# Volvo SuperTruck 2

## Pathway to Cost-Effective Commercialized Freight Efficiency

Project ID: ACE101

Eric Bond (PI)
Jian Li (PM Powertrain)
**Volvo Group North America**


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# Project Overview

## Objectives

Demonstrate >**100% improvement** in vehicle ton-miles per gallon compared with a 'best in class' 2009 truck, with a **stretch goal of 120%.**

Demonstrate **55% Brake Thermal Efficiency** on an engine dynamometer.

Develop technologies that are commercially cost effective in terms of a simple payback.

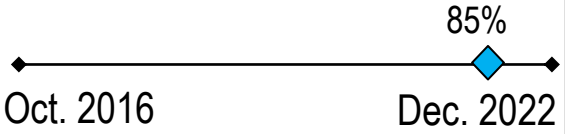
## Barriers

Manage technology trade-offs during complete system integration

Develop complex systems concurrently

Push limits of laws of Thermodynamics

## Timeline




## Funding

- Total project cost > $50 M
  - DOE funds $20 M
- FY2021 funding: $2,214,834
- FY2022 funding: $1,179,552

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OAK RIDGE National Laboratory

MICHELIN

Bergstrom

WABASH

Metalsa

UNIVERSITY OF MICHIGAN

JM Johnson Matthey

motivo ENGINEERING

KNIGHT TRANSPORTATION

