OBD
- Exhaust temperature
- GPS / Route / Traffic info.




Goal: Mitigate increased calibration complexity

- More degrees of freedom
- Calibration optimization more complex

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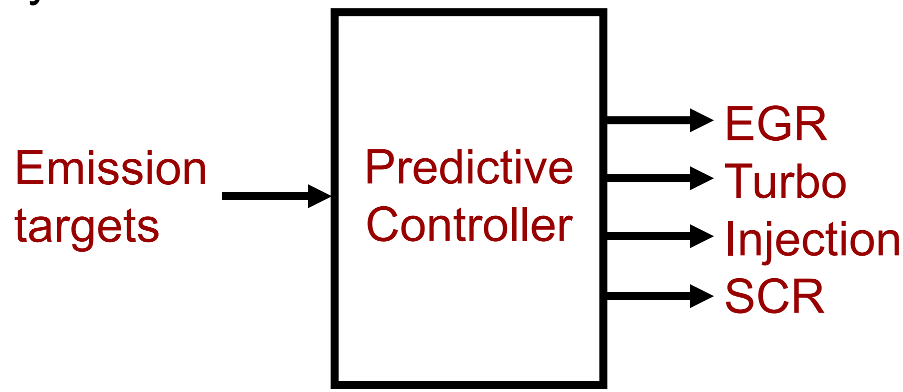
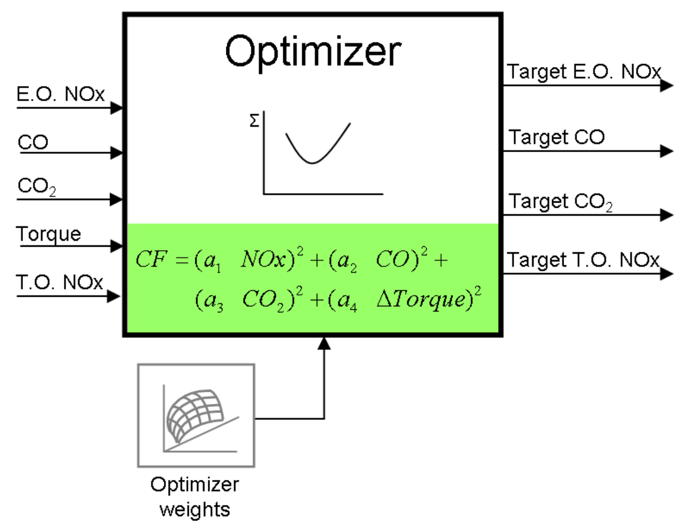
## Technical Approach

- Controller with built-in knowledge of system interactions
  - Nonlinearities
  - Individual system response times
- Inputs: Performance targets
- Outputs: Actuator signals

