DAIMLER

Road Mapping Engine Technology for Post-2020 Heavy Duty Vehicles

Detroit, October 5th 2011

Dr. Igor Gruden, Marc Allain, Craig Savonen

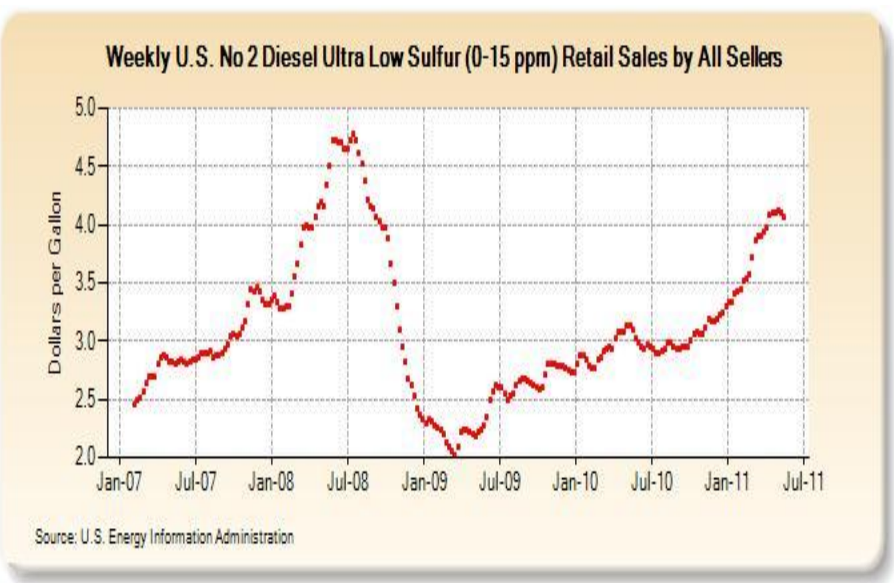
DTNA / DDC Super Truck Team

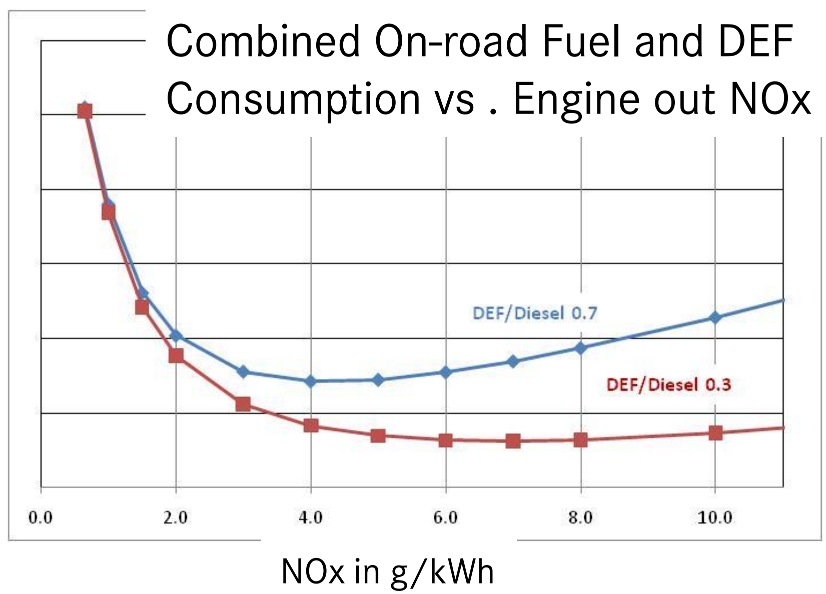
Agenda

- Total operating costs
- CO2 Regulatory
- Truck requirements
- Supertruck Technology elements
  - Downsizing
  - Combustion System
  - Parasitics
  - Integrated Powertrain Optimization
  - Transient control
- Summary Roadmap

Fuel Economy Is Still King

- Fuel Economy Is Expected To Continue To Be #1 Priority From Our Trucking Customers.
- Yet, Their Profitability, If Not Survival Depends Keenly In Knowing and Anticipating Total Truck Life Cycle Operating Costs, Including Reliability /Up-Time, Durability, and Payback Duration For Newer, Higher Complexity Technology.
- Cyclical Fuel Market Trends – Future Optimized NO_x/BSFC Variable Engine Maps Would Adjust Dynamically To DEF/Fuel Price Ratios While Ensuring Regulatory Compliance.





