Heavy Duty and Non-Road IC Engine Future

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SwRI is committed to supporting research and development to meet Worldwide Clean Air and Clean Energy Objectives

Our approach is to offer innovative, realizable solutions to assist commercial and government clients to achieve their goals
SwRI
Commitment to Clean Air and Clean Energy Objectives

SwRI meeting with EPA Administrator, February, 2020
The Energy Picture

Energy consumption and potential GHG emissions are predicted to continue to climb.

Heavy-Duty Trucks and Non-Road Vehicles are about $\frac{1}{3}$rd of the Transport Energy Pie and less than $\frac{1}{10}$th of the overall energy picture.
Solutions to the overall emissions issue are needed - The Electric Truck may be on the way...

But just how far is unclear...
Generally, an option for heavily-regulated urban zones. Large scale mass adoption will depend much more on vehicle miles travelled and the economics of total payback time.
Battery Prices Dropping, making EV attractive for some markets, but not all.

At current battery prices, the premium for a long-haul heavy-duty EV truck more than doubles the purchase price.

This solution is not yet viable for many HD and NR vehicles.
Key Regulatory Drivers

- Criteria pollutants and fuel consumption have been drastically reduced in the last decade.
- Ongoing R&D is showing that we can still do more, creating near zero criteria emissions and large reductions in GHGs.
SwRI’s Clean Hybrid Electric Diesel Pathway

Adopt the best of the new technologies, using a systems approach, reducing all areas of energy loss to increase vehicle efficiency

- Combustion
  - Compression ratio >22:1
  - Increased injector flow
  - Reduced injector losses
  - Thermal coatings
  - 250-300 bar PCP

- Parasitics Reduction
  - Reduced oil flow crankshaft
  - Reduced oil flow pistons
  - Removal of front belt drive
  - Variable accessories
  - Advanced lubricants
  - Bearing optimization

- Air Handling System
  - Optimized exhaust volume
  - Pulse turbocharging
  - Aggressive Miller cycle
  - Thermal coatings

- High BTE Engine Pathway

Combustion Loss
- Heat Transfer
- Exhaust
- Pumping
- Friction
- Brake

Strong increase in BTE, ...
Class 2 Hybrid Passenger / Light Commercial Vehicle

- Start-stop provides about 2.5% benefit over WLTC and less than 1% over US06

- 48v P2 hybrid with small battery and 25 kW motor can improve WLTC CO₂ nearly 15%+

- Stronger hybrid adds more improvement, following trend for small LD vehicles
Heavy Hybrid Class 6-7, Off-road, Vocational Class 8

Strong industry interest in hybrid powertrain strategies
- Downsized diesel engine
- Strong hybrid (high voltage)
- targets vocational and off-road applications

Optimization program ongoing
- Engine + Motor + Battery sizing
- Novel powertrain energy management strategies
- HIL and SIL test cell demonstrations
- Highly downsized engine with P3 machine
- Lower peak power at low vehicle speeds
- Highway cruise capable with engine off
- Minimize weight increase due to hybrid system with half size engine
Mild Hybrid Class 8 Long Haul Truck

- Engine optimized for cruise power of future long-haul truck
- Electrified accessories to further optimize part load operation
- P1 system used for energy recovery to drive accessories
Mild Hybrid Class 8 Long Haul Truck

System optimization to meet 0.02 g/hp-hr NOX and maximize fuel efficiency
- Start – stop for CO₂ reduction and idle elimination (NOX impact)
- Advanced aftertreatment integration

Engine system improvements
- Minimize heat loss, improve exhaust energy
- High efficiency air path designs

Electrification of accessories and components
- Potential for E-Turbo or E-boost to improve cold start / cycle emissions
- Need 48V systems for coolant, oil, motor-generator, etc.
- Heated AT components
Advanced Hybrid IC HD-Vehicle

- Cruise BSFC within 3% of peak BSFC
- Novel electrified air system developed for wide peak efficiency
- EGR Pump for HP EGR only
- High efficiency turbocharger
- Additional eCompressor

Engine concept targets 178 g/kW-hr BSFC

HD 8.5L 4-cylinder concept

20 kW ISG
40 kWh battery
Smart GPS

Passes Eisenhower pass, most challenging in the USA
Seeing the Bigger Picture…
Combining Low NOx Aftertreatment and New Engine Technologies

2017 Cummins X15 Engine

Advanced Low NOx Aftertreatment (Dual SCR-Dual Dosing)

**Goals:**
- FTP/RMC NO\textsubscript{x} 0.02 g/hp-hr
- No adverse GHG impact
Electrifying the Aftertreatment System—Heated DEF Dosing and Electrically Heated Catalyst

In this Example, a 6 kW Heater Reduces TP NO\textsubscript{x} by 50% Compared to Baseline (No Heater)

EHC “On” Time ~ 500s

SCR “Light Off” Range

Aftertreatment System Configuration: PNA+ASDS+EHC+SCRF+SCR/ASC

Cumulative TP NO\textsubscript{x} Mass [g]

0 200 400 600 800 1000 1200
Advanced Hybrid Diesels are the Best Next-Step

- SwRI programs are applying a full systems approach to the analysis, design, and demonstration of next-step technology for HD and NR
- Hybrid systems are key to the approach
- Potential for wide near-term adoption and scalable solution to a variety of markets for immediate carbon reduction
- Protects for future success of higher risk technologies
  - Compatible with sustainable Efuels, CI-Hydrogen, etc;