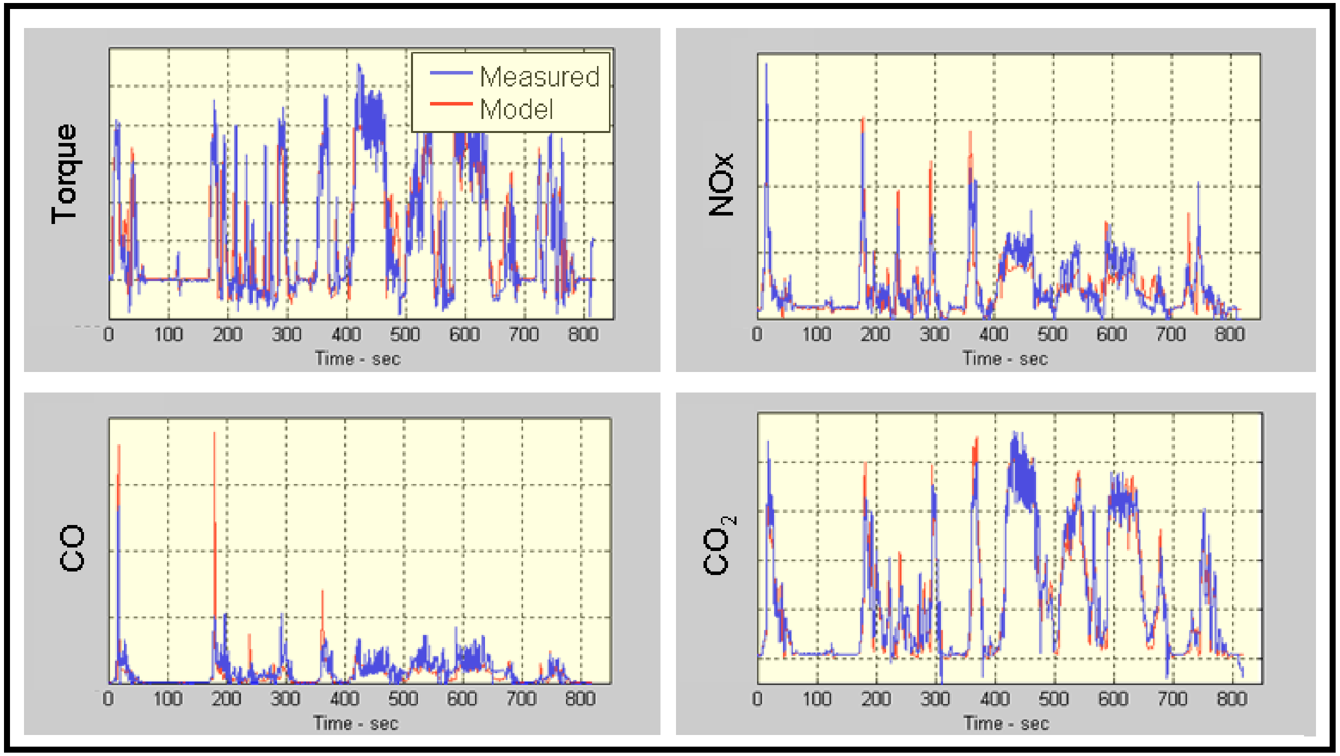



- Includes an optimizer
  - Cost function that minimizes emissions and fuel consumption
  - Optimizes engine operation in real-time



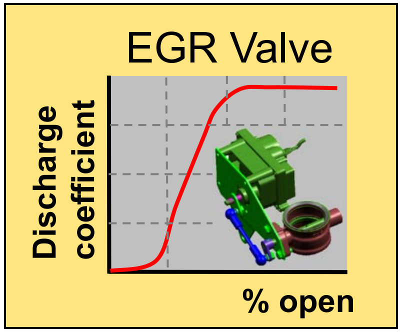
## Technical Approach

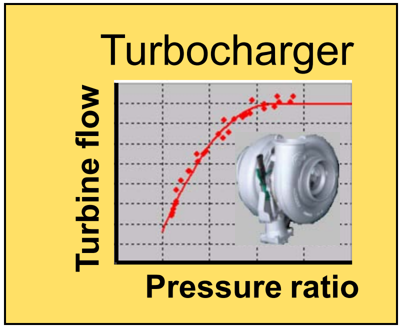
- Controller based on predictive engine models
  - First principle models
  - Neural networks trained with transient engine data