CO_2 Regulatory Activities for Heavy Duty Markets

USA

Legislation Finalized September 2011

- Reduction target between 6 and 23% depending on vehicle class
- (2017 compared to 2010)

Engine targets based on FTP-, SET-cycle tests

Separate vehicle targets based on „bin mapping“ method for 5 technologies.

Class 8 Sleeper Compliance Table (FEL g/ton-mile)

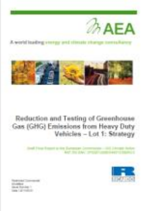
Aerodynamics	Tire RR	Idle Shutdown	Weight Reduction	VSL	FEL
Bin 1	Bin 1	Bin 0	Bin 0	Bin 0	110
Bin 1	Bin 1	Bin 1	Bin 0	Bin 0	103
Bin 1	Bin 1	Bin 1	Bin 1	Bin 0	102.4
Bin 1	Bin 1	Bin 1	Bin 1	Bin 1	101.8
Bin 1	Bin 1	Bin 1	Bin 1	Bin 2	101.2
Bin 1	Bin 1	Bin 1	Bin 1	Bin 3	100.6
Bin 1	Bin 1	Bin 1	Bin 1	Bin 4	100
Bin 1	Bin 1	Bin 1	Bin 1	Bin 5	99.4
Bin 1	Bin 1	Bin 1	Bin 2	Bin 0	101.8
...	...	...	...	...	...
Bin 4	Bin 6	Bin 1	Bin 2	Bin 0	86
Bin 4	Bin 7	Bin 1	Bin 2	Bin 0	85.7
...	...	...	...	...	...
Bin 5	Bin 9	Bin 6	Bin 4	Bin 10	72

Europe

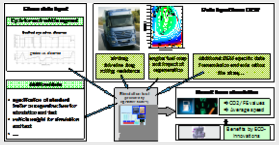
EC Ordered 2 studies:

Policy Options

Measurement procedure of HDV fuel consumption



ACEA proposes simulation based approach similar to Japanese legislation extended by vehicle improvements.



Japan

Legislation in Place Since 2006

- Reduction target 12.2% 2015 compared to 2002 (target tightening expected)

1

Category			Target Consumption km/L
Truck	1	PL≦1.5t	10.83
	2	1.5<PL≦2t	10.35
	3	2<PL ≦3t	9.51
	4	3<PL	8.12
	5	7.5< GVW ≦8t	7.24
	6	8< GVW ≦10t	6.52
	7	10< GVW ≦12t	6.00
	8	12< GVW ≦14t	5.69
	9	14< GVW ≦16t	4.97
	10	16< GVW ≦20t	4.15
	11	20< GVW ≦25t	4.04
Tractor	1	GVW ≦20t	3.09
	2	20t< GVW	2.01

2 **Improvement of 12,2 % compared to 2002**

China

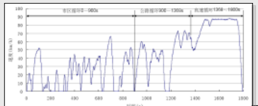
Legislation Targeted To Be Finalized by End of 2012

Proposal for standardized fuel consumption

Chassis dyno test for base type vehicles. Simulation allowed for variants.

C-WHVC (Chinese version).

