The Use of Exhaust Gas Recirculation to Optimize Fuel Economy and Minimize Emissions in Engines Operating on E85 Fuel

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Overview

Timeline

- Start date: September 2007
- End date: October 2010
- Percent complete: 34%

Budget

- Total project funding
  - DOE – $1.93M
  - GM – $1.93M
- Funding received in FY08 and FY09
  - $0.45M

Barriers

- Optimize vehicle operation for ethanol fuels
  - Fuel economy
  - Performance
- Combustion characteristics of ethanol based fuels under boosted conditions with the presence of EGR gas
- System design optimization

Objectives

- Develop and demonstrate an internal combustion engine that is optimized for E85 operation in the areas of combustion regimes, overall engine performance and the application of the engine to a targeted platform, while maintaining flex-fuel capabilities
- Set up and exercise engine and vehicle simulation models to synthesize and optimize the following engine design parameters to meet the required performance targets
  - Fuel handling
  - Exhaust gas recirculation system architecture and components sizing
  - Charge air cooler
  - Turbocharger sizing
- Test and develop engine on dynamometer for model validation
- Design necessary change parts to package in the demo vehicle

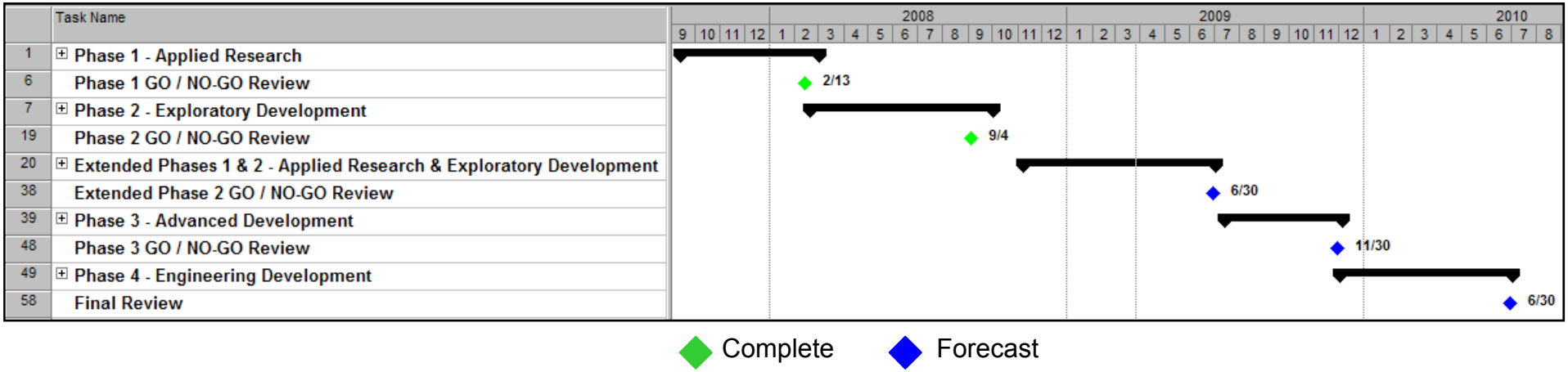
Project Scope Changes

- To get aligned with the fast product mix shift to smaller vehicles and engines which took place in 2008, the following changes were made to the project and approved by DOE
  - Engine: 2.0-L SIDI turbocharged engine, upgraded to be E85 compatible
    - Performance on E85: 390 N-m/209 kW
    - Performance on gasoline: 353 N-m/194 kW
  - Transmission: 6-speed automatic
  - Demo vehicle: FWD Saturn Vue

- Maximize demo vehicle's fuel economy thru systems optimization

Milestones

- Phase 1: simulation analysis to optimize system performance
- Phase 2: test and develop engine on dynamometer
- Phase 3: build vehicle and integrate controls
- Phase 4: evaluate system performance in vehicle



Approach

- Conduct initial engine simulation study by applying our best engineering knowledge
  - To help define the requirements in air flow, EGR flow and exhaust temperature for both E85 and gasoline over the engine operating speed range
  - To help design the system for dyno testing
- Validate simulation results with test data and update models
- Revise hardware specifications for the demo vehicle
- Transfer results to GM flex-fuel products

