2012 DOE Vehicle Technologies Program Review Presentation

Recovery Act—Transportation Electrification Education Partnership for Green Jobs and Sustainable Mobility

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Overview

Timeline

- Start date: **2009/10/01**
- End date: **2012/09/30**
- Percent complete: 90%

Barriers

- Development of lab content
- Recruiting for short courses

Budget

- Total project funding
  - DOE share: $2.5M
  - Contractor share: $735,975
- Funding received in FY11: 730k
- Funding for FY12: 557K

Partners

- A&D in equipment
- GM/Ford/DTE/Bosch in course development and teaching
- GM in short courses

Project Scope-Relevance

Objective:

To develop graduate, undergraduate and short courses and outreach activities in the field of Electrified Transportation

Graduates	Undergraduates	Professionals	Pre-College
Modular Courses available online (UMAA)	Multi-Campus Modular Courses (UMAA,UMD, Kettering) Strong Lab Experience	Web-Based Modular short Courses Face-to-face Short Courses (UMAA,UMD, Kettering)	Education Kits for electric automobile
Graduate students in all engineering disciplines M. Eng. Degree in Energy Systems and Automotive Engineering (UMAA), available through distance learning	B.S. with Energy concentration (UMAA)	Certificate Programs	K-12 student outreach, summer program
Training & Internship	B.S. with Green Mobility Specialty (Kettering)	Graduate degree through distance education	Science Teachers Outreach & Education
	B.S. with concentration in Electric Energy (UMD)		

