Advanced
Technology
Light
Automotive
Systems

ATLAS

U.S. DEPARTMENT OF ENERGY
DEER 2012
DEARBORN
DIRECTIONS IN ENGINE-EFFICIENCY AND EMISSIONS RESEARCH CONFERENCE

Cummins

Thermodynamic Systems for Tier 2 Bin 2 Diesel Engines

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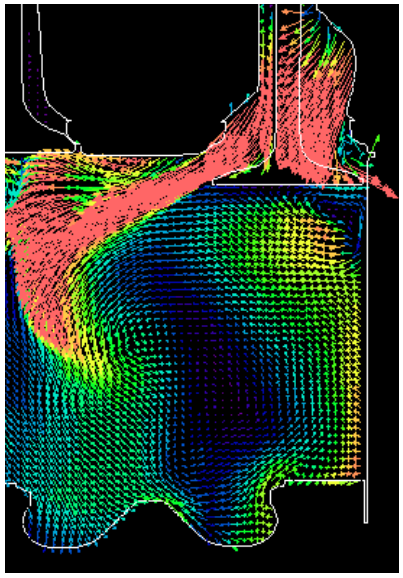
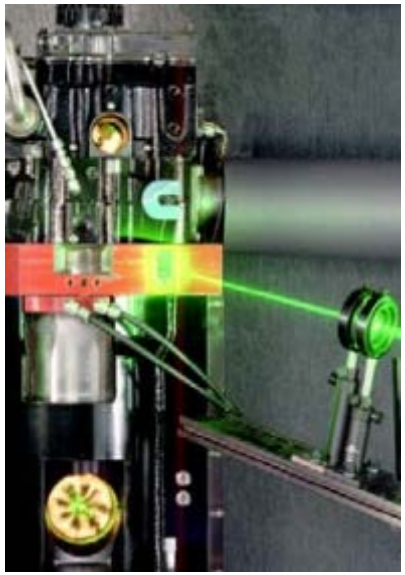




Introduction

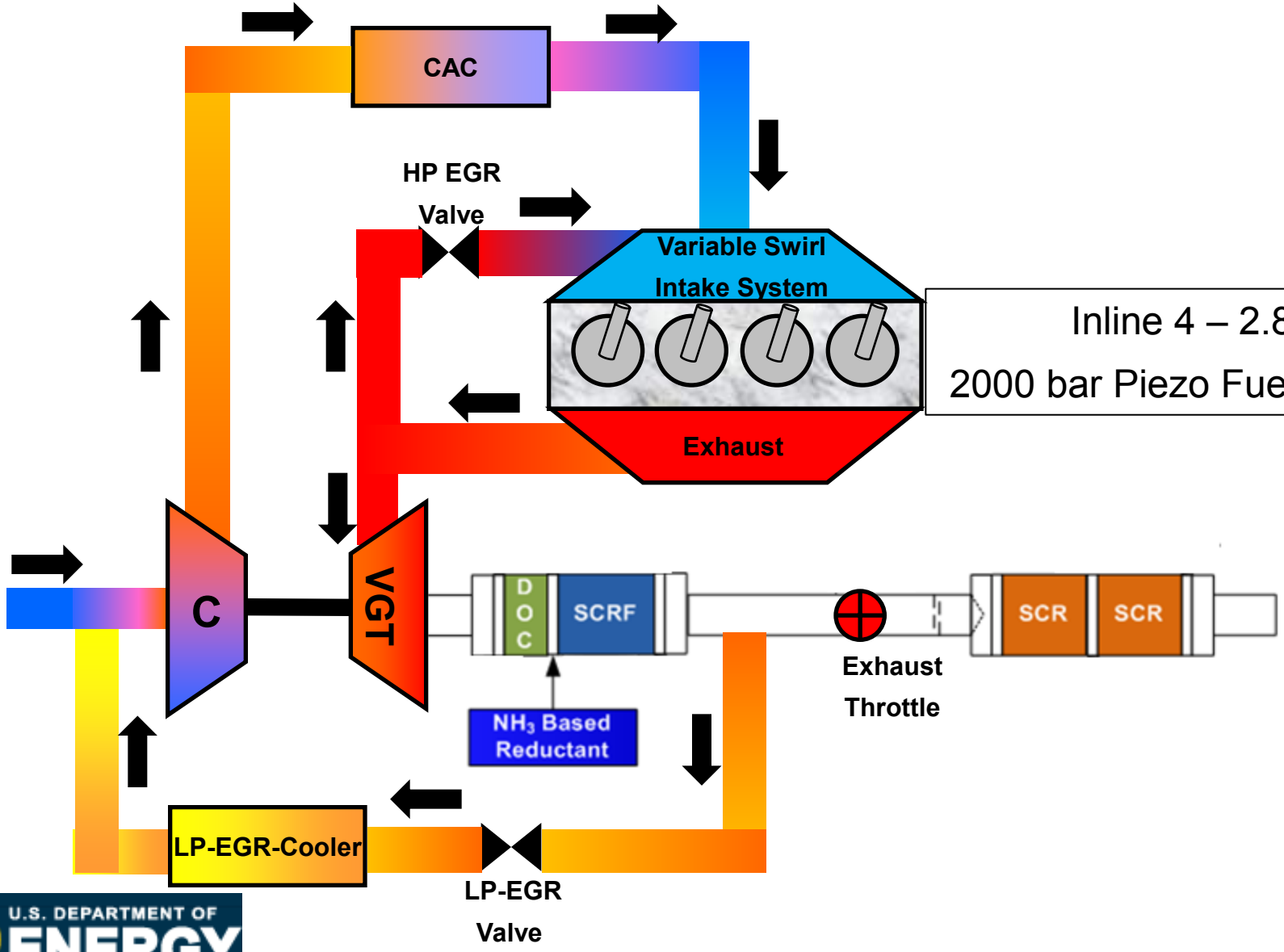
- Baseline Vehicle – 2010 Nissan Titan, 5.6L V8 Gasoline
- ATLAS Development Engine – 2.8L, I4, Euro IV Diesel
- Meet US T2B2 new vehicle standards
  - 5500 lbs test weight
  - Tailpipe NOx = 0.02 gm/mile
  - Tailpipe PM = 0.01 gm/mile
  - Tailpipe NMOG = 0.010 gm/mile

