



*THE LATEST ADVANCED VEHICLE TECHNOLOGY COMPETITION  
2011 MERIT REVIEW*

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MAY 12, 2011*

*Project ID:  
T1013*

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# Overview - EcoCAR

## Timeline

- Started August 2008
- Ends June 2011
- 88% Complete
- Year 3 (vehicle refinement year) completion June 2011

## Budget

### Total over 3 years

- DOE: \$4.5M
- Non-DOE \$7.313M
- Industry Cash/In-Kind \$75M

## Barriers

- Vehicle System Analysis
  - Development of computer powertrain modeling tools
- Vehicle Calibration and Validation
  - Improving University hardware resources to support control system design and validations
  - Improving University access to modern emissions testing equipment and expertise

## Partners

- 30+ Government and Industry Partners (see next page)
- Managed by AVTC team at Argonne National Laboratory



# 2011 Sponsors

Headline



U.S. DEPARTMENT OF  
**ENERGY**



Diamond



Government  
of Canada

Gouvernement  
du Canada

Platinum



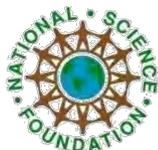
California Environmental Protection Agency  
**AIR RESOURCES BOARD**



The MathWorks



Gold



**WOODWARD**  
MotoTron Control Solutions  
Production Controls in a Flash



**BOSCH**



Silver



Bronze



**SIEMENS EPRI** | ELECTRIC POWER  
RESEARCH INSTITUTE

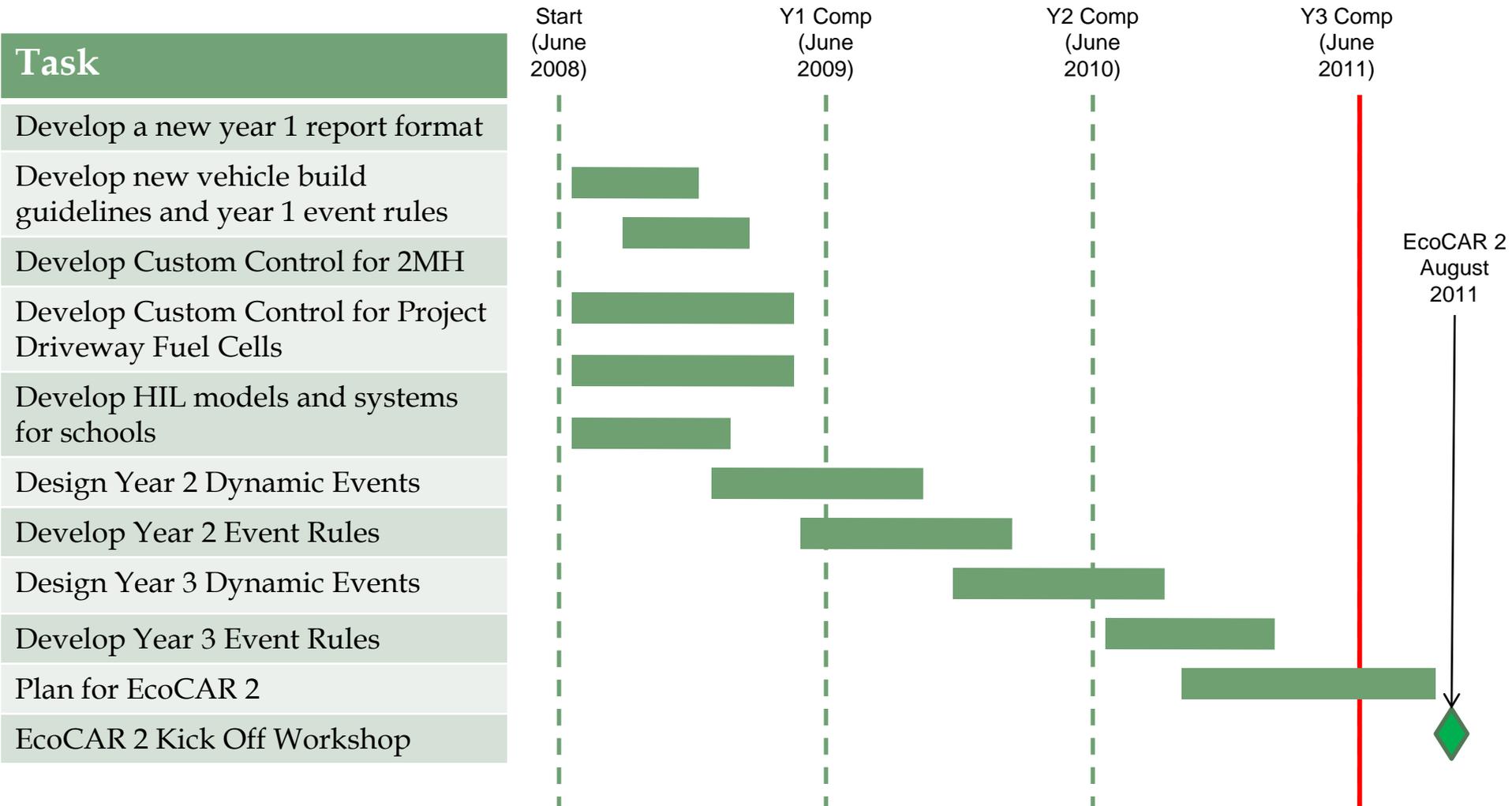
**DELPHI**

**EcoMotors**  
INTERNATIONAL™

**CarSim**™



# EcoCAR Milestones



# EcoCAR Technical Objectives

- Overall Project Objectives
- EcoCAR challenges 16 North American universities to re-engineer a GM donated vehicle to increase efficiency, reduce emissions and outperform its production counterpart while maintaining its consumer acceptability
- Train students for the work force in the areas of:
  - Vehicle, modeling, simulation design, optimization, and testing
  - Mechanical Design and Integration
  - Electrical Design and Integration
  - Control System Design and Integration
  - Battery System Design and Integration
