GEFORCE: Gasoline Engine and Fuels Offering Reduced Fuel Consumption and Emissions

Project ID# FT044

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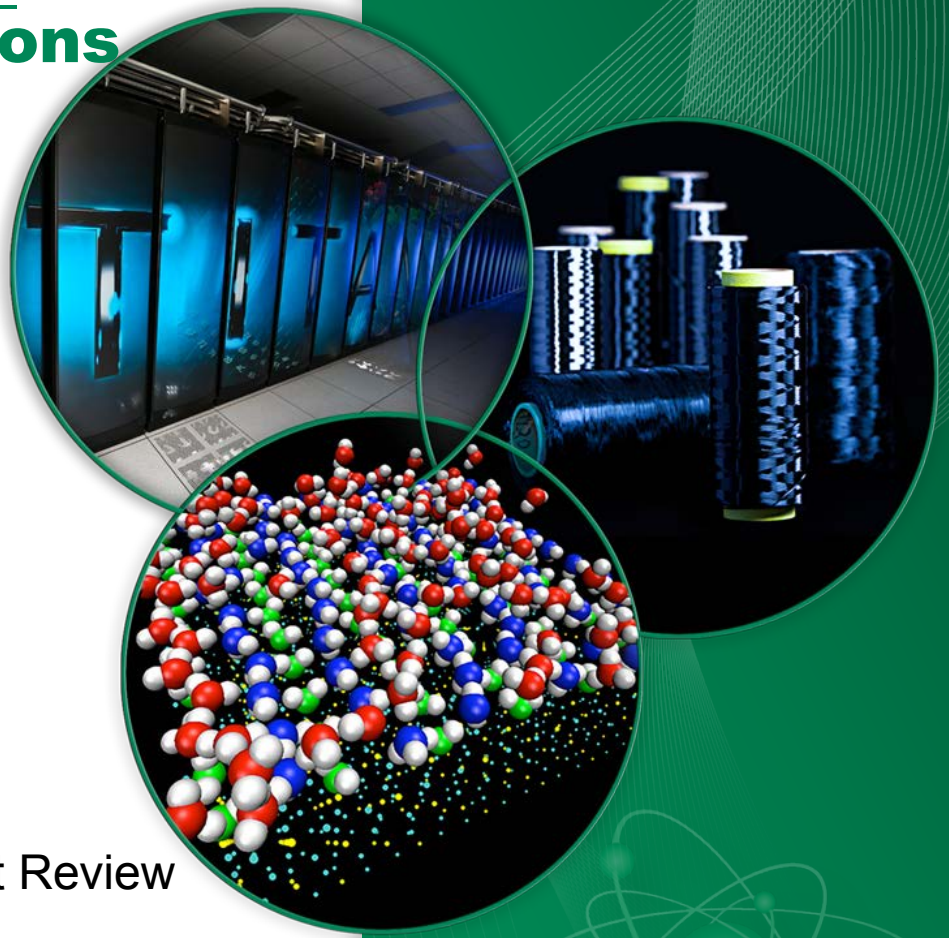

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GEFORCE: A Collaborative Program to Investigate Potential Future Fuel and Engine Design Pathways

Project Timeline

Inception:
- Proposal submitted to FOA 0991, April 2014

Initial Funding Received:
- October 2014

Planned Project Completion:
- September 2017

Technical Barriers Addressed

"Inadequate data and predictive tools for fuel property effects on combustion and engine efficiency optimization"

Project Budget

DOE Funding:
- FY2015: $365K
- FY2016: $320K
- FY2017: $315K (Anticipated)

CRC Support:
- AVFL Committee Project Budget: $300K
- In-kind Research Engines (GM)
- In-kind Technical Guidance and Support

Partner Organization

Coordinating Research Council - CRC

General Motors
Ford Motor Co.
ExxonMobil
Nissan
Daimler
Phillips 66
BP
Shell Oil Products, U.S.
API
Chevron USA
Fiat Chrysler Automobiles
Toyota Tech. Ctr. N.A.
Volkswagen of America
Mitsubishi Motors R&D Am.
Honda R&D America
Marathon Petroleum Co.
Aramco Services

Understanding how engine technology can respond to changing fuel properties to promote SI engine efficiency is a key to reducing petroleum consumption in the U.S. transportation sector.