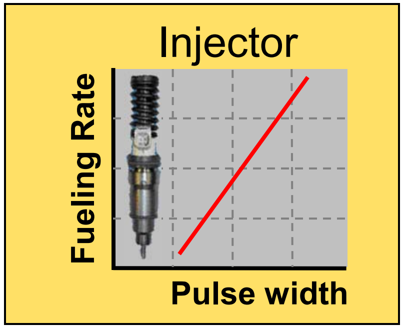



Approach made viable by

- More accurate actuators
- More repeatable systems

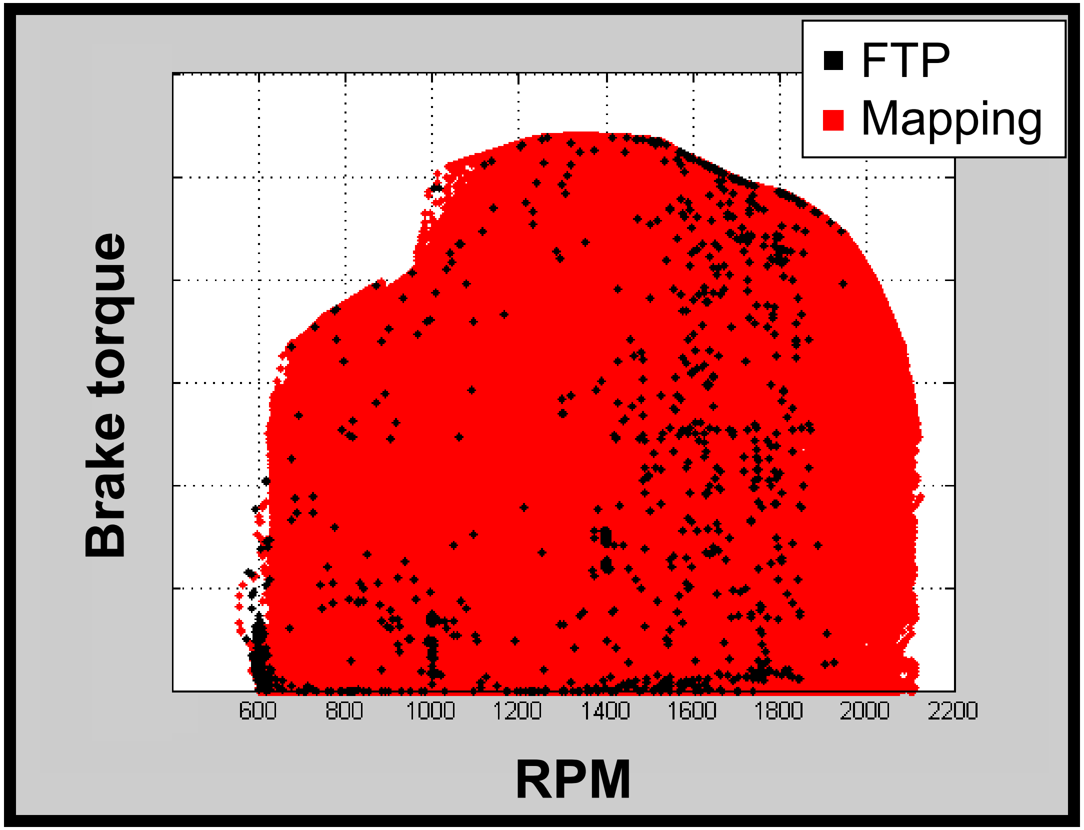


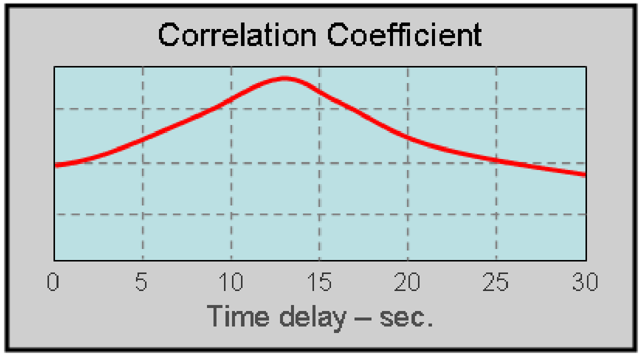



## Technical Approach

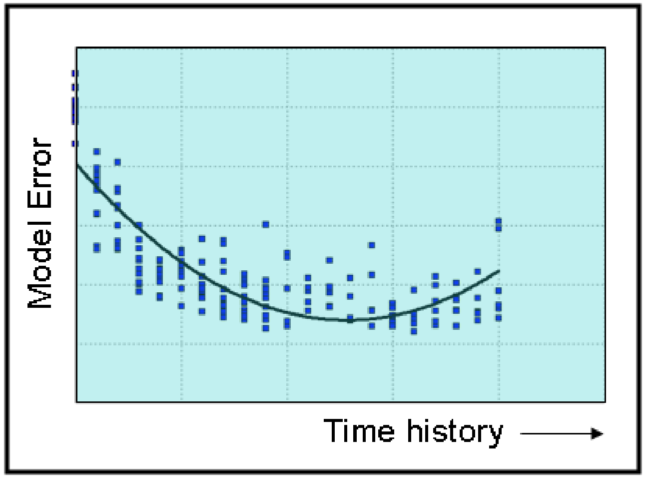