Consumer Education

- Saturday morning seminars
- Web site development, consumer education nuggets

Overview of Project -Approach/Strategy

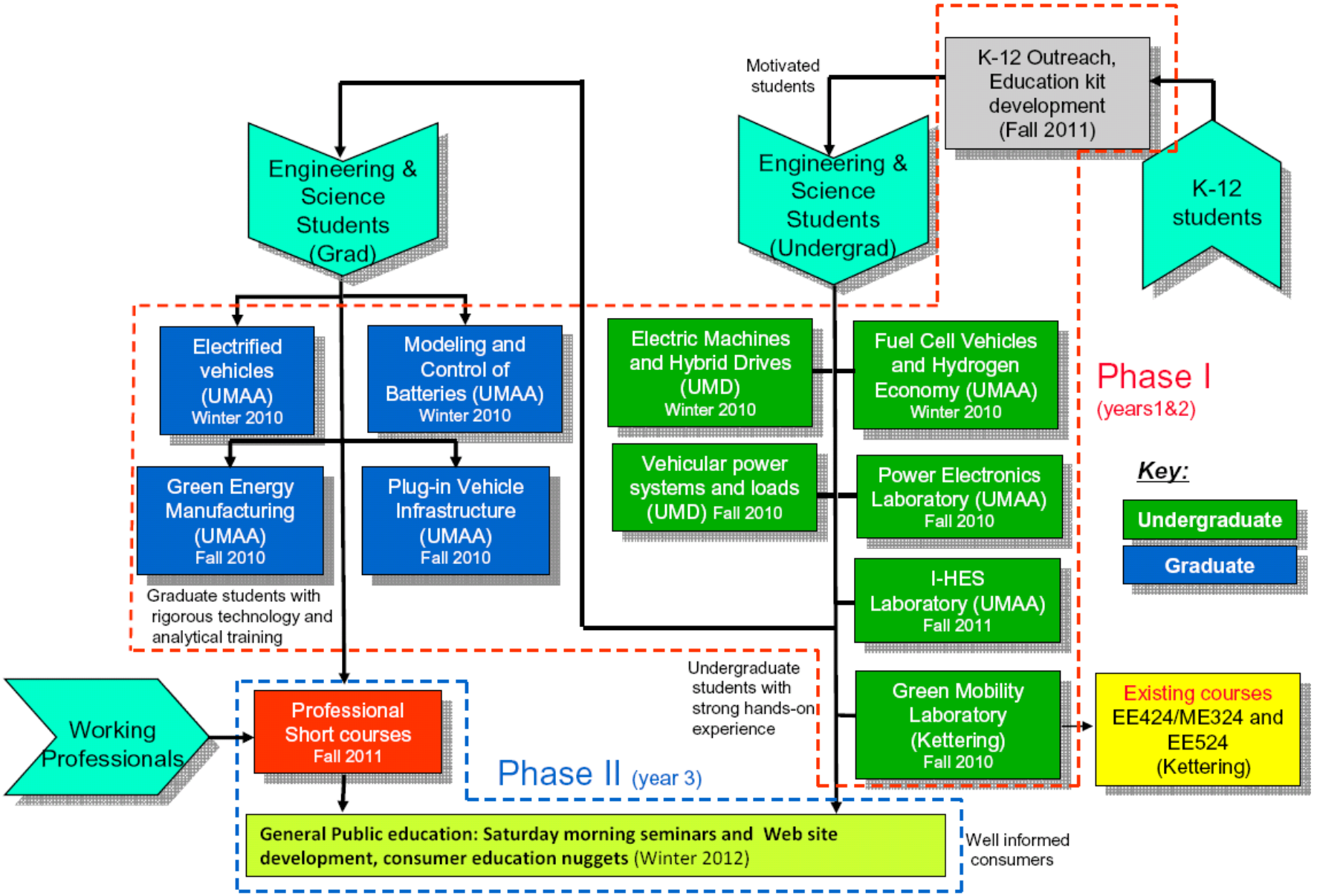
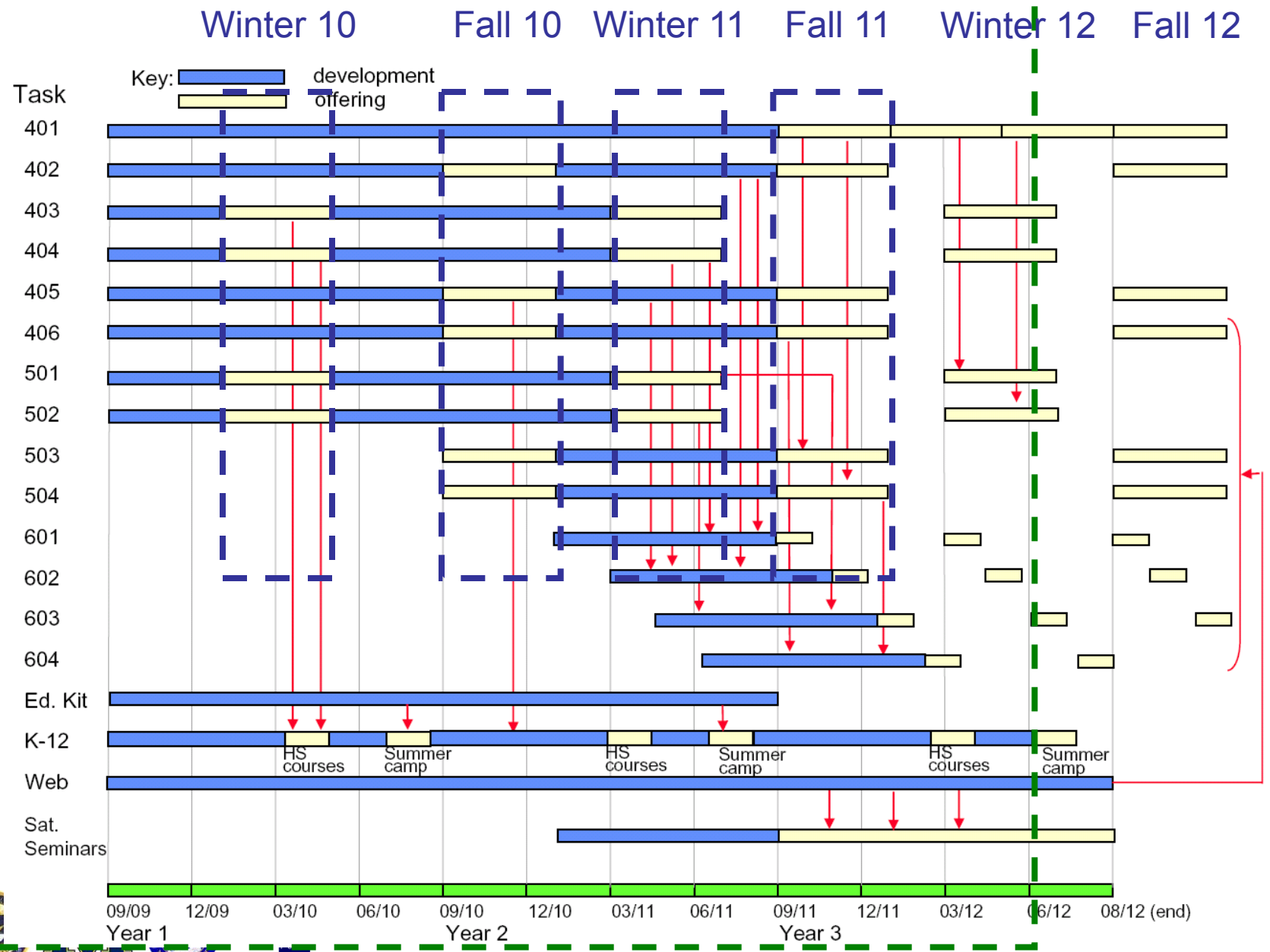


