Advanced Combustion Concepts - Enabling Systems and Solutions (ACCESS) for High Efficiency Light Duty Vehicles

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Hakan Yilmaz
Global Technology Management
Gasoline Systems, Robert Bosch LLC

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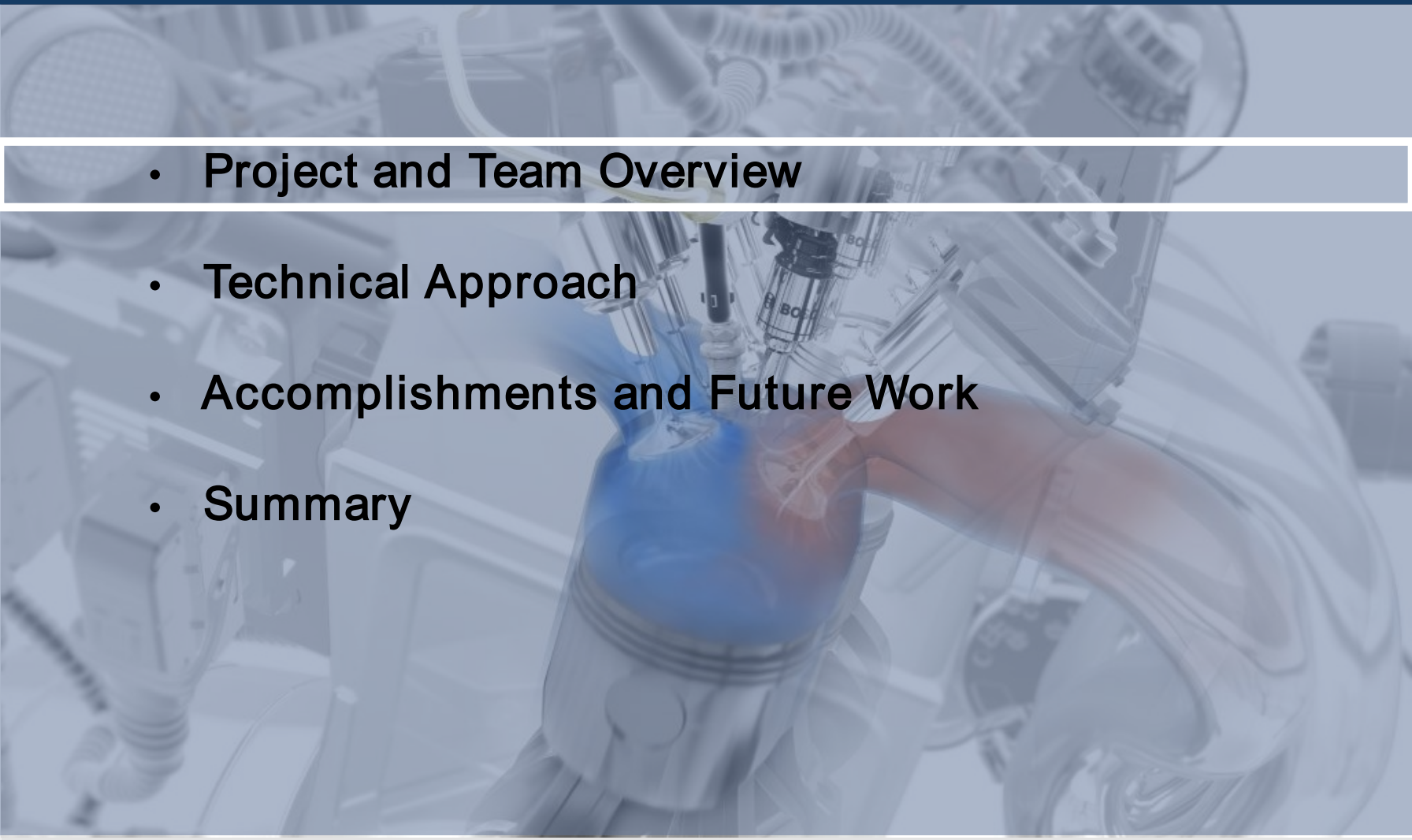
ACCESS for High Efficiency Light Duty Vehicles



- Project and Team Overview
- Technical Approach
- Accomplishments and Future Work
- Summary

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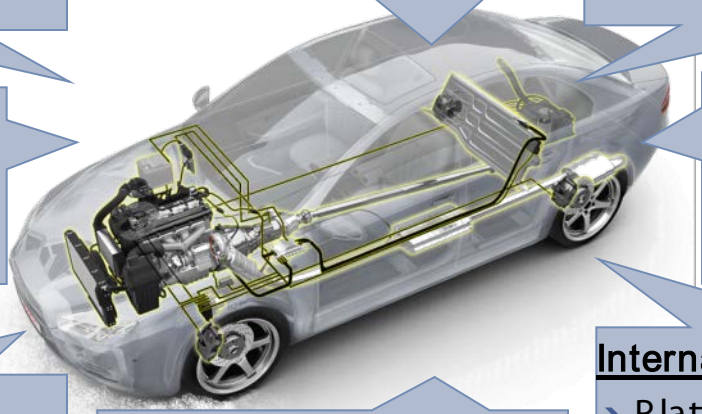
Major Market Drivers of Automotive Powertrain World Wide

Fuel economy and CO_2
- W-EU: 130g CO_2/km in 2012
- US CAFE: 34.1 mpg in 2016
- ww: volatile crude oil prices

Cost
- For entry level mobility
- Cost of Ownership
- Cost Effectiveness

Emissions & Diagnosis
- EU6
- NAFTA SULEV, PZEV, LEVIII
- CARB OBD II



Fun to drive
- Power output
- Low end torque
- Response time

Quality and Safety
- Reliability
- Robustness
- ISO26262

Driving comfort
- Noise, vibration, harshness
- Shift & launch quality
- Easy driving

Brand building
- Brand Identity & -value
- Image, e.g. Innovation

Internationalization
- Platforms (few, flexible)
- Modules
- Purchasing (global)
- Fuel quality differences

→ Costs and fuel economy currently are worldwide the most important market drivers. Emissions and diagnosis are mandatory requirements.