Project Objective:

The GEFORCE project will establish key engine technologies and fuel characteristics that enable very high fuel efficiency with very low emissions in future vehicles, with a goal of finding pathways to achieve 25% reduction in vehicle petroleum consumption.

Objectives for FY2015:

- Execute CRADA with CRC as the legal framework for the project.
- Execute NDA with GM to enable engine and controller information sharing.
- Design and produce research fuels per the target fuel matrix.
- Design and construct advanced research engine.
- Bring engine cell to readiness for the project
- Establish performance targets by baselining a GM 2.0L LTG engine.

Project Milestones for FY2015 and 2016

Establish Engine Platform

1. Deliver engine to ORNL. **(Complete)**
2. Demonstrate engine operability. **(Complete)**

Research Fuels

1. Establish contract with fuel manufacturer. **(Complete)**
2. Deliver first fuel. **(Complete)**
3. Complete delivery of all fuels. **(Complete)**
4. Go/No-go based on project progress. (Complete – GO!)

Optimize and Map Engine

1. Complete 1st fuel optimization. **(On Track)**
2. Establish baseline vehicle fuel economy and emissions levels. **(On Track)**

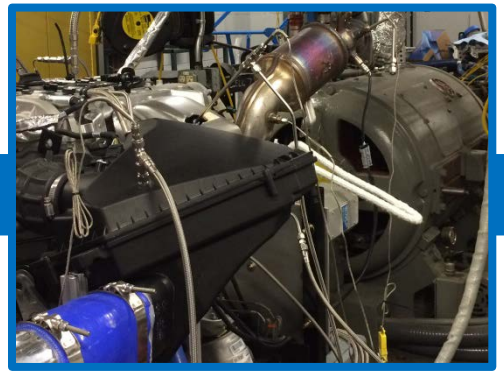
Reporting

1. Submit annual report for project year 1. **(Complete)**
2. Submit annual report for project year 2. **(On Track)**

GEFORCE incorporates an approach using both engine-based experiments with fully-formulated fuels in combination with vehicle system modeling to assess potential pathways to high efficiency and low emissions.

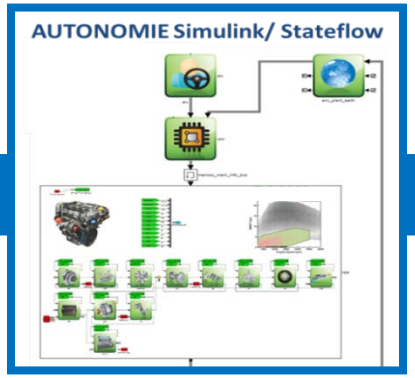
Research Fuels

Include multiple potential future fuel formulations.



Advanced Engine

Experiments using engine technologies anticipated to be mainstream in 15-20 year horizon in an engine research cell.



Vehicle Modeling

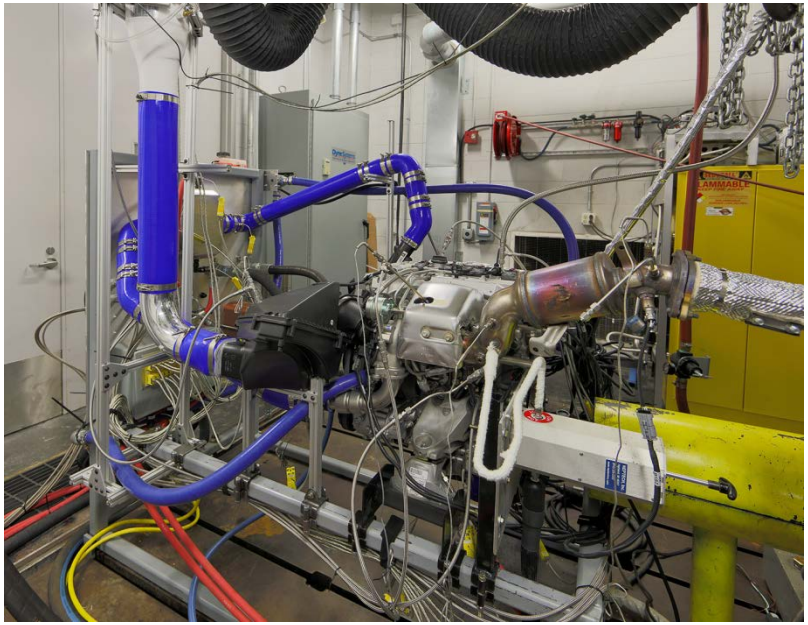
Focus on industry-average mid-size sedan using U.S. drive cycles.