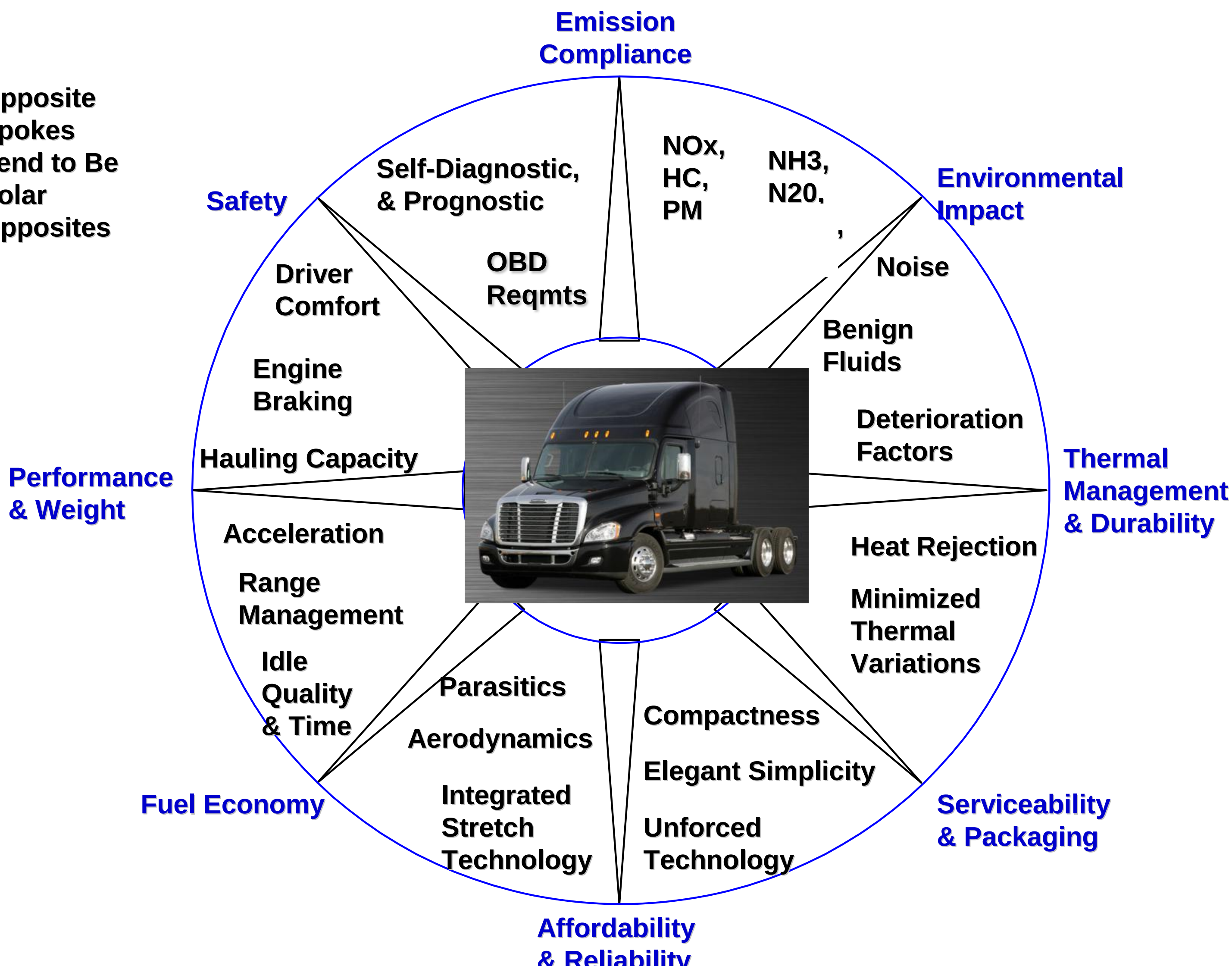
Vehicle class specific target values.



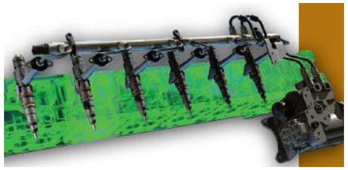
Vehicle category	Gross vehicle weight (GVW) / gross combination vehicle weight (GCW), kg	Share of urban portion, D_{urban}	Share of highway portion, $D_{highway}$
Semi-trailer towing vehicle	9,000 < GCW ≤ 25,000	0	40%
	GCW > 25,000	0	10%
Tipper	GVW > 3,500	0	100%
Goods vehicle	3,500 < GVW ≤ 5,500	40%	40%
	5,500 < GVW ≤ 12,500	10%	60%
	12,500 < GVW ≤ 24,500	10%	40%
	GVW >24,500	10%	30%

The Truck Requirements Wheel

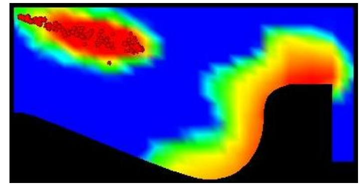
Opposite Spokes Tend to Be Polar Opposites



Super Truck Technology Elements



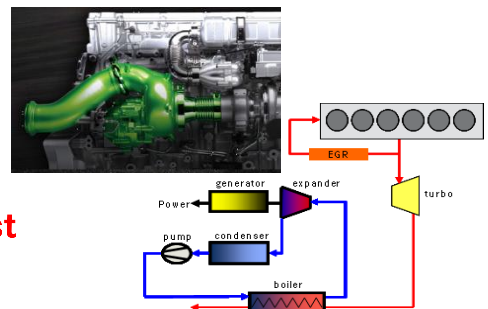
Enhanced high pressure fuel injection system



