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DETROIT DIESEL

Super Truck – 50% Improvement In Class 8 Freight Efficiency

DoE SUPER TRUCK PROGRAM

DAIMLER TRUCKS

U.S. DEPARTMENT OF ENERGY

DEER 2011 DETROIT

Directions in Engine-efficiency and Emissions Research conference

October 5, 2011

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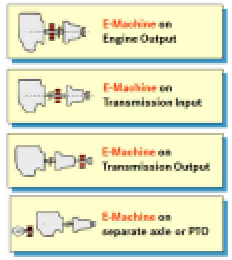
DTNA: Derek Rotz, Maik Ziegler

DTNA and DDC Super Truck Team

Super Truck Cross Functional Work Stream



Engine Downsizing & Hybrid

Powertrain Integration

Engine

Energy Management

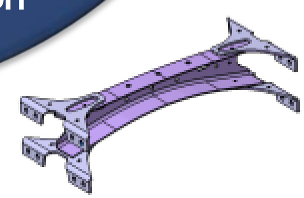
50% Increase In Freight Efficiency

Waste Heat Recovery

Parasitic Losses

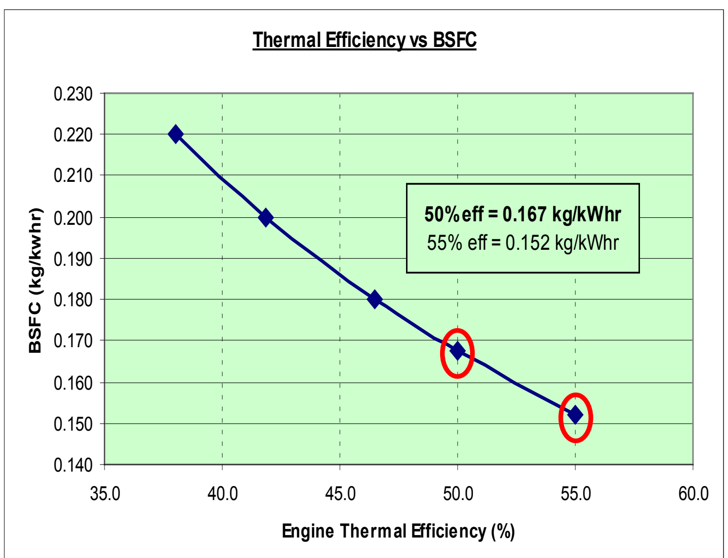
Aerodynamics

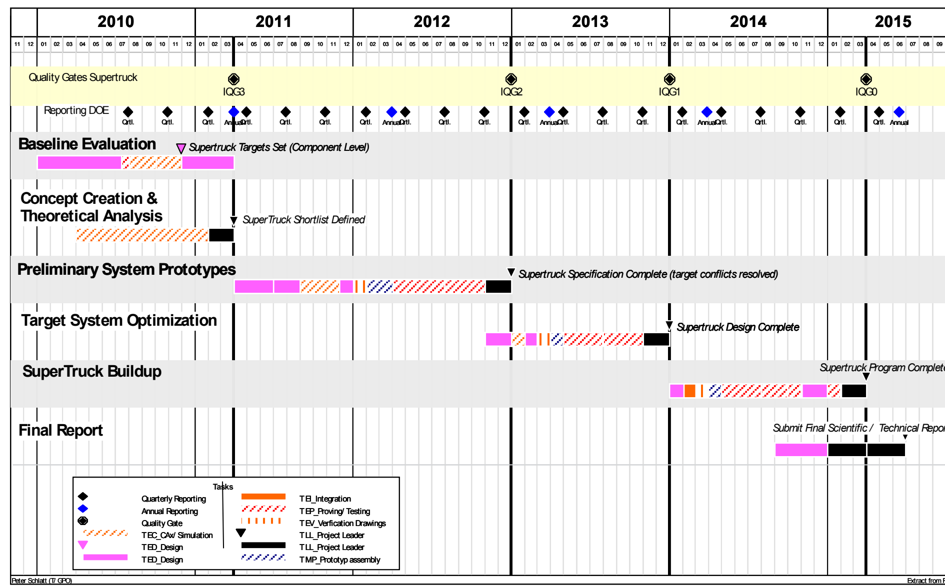
Weight Reduction



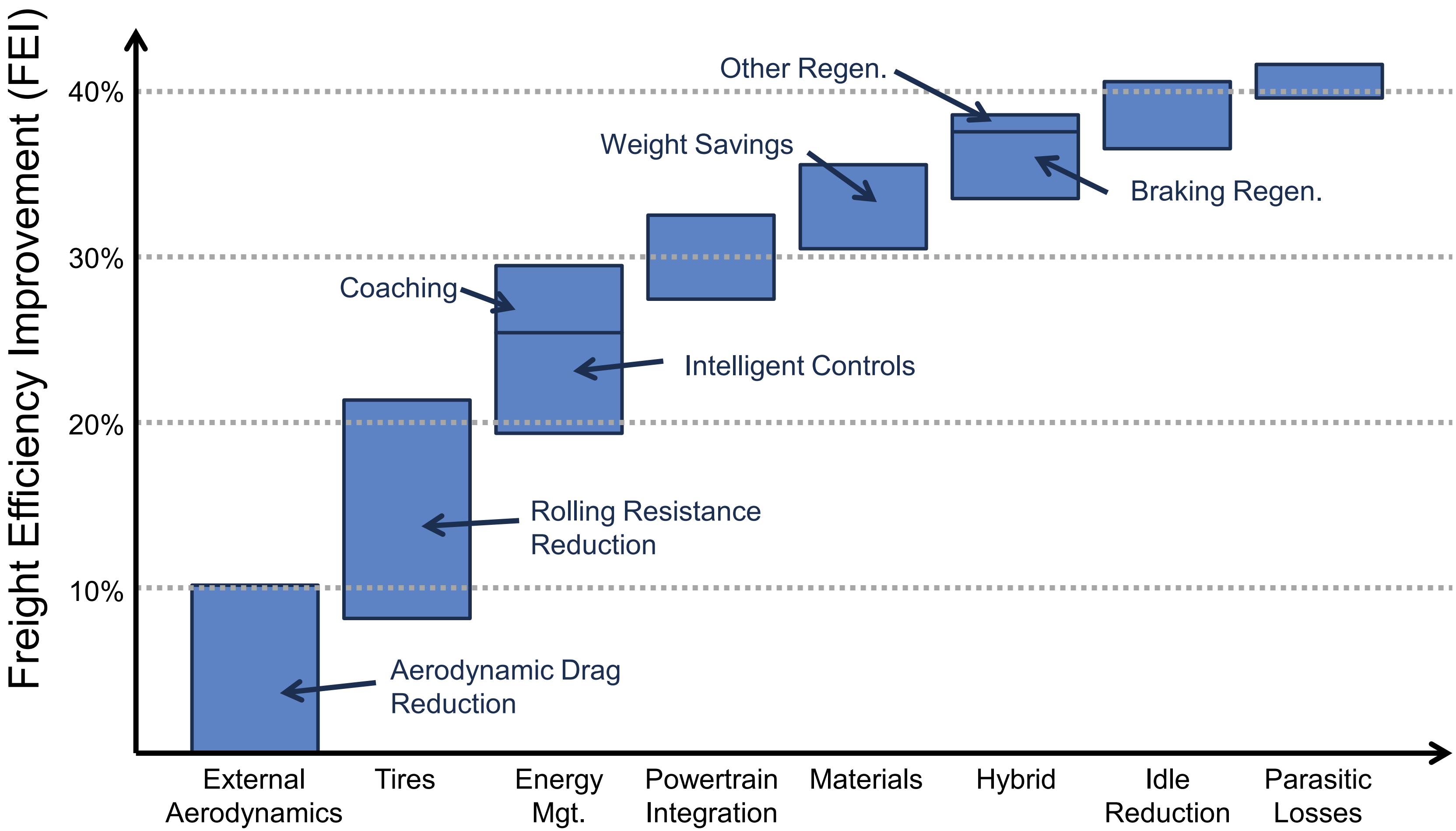
Super Truck Program Objectives

- 50% improvement in freight efficiency
  - Measured in ton-miles/ gallon
  - Baseline: 2009 Cascadia with DD15 engine
- Engine goal: 50% brake thermal efficiency
  - Base engine – 47%
  - Parasitics – 48%
  - Waste heat recovery – 50%