	Baseline vehicle data – V8 Gasoline	DoE Program at Target	ATLAS Target	
FTP – 75 "city"	15.6	21.8	23.5	mpg
HFET "hi-way"	24.5	34.3	34.3	mpg

Overview of Base Engine Thermodynamics

- Air-Handling System
  - Low Pressure [LP] & High Pressure [HP] loop EGR
  - Turbo Matching
  - EGR Split Strategy
- Combustion System
  - Compression Ratio
  - Variable Swirl Ratio
  - Piezo Fuel System & Injector Nozzle
  - Bowl Geometry
- Emissions & Fuel Economy
  - Modal Steady-State Rollup Summary
  - Vehicle Progress

Air-Handling Architecture Schematic



Inline 4 – 2.8L

2000 bar Piezo Fuel System

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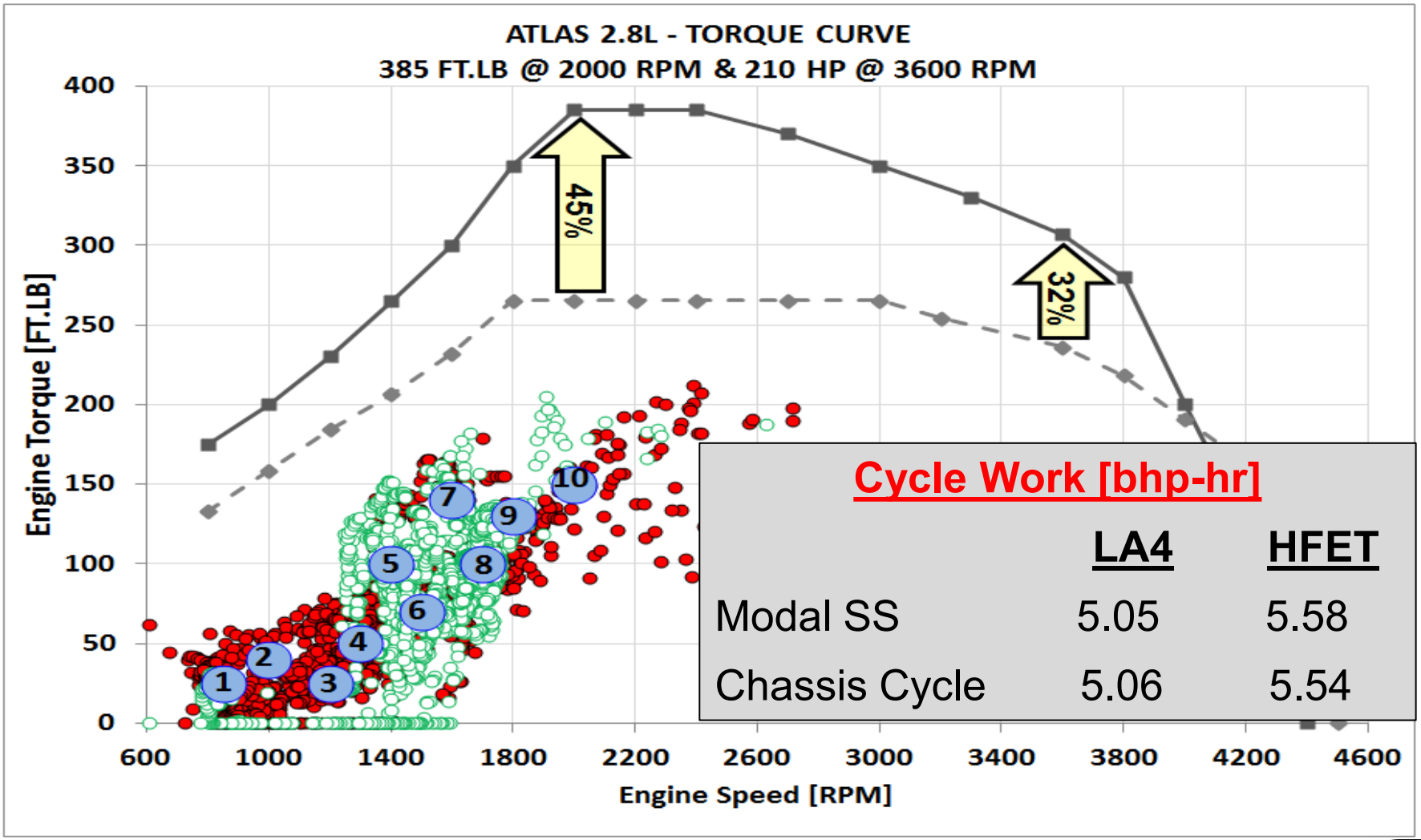
Duty Cycle ➔ Steady-State Modal Points

- Critical process for technology/architecture evaluation



Cycle Work [bhp-hr]