Wegmans

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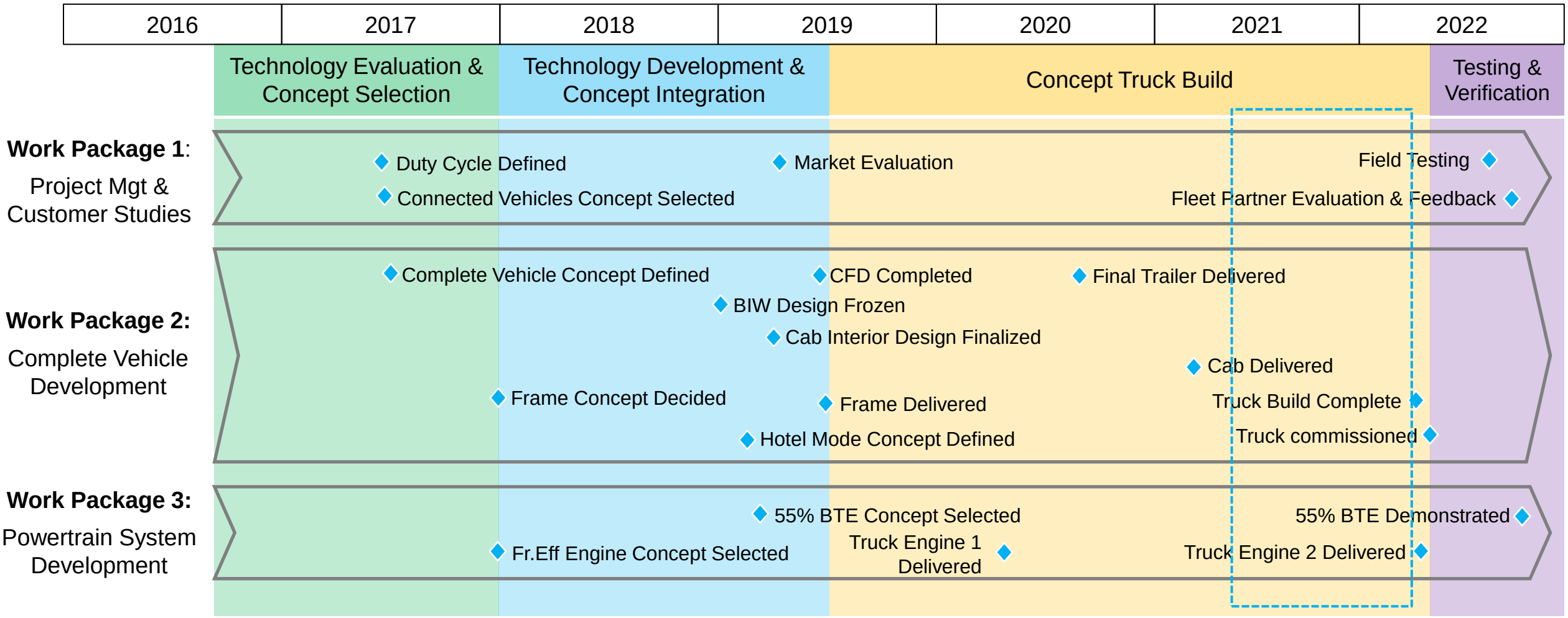
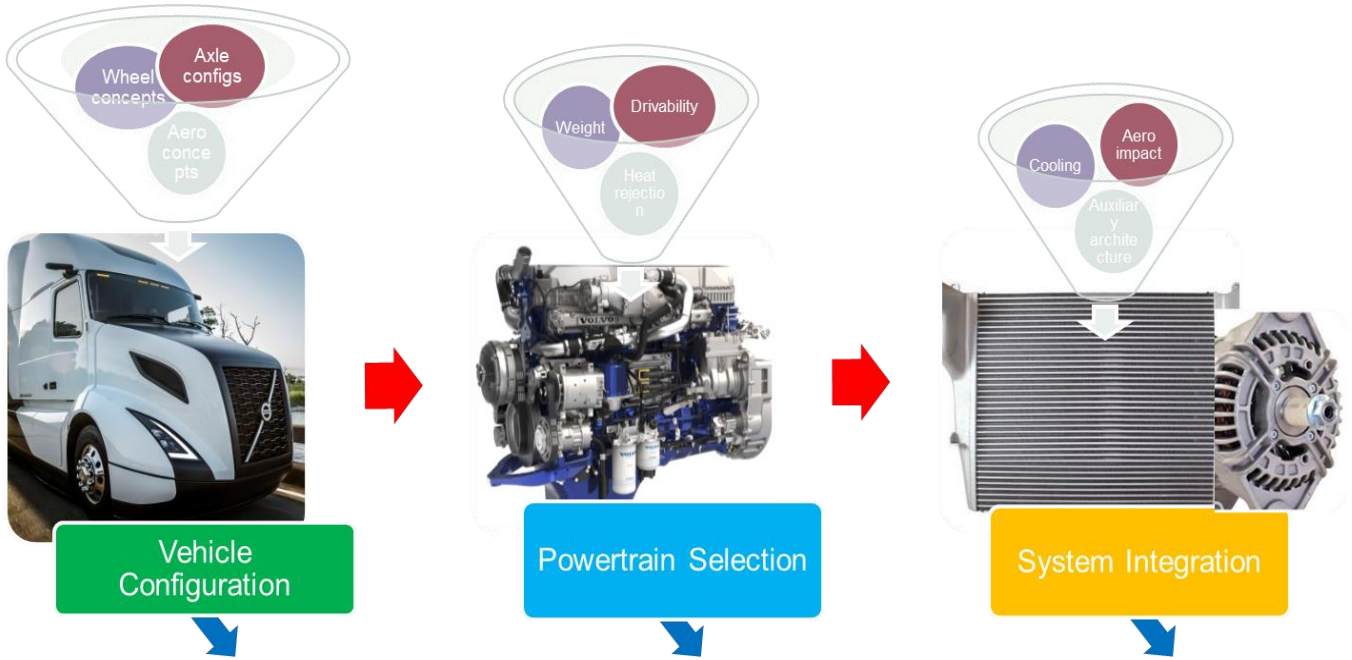
# Approach & Milestones



# Approach & Concept Overview

*Vision: a super-efficient vehicle optimized for 65,000 lbs. and designed for the long-haul drivers of the future*

Design criteria for each subsystem were derived from the program goals and broken down into individual targets or requirements.




**Summary of the concept selected**

4x2 axle configuration

19.5” wheels

Shorter cab w/ optimal interior configuration

<u>27,000 lbs. curb weight</u>

<u>15% better aero than ST 1</u>

325HP 11L powertrain

48V electrification & mild hybrid

All-electric HVAC

Multiple concepts were evaluated using complete vehicle simulations over a variety of duty cycles representing highway fleet operation.

# Accomplishment: Complete Vehicle Build

- Cab modifications complete.
- Cab decked to chassis.
- Headlamps installed.
- Hood tilt mechanism tuned.
- Brake system modifications complete.
- Trailer landing gear replaced.
- Stationary commissioning complete.