Use a combination of simulation and testing to optimize the vehicle system's performance

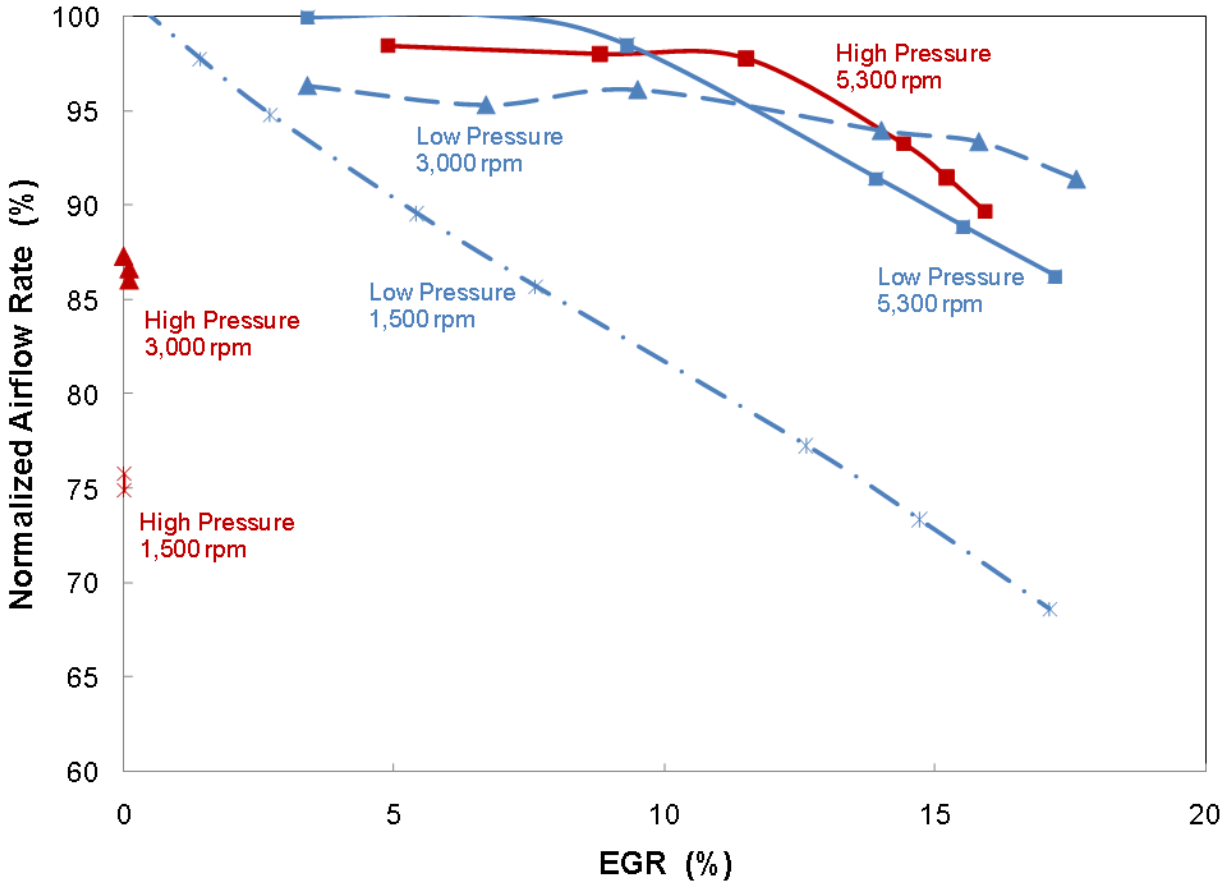
Technical Accomplishments

- Engine and vehicle simulation models have been set up for the new targeted engine and vehicle
- Engine simulation has been exercised to study the effects of
  - EGR system architecture on EGR and air flow tradeoffs under steady-state conditions
  - Fuel, E85 vs. gasoline, on system requirements
  - Transient response of the EGR system at fixed engine speeds
- Vehicle simulation has been exercised to
  - Select steady-state dyno FE test points
  - Investigate transient system behaviors
- Simulation results have been translated into design specifications for EGR system, charge air cooler, and engine management system