Projected Fuel Economy and Petroleum Consumption

Baseline engine platform is operational at ORNL to de-bug test cell instrumentation and generate baseline fuel economy and emissions results.

2.0L 4-Cyl GM LTG Engine

- 86mm Bore x 86mm Stroke
- 9.5:1 Compression ratio
- Turbocharged, Direct-Injection
- Open ECU using ETAS Inca software

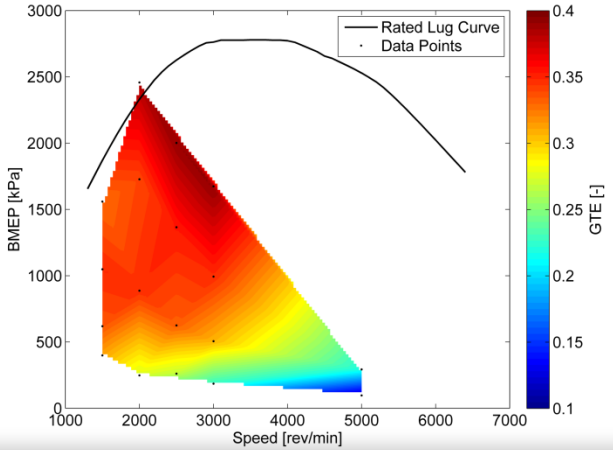


Instrumentation in place to enable 2nd law thermodynamic analysis.

- How do opportunities for improvement change with inclusion of future engine technologies and potential future fuels?

Anticipate baseline map completion in April using certification gasoline.

- Baseline fuel consumption data.
- Emissions guidelines for use in developments of advanced engine calibrations.



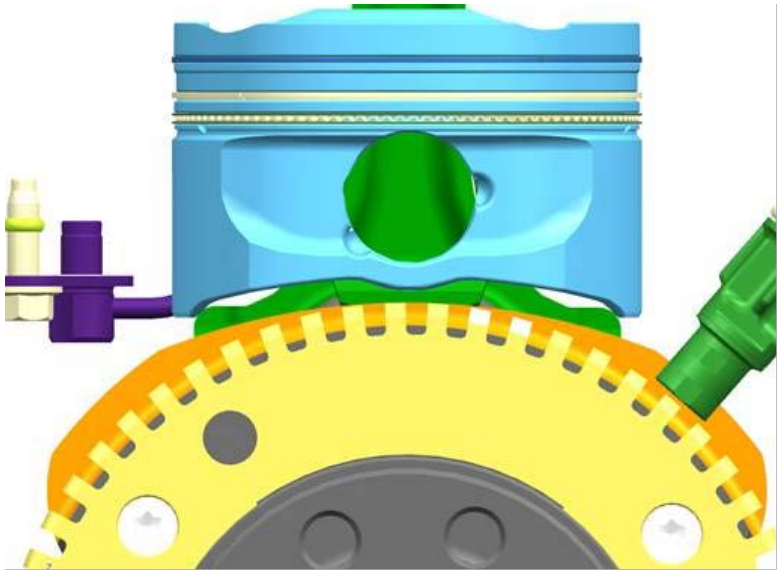
Technical Accomplishments

GM has completed design tasks needed for implementation of the advanced engine hardware.

Drawings prepared to detail required modifications:

- Block (to accommodate new crank)
- Crankshaft wheel and crank sensor location
- Custom connecting rods
- Pistons
- Oil and coolant lines for EGR system and 2-stage turbocharger

Dynamic modeling completed to assure no interferences with new crank/rods/pistons.



Advanced engine implementation (hardware and ECU software) is progressing steadily at GM.