Next Steps:

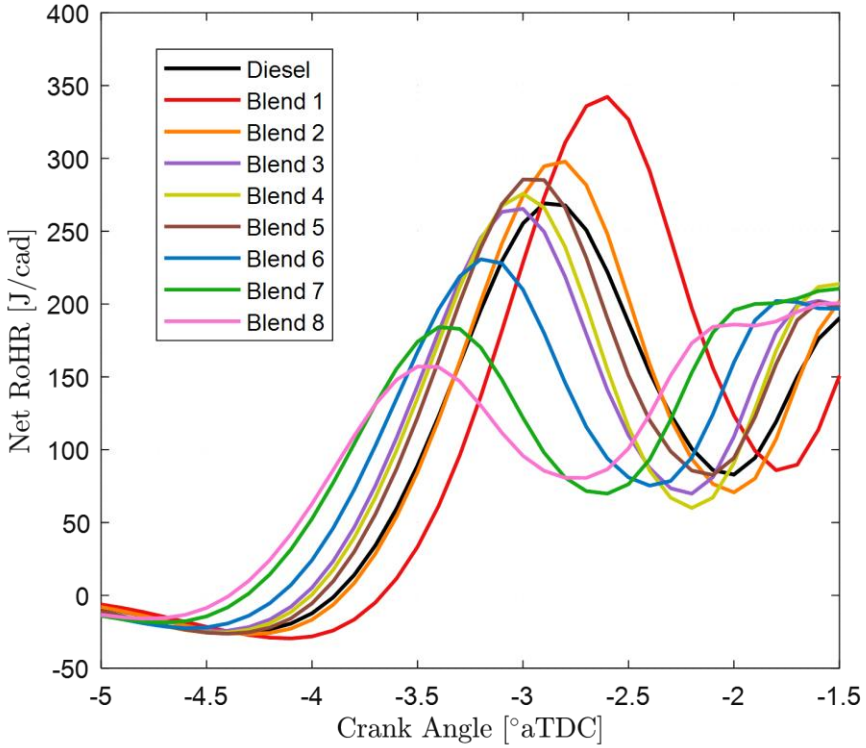
- Final commissioning.
- Road worthiness and freight efficiency testing.

# Accomplishment: Complete Vehicle Items

- HVAC
  - Touchscreen HMI complete
- Doors and Steps (Motivo)
  - Hardware installed
  - Logic refined to optimize door/step timing
- Tires (Michelin)
  - Wear test underway to evaluate 19.5” Tires
    - ST2 tires with 5.5 Kgs/T Rolling Resistance
    - ST2 tires with 5.0 Kgs/T Rolling resistance
    - Baseline 285/70R19.5 production tires

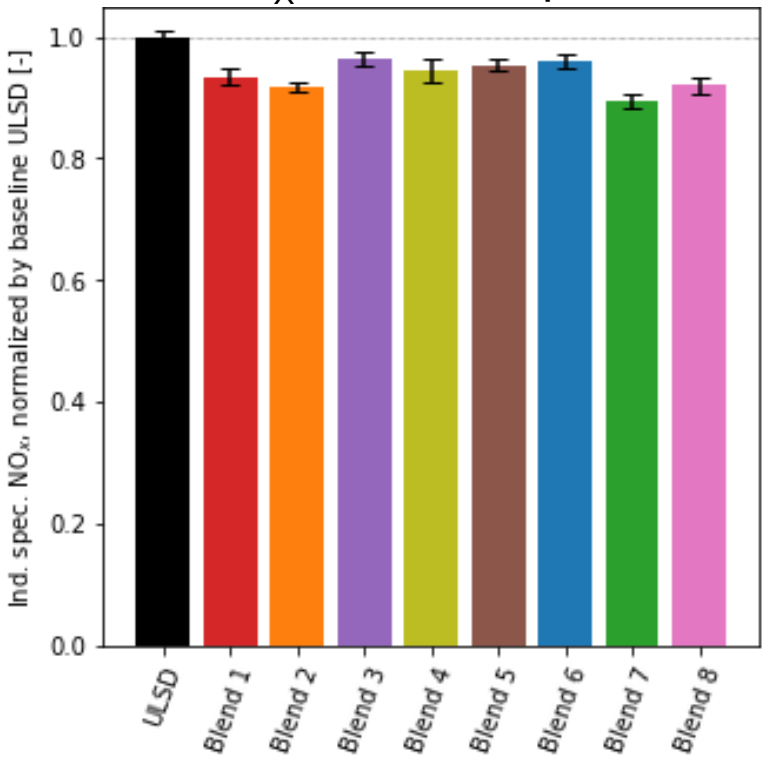

# ExxonMobil – Univ. of Michigan Fuels Evaluation

*Fuel composition effects on criteria emission and performance in a heavy-duty engine*