- Demonstration and testing of 16 distinct advanced technologies on a common vehicle platform



# EcoCAR Technical Objectives

- EcoCAR 1 Year 3 Objectives:
- Continue to foster the Graduate Research Assistant Program
  - ➔ Engineering GRA – Provides continuity and technical leadership and serves as a subject matter expert in a specialized area of research
  - ➔ Outreach GRA – Provides continuity and leadership in Outreach area
- Execute the final (refinement) year of the EcoCAR Vehicle Design Process (VDP)
  - ➔ Oversaw the engineering refinement activities of all EcoCAR universities
  - ➔ Facilitated dynamometer emissions testing at the US EPA's NVFEL
  - ➔ Performed vehicle safety inspections
  - ➔ Modified the Emissions and Energy Consumption (E&EC) on-road testing to the facilities at GM's Milford Proving Grounds
  - ➔ Execute the Year 3 Competition Finals in Milford Michigan and Washington DC



# EcoCAR Approaches

- **EcoCAR 1 Objective 1: Collaborate with the EPA to design and execute an emissions testing summit for the entire EcoCAR fleet**
  - Students were taught about emissions, certification process, and dynamometer testing
  - Students prepared test plans which were review by Argonne and EPA engineers
  - All 16 vehicles were transported to the EPA's NVFEL where teams were able to calibrate their vehicles and perform certification testing
  - Some vehicles were able to take part in full charge PHEV testing to observe transitions to charge depleting to charge sustaining operation – useful for future regulation development
- **EcoCAR 1 Objective 2: New approach to mid year safety inspections to ensure safer more refined vehicles**
  - Typically an inspector travels to each school to inspect vehicles – issue is that vehicles are increasingly more complex, one person does not have the depth in all areas of required expertise
  - All vehicles were brought to one location and a team of SME's were assembled to perform the inspections and teams were given 5 days to work on vehicles – all vehicles left the workshop with all HV and other safety areas addressed