	LA4	HFET
Modal SS	5.05	5.58
Chassis Cycle	5.06	5.54

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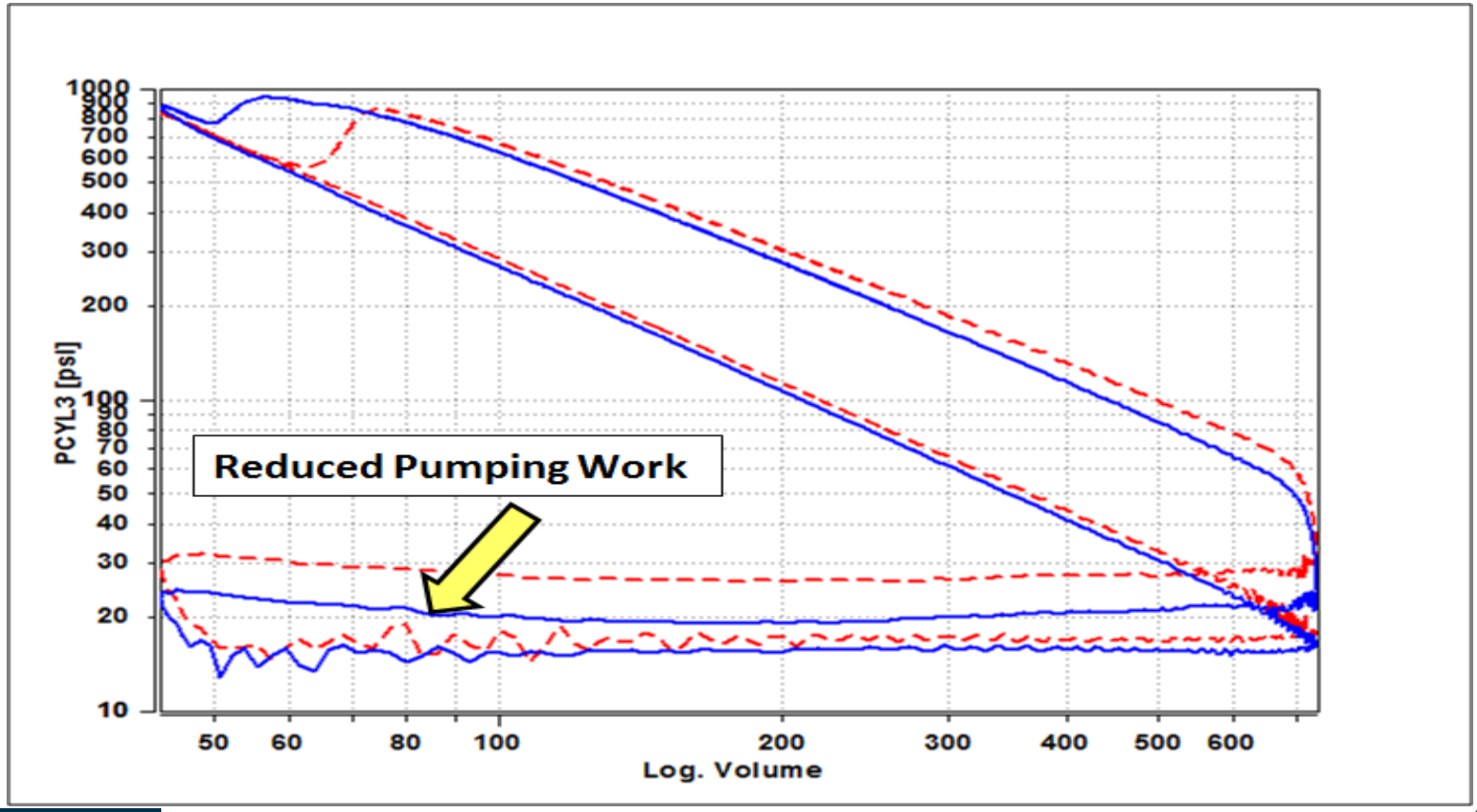
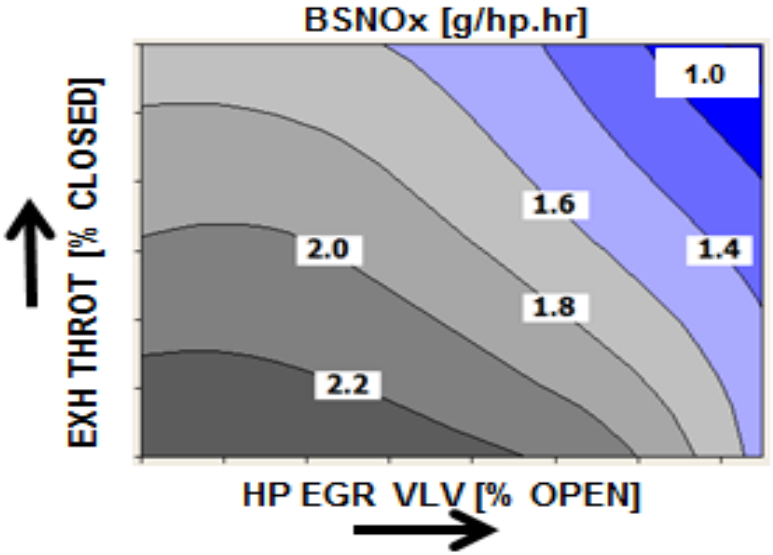
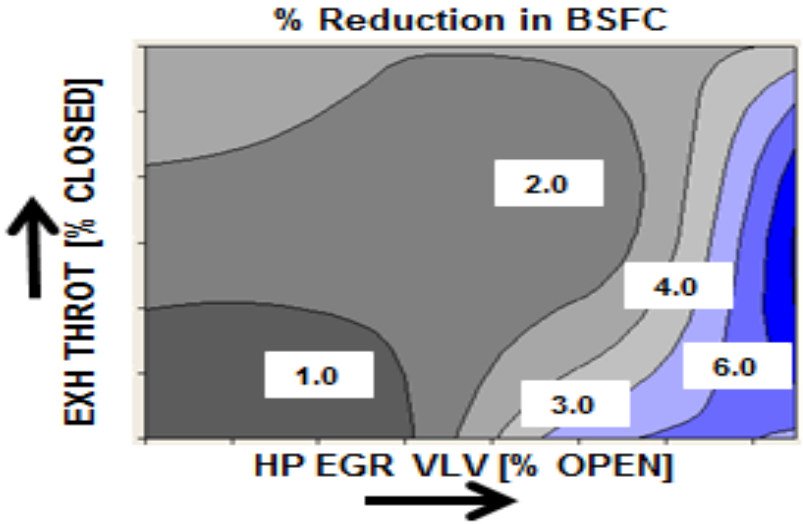
Benefits of Low Pressure [LP] EGR