Figure 4 Flow chart and timing of the proposed educational activities

Project Timeline- Approach/Strategy



Tasks (years 1-2)-- Approach/Strategy

Task 1 – Development of 4 graduate courses

Campus	Course	Faculty	Title
UMAA	501	Peng & Filipi	Electrified Vehicles
UMAA	502	Stefanopoulou & Fathy	Modeling and Control of Batteries
UMAA	503	Hu	Green Energy Manufacturing
UMAA	504	Hiskens	Plug-in Vehicle Infrastructure

Task 2 – Development of 6 undergraduate courses and laboratories

Campus	Course	Faculty	Title
UMAA	401	Filipi & Peng	Integrated Hybrid Electric System (I-HES) Laboratory
UMAA	402	Hiskens	Automotive Power Electronics Laboratory
UMAA	403	Siegel & Stefanopoulou	Fuel Cell Vehicles and Hydrogen Infrastructure
UMD	404	Mi	Electric Machines and Hybrid Drives
UMD	405	Mi	Power Systems (vehicular power systems and loads)
Kettering	406	Gover, Thompson & Hoff	Green Mobility Laboratory

Task 3 – Development of K-12 outreach activities

Campus	Course	Faculty	Title
UMAA	"101"	Hiskens & others	K-12 Outreach
UMAA	"102"	Fathy	Development of an Education kit for Electric Automobiles

Tasks (year 3)-- Approach/Strategy

PHASE II (year 3)

Campus	Course	Faculty	Title
UMAA	"103"	Peng & Borbely	Saturday morning Seminars and Web site development
UMD	"601"	Mi	Power Electronics System Integration
	"602"	Gover	Electrified Vehicle Semiconductor Power Devices and Heat Transfer
UMAA	"603"	Stefanopoulou	Modeling and Control of Batteries
UMAA	"604"	Peng & Filipi	HEV and PHEV System Integration and design

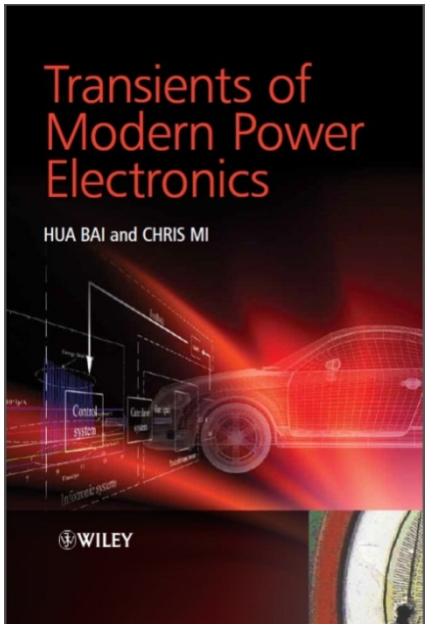
Accomplishments and Progress (Graduate and Undergraduate Courses)