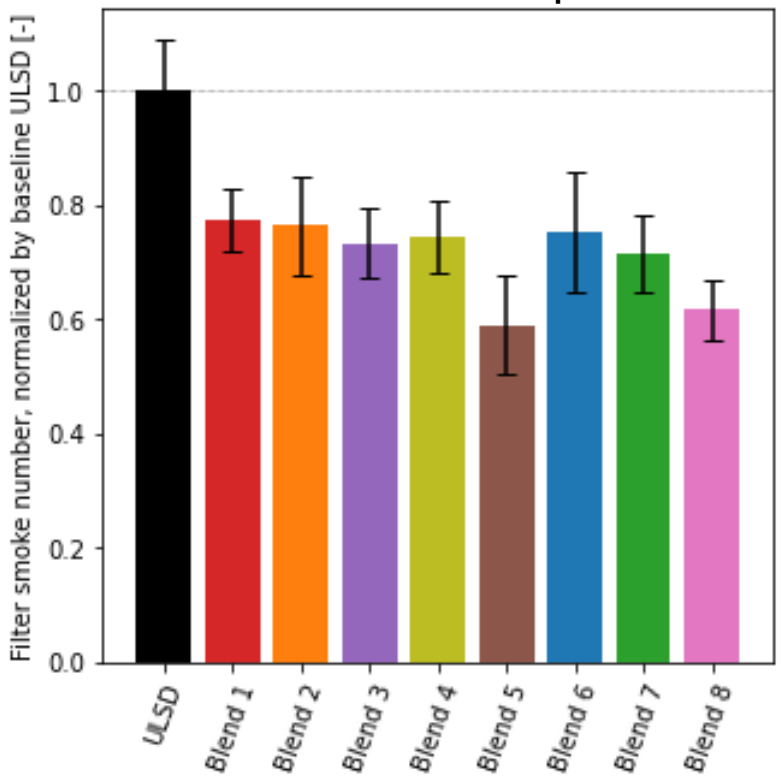



RoHR→ Rate of Heat Release

$NO_X$: Mid load operation




Smoke: Mid load operation




*Data averaged across EGR, injection timing, and injection pressure sweeps at fixed 1160 RPM, 17.6 bar nIMEP. Error bars represent 90% confidence interval*

Achieved 6 to 14 % NOx reduction and 23 to 40% smoke reduction by changing the fuel composition while maintaining performance – calibration not optimized for blends

# Approach – Freight Efficiency Optimized Powertrain

ISG

**48V hybrid system recovers kinetic energy**

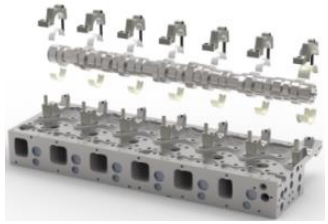
- Integrated starter / generator on rear PTO
- 2-speed gearbox for optimal torque/RPM
- 14 kWh Li-Ion battery system for energy storage

**Improved air handling system**

- EGR pump maximizes expansion
- Re-optimized fixed turbo system
- Miller camshaft enables more pumping reduction