- Improved "EGR-Fresh Air Mixing" ➔ lower engine out smoke emissions @ constant engine out NOx.
- Higher Turbine Efficiency ➔ Reduced Pumping Work ➔ Lower Fuel Consumption



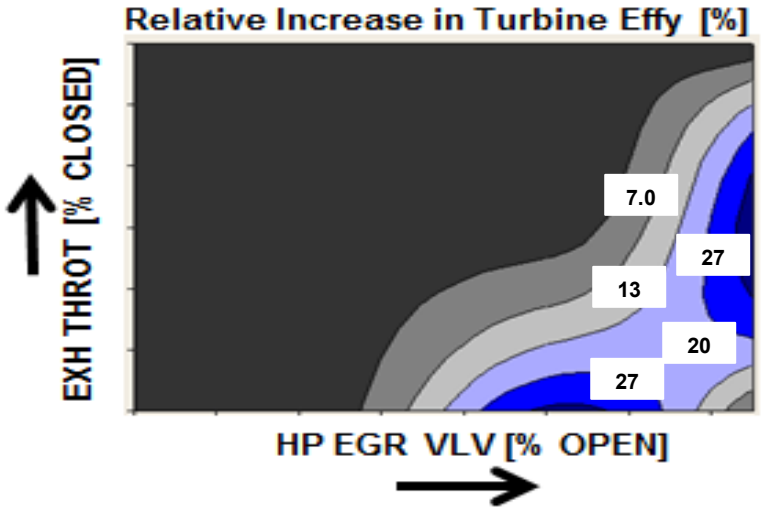
Dual Loop EGR ➔ Added Flexibility to meet Emissions & Reduce Fuel Consumption