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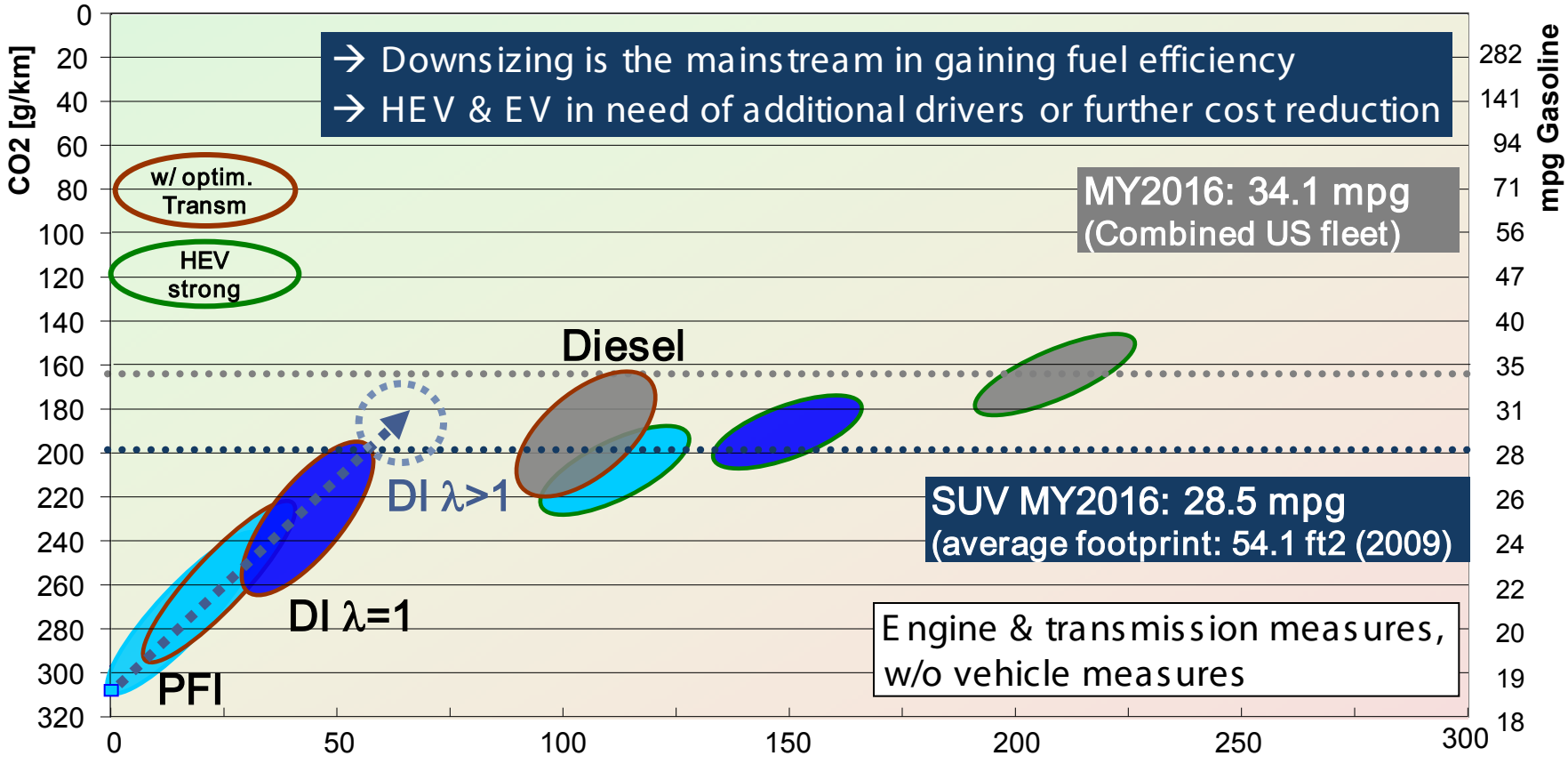
Bridging the Technology Gap



