2013 DOE Vehicle Technologies Annual Merit Review
Plug-in Hybrid (PHEV) Vehicle Technology Advancement and Demonstration Activity

PI: Greg Cesiel
Presenter: Sandra Monterosso
General Motors LLC
May 16, 2013

Project ID #: VSS018

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Overview

Timeline
- Project Start: 9/30/08
- Project End: 9/30/13
- Percent Complete: 88%

Barriers
- High cost of advanced technology
  - Drive cost down
- Infrastructure
  - Interface and interaction with electric power grid

Budget
- Project Funding: $67.1 M
  - DOE Share: $9.3 M
  - MEDC Share: $2 M
  - GM Share: $57.8 M

Partners
- Michigan Economic Development Corporation (MEDC) - Funding
- University of Michigan Advanced Battery Coalition for Drivetrains – Research

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Advanced Propulsion Strategy

- Improve Vehicle
  - Fuel Economy
  - and Emissions

- Displace Petroleum

- Hybrid-Electric Vehicles (including Plug-In HEV)

- IC Engine
  - and Transmission Improvements

- Hydrogen Fuel Cell-Electric

- Extended-Range Electric Vehicles (E-REV)

- Energy Diversity
  - Petroleum (Conventional and Alternative Sources)
  - Biofuels (Ethanol E85, Biodiesel)
  - Electricity (Conv. & Alternative Sources)
  - Hydrogen

Time
Objectives

- **Overall Program Objective**
  - Develop components and subsystems required for a plug-in hybrid electric vehicle (PHEV) and fully integrate them in a production-intent vehicle
  - Incorporate advanced lithium-ion battery technology
  - Feature high tech E85-capable Flex Fuel engine technology
  - Balance fuel economy, emissions, vehicle performance and battery life trade offs
  - Achieve battery cell performance and life requirements

- **Phase 1 – Development of Year 1 Mule Vehicles**
  - Achieve performance targets and proceed to Phase II
  - Hot weather, cold weather and altitude development
  - Engineering development
    - Charge depletion
    - Lithium-Ion battery development
    - Battery system integration
      - Charger development
  - Vehicle and Powertrain systems integration

- **Phase 2 – Development of Year 2 Integration Vehicles**
  - Merge developed components and subsystems with production intent hardware content
  - Produce and refine calibrations/software with Integration level vehicles
  - Engineering development
    - Charge depletion
    - Lithium-Ion battery development
    - Battery system integration
    - Charger development
    - Vehicle and Powertrain systems integration
Objectives

- **Phase 3 – Battery Thermal Development of Alpha Module**
  - Development of a new thermal management design to help maintain proper operating temperatures
    - Increase range
    - Improved reliability
    - More durable
    - Reduced complexity → more cost efficient design

- **Phase 4 – Battery Thermal Development of Mule Module**
  - Further development and refinement of the new thermal management design (thermal, vibration, aging, sealing evaluations)
Battery module concept work initiated with FEV, Inc and concept selection complete
  ◦ January 27, 2012

Onsite DOE Technical Reviews
  ◦ April 3, 2012
  ◦ September 18, 2012
  ◦ April 16, 2013
  ◦ September 2013

Battery module Proof of Concept
  ◦ Procurement – October 15, 2012
  ◦ Assembly complete – December 13, 2012

Battery module development testing complete
  ◦ June 15, 2013

Battery module design refinement complete
  ◦ July 31, 2013
## Approach/Strategy

- **Hot Weather, Altitude and Cold Weather Development Trips**
- **Integration Vehicle Build**
  - Integration vehicles produced
  - Significant technology improvements
- **Argonne National Lab**
  - Vehicle dynamometer testing
- **Module Thermal Development**
  - Total temperature of the module
  - Internal heat temperature difference of the module
  - Maximum & minimum cell temperature
  - Module temperature at beginning & end of test
  - Heat capacity of the battery coolant
- **Module Vibration Development**
  - Verification of structural integrity of the module to vibration
- **Module Aging Evaluations**
  - Verification of brazing integrity after thermal aging of the:
    - Heat exchanger braze
    - Hose to outlet/inlet interface
    - Heat sink to outlet interface
- **Module Sealing Evaluations**
  - Determine brazing capability with coolant of the:
    - Heat exchanger braze
    - Hose to outlet/inlet interface
    - Heat sink to outlet interface
- **Thermal Cycling Life Assessment of Module Sealing System**
  - Braze integrity and hose interface capability after thermal life assessment
    - Overall braze integrity
    - Hose to outlet/inlet interface
    - Heat sink to outlet/inlet interface
• OnStar data collection was customized to meet DOE reporting requirements
• Virtual modeling and simulation of vehicle hardware completed
Technical Accomplishments & Progress

- Two physical builds completed producing vehicles for internal deployment at General Motors
  - 50+ vehicles built
  - 180,000+ miles driven

- Charge depleting (CD) and charge sustaining (CS) hybrid functionality has been successfully completed and demonstrated to the DOE

- Cold weather testing was performed and exceeded technical specification using both gasoline and alcohol fuels

- Analytical and physical development of available module designs, down-selected to one concept based on developed thermal design concepts

- Conducted detailed design and engineering analysis based on developed module performance metrics and manufacturability requirements
Technical Accomplishments & Progress

- Fabricated prototype components of down-selected concept for early development phase
- Assembled prototype modules/sections (different sizes) from these components to enable building 2 sections and 3 modules
- Testing soon to be initiated on prototypes for critical functions – thermal performance structural performance and manufacturability
- Analyze test results to improve the initial design to deliver a refined design, based on test results and physical build evaluations
University of Michigan Advanced Battery Coalition for Drivetrains
  - Cooperative agreement between U of M and GM
  - Five year development agreement
  - Within Vehicle Technology scope as it related to alternative energy resources and efficient hybrid vehicles
  - Task completion mid-2012

FEV, Inc
  - Collaboration of design and development of new module thermal management system
Future Work

- DOE Onsite Visit
  - April 16, 2013
- Battery module development testing complete
  - June 15, 2013
- Battery module design refinement complete
  - July 31, 2013
- Final review – Washington
  - September 2013
Project Summary

- Project extended to Q3 2013 to ensure a successful completion
- On track to meet new program milestones and project deliverables
- Project development testing and refinement defined and on track to meet program completion in the third quarter of 2013