Charge-air cooler

2-Stage Turbocharger

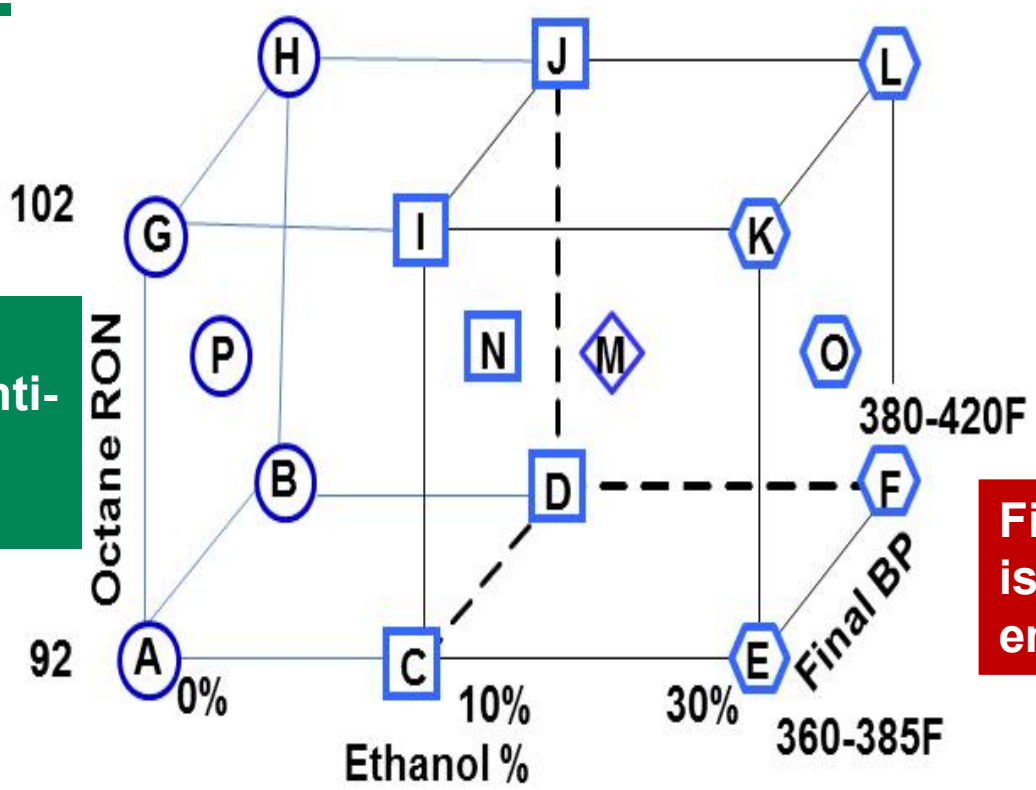
Modified Crank, Custom Connecting Rods, Pistons (Internal)

Modified Block

EGR system hardware integration is also underway, but not shown in photos.

Project team developed a fuel matrix that incorporates potential future gasoline formulations that may enable higher efficiency and lower emissions.

RON is the most applicable fuel anti-knock metric for modern engines.



Final boiling point is important to PM emissions.

Ethanol is currently the most prolific and economical biofuel enabling GHG reductions.

Technical Accomplishments

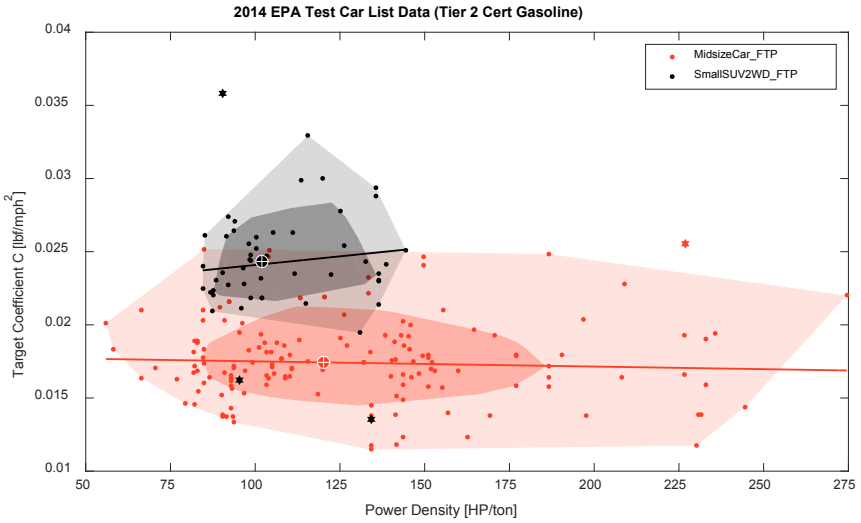
CRC contracted with Gage Products to blend the fuels; production of all fuels has been completed.