Basic system: SUV class (2300 kg); 4.0 l (8 cyl.) PFI; λ=1; CO_2 308 g/km

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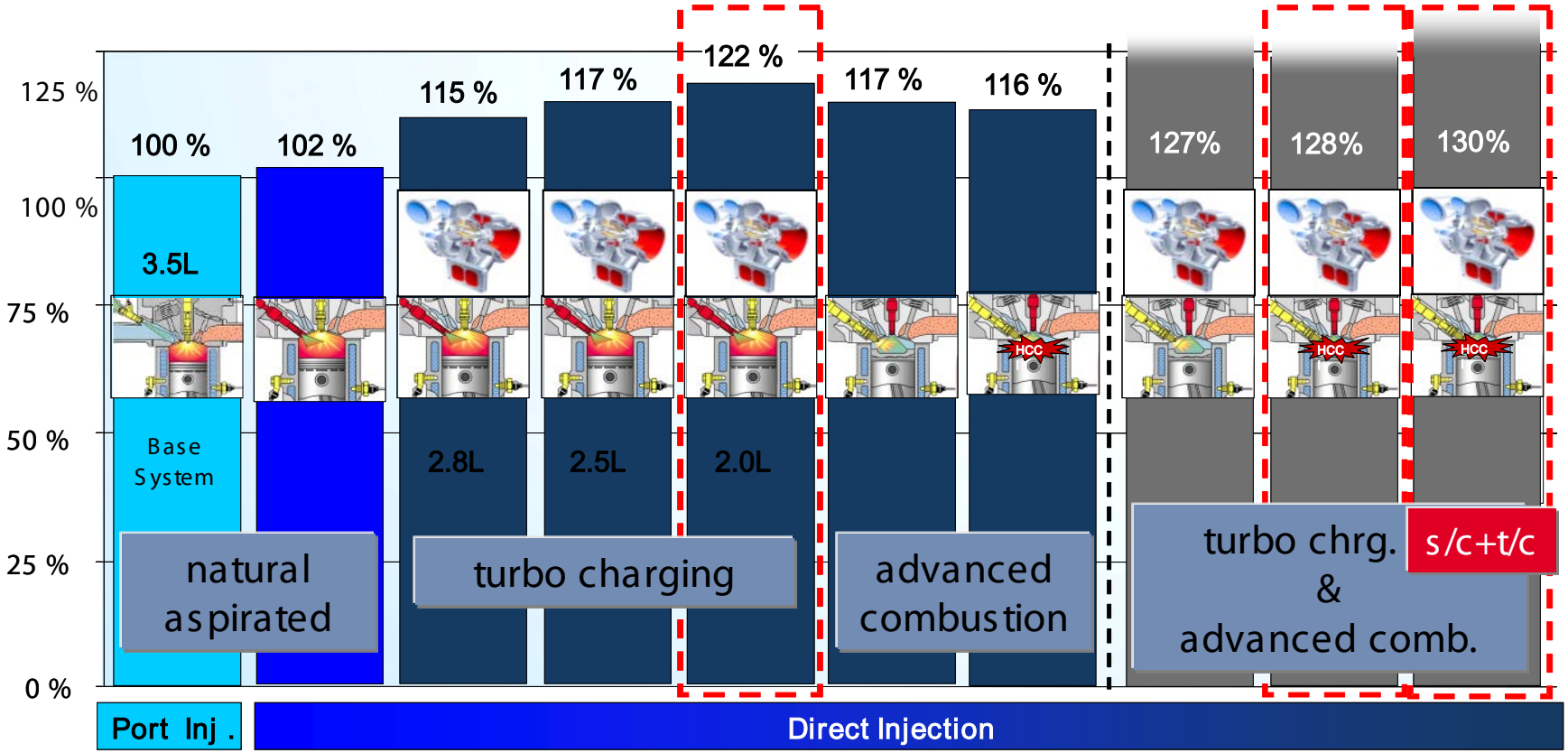
Advanced Combustion Concept – Homogenous Charge Compression Ignition (HCCI)



→Homogenous pre-mixture of air, fuel & residuals
→Controlled auto-ignition and flameless combustion

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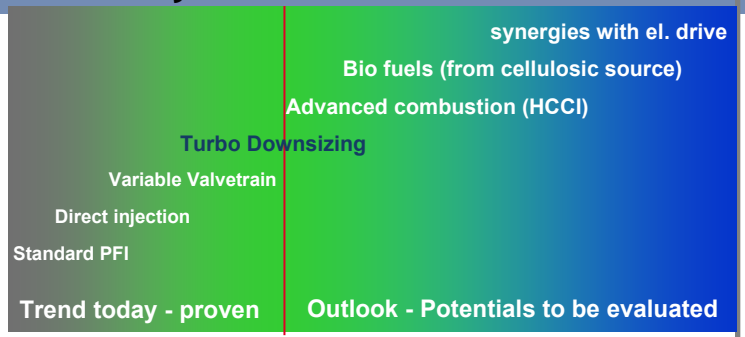
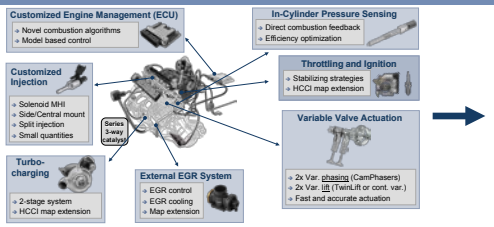
ACCESS (Project size 24M USD)



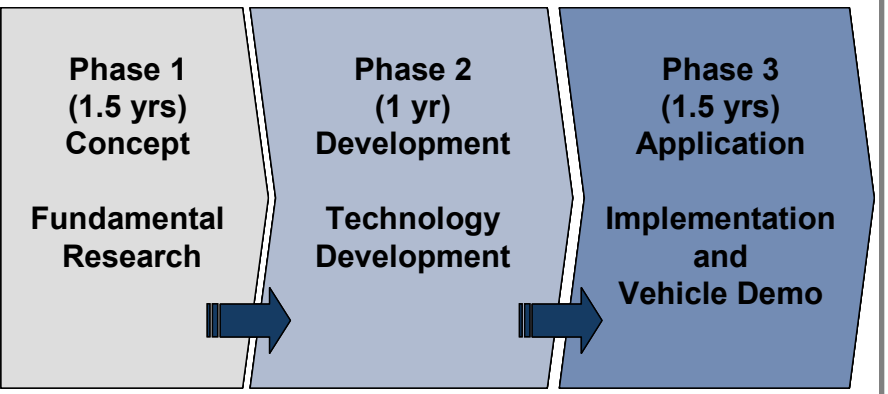
ultimate combustion engine →
SI/HCCI, DI, TC, VVT/VVL, eEGR, FFV

Project Targets



- Targets
  - 30% fuel efficiency improvement
  - SULEV emissions
  - Enabling key systems and controls

Timeline



Partners

- US Department of Energy
- Robert Bosch LLC
- AVL
- University of Michigan, Ann Arbor
- Stanford University
- Emitec