- On-board models based on extensive engine mapping
- Transient test cell data
  - Filtering
  - Time-alignment of emissions data



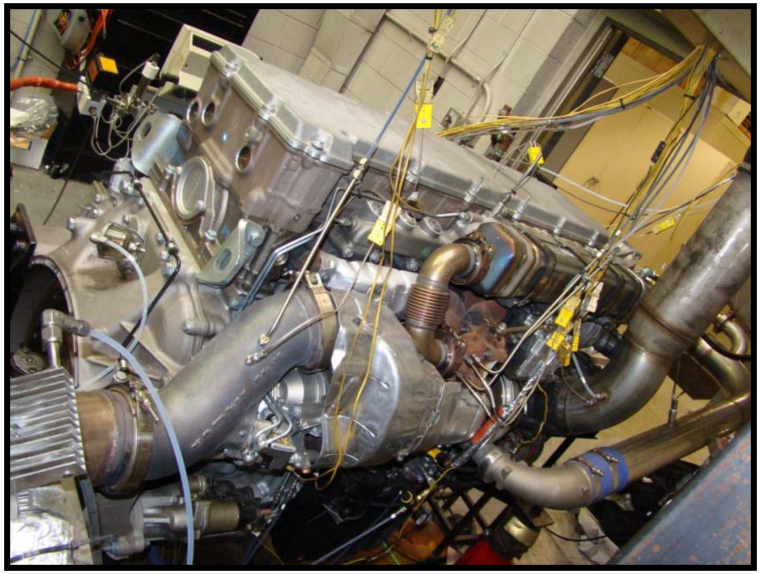

$CO_2$ vs. fueling rate correlation




Requires input "history"