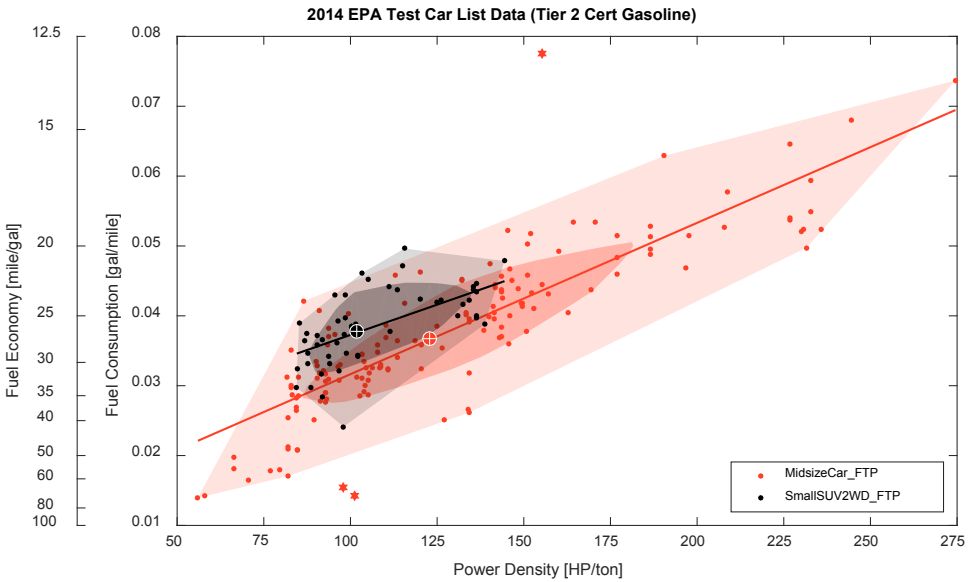
Fuels stored at Bay Logistics in the Detroit area for shipment to ORNL as needed throughout the project.

A vehicle model has been constructed in Autonomie based on real-world data for mid-size sedans.

- Mined EPA certification database to determine industry-average parameters for mid-size sedan.
  - A, B, C, ETW for vehicle model.
  - Fuel economy for rationality check on results.
- Specific vehicle examples provided a means for determining gear ratios for use in the vehicle model.

Method	Term	Midsize Car	Small SUV 2WD
LTG Engine	Rated Power [HP]	259	
EPA 2014 Median	ETW [lbs]	4000	4000
EPA 2014 Power Density Regression Line	A [lbf]	34.7297	31.0083
	B [lbf/mph]	0.2821	0.3326
	C [lbf/mph^2]	0.0174	0.0248
2015 Real Vehicles w/ Similar Power Density	1st gear	4.484	4.618
	2nd gear	2.872	2.898
	3rd gear	1.842	1.877
	4th gear	1.414	1.416
	5th gear	1.000	1.000
	6th gear	0.742	0.759
	Final Drive Ratio	2.77	3.29