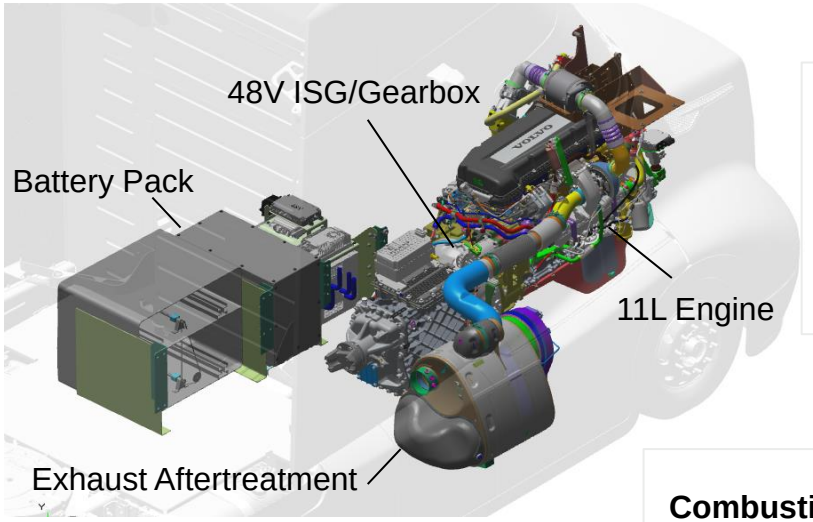
EGR Pump

Bearing



**Parasitic loss reduction with improved base engine**

- Synthetic overlay bearings
- Long Connecting rod
- Short CH piston
- Low friction ring pack
- Variable oil pump




**Redesigned Aftertreatment system**

- Low back pressure with short DPF/SCR
- Low restriction exhaust diffuser design
- Electrically heated catalyst

EATS Box

e-Coolant Pump

**More parasitic loss reduction enabled by 48V hybridization**

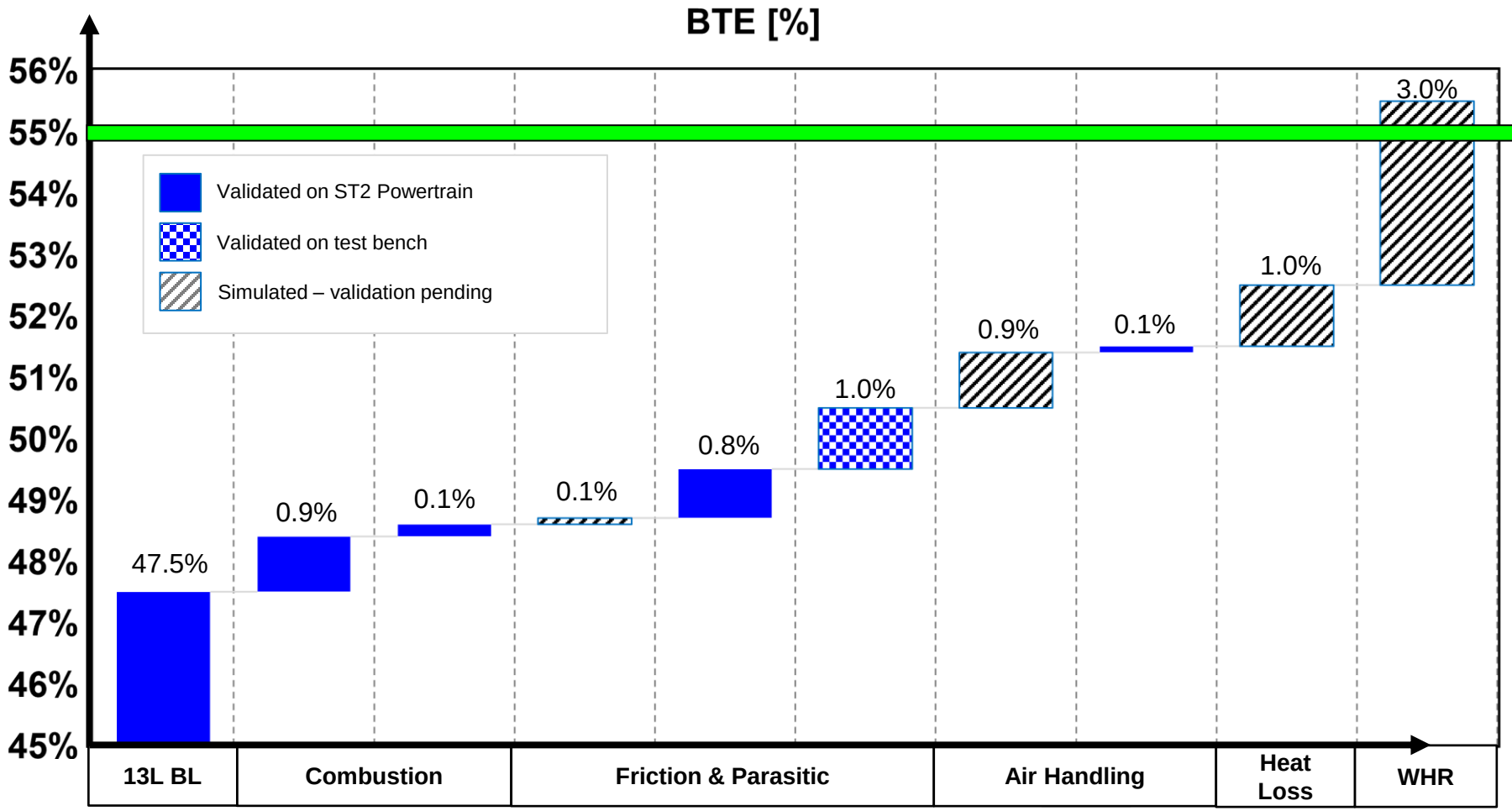
- Front Engine Accessory Belt removal
- Electric coolant pumps
- Electric radiator fan
- Electric EGR pump