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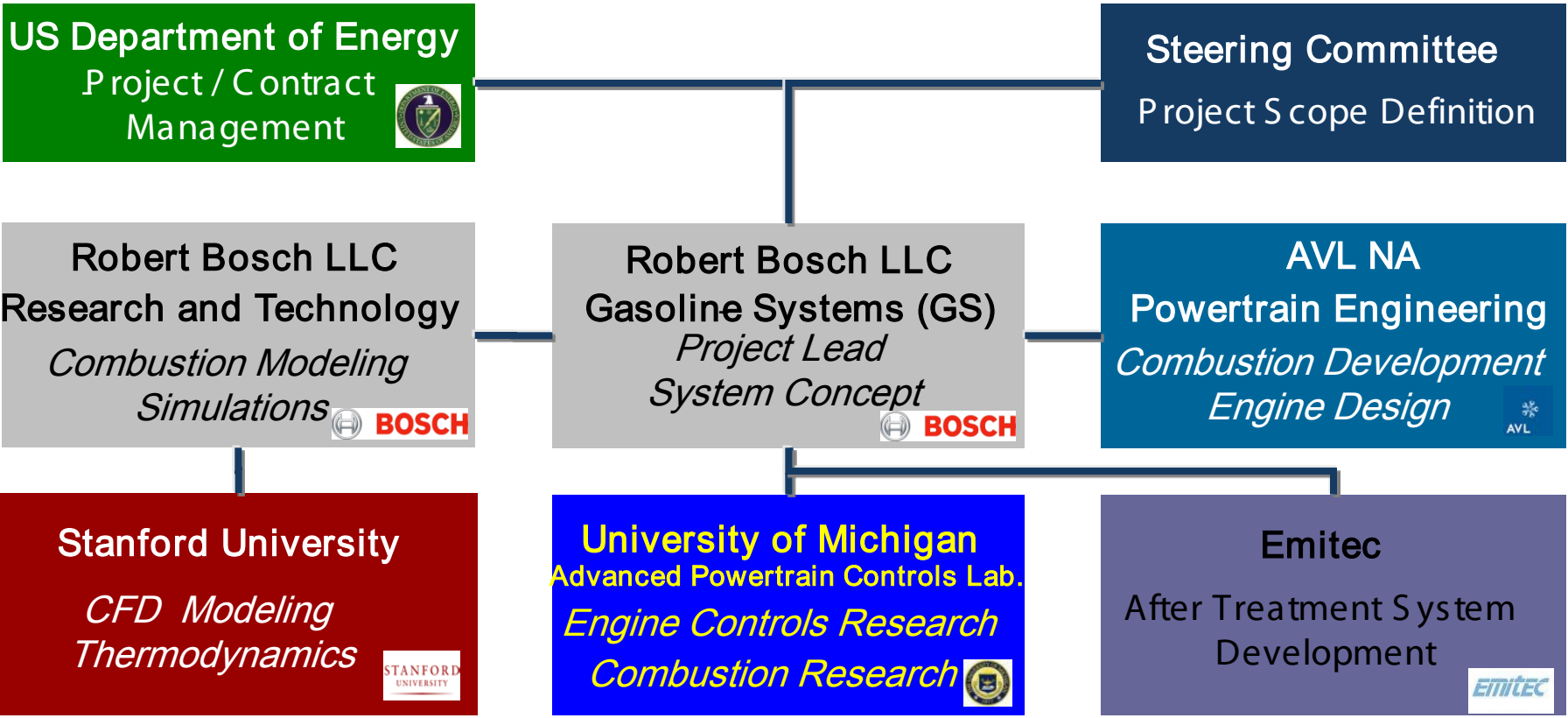
ACCESS Project Organization



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35+ Researchers and Staff from Industry and Academia!

UofM & Bosch

AVL & Bosch

UofM & Bosch

Stanford & Bosch

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Overall Project Objectives

- Baseline Powertrain: 3.6L V6, PFI, 6 Speed
- Target Powertrain: 2.0L I4, DI, Turbo, 6 Speed –Multi Mode Combustion SI/HCCI
- 30% Fuel Economy Improvement Compared to Baseline
- SULEV Emissions Capability
- By mid 2014 commercially viable, production feasible, system solution

Multi Mode Combustion System

- Spark Ignited (SI) Combustion with High Compression Ratio and High Boost assisted with cooled external Exhaust Gas Recirculation (EGR)
- Homogenous Charge Compression Ignition (HCCI) with Boost, and Fueling strategies for operation range extension
- Port assisted Direction Injection (PDI) – Dual injection system for combining the benefits of Port Fuel Injection (PFI) and Direct Injection (DI), and enabling Dual Fuel System approach
- Two Stage Boost – Small Super Charger for HCCI, regular Turbo Charger for downsizing
- Start-Stop and Thermal Management Systems to eliminate fuel consumption at idling conditions and enhance engine warm-up behavior

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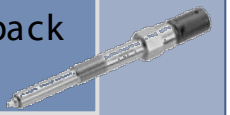
Multi Mode Combustion System Configuration

Customized Engine Management (ECU)

- Novel combustion algorithms
- Model based control

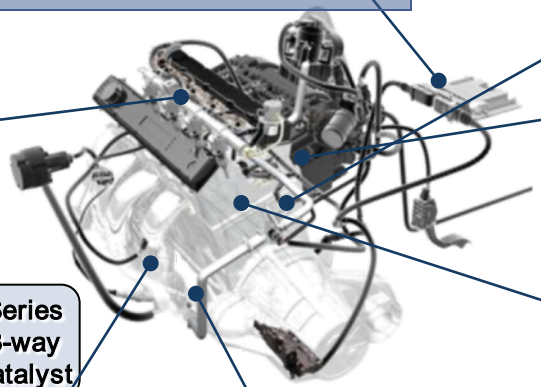
In-Cylinder Pressure Sensing

- Direct combustion feedback
- Closed loop control



Customized Injection

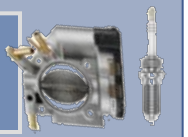
- Solenoid Multi-Hole
- Central mount
- Split injection
- Small quantities
- Variable hole size



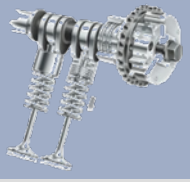
Series 3-way catalyst

Throttling and Ignition

- Stabilizing strategies
- HCCI map extension



Variable Valve Actuation



- 2x Var. phasing (CamPhasers)
- 2x Var. lift (TwinLift or cont. var.)
- Fast and accurate actuation