Optimized Combustion Including VVT

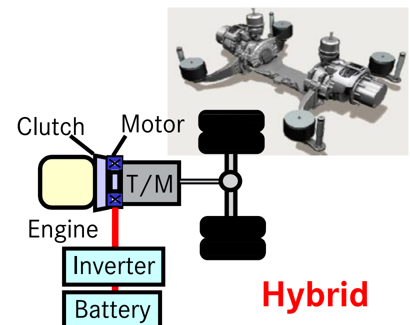
Hybrid Transmission Concepts

SUPERTRUCK

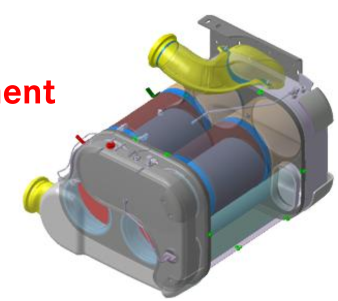


Exhaust Heat Recovery & turbocharging

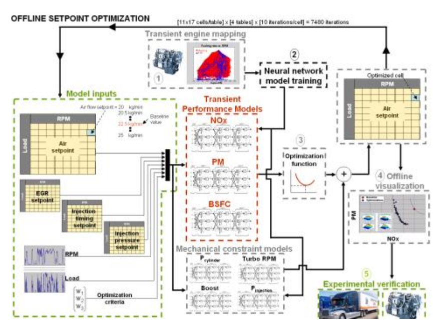
Aerodynamics



Hybrid Concepts



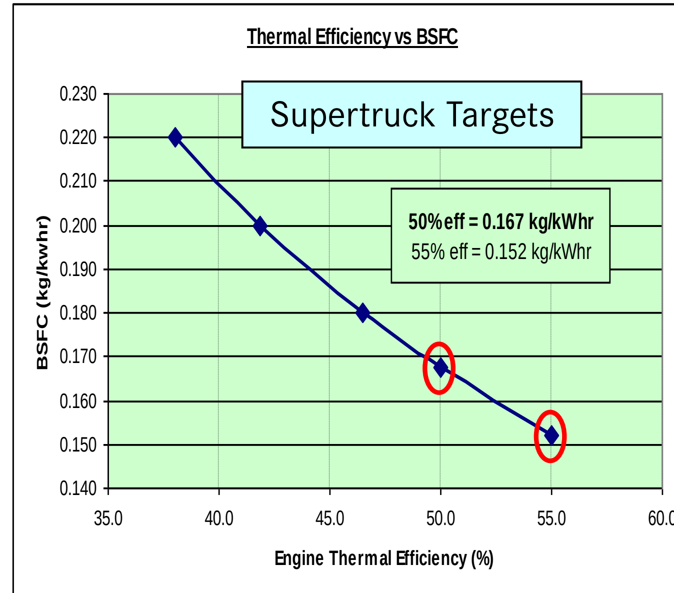
Optimized Aftertreatment



Next Generation Controller

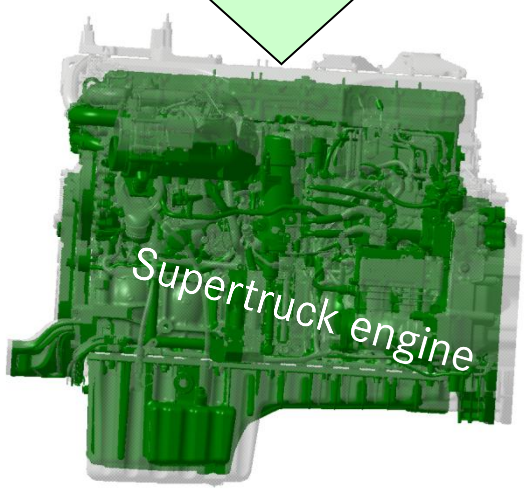
Predictive Torque & Auxiliary Management

Engine Technology Forged To Meet Future Requirements



Engine / Drivetrain / Vehicle Speeds

Reduced Gas and Fluid Parasitics, Optimized Engine/Vehicle Aerodynamics & Cooling Reduced cruise load

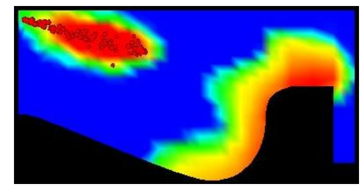


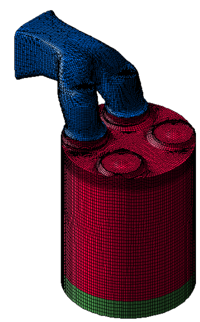
Reduced Weight & Space Claim, Higher BMEP / lower ISFC, Optimized Exhaust Thermal Signature, Freight Efficiency