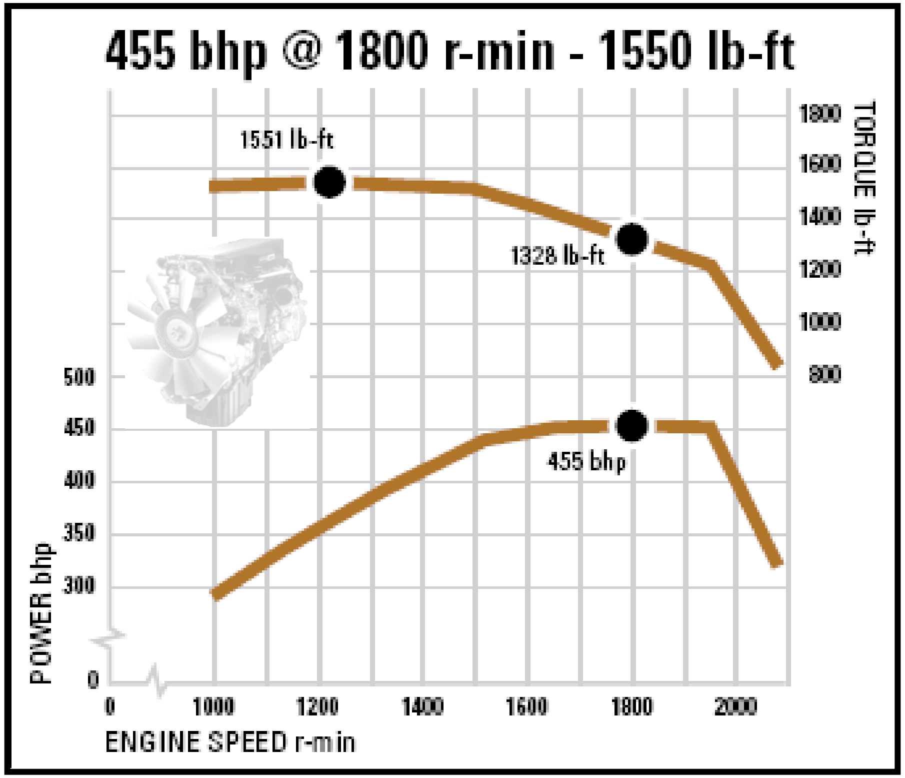


## Experimental Setup



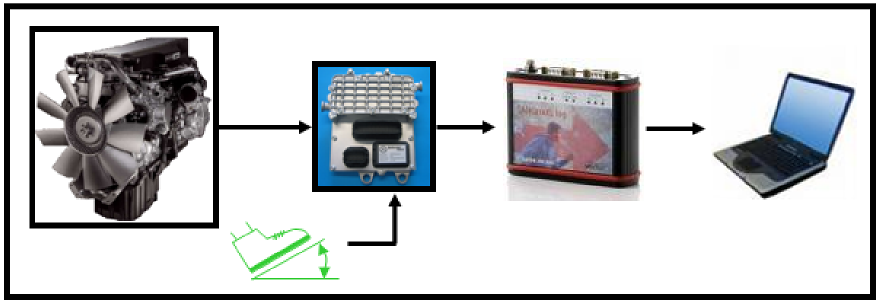
Baseline engine

- 2010 Detroit Diesel DD15
  - 14.8-liter inline 6-cylinder




ECM bypass

- Air / EGR / Fuel / SCR