Semester	W10	F10	W11	F11	W12
401 I-HES Lab					
402 Power elec. Lab		24		41	
403 FC and H2	47			30	
404 Elec. Mach. and Drive	47		25		25
405 Veh. Power and loads		19		35	
406 Green Mobility Lab		10		20	
501 Electrified Vehicles	93		78		101
502 Batteries	59		41		52
503 Green Manufacturing			20		
504 Plug-in Infrastructure		20			
Total	246	73	164	126	178

Accumulated enrollments: 787

Achievements in 2011-2012

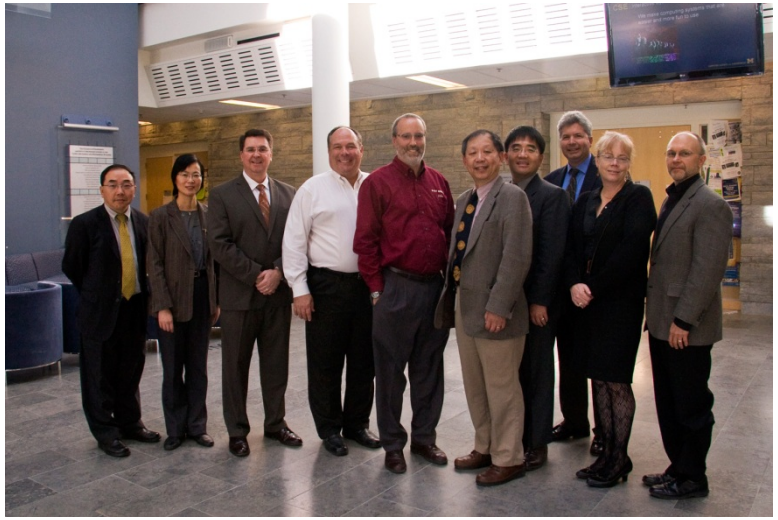
- Developed and Offered the 9th course—Green Manufacturing (UMAA)
- Finished the development of the Green Mobility Lab (Kettering) and used it for two courses
- Continue to develop the Integrated Hybrid Electric Systems (I-HES) Lab (UMAA)
- Offered two more short courses
- Summer Camp
- Automotive Educational Kits



Achievements--Green Manufacturing Workshop

Part I: PV manufacturing
Introduction: motivation, PV principles, and materials
PV system, performance metrics
Thin film cell production: TCO sputtering process
Thin film cell production: CIGS deposition process
Module assembly process: gridline printing process
Efficiency testing and accelerated life testing
Part II: Lithium batteries
Introduction: Battery types and structure
Cell manufacturing
Assembly and packaging
Quality assurance
Testing and performance
Part III: Others
Guest lecture: Electrification vehicle and fuel cell (Prof. Huei Peng in ME)
Guest lecture: Wind turbine system (Joseph Abbud, VP, Danotek Motion Technologies)

Audience



Speakers

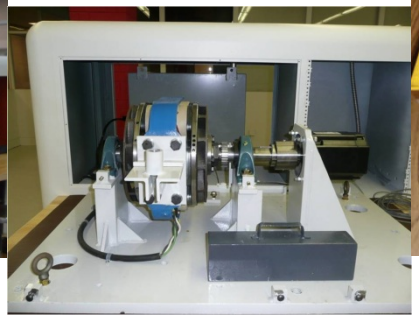
Course Content (Green Manufacturing, UMAA)