1300 RPM, 50 FT.LB – Mode 4

LP EGR VALVE WIDE OPEN



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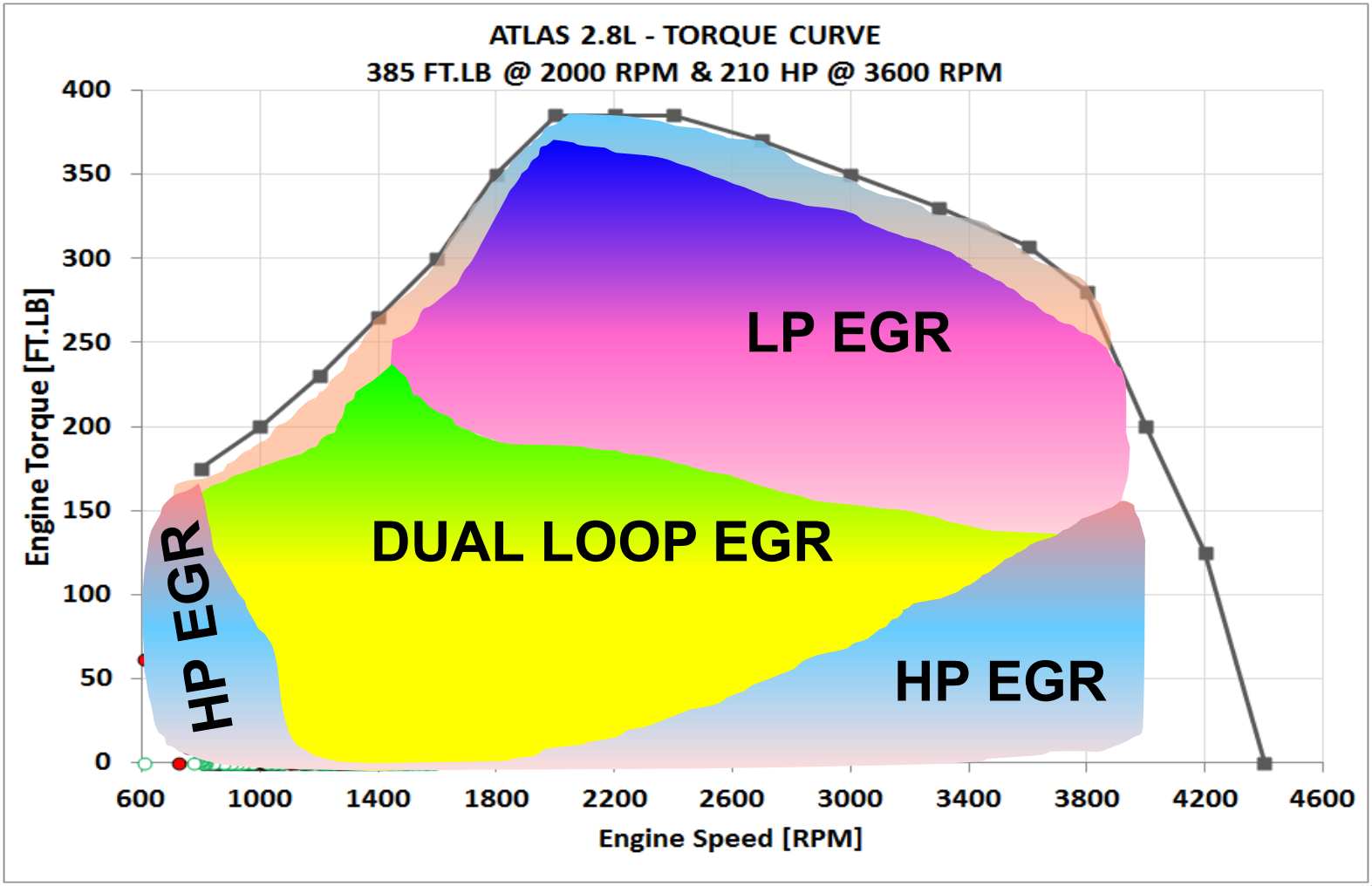
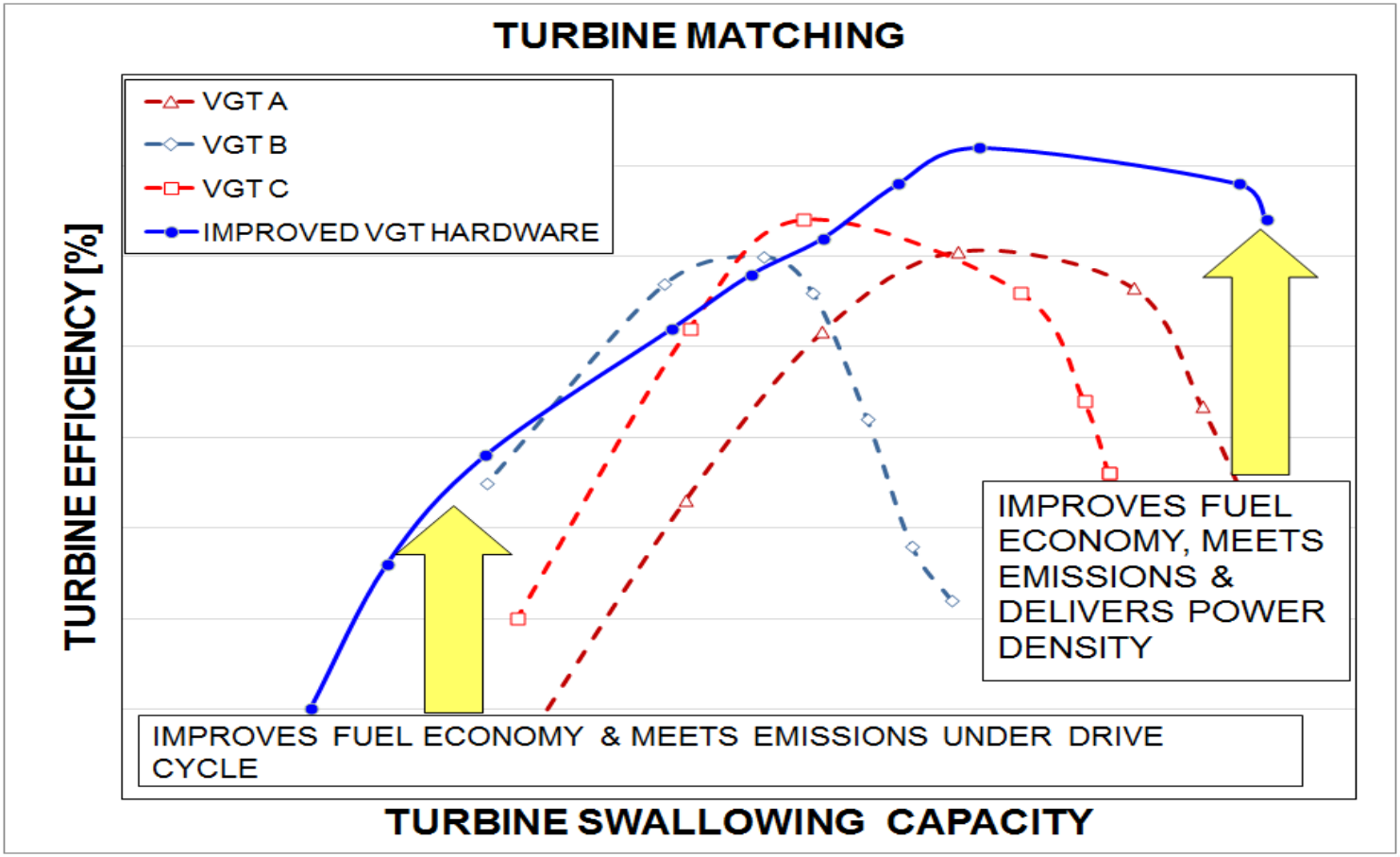
High Level Visualization of EGR Strategy

- Synergy between HP & LP EGR loops to achieve "Efficient Thermodynamics ➔ Improve Fuel Economy"



