2010 DOE Annual Merit Review

Plug-in Hybrid (PHEV) Vehicle Technology Advancement and Demonstration Activity

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General Motors Corporation

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Project ID #: vss018

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Overview

Timeline

- Project Start: September 30, 2008
- Project End: July 31, 2015
- Percent Complete: 65%

Budget

- Project Funding: $54 M
  - DOE Share: $10 M
  - MEDC Share: $2 M
  - GM Share: $42 M
- Funding received in FY08: $64.7K
- Funding received in FY09: $4.6M

Barriers

- High cost of advanced technology
  - Drive cost down
- Risk aversion
  - UMTRI collaboration to address consumer behavior and increase public excitement
- Infrastructure
  - Interface and interaction with electric power grid

Partners

- Michigan Economic Development Corporation (MEDC) - Funding
- University of Michigan Advanced Battery Coalition for Drivetrains – Research
- University of Michigan Transportation Research Institute (UMTRI) – Consumer Behavior

Objectives

- Overall Program Objective
  - Develop components and subsystems required for a plug-in hybrid electric vehicle (PHEV) and fully integrate them in a production 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
    - Plug-in charging at 110 & 220 volts
    - New customer focused gauges and displays

- Phase 1 – Development of Year 1 Mule Vehicles
  - Achieve performance targets and proceed to Phase II
    - Hot weather, cold weather and altitude development
- 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
- Phase 3 – Validation of Year 3 Vehicles
  - Validate vehicle systems and produce preproduction vehicles
- Phase 4 – DOE Demonstration Fleet Data Collection
  - Vehicle performance data collection utilizing OnStar
  - UMTRI consumer behavior data collection and analysis
  - OnStar to provide remote diagnostic reports

Milestones

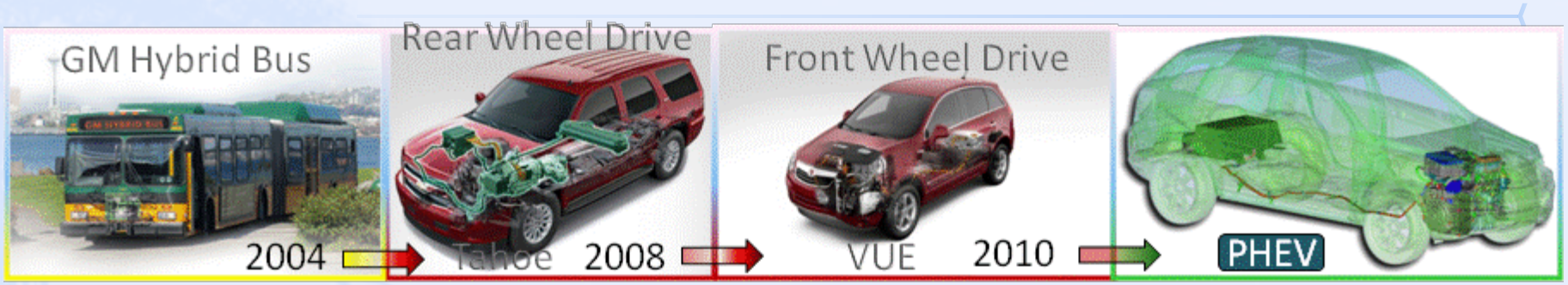
- Deep dive DOE Onsite Reviews: 4/21/09, 10/6/09 and 3/26/10
  - DOE feedback from reviews demonstrates exceptional development progress
- April 17, 2009 – 50% Calibration Ride
- May to September 2009 – Mule vehicles updated
- September 2009 – Hot Weather Development Trip
- September 2009 – Integration Vehicle Build
- January and February 2010 – Cold Weather Development Trips
- March 25, 2010 – 65% Calibration Ride

Kapuskasing, Ontario

Death Valley, California

Approach/Strategy

- Build upon the success of the GM 2-mode strong hybrid family



- PHEV is a blended gas and electric drive propulsion system
- PHEV is an extension of the 2-mode hybrid charge sustaining technology
  - Two electric motors/generators for traction and regenerative braking
  - Two fixed mechanical gears for performance and fuel economy
  - Replaced nickel metal hydride power battery pack with lithium-ion energy battery pack

- PHEV is real-time optimized for fuel economy

Approach/Strategy (cont'd)