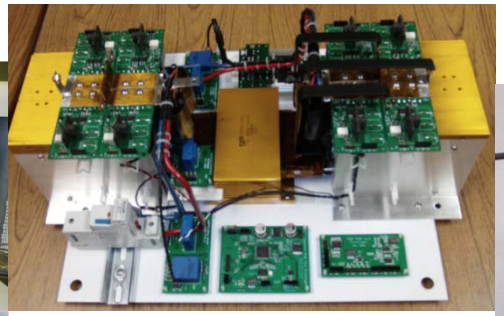
		Topic
Lecture	**Date**	**Part I: PV manufacturing**
1	3/8	Introduction: motivation, PV principles, and materials
2	3/10	Thin film cell mfg 1: ITO sputtering process
3	3/15	Thin film cell mfg 2: CIGS deposition process
4	3/17	Module assembly process: gridline printing process
5	3/22	Efficiency testing and accelerated life testing
6	3/24	PV system, performance metrics, and product lifecycle
		Part II: Wind, Electrification Vehicle & Fuel Cell
7	3/29	Guest lecture: Overview of wind energy technology (Joseph Abbud, VP, Danotek Motion Technologies)
8	3/31	Guest lecture: Overview of electrification vehicle and fuel cell (Prof. Huei Peng in ME)
		Part III: Lithium batteries
9	4/5	Introduction: Battery types and structure
10	4/7	Cell manufacturing
11	4/12	Assembly and packaging
12	4/14	Quality assurance and testing
13	4/19	Exam at 3:30~5:30pm
	4/26	Final group project presentation

To be offered again in Fall 2012 as a full-term course

Achievements: Green Mobility Lab (Kettering)

- Three laboratory stations have been built for the Green Mobility Laboratory.
- The lab is currently used by two courses
  - EE524, Fuel Cell System Integration and Packaging did use the Green Mobility Laboratory (Winter)
  - EE424, Power Electronics (enrollment: 12 (Su 11), 14 (Fall 11), 32 (Winter 12), 14 (Sp 12)
  - EE 591, Battery Management Systems (summer)
- Created 9 jobs: 5 co-ops, 1 post-doc, 1 research scientist, 2 research scholars. Research Funds in 2011~2012: 5 industrial contracts ($ 527,599)



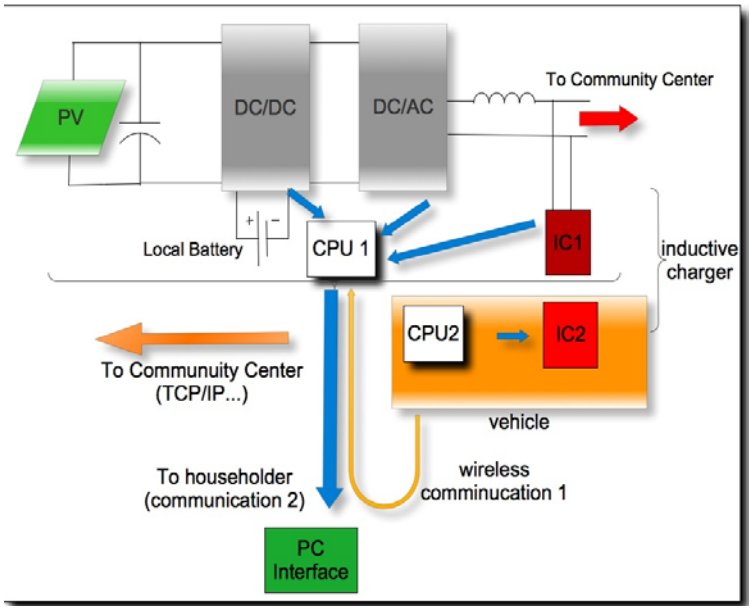


10kW 95%-efficiency CoolMOS Charger for PHEV

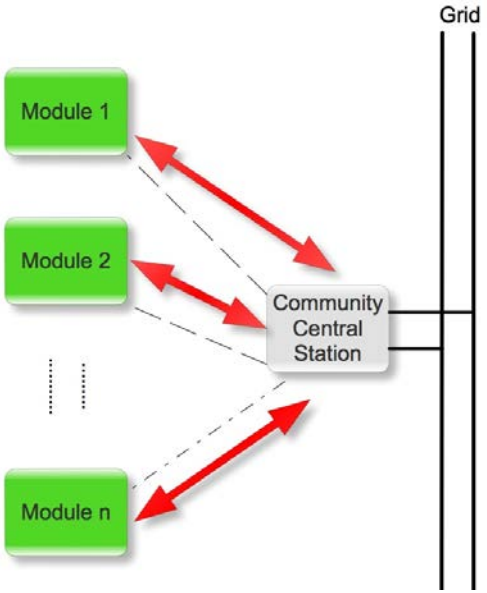
10kW 97%-efficiency DC Charger for PHEV

Work in Progress: Green Mobility Lab (Kettering)