Turbo-charging

- 2-stage system
- HCCI map extension

External EGR System

- EGR control
- EGR cooling
- Map extension

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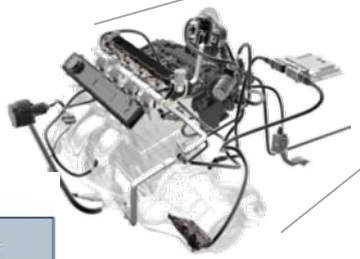
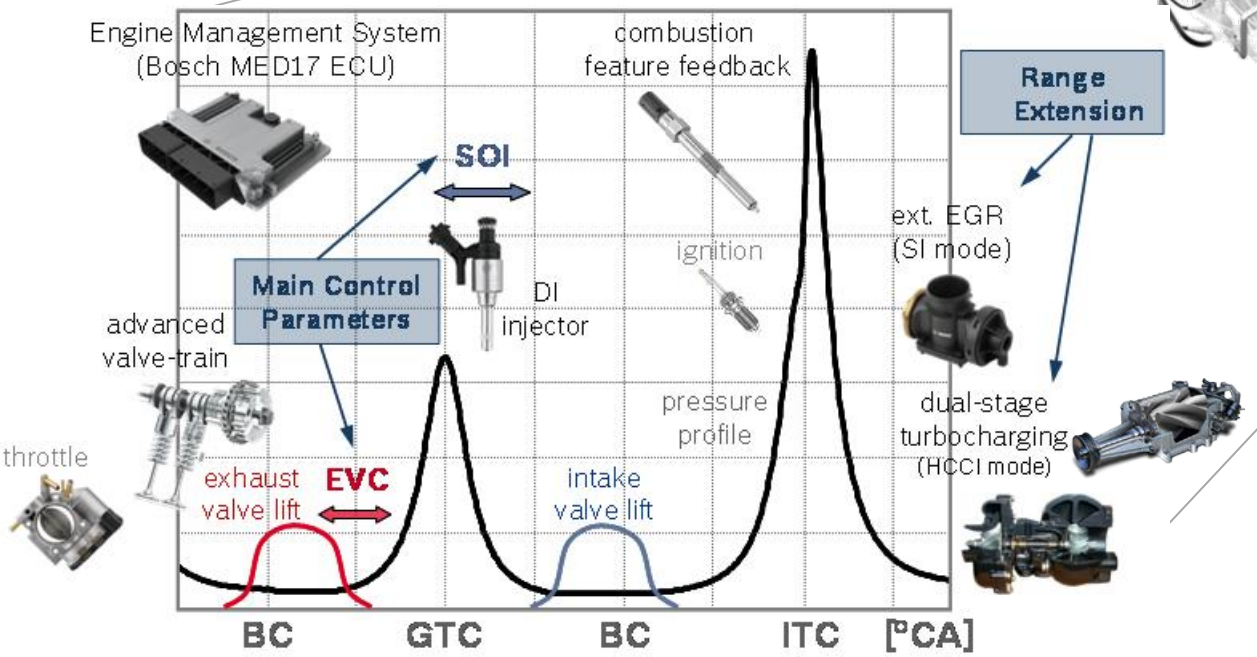
Enabling System for Multi Mode Combustion





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Engine Test Cells at University Partners

- Single-cylinder research engine lab with Fully Flexible Valve Actuation (FFVA) at Stanford operational
- Multi-cylinder engine lab at University of Michigan operational with support of Bosch
- State-of-the-art multi-cylinder transient engine dynamometer
- Resident Bosch engineers at both universities

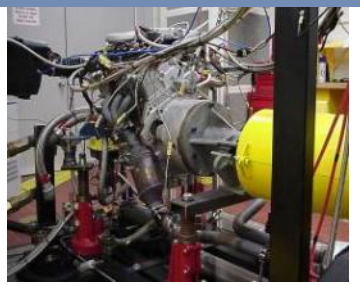
Stanford

Michigan

Engine Test Cells at Industry Partners

- HCCI combustion development and parameterization at AVL test cell
- SI development and calibration at Bosch test cell
- All experimental set-ups will have same Engine HW and Engine Management System

AVL



Bosch

→ Industry support enables University researchers to focus on innovation

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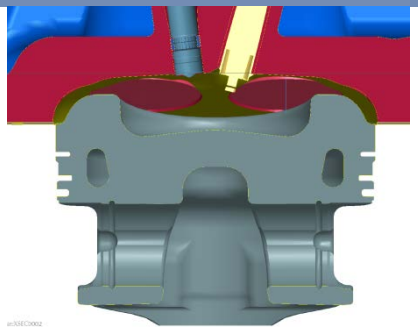
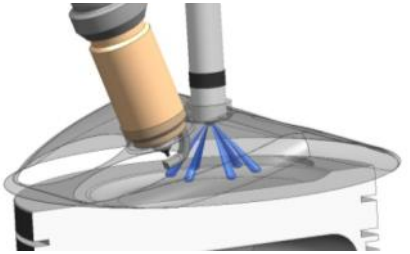
Prototype 1 Engine Design (AVL, Bosch)

- Target Multi Mode Combustion Engine will be based on GM Ecotec 2.0 L DI Turbo platform
- All Base Engine HW design and improvements for target engine configuration in progress, lead by AVL
- All Engine Management System design and improvements for target system configuration in progress, lead by Bosch
- All Aftertreatment System design and improvements for emission concept in progress, lead by Emitec