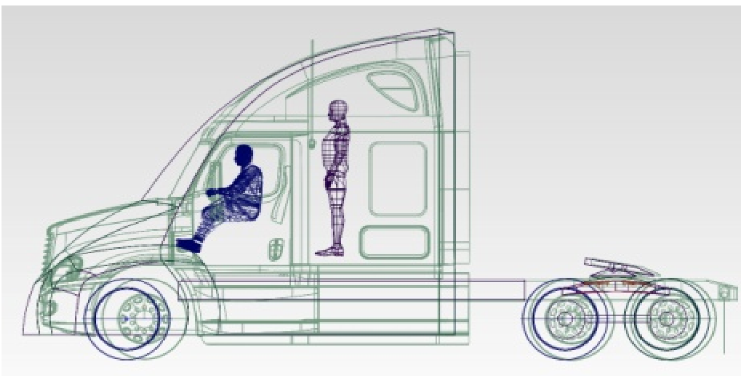


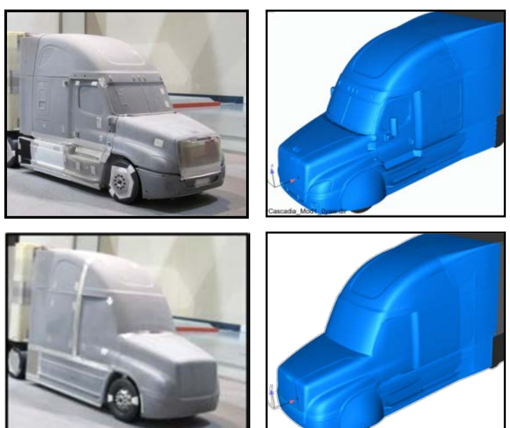
Roadmap: Vehicle-Side Technologies



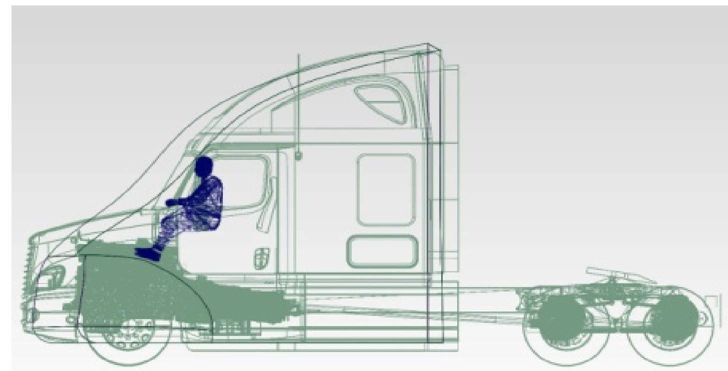
External Aero: Wind Tunnel and CFD Study

Design Option 1





Design Option 2



Idle Reduction Technologies

Objective: 4% Freight Efficiency Improvement over baseline *(main engine idling)*

Solid-Oxide Fuel Cell APU

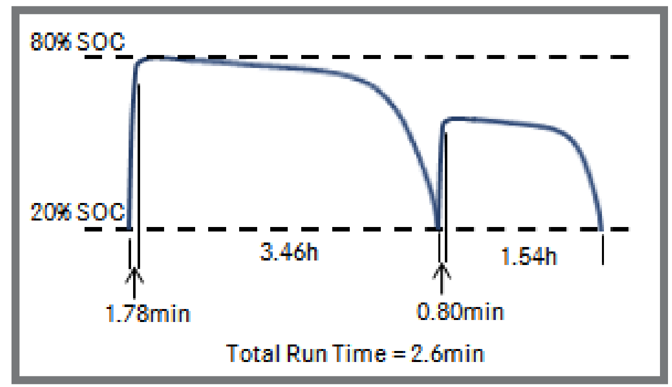
Image shown with permission from Delphi Corporation

Results: SOFC-APU installed & tested on Cascadia, fuel measurement

Characteristics:

- Enables full-engine off operations

Hybrid System



Results: concept defined, preliminary energy calculations completed

Charactersistics:

- Fast on/off time
- No dedicated added weight

➔NEXT STEPS: evaluation / selection of preferred SuperTruck concept based on representative test cycles