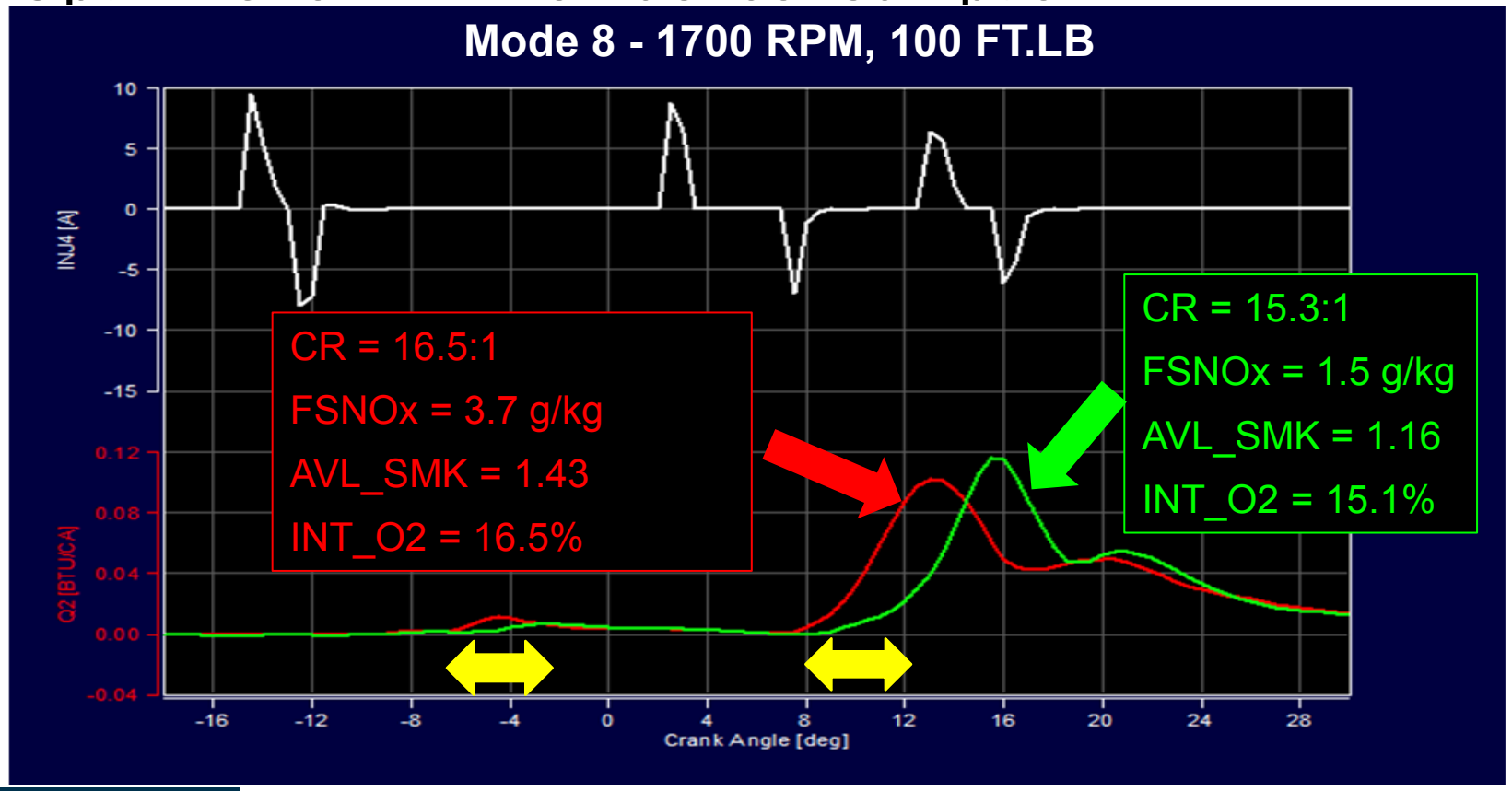
TURBO MATCHING

- Higher Efficiency
- Increased turbine swallowing capacity
- Wider compressor map width



Combustion System

- Reducing "Compression Ratio" favors PCCI like Combustion recipe with longer ignition delay ➔ ***Low NOx & Low Smoke***
- Optimize for minimal fuel consumption

