ME 261 - Fall 2008

Senior Design Project

Title "GM Powertrain Architecture Selection for EcoCAR"

Introduction:

This design project is focused on conceptual design in support of the GM powertrain architecture selection process for the new EcoCAR (2009 Saturn VUE – Fig. 1). Specifically, the ME 261 team (s) will work collaboration of the recently formed Missouri S&T EcoCAR Team during the Fall 2008 semester.

Background on EcoCAR Challenge:

EcoCAR: The NeXt Challenge is a new collegiate advanced vehicle technology competition (AVTC) kicking off in the fall of 2008. Sponsored by the U.S. Department of Energy (DOE) and General Motors (GM), as well as by Natural Resources Canada and other industry leaders, EcoCAR challenges engineering students from universities across North America to re-engineer a GM vehicle (2009 Saturn VUE), minimizing energy consumption, emissions, and greenhouse gases while maintaining the vehicle's utility, safety, and performance.

In EcoCAR**,** students will design, build, and integrate advanced propulsion technologies into their competition vehicles, which will be classified in categories similar to the vehicle categories from the California Air Resources Board (CARB) zero emissions vehicle (ZEV) regulations. Students are encouraged to explore a variety of solutions, including electric, hybrid, plug-in hybrid, and fuel cell powertrains. In addition, they will incorporate lightweight materials, improve aerodynamics, and utilize alternative fuels such as ethanol, biodiesel, and hydrogen. GM will provide the teams with production vehicles and parts, seed money, technical mentoring, and operational support throughout the three-year program. The DOE and Argonne National Laboratory will provide competition management, team evaluation, technical guidance, and logistical support. EcoCAR follows the successful student engineering competition, "Challenge X: Crossover to Sustainable Mobility," also sponsored by GM and DOE.

Figure 1. EcoCAR Saturn VUE

Background on Missouri S&T Hydrogen Facilities:

Missouri University of Science and Technology is working towards making the hydrogen-powered society of the future a reality by evaluating the entire process of hydrogen production, compression, storage and dispensing. In addition, Missouri S&T is currently implementing a hydrogen-powered rural transit test bed under an initial grant provided by the Defense Logistics Agency (DLA) with additional support being provided by the Federal Transit Administration (FTA), Ford Motor Company, Gas Technology Institute (GTI), and the Missouri S&T National University Transportation Center. There is a potential that in the future each region may use a different combination of resources to produce hydrogen depending on local resource availability.

Our facilities includes a brand new EcoCAR Garage, Hydrogen Fueling Station, Renewable Energy Design Center, along with an Advance Vehicle Modeling & Simulation Lab. The hydrogen fueling station consists of several leading technologies including an on-site steam methane reformer and electrolyzer, steel and carbon composite storage tanks, a 350 bar hydrogen dispenser and a stationary polymer electrolyte membrane (PEM) fuel cell. Further, by integrating on-site solar and wind energy into the test bed, this site demonstrates that hydrogen is not just a clean-fuel, but that it can be produced through renewable, energy-efficient means.

The Missouri S&T EcoCAR garage (Fig. 2) will serve as the headquarters for the Missouri S&T EcoCAR team. Within the garage students will gain real-world, hands-on experience by transforming a standard production vehicle into a state-of-the-art-car utilizing cutting edge power train technologies. The EcoCAR garage will be equipped with the necessary equipment for the team to build a re-engineered student vehicle prototype (within 2 years of production readiness) which minimizes energy consumption, emissions, and greenhouse gases while maintaining the vehicle's utility, safety, and performance.

Figure 2. Missouri S&T EcoCAR Garage on Collegiate Blvd.

The Missouri S&T Renewable Energy Transit Depot is a new "green-building" fabricated from four recycled shipping containers. The overall design emphasizes state-of-the-art strategies for sustainable site development, water savings, energy efficiency, material and resource selection, and indoor environmental quality. This transit depot will be a multifunctional building acting as the terminus of the hydrogen shuttle bus service, home of the EcoCAR team offices and training space, architectural wind turbines and a solar photovoltaic canopy. Architectural wind turbines will provide an attractive and cost effective renewable energy technology option when installed on buildings. The utilization of green building design concepts (such as the solar canopy) and construction methods provide immediate and measurable results for building owners and occupants.

The modeling and simulation lab in the Engineering Management Building is being equipped with the latest software used for vehicle development through General Motor's Global Vehicle Development Process - the modeling and simulation process currently used to develop all of GM's vehicles. Sophisticated hardware in the loop (HIL) and software in the loop (SIL) systems will be utilized to model and simulate the integration of the vehicle subsystems into the overall vehicle design. Overall, the emphasis is on optimizing a practical, realizable vehicle design.

Design Problem*: Architecture Selection Process for Powertrain*:

The architecture selection process for the powertrain of the EcoCAR is shown in Figure 3. Thus the conceptual design process requires the selection of a vehicle architecture (split, series, parallel, belt alternator starter (BAS+), etc.) that meets both the goals of the competition and the team's Vehicle Technical Specification (VPS). The VTS is a set of requirements that define critical vehicle parameters, for example: Fuel Economy and Emissions; Acceleration and

Stopping Distance; and Safety Requirements. It should be noted that a complete VTS identifies the critical requirements for the entire vehicle. Identification of these vehicle-level requirements enables balance between imperatives. Fuel Economy is important, but without drive quality balance, Consumer Acceptability may be sacrificed.