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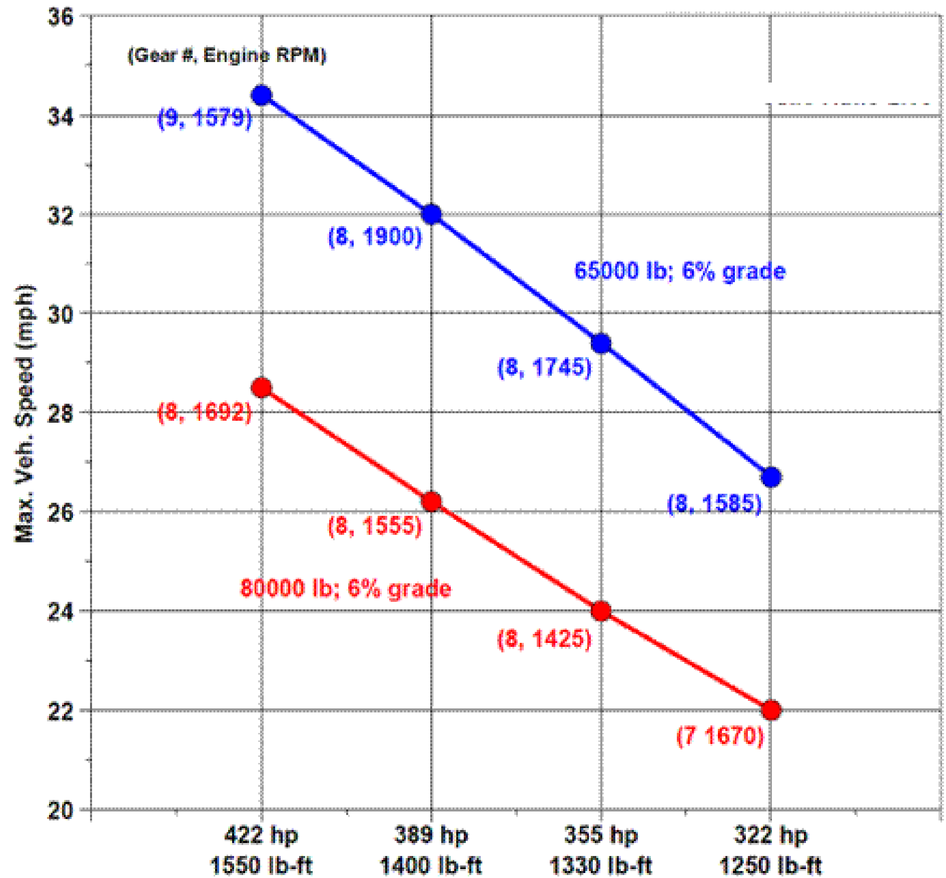
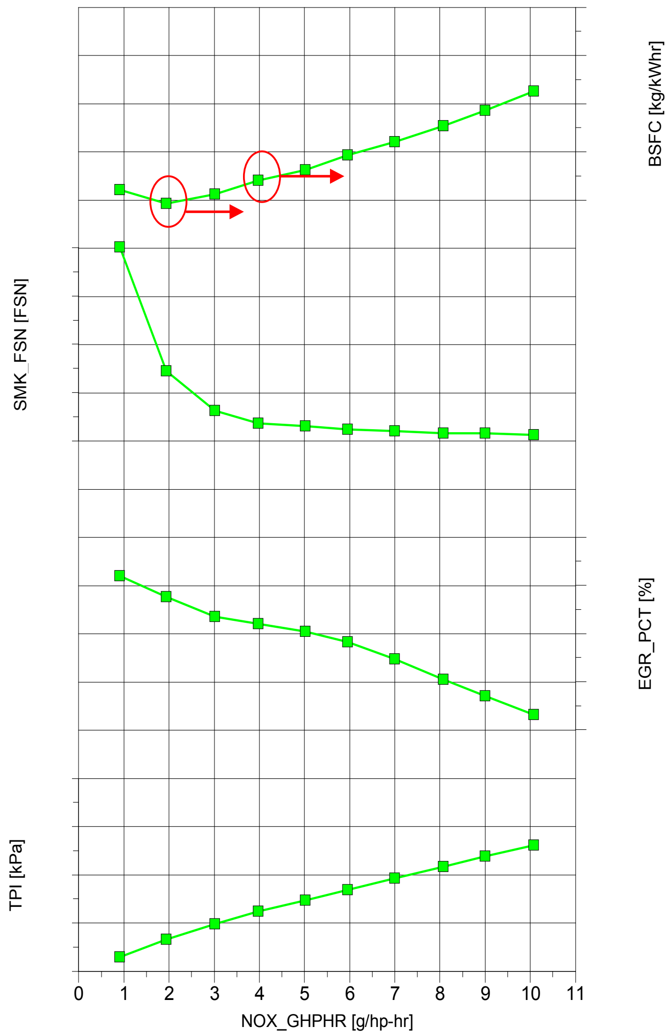
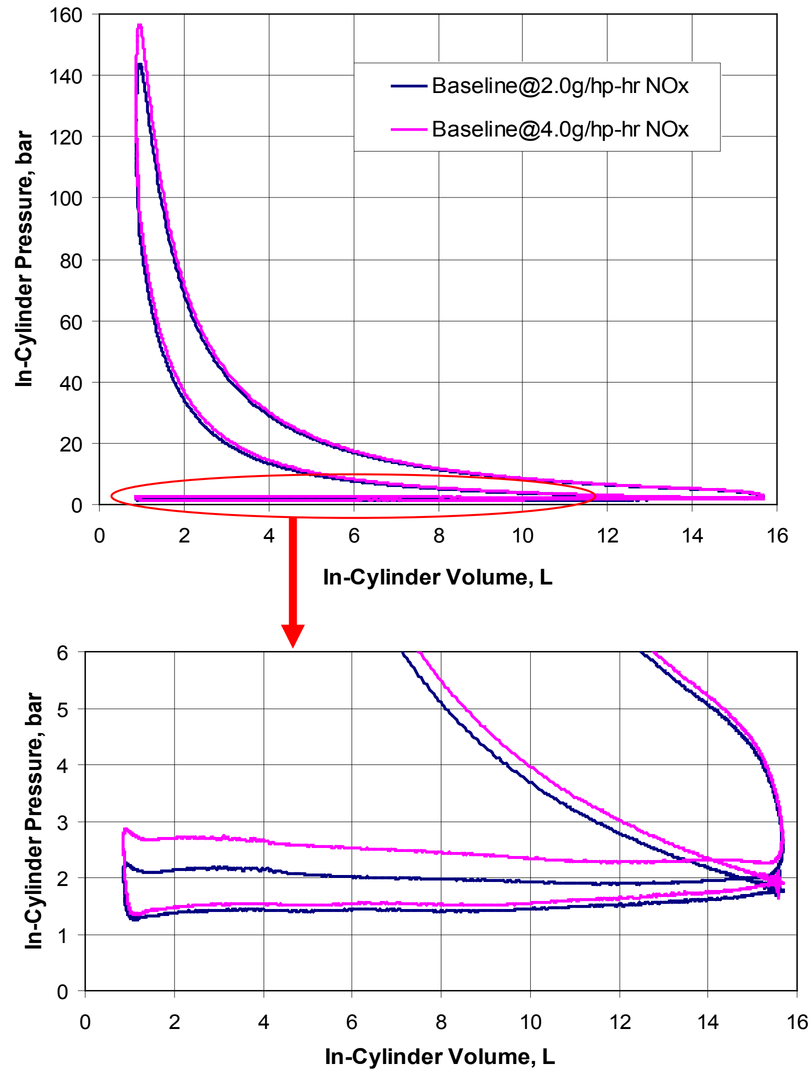
Horsepower Rating Criteria