# EcoCAR 2 Technical Objectives

## ■ Overall Project Objectives

- EcoCAR 2 will again challenge 16 North American universities to re-engineer a GM donated vehicle to increase efficiency, reduce emissions and out perform its production counterpart while maintaining its consumer acceptability
  - Key distinctions between EcoCAR and EcoCAR 2 revolve around enhanced control system, Emissions and Energy Consumption testing, and Human Machine Interface development
  - Anticipatory control system development is being added to the EcoCAR design portfolio
  - Emissions and Energy Consumption testing is being enhanced with principles based on 5-Cycle emissions testing to better mimic real world driving conditions
  - EcoCAR is bringing hardware and subject matter expertise together to support more advanced Human Machine Interface (center stack) development
- ## ■ EcoCAR 2 will again demonstrate and test 16 distinct advanced technologies on a common vehicle platform (mid size car platform)



# EcoCAR 2 Technical Objectives

- Lay the ground work and design for EcoCAR 2: Plugging In To the Future
  - ➔ Research new content and capabilities for the EcoCAR Competition Series
    - Anticipatory control systems development and evaluation
    - E&EC enhancement through 5 cycle based testing adapted for on-road
    - Collaboration with sponsors to expand upon the critical consumer appeal aspects (HMI) of EcoCAR 2
    - Bring state of the art Finite Element Analysis and Computational Fluid Dynamics capabilities to EcoCAR
  - ➔ Perform research and simulations for upstream environmental impacts as points distribution as they apply to scoring and architecture selection



# EcoCAR 2 Technical Objectives

- EcoCAR 2 helps to support technical objectives by funding Graduate Research Assistants (GRA's) for engineering and outreach
- These students are co-funded by DOE and typically specialize in a research area
- GRA's enhance the technical depth of an EcoCAR team
  - ➔ Their multi-year involvement provides continuity and contributes to knowledge carryover
  - ➔ They mentor incoming students
  - ➔ They provide technical leadership and allow for complex engineering research
  - ➔ They provide Communications and Business leadership, allowing for more involved activities



# EcoCAR 2 Approaches

- **EcoCAR 2 Objective 1: Collaborate with dSPACE and GM to create an Anticipatory Control System development program with EcoCAR**
  - Define training objectives and deliverables to guide students through planning and research, SIL/HIL, and finally on-road testing
  - Team vehicle will take data such as trip length, traffic, grade, etc... and adjust as necessary to achieve the lowest fuel consumption
- **EcoCAR 2 Objective 2: Enhance the current E&EC testing methods to shift from CAFE to 5-Cycle based testing**
  - This satisfies a desire to make on road emissions and energy consumption measurements reflect more real world driving conditions
  - Challenges students to explore powertrain operating efficiencies over a wider band than is typical of more mild CAFE based drive cycles
  - This accomplished by parameter-izing and adapting applicable certification cycles to on road applications
  - To retain the J1711 based testing structure for the EcoCAR PHEV fleet



# EcoCAR 2 Approaches

- **EcoCAR 2 Objective 3: Enhance the holistic approach to vehicle design by better enabling HMI and critical information display**
  - ➔ Advanced EcoCAR powertrains require information display not available in the donate (conventional) vehicle
  - ➔ Collaborate with Freescale Semiconductor to craft the proper training and hardware support to enable this work
    - Design, SIL, HIL, and finally vehicle integration and refinement
  - ➔ Better center stack console design support brings more electrical engineering depth into EcoCAR 2
- **EcoCAR 2 Objective 4: Improve the technological neutrality through research and simulation**
  - ➔ Use tools such as GREET and Autonomie to simulate likely EcoCAR powertrain configurations utilizing donated hardware
  - ➔ Use results to predict performance in the areas of fuel consumption, petroleum energy use, greenhouse gas emissions, acceleration, passing on grade, and range.
  - ➔ Design competition point system permit many engine, fuel, motor, and battery combinations to succeed through quality of design and execution



# EcoCAR 1 Technical Accomplishments

- **Task 1: US EPA emissions testing summit was a resounding success**
  - ➔ Teams gained valuable knowledge of how their powertrains and control strategies interact with their emissions production
  - ➔ EPA acquired data that is unique to vehicles such as these with extended electric propulsion range (blended and pure EV)
  - ➔ Argonne and the AVTC's benefit from the continuing involvement and support of the EPA
- **Task 2: New method of vehicle safety inspections**
  - ➔ Bringing in an inspection team to replace the former single inspector allowed many more safety issues to be identified
  - ➔ Allowing the students time to address issues ensures the safety items are addressed upgrade AVTC vehicle safety
  - ➔ Safer more complete vehicles mid year typically means more vehicles run more events at the competition finals