- **Smart-grid System Using Solar Energy**



(a) one charging system in the house



(b) connections of charging systems in the community

A combination of renewable energy and EV/PHEV will create an environmental friendly system to alleviate the grid stress when an excessive number of vehicles are simultaneously charged. This research is expected to accelerate the research of micro-grid system which is a promising way to cope with the grid blackout.

Achievements: Green Mobility Lab—EE424

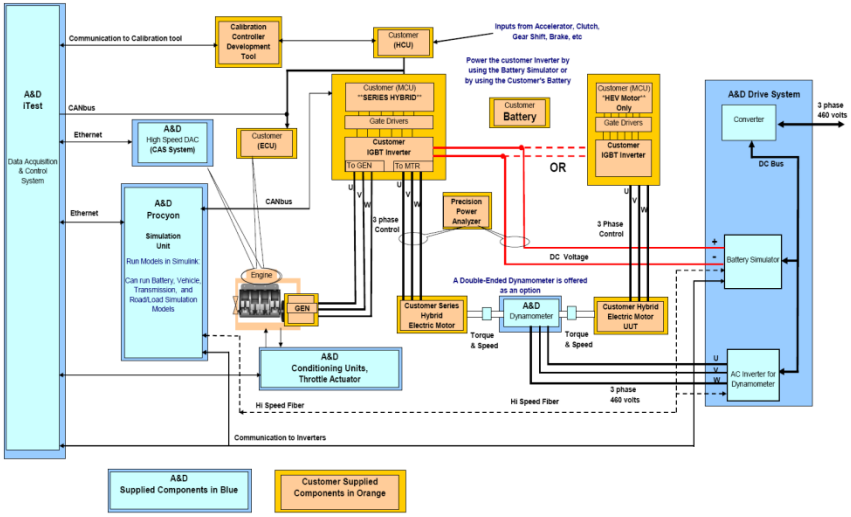
- Technical content
  - State variable modeling of classical DC-DC converters: buck, boost, buck-boost and Cuk. Models are amenable to PI or PID controls.
  - State variable modeling of advanced DC-DC converter topologies: floating interleaved dual boost converter, floating double-interleaved dual boost converter, floating double boost double stage boost converter, and isolated full H-bridge converter.
  - Single phase inverter design
  - Three phase, six-step inverter design
  - Sinusoidal pulse width modulation of inverters
  - Harmonic elimination pulse width modulation of inverters
  - Space vector modulation of inverters
  - Space vector modeling of motor drives for permanent magnet motors and induction motors.
  - A module on electromagnetic radiation generated in power electronics was developed and taught as a short course at the 2010 IEEE Vehicular Power and Propulsion Conference.
  - Future development will include linking the state variable and state space models to control systems.

Achievements: I-HES Lab (UMAA, 1070 AL)

Achievements: I-HES Lab (UMAA, 1070 AL)

Achievements: I-HES Lab

- Double-ended dyno to test both electric motors and engines
- High speed simulation module
- Combustion analysis system
- To be used for two courses: “501” (created) and “Internal Combustion Engines” (existed) with 150 students/year