- Over the past 20 years, ratings drifted higher, resulting in higher speed on grades, fewer shifts and increased driver satisfaction.
- Balancing driver satisfaction vs. fuel economy is an interesting challenge.



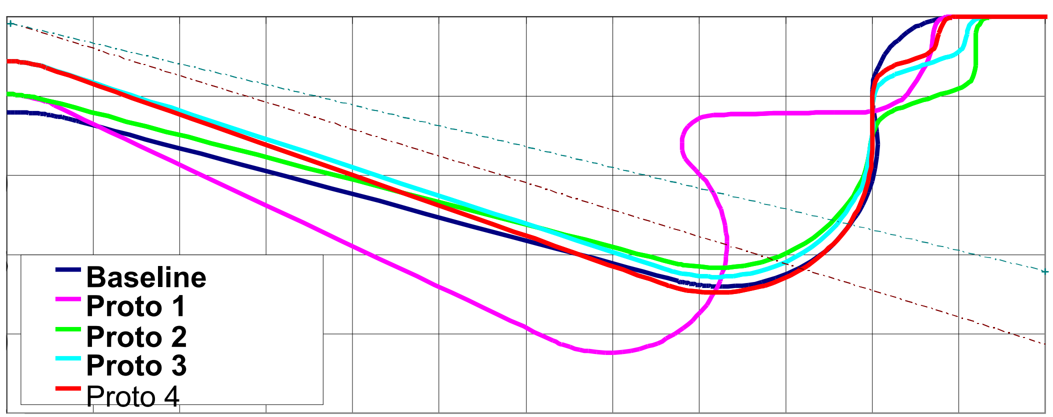
2009 Engine Performance at Higher NOx





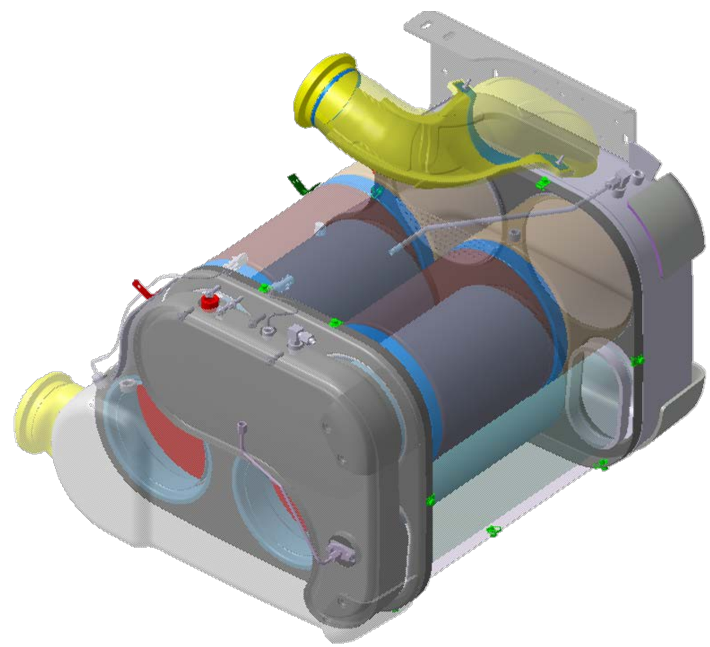
Combustion System Investigations

- Evaluating various 2-step piston bowls
- Results vary by bowl shapes, but overall 2-step bowls show significant smoke reduction, but no bsfc improvement.
- Follow-on: heads with higher swirl level are being procured to quantify potential impact.