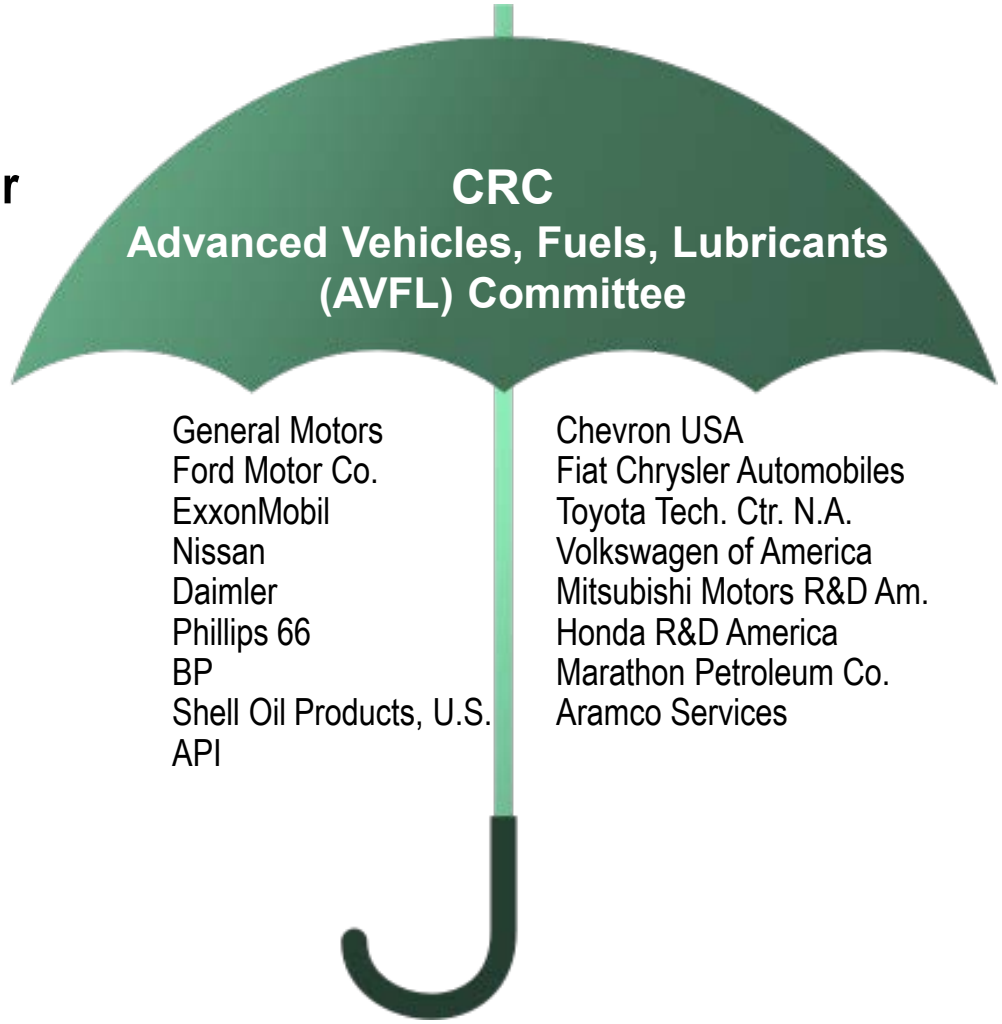
Technical Accomplishments

GEFORCE has not been previously presented at the Merit Review, and as a result, we do not have previous comments to address. We welcome input from this year's reviewers.

Reviewer Comments

Partnering with CRC provides a unique collaborative environment for the GEFORCE project.

- Auto and oil Companies working under one research umbrella.
- Opportunities for non-members to participate in specific projects.
- Regular committee meetings with project updates.
- Involvement of experts from a breadth of technical areas.
- Advantage of lessons-learned from related CRC projects.
- Consensus-based decision making.



Collaboration

Challenges

- Legal agreements that were needed to get the project started have taken longer than anticipated, but this challenge has been overcome.

- GM is performing a substantial amount of work on the advanced engine; schedule flexibility is needed since GM staff must also support core business needs.

- An upcoming challenge at ORNL is making the transition to the largest task of developing engine calibrations for each fuel. Care must be taken develop only the data needed to adequately support vehicle models while making good progress toward completion of the overall project.

Plans for FY16 and FY17 focus on generating data using the advanced engine to support vehicle fuel economy modeling.

Next steps are defined by the project proposal document.

- Bring advanced engine to operational status at ORNL.
- Complete engine calibrations for each research fuel to support vehicle modelling.
- Utilize vehicle model to evaluate fuel economy and emissions results in order to measure the potential impacts of each fuel.
- Report final project results to DOE and CRC.

Future Work

GEFORCE Project Summary

Relevance

- Identifying promising potential pathways to higher efficiency and lower emissions through fuel and engine co-development.

Approach

- Experimental focus on fully-formulated potential future fuels with engine technologies anticipated to be mainstream in 20 years; vehicle modeling to establish fuel consumption, and emissions results.

Technical Accomplishments

- Legal agreements completed, fuels produced and ready; baseline engine operational; advanced engine nearing completion and readiness for experimental studies.

Collaboration

- Partner organization is CRC, enabling close involvement of both auto OEMs and Petroleum companies in the project.

Future Work

- As defined by the FOA project proposal; moving into development of engine calibrations with research fuels followed by vehicle modeling.