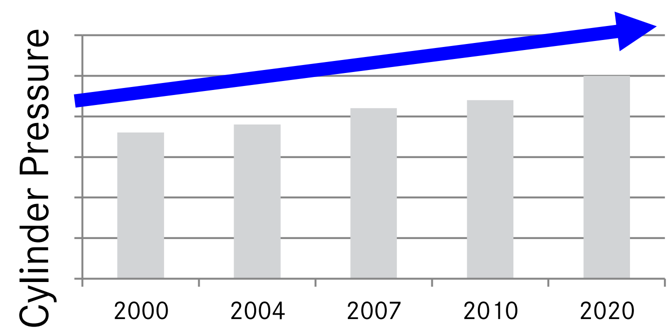
Heavy Duty Engine Displacement

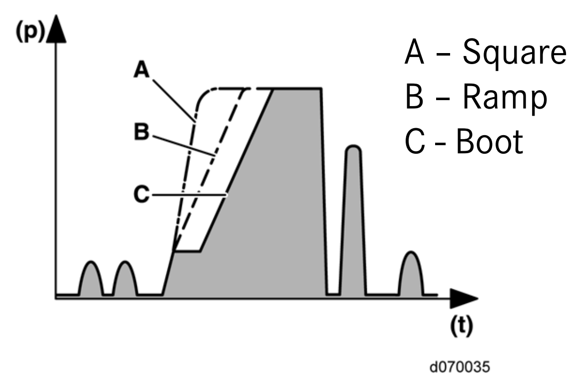
Perennial Combustion System Levers

- Combustion Chamber
  - Piston / Head / Liner Shape & Robustness Refinement
  - Increased Compression Ratio & Cylinder Pressure
  - Thermal Coatings & Focal Point Cooling
- Injection
  - Evolutionary Nozzle Geometry
  - Optimized Hydraulic Flow
  - Dynamic Rate Shaping
  - Increased Injection Pressure
  - Multiple Injection



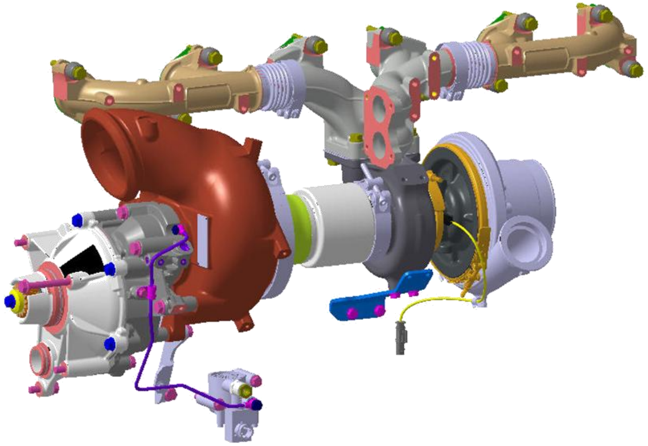


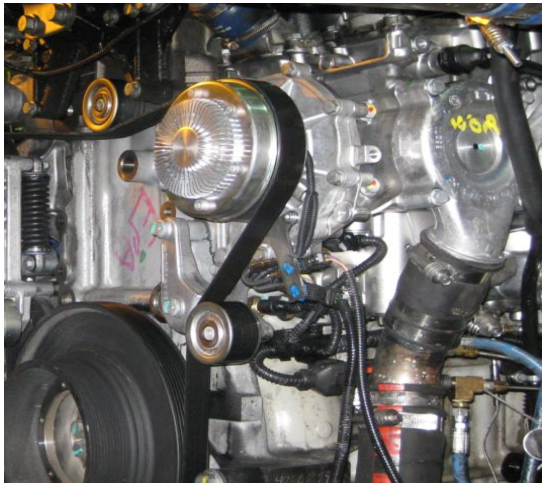




Parasitic Management

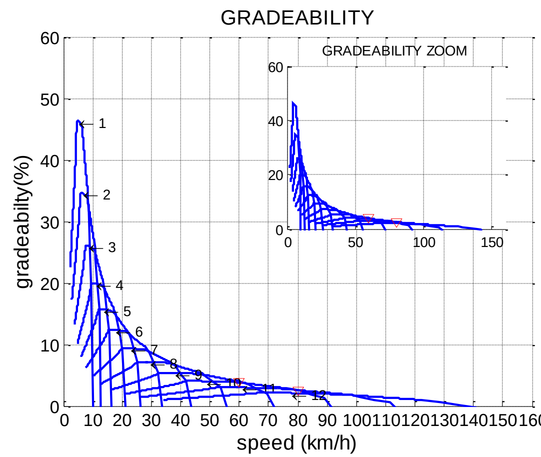
- Smarter Use Of Optimized Accessories And Pumps
- Increased Flexibility In Component Outputs
- Tighter Control of Emission Constituents
- Self-Learning Feedback Control System