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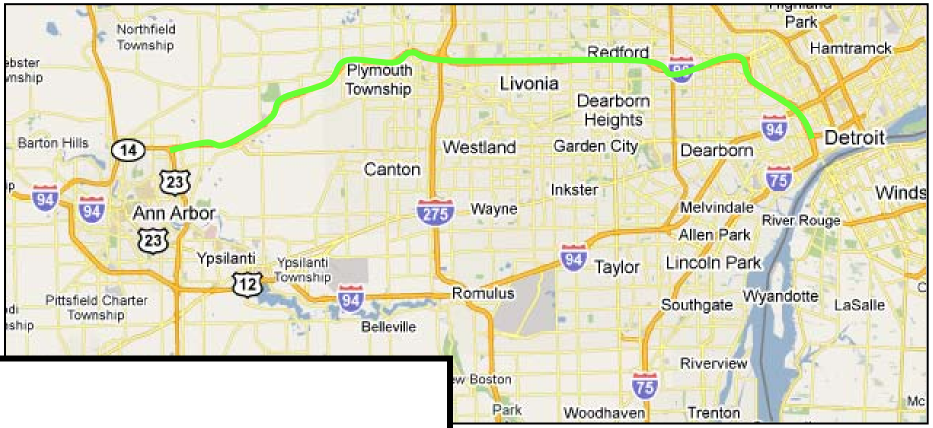
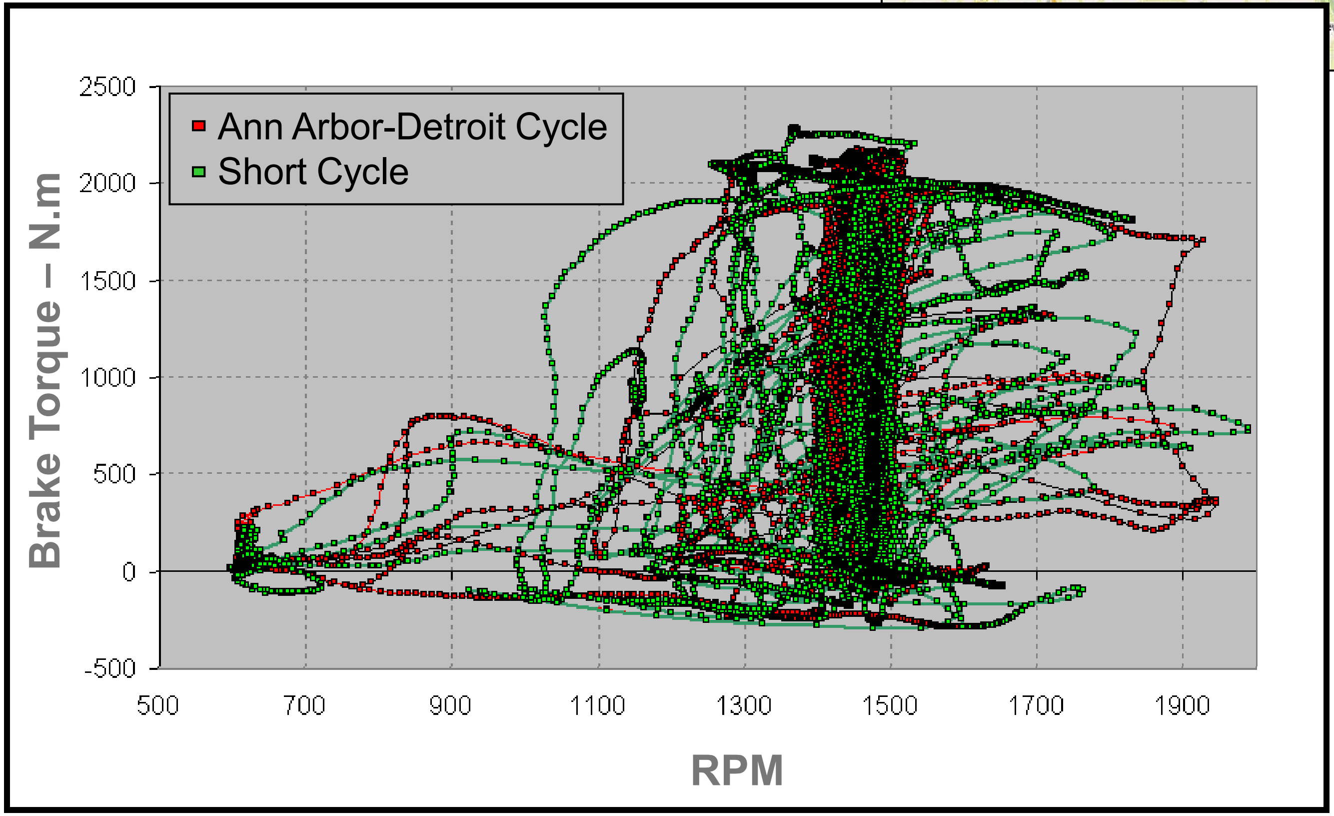
## Experimental Setup

- 20-minute dynamometer cycle
- Shortened version of Detroit-Ann Arbor vehicle load cycle