Aftertreatment Development

- Aftertreatment focused on next generation materials
  - Lower dP and improved DEF-SCR efficiency
    - New DOC material for reduced back pressure
    - New DPF material for lower pressure drop while maintaining soot storage capability
    - New DEF-SCR for higher efficiency
  - All hardware at canner
  - Testing will be initiated shortly



Parasitic Reduction – 4% bsfc

- Multiple systems being optimized.
  - Kit and engine friction, and "smarter" accessory loads
- Progress to date
  - 1.5% improvement demonstrated in test cell and on vehicle.
  - Parts on order to allow demonstration of an additional 1.5%
  - Feasibility study underway for further improvements of >1%
    - Partnered with Massachusetts Institute of Technology (MIT)

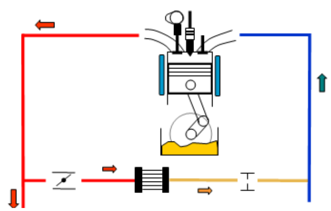





Massachusetts Institute of Technology

Predictive Controls

Component Level



System Level

Engine Level

Truck Level

- Increasingly complex calibration
  - More degrees of freedom
  - Additional actuators
  - Vehicle integration
  - Refined optimizations

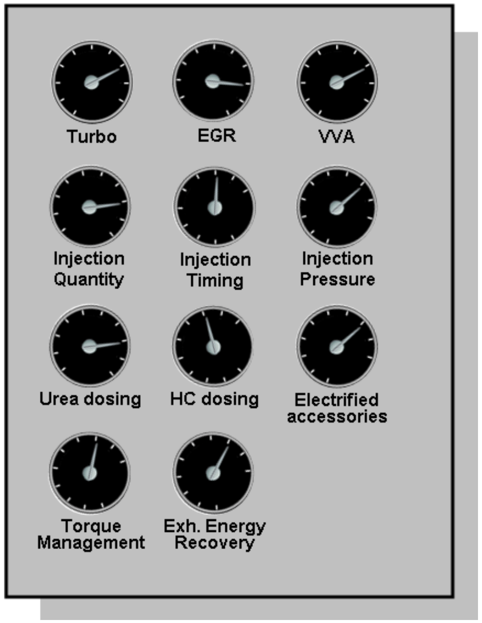
- More stringent requirements
  - Control stability
  - Transient response
  - Fuel economy
  - Urea consumption
  - Emissions
  - Life-cycle cost
  - Durability
  - Diagnostics

Control System Features

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

Calibration Constraints

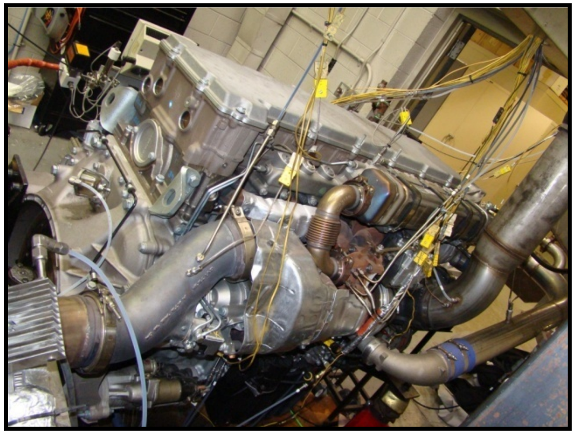
§ Drivability
§ Durability
§ Fuel economy
§ Life-cycle cost
§ NOx / PM / NMHC / CO_2
§ OBD
§ Exhaust temperature
§ GPS / Route / Traffic info.