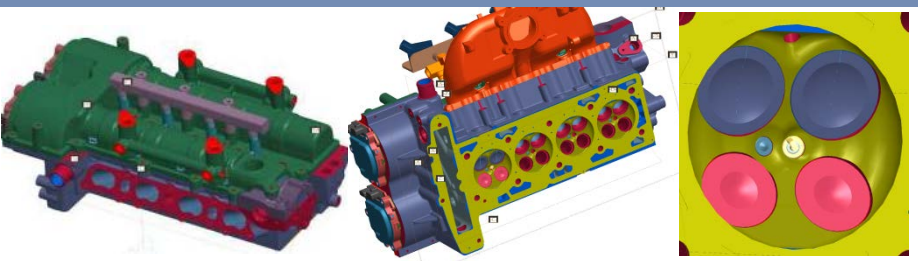
Combustion and Spray Optimization





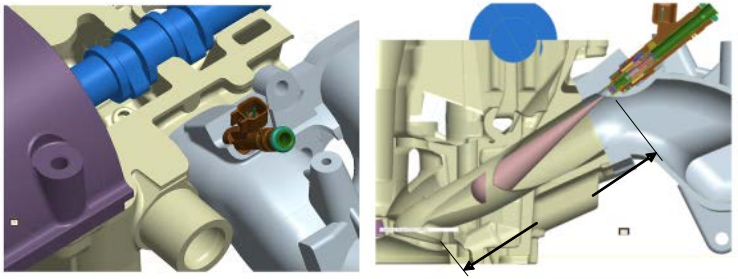
Combustion chamber, piston crown and injection spray designs for Prototype 1 engine are completed

Cylinder Head with Central Mount Injection



Cylinder Head Design for Central Mount Direct Injection and Variable Valve Actuation is completed

Dual Injection Design DI + PFI



Dual Injection System design with DI + PFI is completed

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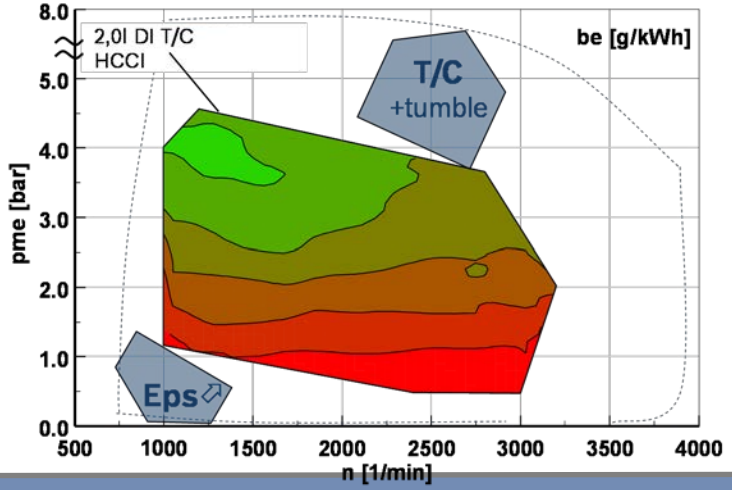
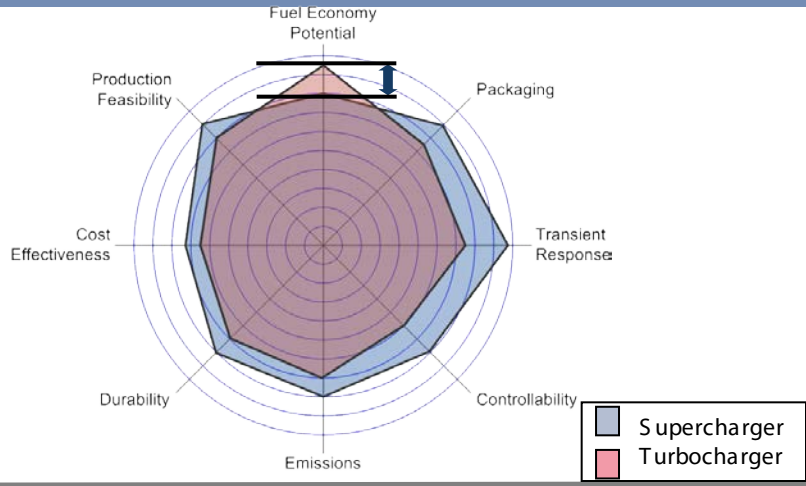
HCCI Range Extension w/ Boosting



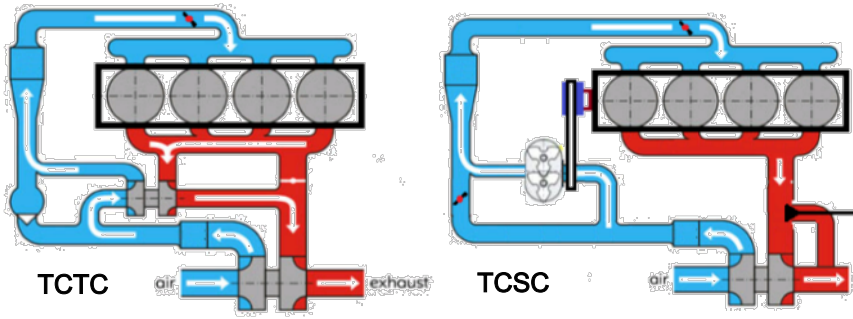
Turbo Charger vs. Super Charger



Accomplishments

- Simulations of dual-stage boosting in GT Power completed
- Experimental data from Boosted HCCI Mule engine was used for simulation validation
- Comprehensive analysis of boosting system options was performed