Technical Accomplishments
(continued)

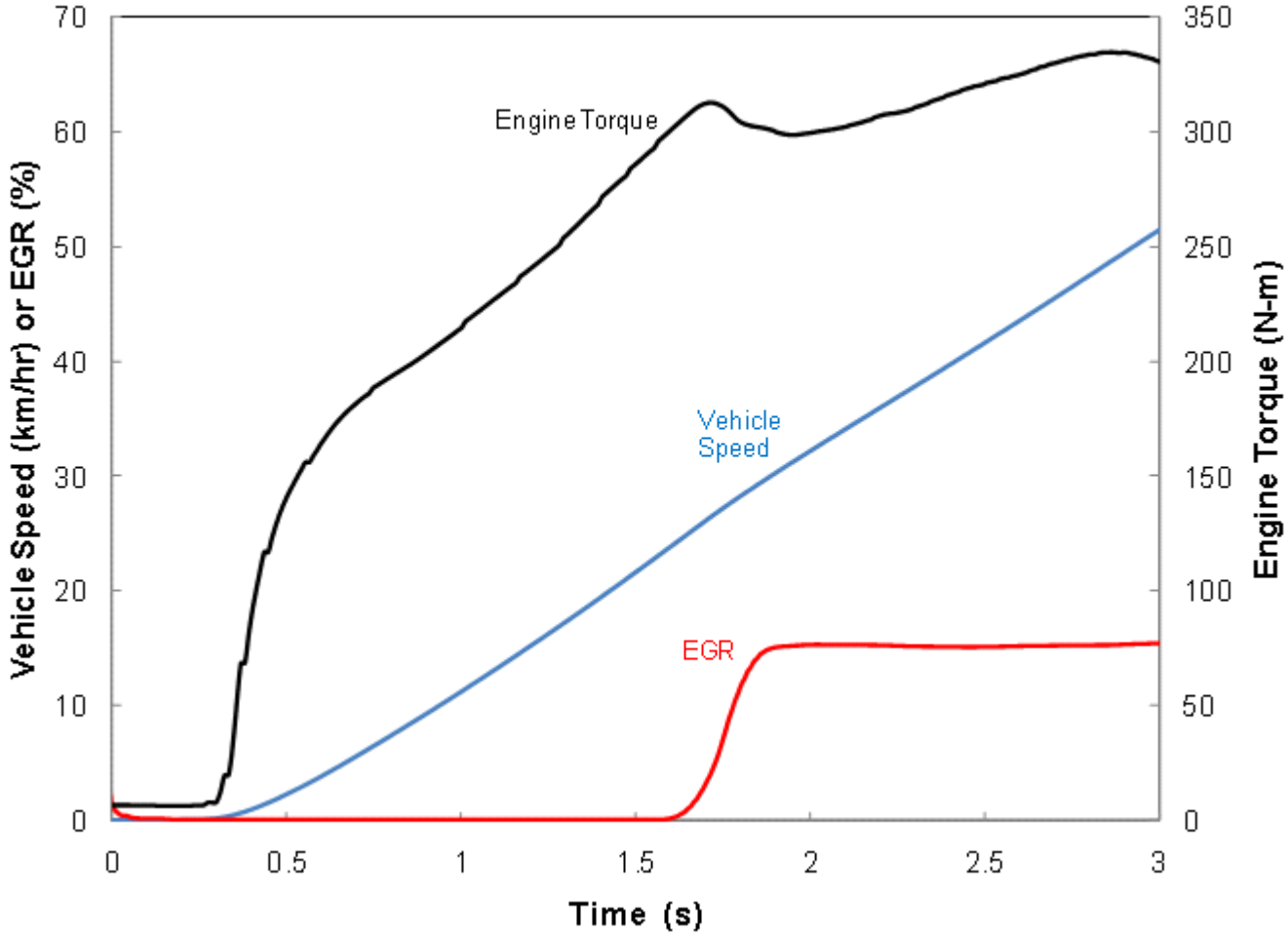
- Vehicle packaging is in progress
- Engine management system to incorporate the required functionalities is being developed