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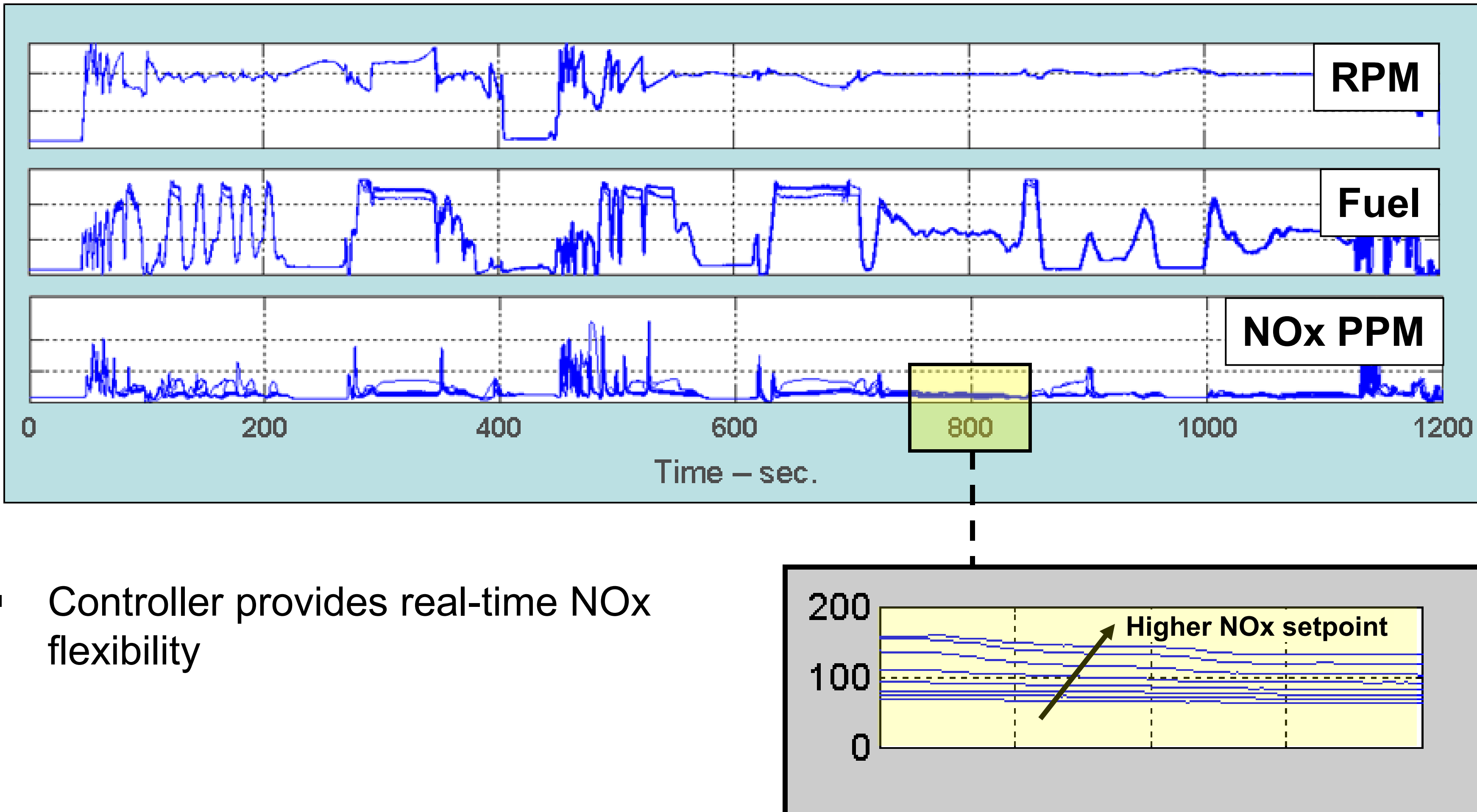
## Experimental Results