- September 2008 to August 2009 – Mule Vehicle Build
  - Completed mule phase of development (Battery, Charging, Powertrain & hybrid controls , Thermal management, Vehicle controls, Fuel Economy)
- April 17, 2009 – 50% Calibration Ride
  - Workable calibration with basic vehicle systems functionality; emission architecture demonstrated capability to targets
- September 2009 – Hot Weather & Altitude Development Trip
  - Demonstrated powertrain & battery thermal stability and capability in hot climate conditions
  - Engine cold starts, PT calibrations, battery thermal calibrations, Plug-in Charging
- November 2009 – Integration Vehicle Build
  - Integration vehicles produced
  - Significant technology improvements
- January and February 2010 – Cold Weather Development Trip
  - General drive ability and diagnostics development
  - Engine cold starts, PT calibrations, battery thermal calibrations, HVAC Cabin warm up, Plug-in charging => environmental temperatures down to -40C with successful operation
- March 25, 2010 – 65% Calibration Ride
  - Demonstrate production intent vehicle hardware and compliance to vehicle performance requirements

Technical Accomplishments & Progress

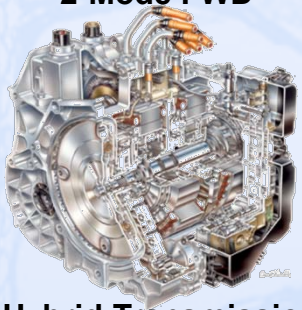
- Objective Phases on track to completion
  - Engineering development of year 1 Mule vehicles successfully completed
  - Partial Phase 1 Mule vehicles updated with the latest production intent batteries, thermal systems, Powertrain systems and battery chargers
  - Integration vehicles successfully built to enable Phase 2 development

- Testing and Development Accomplishments
  - Fuel economy and emissions development on track to meet technical specifications
  - Charge depleting (CD) and charge sustaining (CS) hybrid functionality continues to be successfully completed and demonstrated to the DOE
  - Cold weather testing was performed and exceeded technical specification using both gasoline and alcohol fuels
  - High voltage battery thermal management system proves capable to provide a good balance of fuel economy & battery life
  - Plug-in charging system proved capable in extreme cold and hot temperatures

Technical Accomplishments & Progress

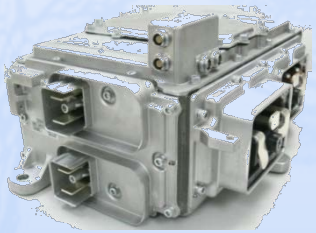
- OnStar data collection was customized to meet DOE reporting requirements
- Virtual modeling and simulation of vehicle hardware completed

2-Mode FWD



Hybrid Transmission

High Voltage



Power Electronics

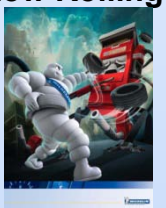
SIDI High Tech

Flex Fuel Engine

Advanced

Lithium-ion Battery

Low Rolling



Resistance Tires

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Collaboration/Coordination with Other Institutions

- 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 relates to alternative energy resources and efficient hybrid vehicles

- University of Michigan Transportation Research Institute (UMTRI)
  - GM Prime/U of M Sub
  - UMTRI to develop a survey to capture consumer behavior and experience with the PHEV
  - Within Vehicle Technology scope based on successful development of such technologies as it relates to the consumer will add to the public excitement

Future Work

- Elimination of Saturn nameplate drives new architecture work
  - Hybrid component packaging starts over
  - New crashworthiness solutions required
- Changes to new architecture required to support hybrid content
  - Structure and cradle changes
  - Electric Power Steering
  - Hybrid Brake Control
  - Aero enablers and mass reduction enablers
- Moving to new architecture presents several challenges & opportunities
  - Packaging and integration of hybrid systems
  - Balancing of performance objectives
    - Customer expectations vs. fuel economy
- Argonne National Lab – collaborative testing of GM supplied PHEV
  - October 2010 (2 weeks of FE & emissions testing)
- Next onsite review scheduled
  - October 11, 2010
- Phase 3 Engineering Validation
- DOE Demonstration and Data collection
  - Vehicle performance data collection utilizing OnStar
  - UMTRI consumer behavior data collection and analysis

Project Summary

- Production program, building on proven GM 2-mode strong hybrid technology
- On track to meet new program milestones and project deliverables
- Objective Development Phases on track to a successful completion
- Data collection and analysis parameters identified

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