Technical Accomplishment



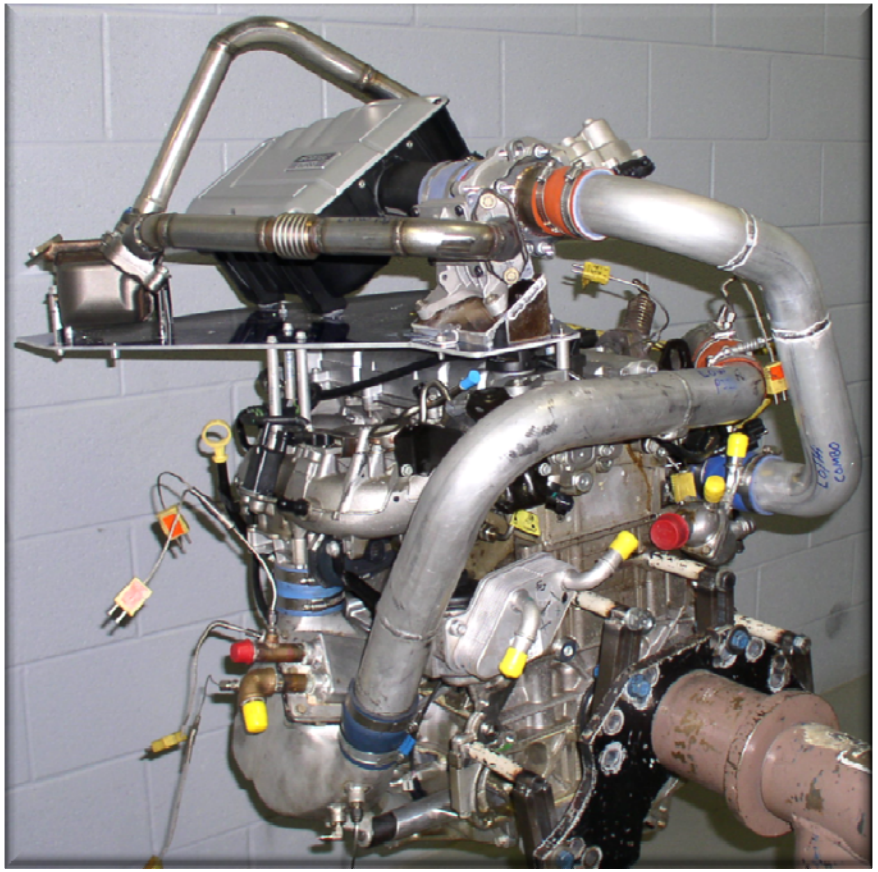
EGR systems compared and optimized by simulation - an optimized low-pressure system has a broader operating range than a high-pressure one

Technical Accomplishment



Vehicle system optimized by simulation - EGR rate target, 15% as engine torque exceeds 300 N-m, can be met during vehicle launch

Technical Accomplishment



A fully instrumented dyno engine with the low-pressure EGR system optimized by simulation

Future Work for 2009 Fiscal Year

- Conduct dynamometer evaluation of both low pressure and high pressure EGR systems for both E85 and gasoline fuels
- Develop control strategies based on both steady state and transient results
- Revise system design based on findings from dyno tests
- Finalize vehicle packaging
- Build demo vehicle
- Develop dyno-based calibration
- Begin vehicle development

Summary

- Develop a flex-fuel internal combustion engine that is optimized to operate efficiently with ethanol fuels by integrating the following fuel economy technologies
  - Downsizing and turbocharging
  - Direct fuel injection
  - Continuously variable cam phasing on both intake and exhaust
  - Cooled exhaust gas recirculation, especially under boosted conditions, which enables engine operation at stoichiometric air-fuel ratios and more favorable spark timings
- Optimize the system design iteratively thru simulation and dynamometer development to ensure achieving the program targets

Summary
(continued)

- Completed simulation studies to generate the required specifications for meeting the performance and fuel economy targets
- Project with the revised scopes is progress well
- Project aligned with GM's product plan for consideration for future production rollout
- Execute the program by leveraging GM's product development and engine management system expertise