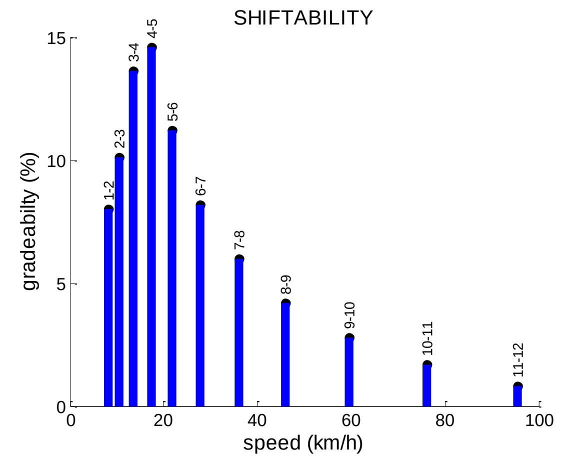


Integrated Powertrain Performance Metrics

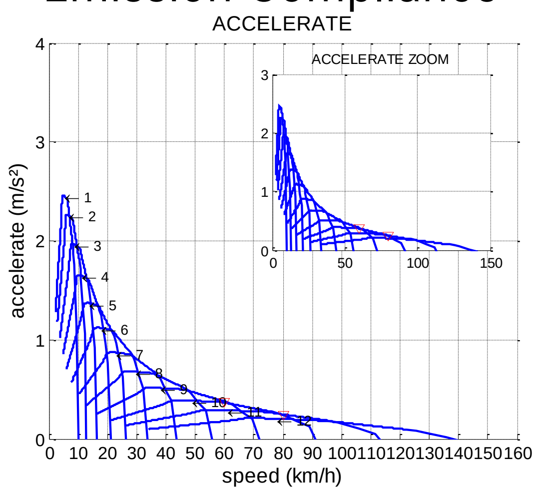
- Load Response
- Drive Time
- Driveability
- Low Speed Maneuvering
- NVH
- Thermal/Mechanical Stress
- Surge Margin
- Emission Compliance