TCTC vs. TCSC Configuration



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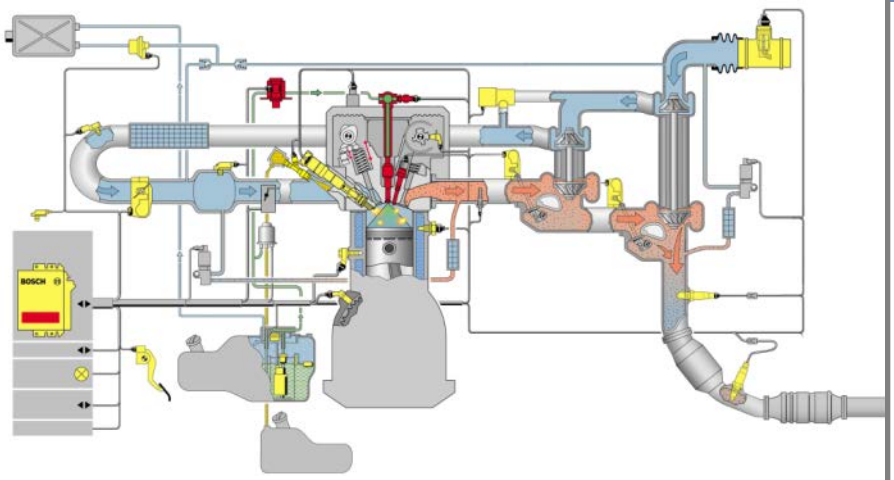
Overview – Combustion System



Approach

- Engine-in-the-loop vehicle simulation
- Single cylinder engine with full VVA
- Predictive Combustion Model for GT Power
- Comprehensive CFD models

Accomplishments

- Turbocharged HCCI data collected
- Transient dyno installed at Univ of Michigan
- Vehicle simulation completed by AVL
- Single Cylinder data collect. under progress

Next Steps

- First fire Prototype 1 at new transient dyno
- Validation of Prototype 1 ECU at AVL
- Combustion development with hardware
- Verification of combustion models

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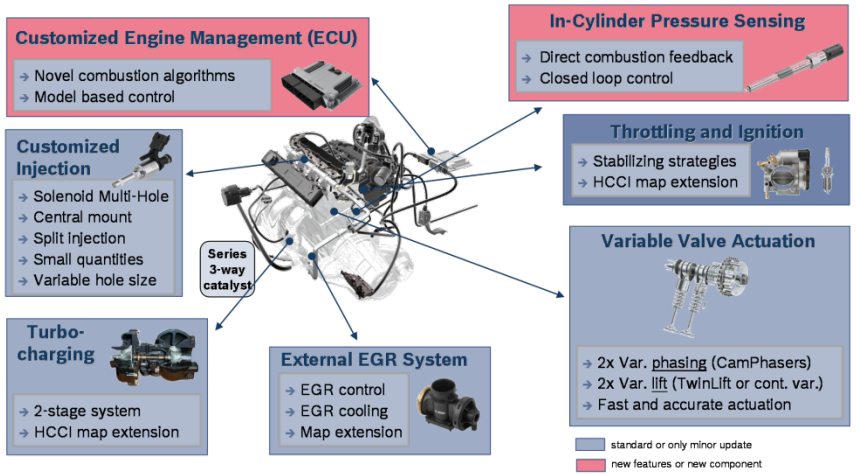
Overview – Control System



Approach

- Model-based combustion / air path control with cylinder pressure sensing feedback
- Engine-in-the-Loop (EIL) control algorithm validation via rapid prototyping techniques
- Demo with ECU integrated controls for multi-mode combustion for a production-feasible solution

Accomplishments

- Reduced-order models established for target engine platform under SI&HCCI combustion
- Model-based controls developed for HCCI combustion and turbo charging
- Baseline HCCI control algorithms integrated into Prototype I Bosch MED17 ECU

Future Work

- Validate ECU integrated sub-system controls on Prototype I engine
- Establish controls for HCCI & SI combustion with TCSC boosting system
- Finalize control strategy architecture for a multi-mode combustion engine

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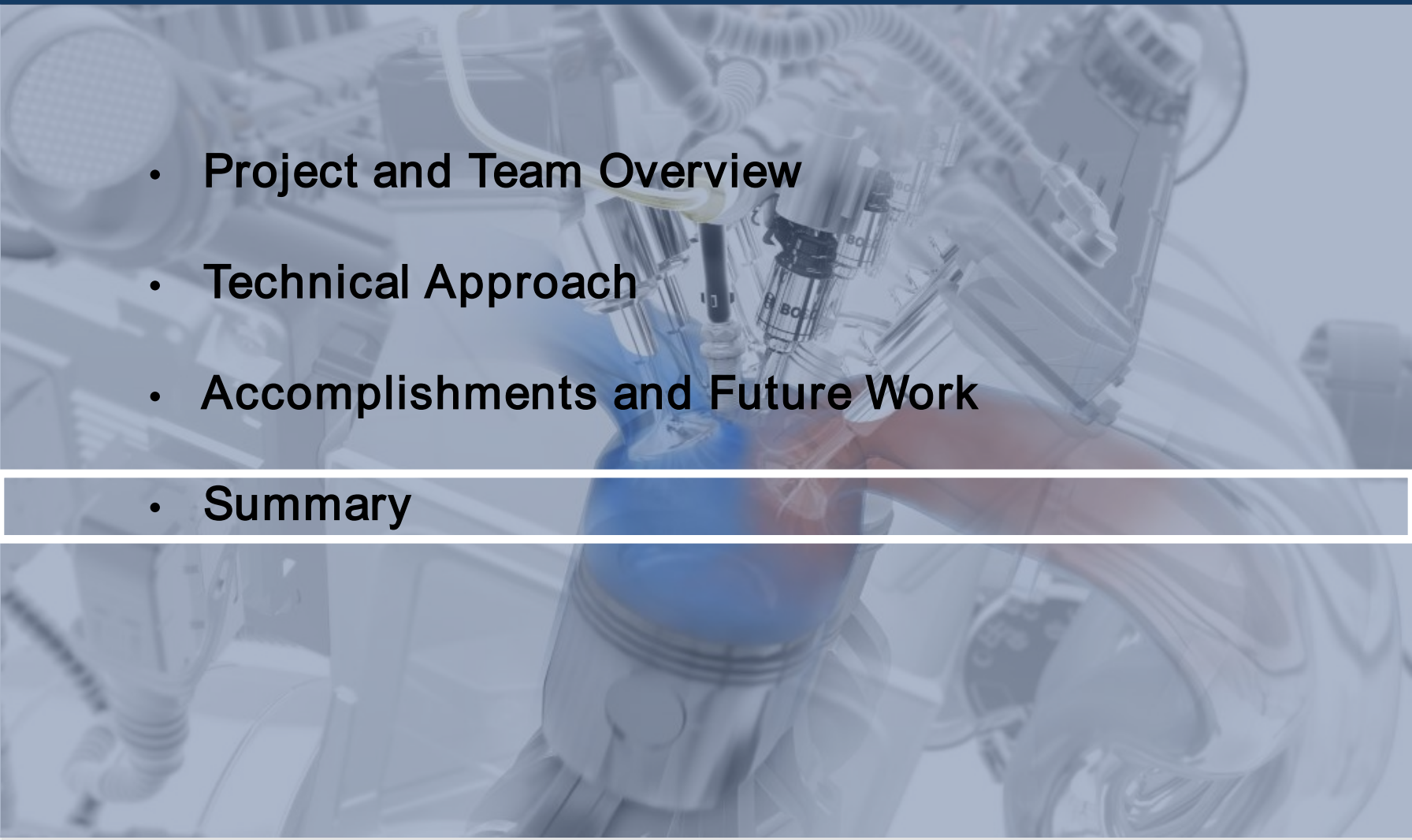