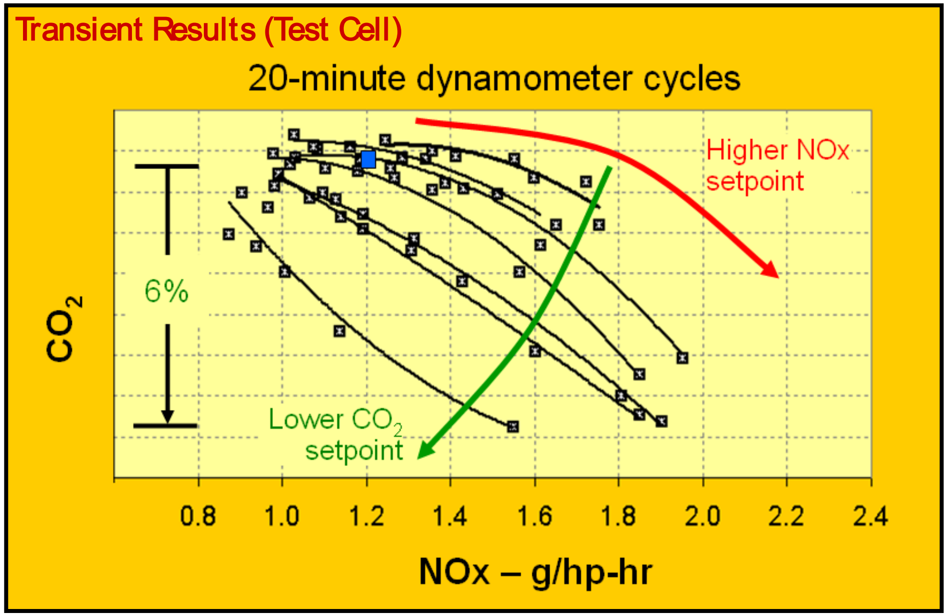


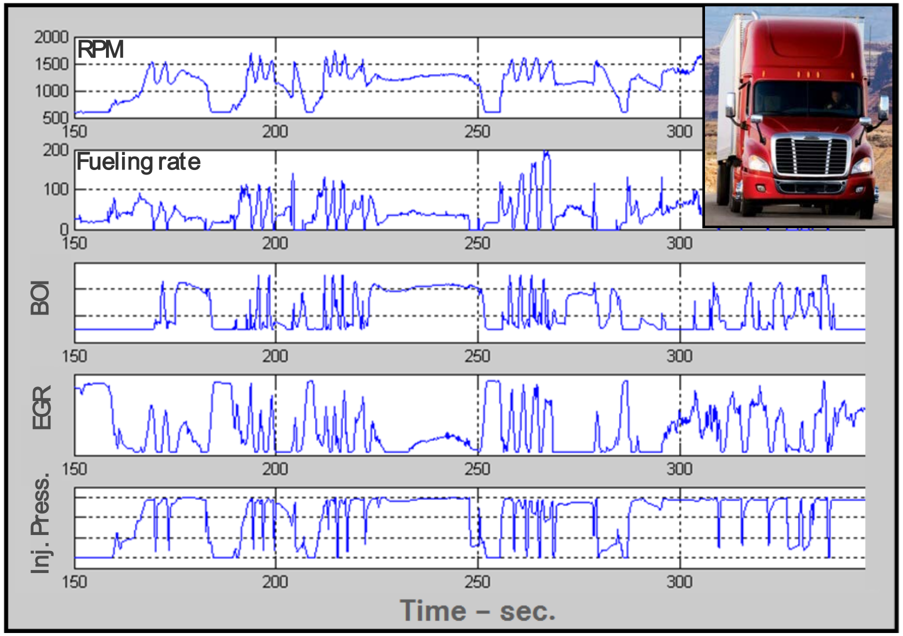
- Easier to calibrate (mitigate control complexity)
- Remain optimized through transient operation.

Engine Controls – Test Data

- Controller fully operational – validation and development in transient test cell
- Preliminary vehicle testing initiated