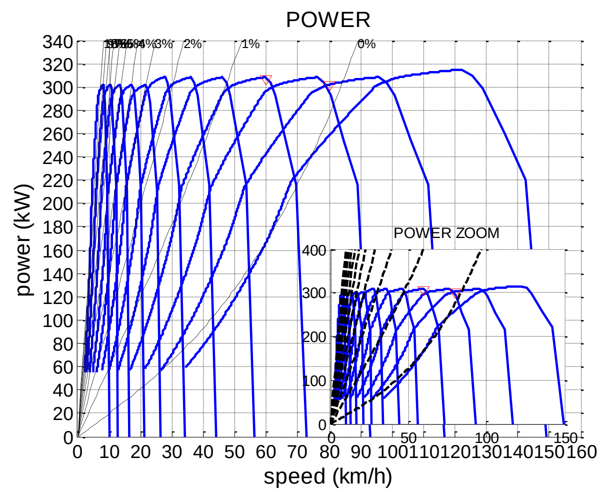
Gradeability



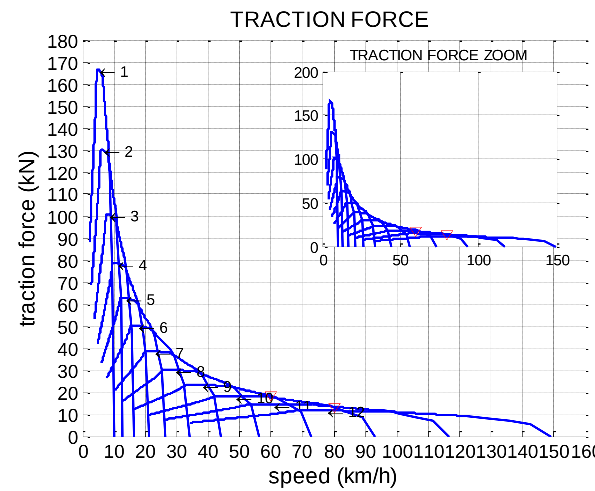
Shiftability



Max.Acceleration



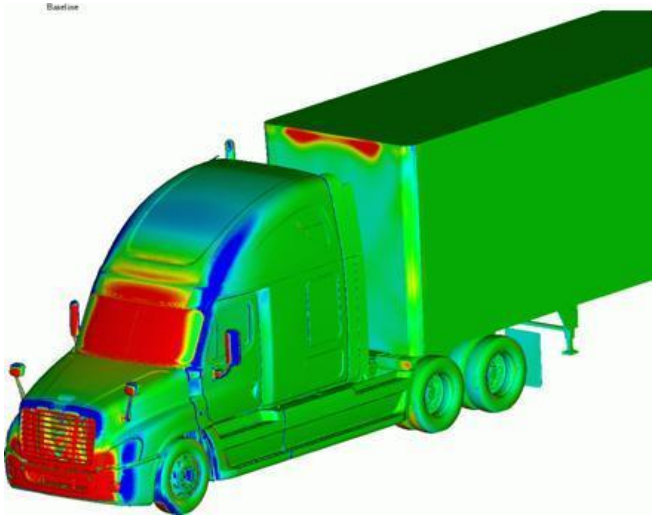
Max.Power

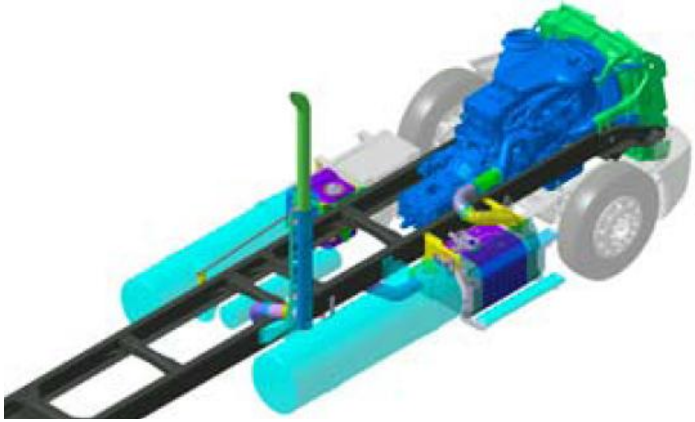


Traction Force

Post-2020 Powertrain Optimization

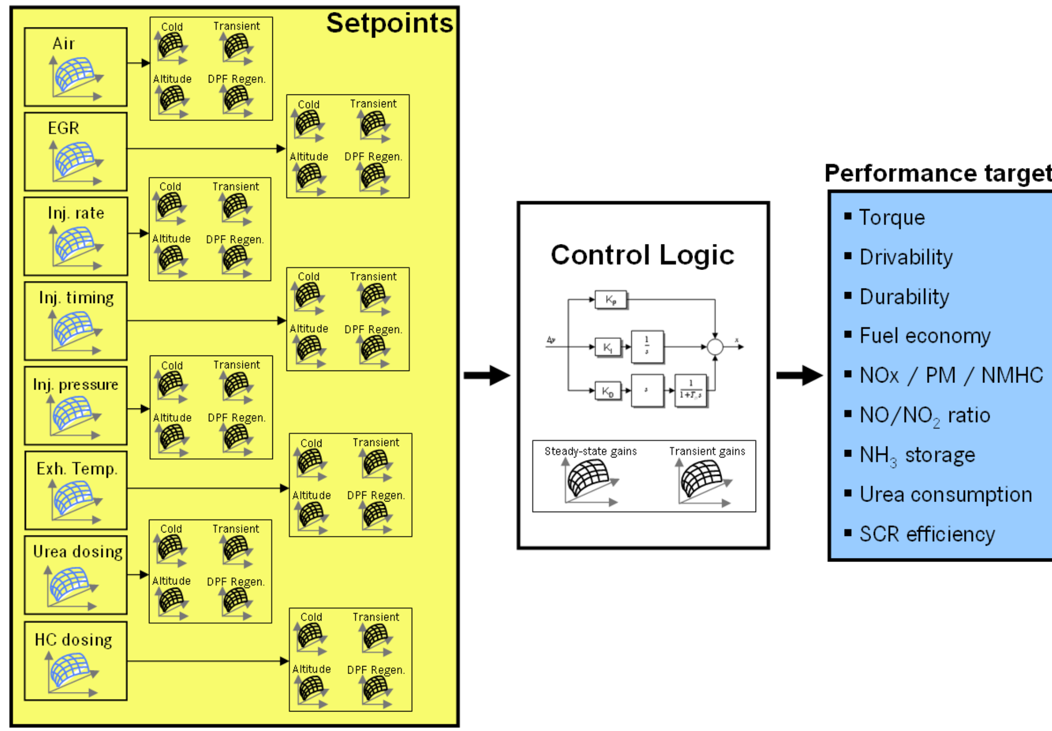
- Optimized Powertrain Interface
  - Torque
  - Cooling & Heating Flows
  - Data Exchange
- Engine – Exhaust Aftertreatment Thermal Marriage
- Turbo Compounding
  - Mechanical
  - Electrical
- Waste Heat Recovery System