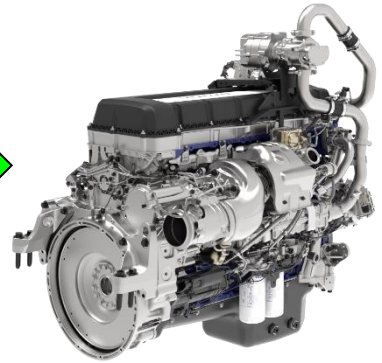
**Combustion efficiency improvement**

- 20:1 compression ratio wave bowl
- 250 bar peak cylinder pressure
- Optimized heat release w/ improved common rail

Wave Bowl

# Progress – Validation of Powertrain Technologies



**Powertrain optimized for thermal efficiency**
Engine Dyno Demo

**55.5%**

- MD13 TC
- Low friction rings
- Improved bearings
- Variable oil pump

- CR 23:1 Wave
- PCP 270 bar
- Miller Cam
- Remote CRS
- Reshaped HR

- Electrical coolant pump
- Reduced piston cool.
- Low viscosity oil

- Optimized turbo
- EGR pumping
- DST
- EGR cooler
- New EATS

- TBC bowl
- TBC cyl. head
- TBC exh. Port
- High therm piston

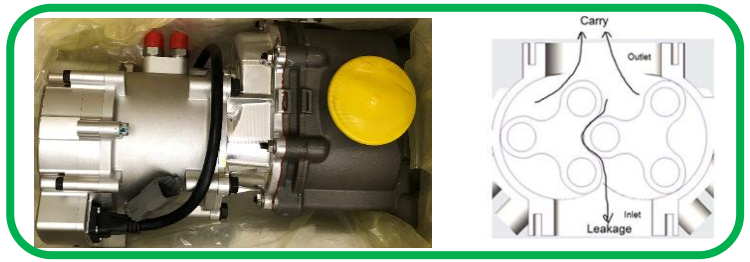
- Tailpipe WHR
- Coolant WHR

# Accomplishment – Advanced Combustion/Pumping System

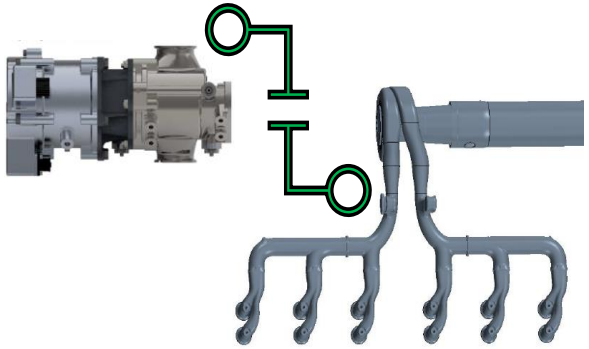
SuperTruck Advanced Combustion / Pumping System with high compression ratio 20:1 wave pistons, 48v EGR Pump, Miller Cam, and high efficiency Turbocharger