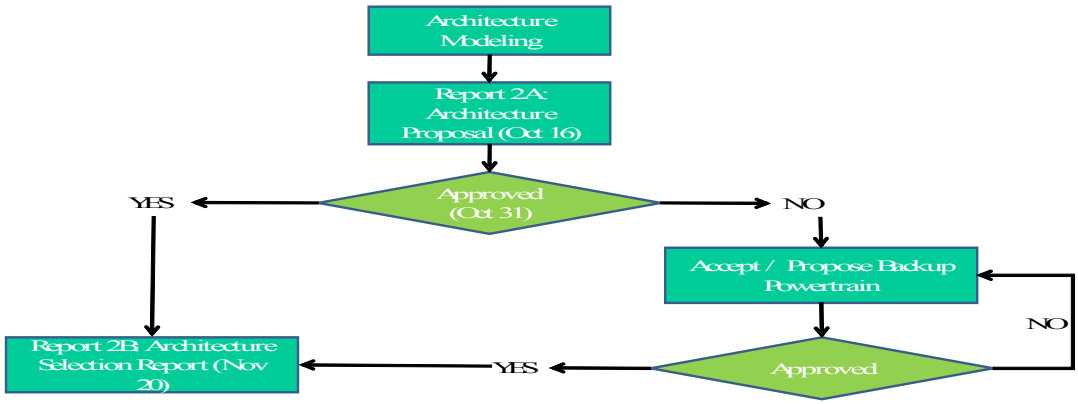

Figure 3. Architecture Selection Process

The Fall 2008 schedule for the EcoCAR Challenge is noted Table 1 below.

Table 1. EcoCAR Schedule for Fall 2008

Fall 2008 Dates	**EcoCAR Team Deliverable**
September 12, 2008	Report 1: Production vehicle modeling report
October 16, 2008	Report 2A: Architecture Selection Proposal
November 20, 2008	Report 2B: Architecture Selection Report

The goals of the Architecture Selection Report #2A are as follows:

- Perform and document the design and research needed to appropriately choose a vehicle architecture that meets both the goals of the competition and the team's Vehicle Technical Specification.
- Teams will also need to consider what vehicle powertrain components and powertrain subsystems are capable of achieving their specified goals.

In addition, Report 2A must include a conceptual packaging diagram of the major components and subsystems that will be added to the vehicle for their architecture selection. Teams are allowed (but not required) to consider more than one packaging design for a given vehicle architecture.

The vehicle powertrain modeling, simulation, and analysis goals include the following:

- Performance models will be delivered by fall workshop
- Teams are to evaluate multiple powertrain components and subsystems using Powertrain System Analysis Toolkit (PSAT) or other modeling software.
- The analysis should reflect consideration of the competition goals and the teams Vehicle Technical Specification (VTS) requirements.
- Documentation of the performance metrics and how they are used in the decision process is required.

The competition requirements are given in Table 2.

Table 2. Competition Requirements

Specification	**Requirement**	
EcoCAR	**Production VUE**	**Competition**
Accel 0-60	10.6 s	≤14 s
Accel 50-70	5 s	≤10 s
Towing Capacity	680 kg (1500 lb)	≥680 kg @ 3.5%, 20 min @ 72.4 kmh
Cargo Capacity	.83 m3	TBD
Passenger Capacity	5	≥4
Braking 60 - 0	37.5 m- 42.7 m (123 -140 ft)	< 51.8 m (170 ft)
Mass	1758 kg (3875 lb)	≤ 2268 kg* (5000 lb)
Starting Time	≤ 2 s	≤ 15 s

The competition targets are given in Table 3.

Table 3. Competition Targets

EcoCAR	**Production VUE XE**	**Competition Target**
Fuel Economy, CAFE Unadjusted, Combined	8.3 l/100 (28.3 mpgge)	7.4 l/100 (32 mpgge)
Petroleum Use	0.73 kWh/km	0.65 kWh/km
Emissions	Tier II Bin 5	Tier II Bin 5
WTW GHG Emissions	246g/km	217 g/km
Range	> 580 km (360 mi)	≥ 320 km (200 mi)
Ground Clearance	198 mm (7.8 in)	≥178 mm (7 in)

ME 261 GM Project Schedule is noted in Table 4.

Table 4. ME 261 GM Project Schedule

Week	Activity	Item(s) Due	Due Date
2	Task 1	Review project team resources to support the project Establish Team communication, critical milestones and review concepts with mentor.	TBD
2-3	Task 2	Kick off Meeting with Sponsor Research the provided materials and review the operational requirements and restraints.	TBD
3-6	Task 3	Brainstorm, research and conceptual development; drawings of 2 to 3 prioritized design concepts; *discussion* of pros and cons of each concept	TBD
7-8	Task 4	*Extensive discussion* of pros and cons of *chosen* concept; design iterations for optimal performance; first draft of report *Introduction, Cost Estimate and Project Schedule*. Begin detailed design	TBD
	Mid-Term	Advance copy to be submitted to the Sponsor prior to the formal Presentation Presentation and Update	TBD
9-10	Task 5	Complete *detailed* design and components necessary to support testing of this technology.	TBD
11-13	Task 6	Lab test components and/or model pro-type.	TBD
14-16	Task 7	Finalize test results and details	TBD
	Show Case	Advance copy to be submitted to the Sponsor prior to the formal Presentation Project Presentation for Show Case Review Poster summary of final design Project report copies for Sponsor	