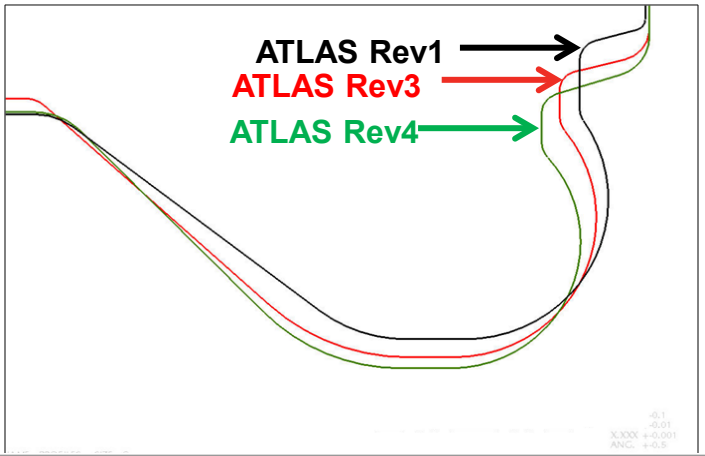


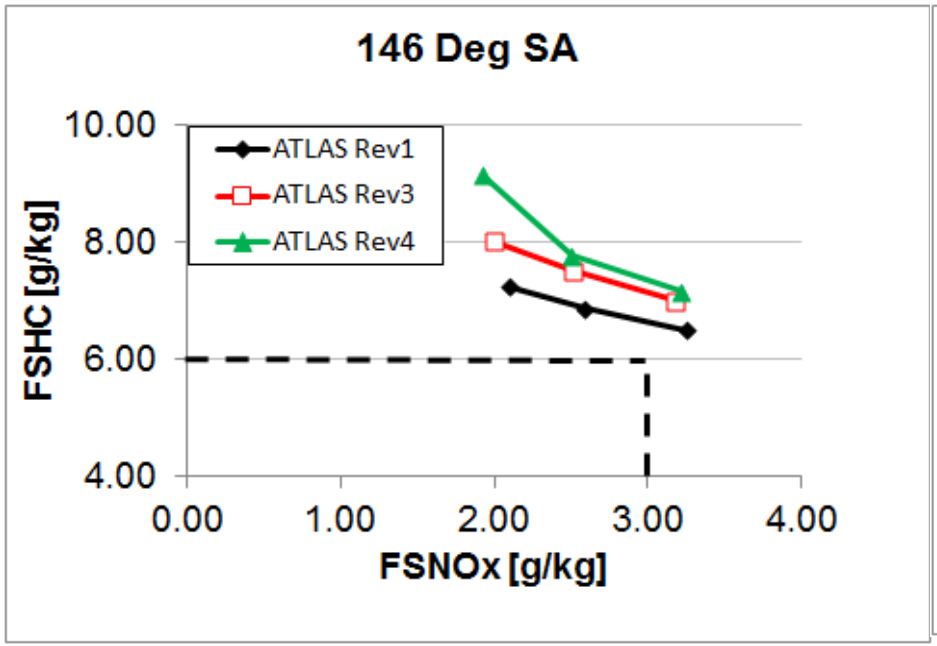
Combustion System Optimization

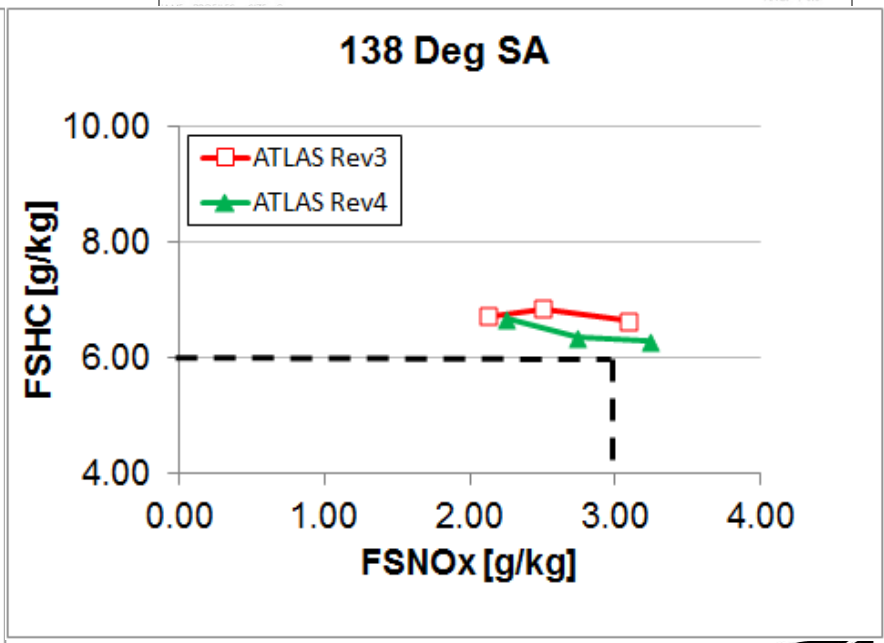
- Combustion CFD analysis for bowl geometry & injector nozzle optimization ➔ “Merit Function Approach”

Mode 4 ➔ 1300 RPM, 50 FT.LB

Fixed CR – 15.3







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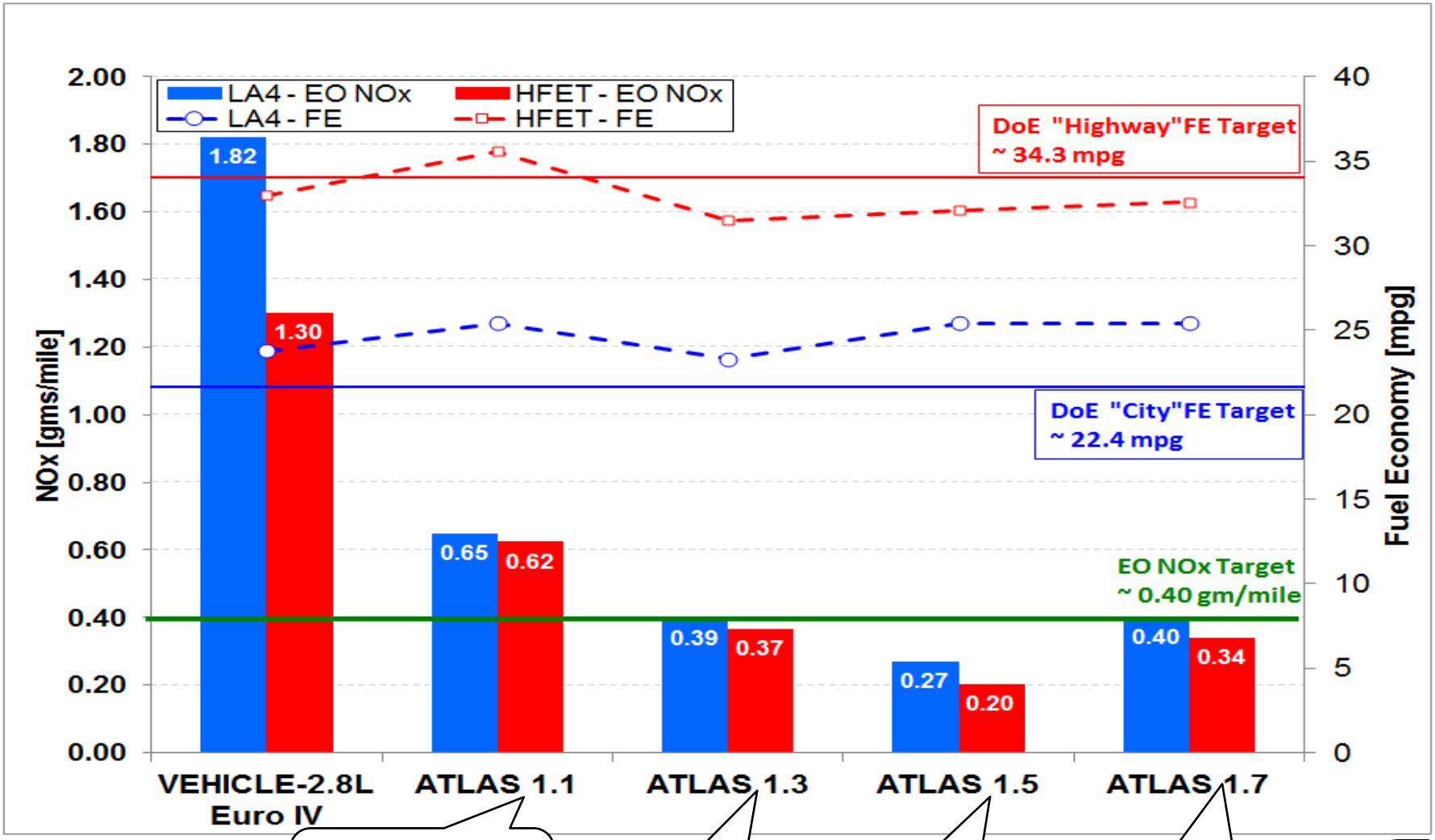
Fuel Economy – Modal Point Summary