- 48v EGR pump enables de-coupling EGR drive from turbo and cam
  - High air-fuel ratio to improve combustion efficiency
  - Positive pumping work
  - To specify high efficiency turbocharger
- Aggressive Miller cycling
  - Retain high expansion ratio
  - Combined with high geometric compression ratio pistons for over-expansion
- High compression ratio bowl
  - Significant gross ITE improvement
- Verified BTE gains over 2%
- On-road testing in Summer 2022

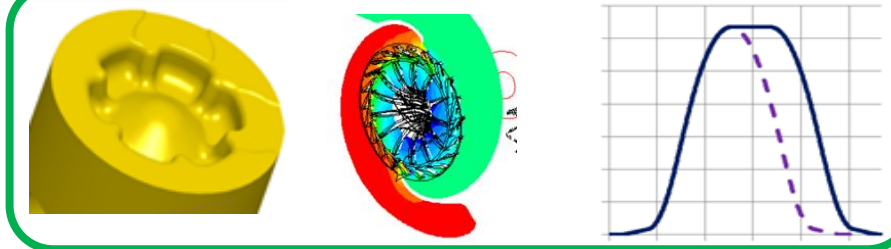
EGR Pump




***De-couples EGR drive from turbo and cam***
***→ performance balance beyond what EGR pusher can achieve***



Wave Bowl FGT Miller



# Accomplishment – 55% BTE Engine Development

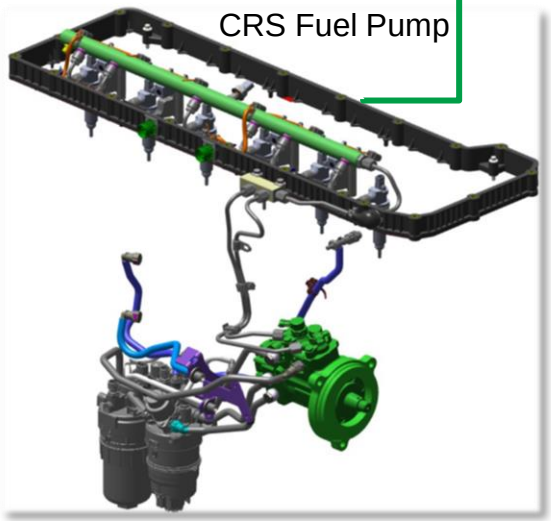
- **Advanced Combustion System**
  - Re-designed high compression ratio 23:1 wave pistons
  - Gen3 48V EGR Pump
  - Aggressive Miller cycling
  - High efficiency turbocharger system
  - Estimated up to 2.3% BTE gains from 55% BTE 13L demo engine with a similar combustion/pumping system
- **HP CRS Remote Fuel Pump**
  - 2700 bar HP Common Rail system
  - Next generation high efficiency/speed remote HP pump
  - Estimated up to 0.3% BTE gains
- **48v Electric Coolant Pump**
  - High efficiency 1.7 kW electric coolant pump enables Front Engine Accessory Drive removal with reduction of both friction loss and Pumping loss

Wave Bowl

55BTE Engine

e-Coolant Pump

CRS Fuel Pump



# Accomplishment – Waste Heat Recovery Systems

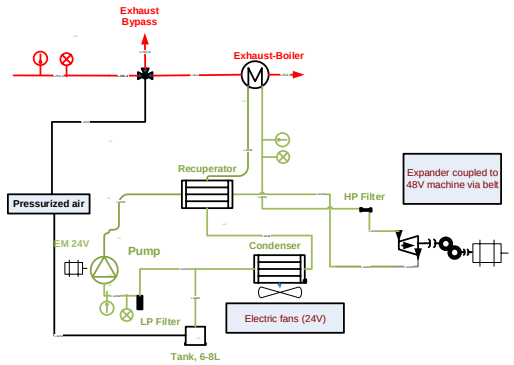
**Approach**

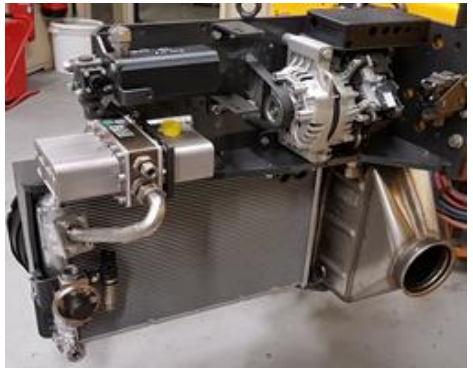
- Electrical Waste Heat Recovery systems for engine efficiency improvements
- Exhaust recovery system
  - ~2% estimated BTE gain
  - Working fluid: Cyclopentane
- Coolant recovery system
  - ~1% BTE gain
  - Working fluid: Refrigerant
- 48V electrical power system
- Compact design

