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DoE Optimally Controlled Flexible Fuel Powertrain System

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This presentation does not contain any proprietary or confidential information

Purpose of Work

- The key objective is to develop, optimize and demonstrate using design analysis, computer modeling and a prototype engine, a pathway towards:
  - Flex Fuel Vehicles (FFV's) that show a minimized fuel economy penalty when operating on any blend level of ethanol up to E-85 as compared to a conventional gasoline fueled vehicle
  - FFV's that meet US Environmental Protection Agency (EPA) and State emissions regulations (Ultra Low Emissions Vehicle (ULEV))
- Demonstrate a new, commercially viable engine which is optimized for E85 operation, with seamless optimization for other blends:
  - Show minimum economy impact of running E85 when compared to gasoline
  - Show no degradation in vehicle emission running E85 when compared to gasoline
  - Allow the engine to run at various levels of ethanol fuel content up to 85 percent
  - Show increased efficiency when running gasoline (E10) with minimal compromise of engine performance
  - Demonstrate superior engine performance by fully exploiting the properties of E85
    - Performance increase is incentive for E85 use – displacing more petroleum
  - Help DOE promote the economy and social benefits, to the nation, of using E85 fuel

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Barriers

- Very early in the project – we don’t know what we don’t know, yet!
- However, identified challenges to success include:
  - Achievement of best compromise between compression ratio and boost level, while maintaining peak cylinder pressures within engine design limit (currently 140bar (2030psi))
  - Utilization of large quantities of EGR and its cooling
  - Use of Closed Loop Combustion Control to optimize multiple parameters
  - Achieving good compromise between full E85 optimization and maintaining reasonable E10 and other ethanol blend performance levels
  - Increasing efficiency when operating on E10

Approach – Based on existing MAHLE R3 design

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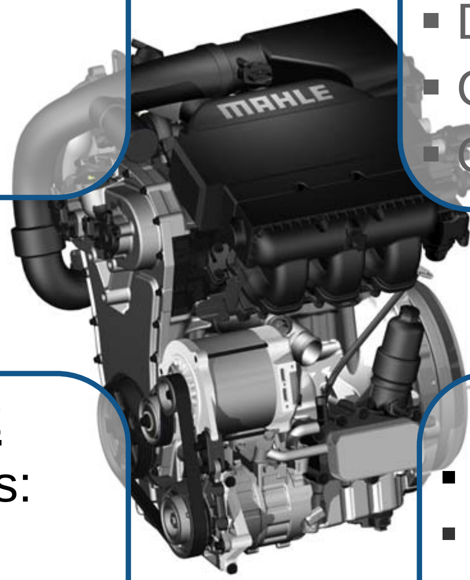
Simulation

- Combustion system (GT-Power)
- Vehicle effects (ADVISOR)
- Social benefit (GREET)
- High-level component requirements

Combustion System Design

- Injector analysis (CFD)
- Ignition system design
- Detailed 1D (GT-Power)
- Control system design (CLCC)
- Optical engine design



System Assembly/Baseline

- LPDI Injector build, Spray tests
- Ignition/Control system build
- E85 Optimized engine build
- Optical single cylinder tests
- Baseline engine tests (P & E)
- Highly diluted combustion study

System Development

- E85 Optimized engine tests:
- Cold start
- Performance & Emissions
- Results Analysis, model update
- Commercialization study

Approach – Modifying/Integrating/tuning existing technology

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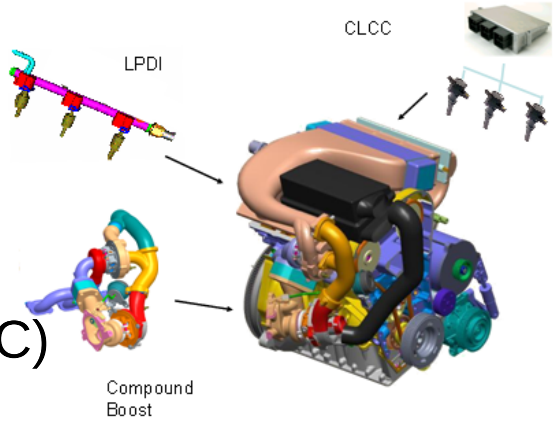
- MAHLE R3 prototype engine design includes enabling features:
  - Downsized, high output (150kW, 30bar BMEP), 3 cyl., DOHC, 1.2L
  - 2 stage turbocharging
  - Dual independent camshaft phasing
  - Lightweight, low friction components
  - High peak cylinder pressure design limit (140bar)
  - High volume EGR circuit



- Visteon Closed Loop Combustion Control (CLCC)
  - Proven concept utilizing ignition coil ionization sensing
  - Monitors/optimizes spark, EGR, knock and misfire on cylinder by cylinder basis
  - Can be used to determine concentration of ethanol in fuel
  - Tested on passenger car and motorcycle engines
- Visteon Low Pressure Direct Injection
  - Demonstrated to provide small droplet size spray
  - Reduced fuel pump parasitic load

Performance Measures and Accomplishments

- Project only just started
- Task 1.1 (Confirmation of Engine Design and Specifications) complete
  - Report ‘DoE Optimally Controlled Flexible Fuel Powertrain System – Task 1.1’ published
- Task 1.2 (Engine simulation and analysis) underway and feeding into:
  - Task 1.2.1 – Vehicle simulation
  - Task 1.5 – Social Benefit Analysis

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Technology Transfer

- Technology and techniques developed during this program will be directly applicable to future ‘downsized’ Flex-Fuel engines
- Estimated benefits of 25 to 30% improvement in thermal efficiency over an existing, gasoline, baseline engine of similar performance
  - Application to U.S. vehicle fleet will significantly reduce energy use and better utilize available ethanol based energy

Plans for Remainder of Fiscal Year

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- Complete Phase 1 modeling, assess technical feasibility:
  - Engine (GT Power)
  - Vehicle (ADVISOR)
  - Social benefit (GREET)
  - Milestone #1 at end of Phase 1
  - Continuation decision point, based on technical feasibility assessment
- Commence Phase 2 design/procurement:
  - Optical engine design
  - In-cylinder modeling (CFD)
  - Injector nozzle design
  - High energy ignition system design

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Summary

- Very early in program….
- Potential for petroleum displacement:
  - Initial estimate (to be refined) indicates up to 9 million barrels per day by 2050
- Approach utilizes modified versions of existing designs/hardware for prototype engine (MAHLE R3) and Visteon’s CLCC and LPDI technologies – High likelihood of success
- Approach also gives high feasibility of commercialization
- Initial engine specification and parameter ranges for modeling agreed
- Engine and vehicle modeling, and social benefit analysis underway
- Plan to complete initial models, assess design feasibility and then progress into design and procurement of engine, control system and fuel injection components
- Plan could be accelerated if oil company funding for similar studies is secured