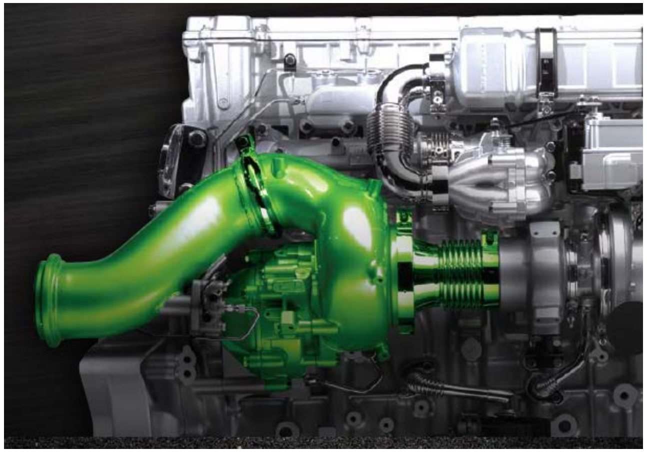


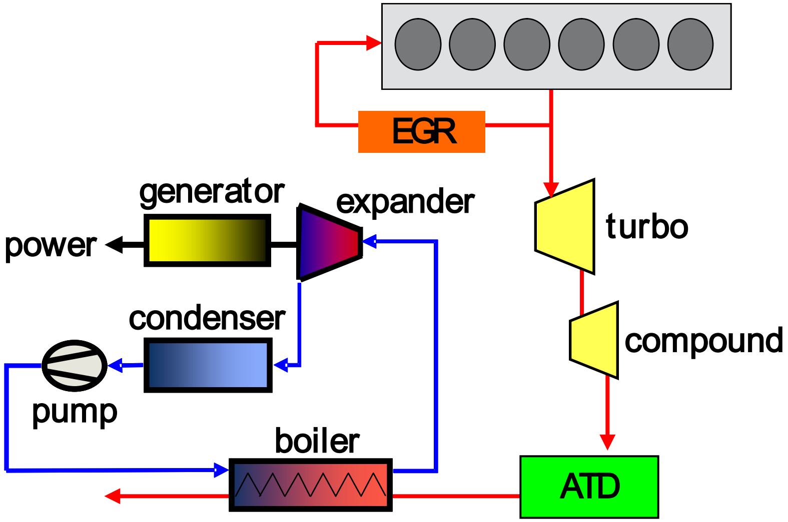




Waste Heat Recovery

- Approx. 55%of fuel energy is “waste heat”
- Waste heat recovery
  - Turbocompound – being evaluated
  - Rankine cycle – recover energy from EGR and/ or exhaust gases
    - 5%BSFC improvement targeted.
    - Significant technical challenges
      - Heat exchangers, expander, compressor, packaging, engine integration, etc
- Development Partners
  - Oak Ridge National Laboratory
  - Daimler Advanced Engineering Group

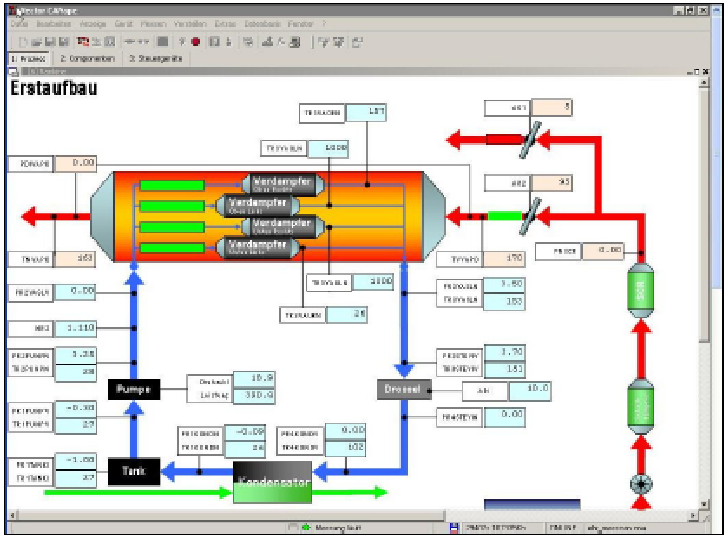


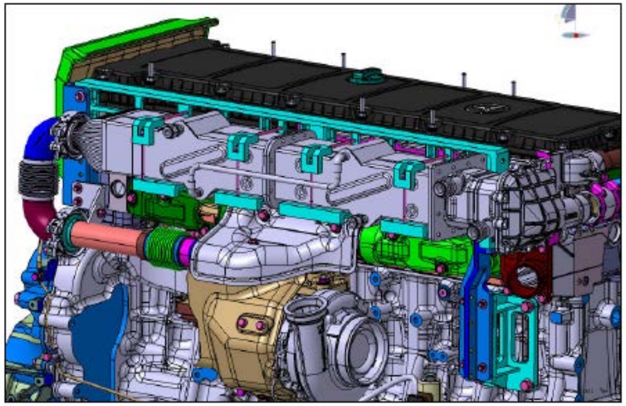


Simulation and Packaging

- Multiple simulation tools being used
  - Performed at ORNL and Detroit
- Component testing @ Daimler Research
- Packaging studies underway

Test bench display

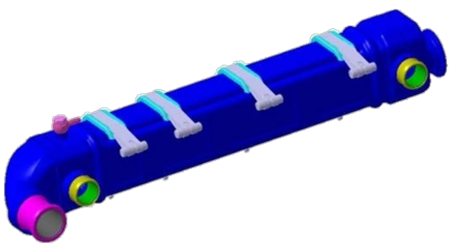




Rankine System – Major Components

Evaporator

Transfer exhaust and/or EGR energy to working fluid.

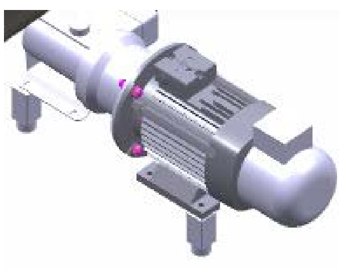


Expander

Handle 2-phase flow, high speed operation for electricity generation

Working Fluid

Ethanol
Low environmental impact.
Suitable thermodynamic properties



Hermetically sealed Diaphragm pump

Pump

Rejected heat will be released under hood

Condenser

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