**Progress**

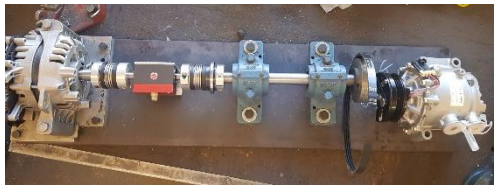
- Tailpipe WHR system in testing at SwRI
- Coolant WHR system in testing at University of Liege

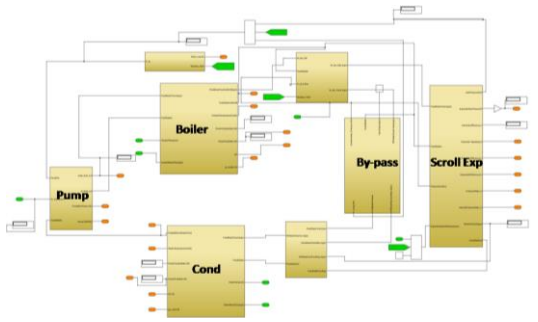
Exhaust WHR



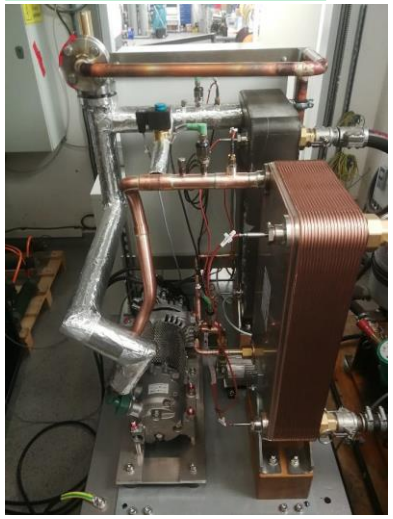



Expander Bench






Coolant WHR





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# Project Summary

- **Relevance**

  The goals of this project are aligned with the key barriers to higher fuel efficiency of highway transportation. Each task in the project scope addresses a specific technical challenge e.g., aerodynamic improvement, friction reduction.

- **Approach**

  Volvo's SuperTruck 2 program is finishing the third phase, which focuses on integrating the technologies. As we take the final steps in the concept truck build and commissioning, we will move into the fourth and final phase of testing and verification.

- **Milestones & Technical Accomplishments**

  In this reporting period, we continued progress in the complete vehicle and powertrain areas. Major vehicle subsystems, including the complete cab, bumper, hood and headlamps have been installed. Build and commissioning are nearing completion for the vehicle demonstrator. Testing and development continue for the technologies selected for the engine BTE goal. Despite the challenges, we are well on our way to demonstrating >120% freight efficiency improvement for the complete vehicle, plus verifying the 55% BTE engine goal.

- **Future Work**

  Finalize the build and commissioning of the ST2 demonstrator and complete testing and verification. Optimize the performance of the vehicle sub-systems. Continue to develop, integrate, and validate the technologies selected for the 55% BTE engine demonstration.

Any proposed future work is subject to change based on funding levels



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# Team Members

| Organization | Main Responsibility |
|---|---|
| **Volvo Group** | Project lead, powertrain development, complete vehicle integration, testing |
| **Metalsa** | Lightweight Chassis Frame Concepts |
| **Michelin** | Advanced low-friction tires (steer, drive, tag, trailer) |
| **Wabash** | Trailer Technologies (weight & aero) |
| **Bergstrom** | Advanced cab climate control concept |
| **University of Michigan** | 11L SCRE experiments |
| **ORNL** | Aftertreatment testing |
| **Motivo Engineering** | 48V system rapid development & testing |
| **Johnson Matthey** | Aftertreatment concepts & Catalysts |
| **Knight Transportation & Wegmans** | TCO discussion, driver clinics, etc |

# Thank you


# See You Soon!



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