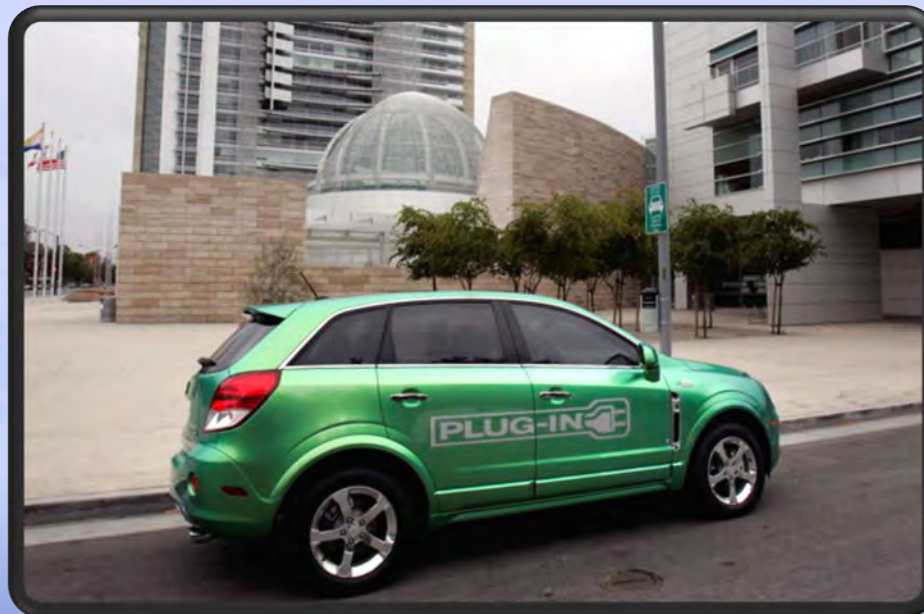


2011 DOE Annual Merit Review

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

Greg Cesiel
General Motors LLC
May 11, 2011



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
- Funding received in FY10: \$3.1M



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 120 & 240 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

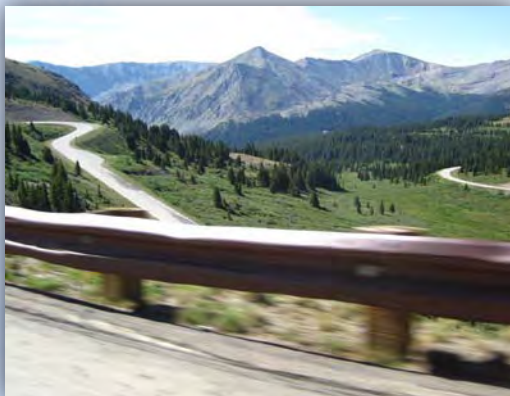


Milestones

- Deep dive DOE Onsite Review: 10/22/10
 - DOE feedback from review demonstrates exceptional development progress
- Hot Weather Development Trip
- Calibration Ride
- Cold Weather Development Trips
- Integration Vehicle Builds
- High Altitude Development Trip



Cold Weather Canada



High Altitude Colorado

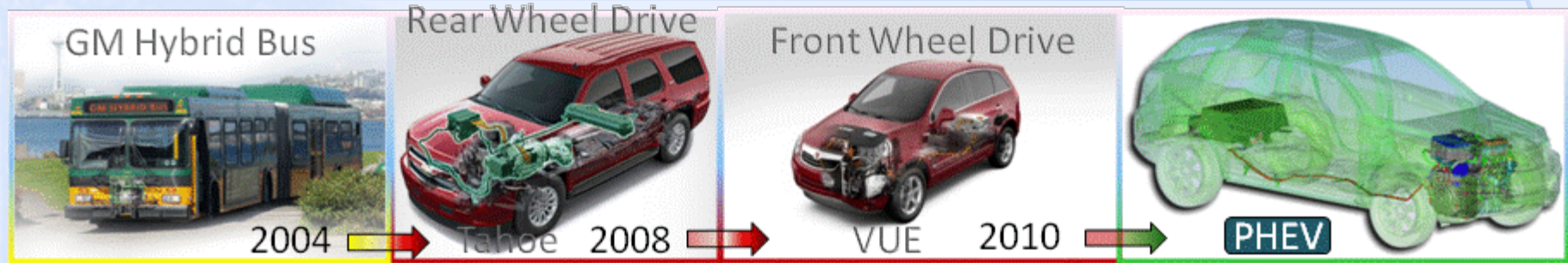


Hot Weather Arizona

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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 Controls operate in real-time, optimized for fuel economy

Approach/Strategy

- Hot Weather & Altitude Development Trip
 - Demonstrated powertrain & battery thermal stability and capability in hot climate conditions
 - Engine cold starts, Powertrain calibrations, battery thermal calibrations, Plug-in Charging
- Argonne National Lab
 - Collaborative testing of GM supplied PHEV
 - 2 weeks of Fuel Economy & emissions testing
- Integration Vehicle Build
 - Integration vehicles produced
 - Significant technology improvements
- Cold Weather Development Trip
 - General drive ability and diagnostics development
 - Engine cold starts, Powertrain calibrations, battery thermal calibrations, HVAC Cabin warm up, Plug-in charging => environmental temperatures down to -40C with successful operation



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, and battery chargers
 - Integration vehicles being built to enable Phase 2 development
- Testing and Development Accomplishments
 - Fuel economy and emissions development continues to be on track to meet technical specifications
 - 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
 - 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

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 as it relates to the consumer and adds to the public excitement from development of technology



Future Work

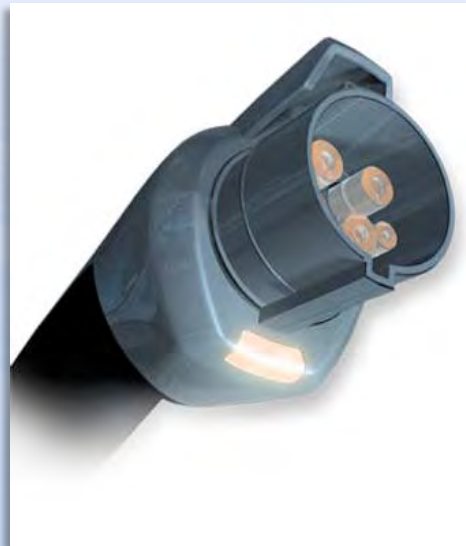
- Demonstrate architectural changes required to support plug-in content
 - Structure, chassis & mounting changes
 - Electric Power Steering
 - Hybrid Brake Control
 - Enhanced thermal management systems capabilities
 - Aero enablers and mass reduction enablers
- Argonne National Lab – collaborative testing of GM supplied PHEV
 - October 2011 (2 weeks of Fuel Economy & emissions testing)
- Next onsite review scheduled
 - Q2 2011
 - Q3 2011
- Phase 3 Engineering Validation
- DOE Demonstration and Data collection
 - Vehicle performance data collection utilizing OnStar
 - UMTRI consumer behavior data collection and analysis



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Project Summary

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



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