# EcoCAR 2 Technical Accomplishments

- **Task 1: Anticipatory Control System Development**
  - Maintains the significance of HIL control development well into the third competition year
  - Opening another avenue of research for EcoCAR universities - resulting publications create more opportunities for EcoCAR to take part in the technical community
  - Curriculum developed that introduces students to the hardware and capabilities
  - Deliverables defined to guide the development in stages
- **Task 2: Enhance the current E&EC testing methods to shift from CAFE to 5-Cycle based testing**
  - Complex 5-Cycle weighting has been broken down and parameterized for on-road drive cycle construction
  - Data is used to simulate impacts on a likely EcoCAR fleet to aid in testing development
  - E&EC will retain the J1711 based testing structure for the EcoCAR PHEV fleet



# EcoCAR 2 Technical Accomplishments

## ■ Task 3: Information (Center Stack) display design

- ➔ Hardware and technical support has been secured through Argonne collaboration with EcoCAR sponsor Freescale
- ➔ Argonne has integrated the design into the EcoCAR VDP deliverables to guide development
  - Design, SIL, HIL, and finally vehicle integration and refinement
- ➔ EcoCAR 2 schools have been made aware of the subject matter requirements to help them properly staff their teams with electrical engineering support

## ■ Task 4: Vehicle performance research and modeling

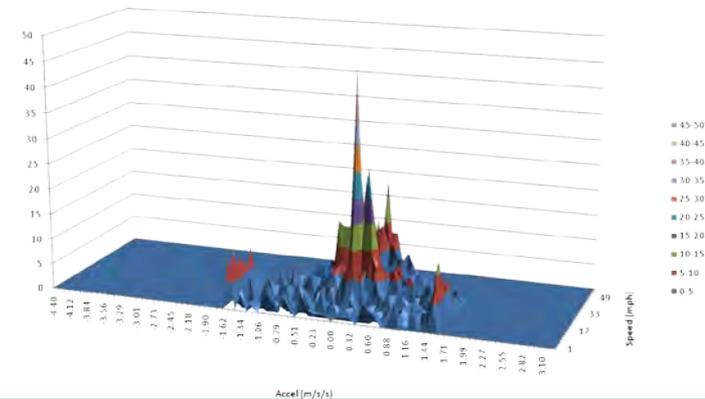
- ➔ ANL has performed an extensive simulation exercise based on donated hardware and available commercial components packaged in architectures likely to take part in EcoCAR 2
- ➔ Points and rules have been adjusted to reflect these values
  - Encourages model based design through a more technologically neutral point based incentive structure
- ➔ While it was impractical to enable all possible powertrain architectures to compete equally, many architectures, engines, fuels, and energy storage capacities can be applied in such way that no one component architecture is favored



# EcoCAR 2 Future Work

## ■ Drive Cycle development

- ➔ Drive cycle parameter criteria is to be applied to EcoCAR on-road testing facilities in Years 2 and 3
- ➔ Enhancing the J1711 based on road testing to mimic 5 cycle dynamics to better incorporate real world powertrain loads into the design process
- ➔ Building upon techniques developed in EcoCAR 1 which utilized drive cycle parameterization to ensure adequate correlation to standard test procedures
- ➔ Critical Milestones: June 28<sup>th</sup> for ANL approval of cycle and techniques, August 15<sup>th</sup> for TSC approval of cycle and techniques



# EcoCAR 2 Future Work

- Anticipatory control system development
  - ➔ Research is underway to find the best combination of traffic events that will exploit the benefits of anticipatory control systems using tools like Autonomie
  - ➔ Testing will take place on a closed course at a GM proving ground
  - ➔ Traffic conditions will be simulated through a collaboration between dSPACE and Navteq
  - ➔ Work is under way to define the method traffic and road data will be broadcast to EcoCAR vehicles during the on-road event in EcoCAR 2 Year 3



# Questions?