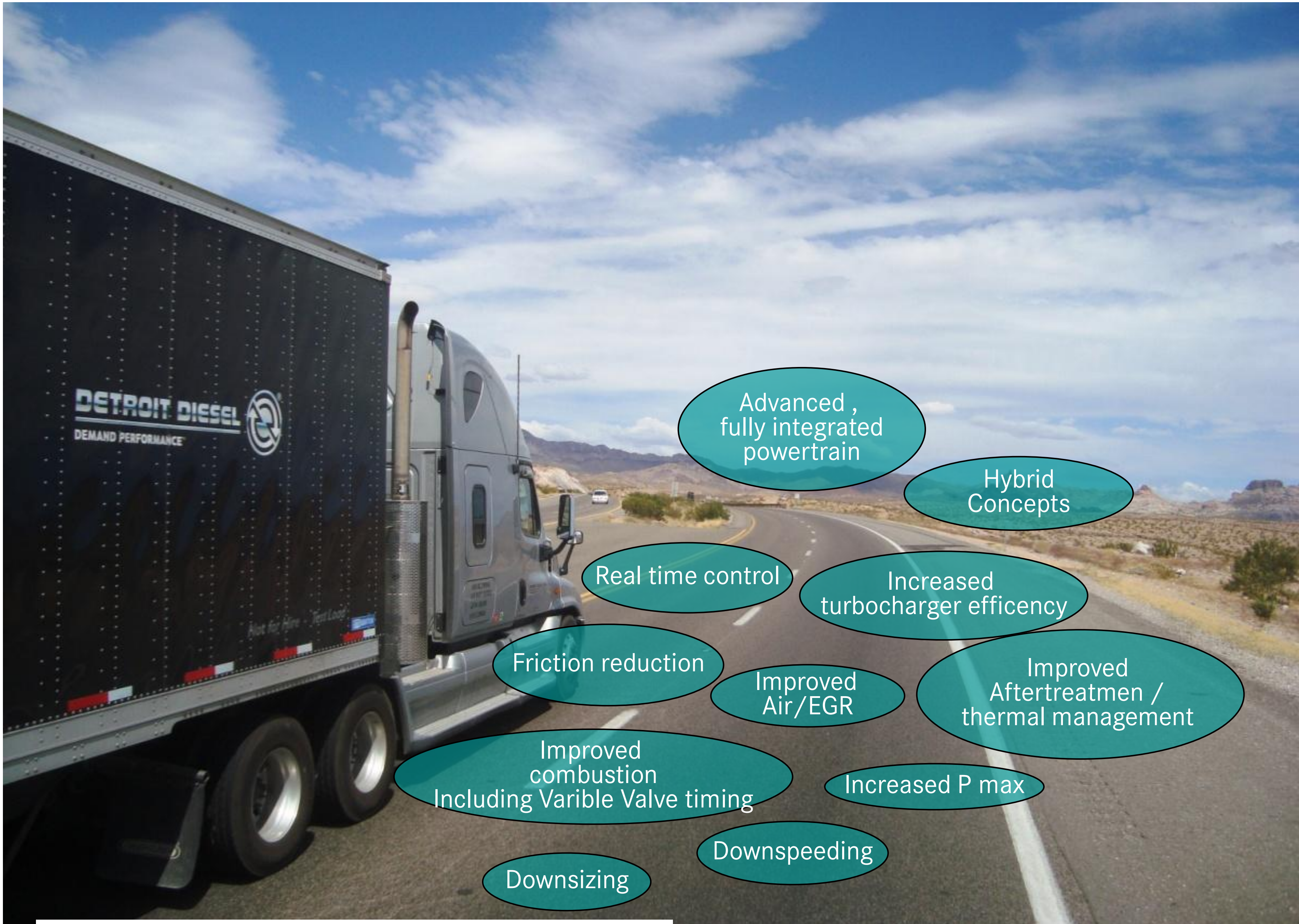
Transient Road Mapping

- Factorial Increase In Calibration Space
- Multiple Performance Targets
  - Cost Function That Minimizes Emissions And Fuel Consumption
  - Optimizes Engine Operation In Real-time
- Use of Neural networks
- Predictive Control In Vehicle



DAIMLER

Summary Supertruck Technology Road Map



Acknowledgments

Department of Energy Headquarters

- Gurpreet Singh
- Roland Gravel

National Energy Technology Laboratory

- Carl Maronde

This material is based upon work supported by the Department of Energy National Energy Technology Lab under Award Numbers 409000-A-N8, DE-FC26-00-OR22805, and DE-EE-0003348.

Thank you for your attention !