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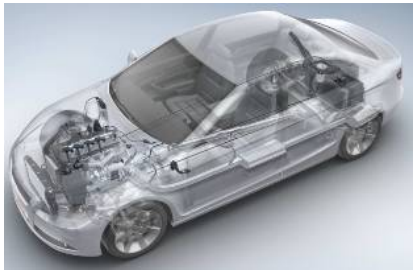
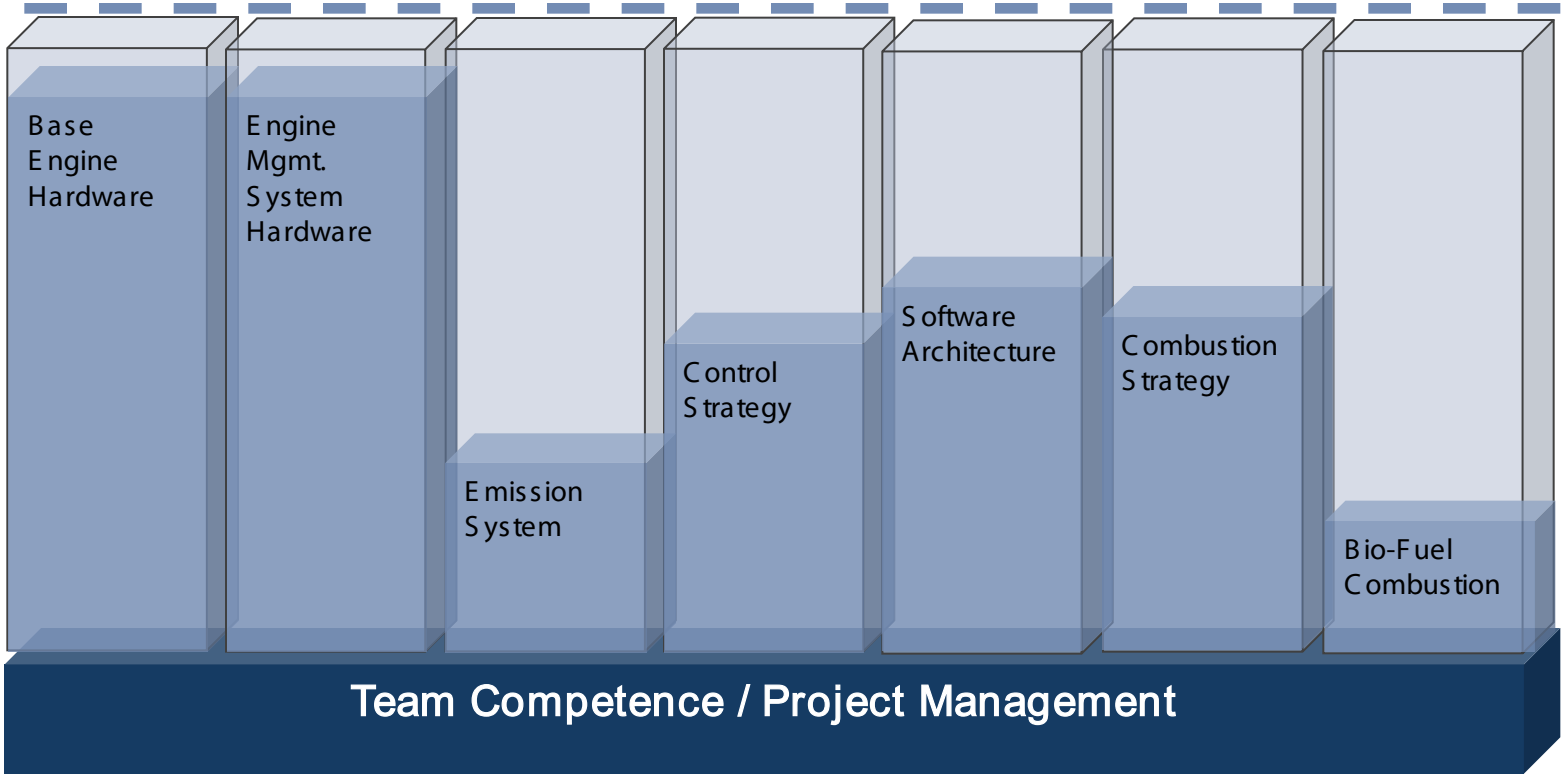


- 30% FE↑
- SULEV Capable
- Commercially Viable

Target



ACCESS Team