Multiple cycles with varying NOx / CO / $CO_2$ setpoints




- Controller provides real-time NOx flexibility

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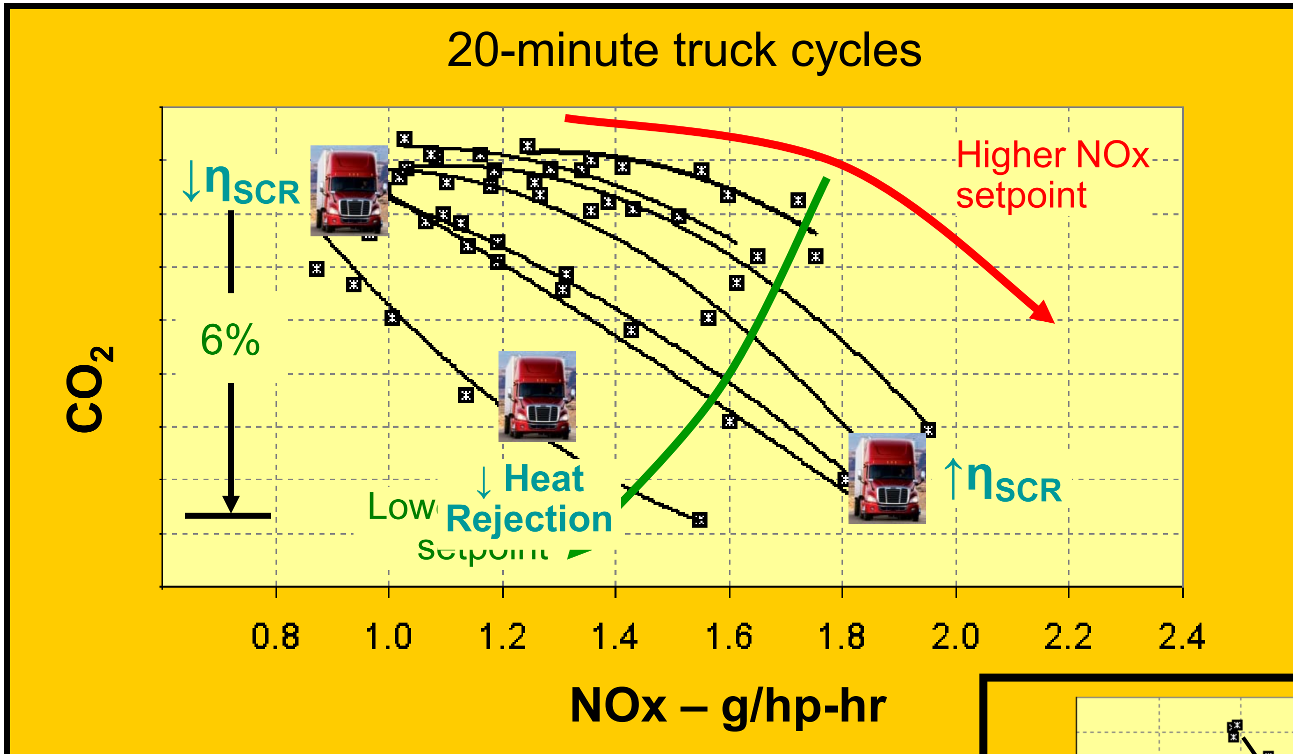
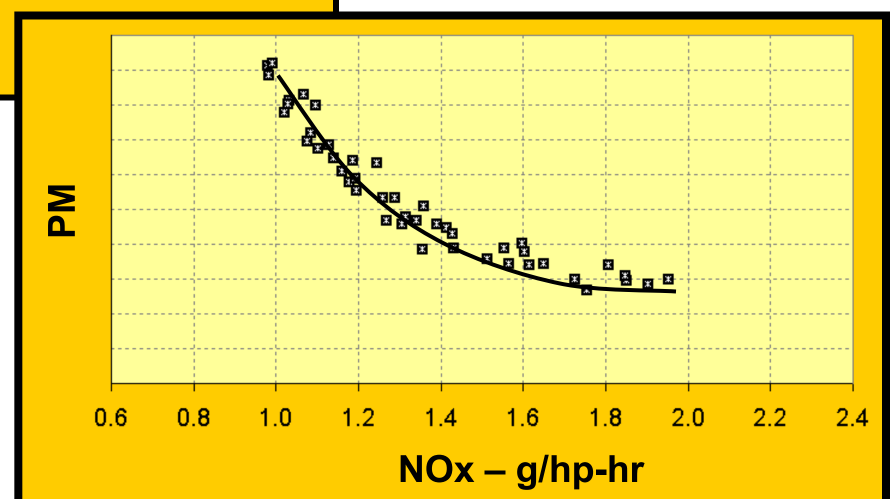
## Experimental Results




- Flexible engine control
- Modulates NOx & $CO_2$ output



## Summary & Next Steps

- Empirical, predictive engine control concept is viable
  - Concept demonstrated in test cell on truck cycles
  - Provides flexible engine control
  - Significant reduction in calibration effort

- Main limitation of the approach
  - Vehicle-to-vehicle variability
  - Mitigated by over-the-road adaptation

- Next Steps
  - Integration of additional control variables
    - Vehicle Predictive information
    - Waste Heat Recovery
    - Electrified Accessories

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