- Significant progress has been made in reducing emissions & increasing fuel economy ➔ "Modal Steady-State Roll up"



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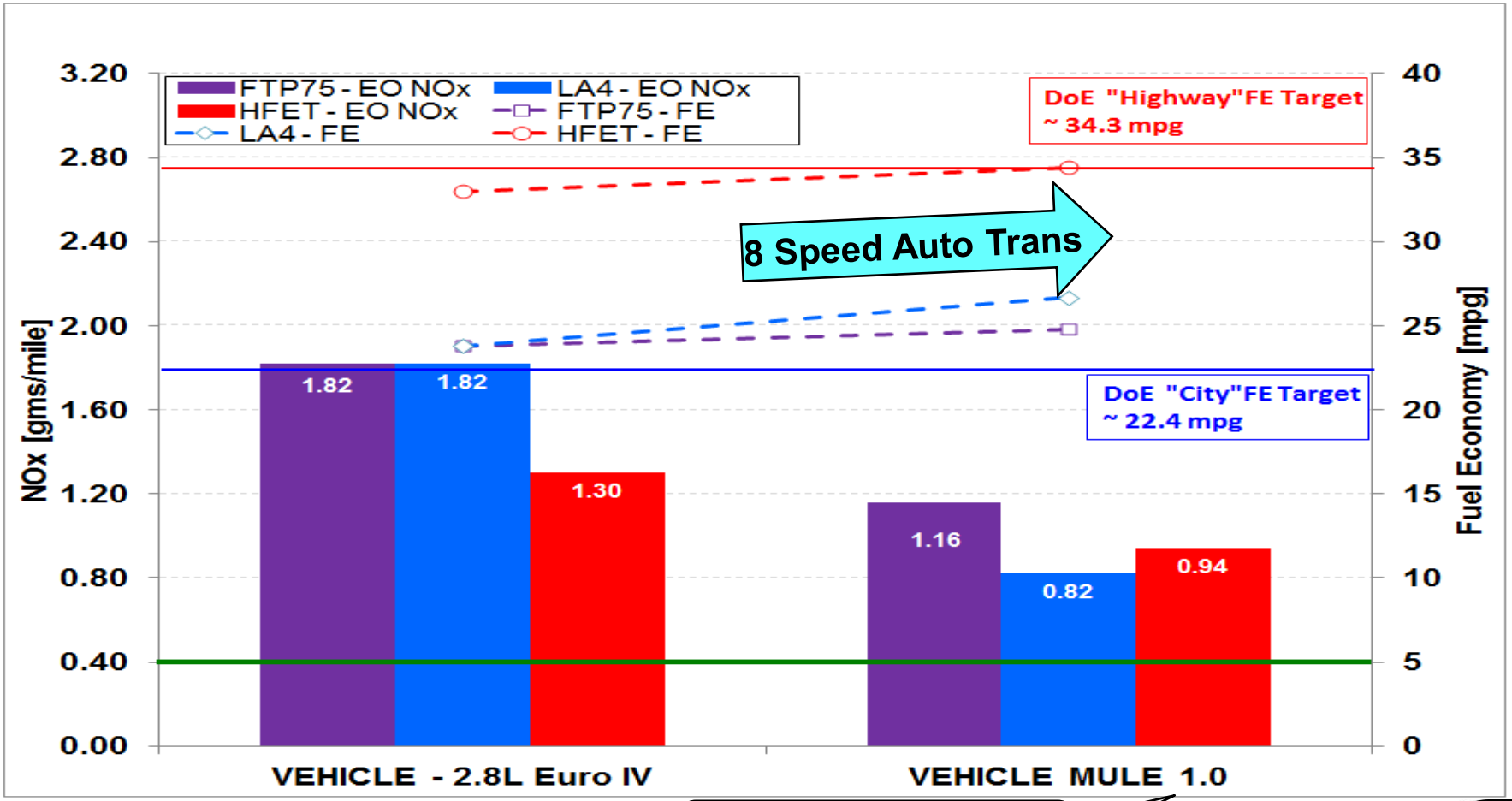
Vehicle Progress – Chassis Dyno Results

- With HP Cooled EGR architecture ➔ Significant progress in reducing emissions & improving FE
- 8 speed automatic transmission has a positive impact on FE



"Improved VGT" + 15.3 CR + 8 spd Auto

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Summary & Path Forward

- Demonstrated engine technology architectures capable of meeting Tier 2 Bin 2 emission levels.
- Demonstrated Fuel Economy numbers on both test bed and vehicle ➔meeting or exceeding DoE targets.
- Demonstrated power density capability.
- Future work will involve transient calibration development & optimization for improving FE & reducing HC emissions.
- Integrated system out demonstration on vehicle will be the ultimate goal.

Thank You!

- U.S. Department of Energy
  - Carl Maronde & Roland Gravel
- Partners
  - Nissan Motors Light Truck – Vehicle development
- Cummins management and team members