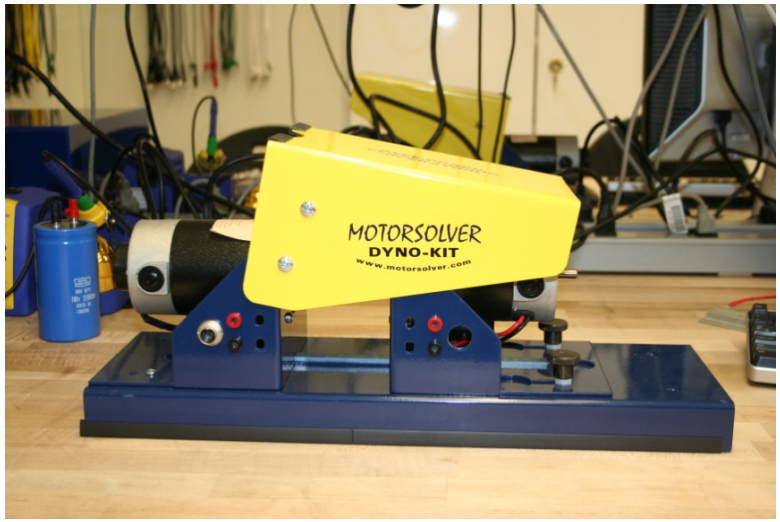


Equipment		
1	241HP (180kW) AC Dynamometer System	A&D
2	180 kW Battery Simulation System	A&D
3	iTest Data Acquisition and Control System	A&D
4	iCentral Lab and Data Management Suite	A&D
5	High Speed Combustion Analysis System	A&D
6	Procyon Simulation and Control System*	A&D
7	(8) Compact ADX – AD70110EVA (Contingent Upon PO)	A&D
8	iConnect Distributed I/O System	A&D
9	Facilities Interface Cabinet (FIC)	A&D
10	Operator Control Console	A&D
11	A&D Coolant Conditioner (HEV only)	A&D
12	A&D Oil Conditioner (HEV only)	A&D
13	A&D Fuel Conditioner (HEV only)	A&D
14	A&D Battery Chiller	A&D
15	A&D Throttle Actuator (HEV only)	A&D
16	Interconnect Materials (cables, conduits, for A&D supply)	A&D
17	Yokagawa Power Analyzer / Probes	U-M
18	Bedplate(s) (if required for HEV ICE or Generator)	U-M
19	iCentral Server	U-M
20	Phoenix CAS PC or Laptop	U-M
21	Pods / Transducers for Cylinder Pressure Measurements	U-M
22	ECU / MCU / HCU (all control units)	U-M
23	Unit Under Test Motor / ICE / Generator / Inverters / Battery	U-M

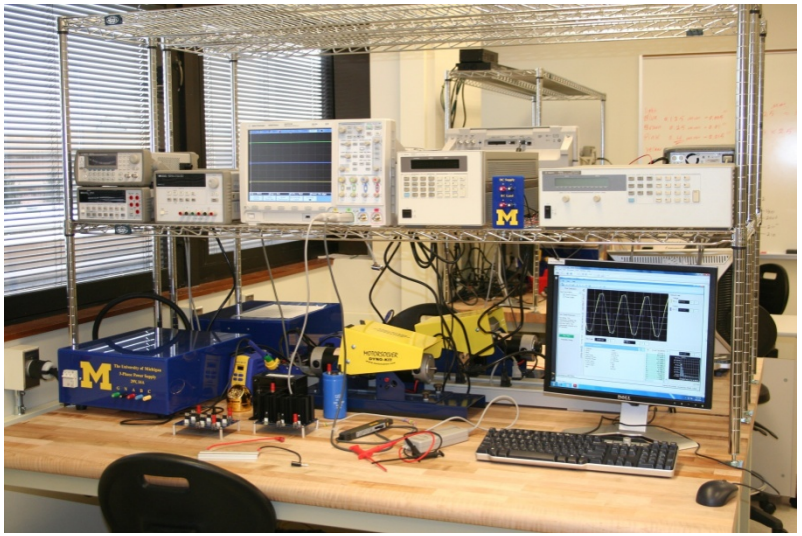
Achievements: UofM Ann Arbor EECS Power/Energy Instructional Lab

- 8 lab stations (plus instructor station)
- Key equipment for each station:
  - Agilent 6654A 500W DC power supply
  - Agilent N3301A DC electronic load
  - Agilent U1881A Power Measurement and Analysis Software
  - Custom-designed 500W 3-phase AC Power Supply
  - Motor/Generator Dyne w/ DC, DC Brushless, AC Induction Machines
  - dSpace 1104 Microcontroller Card
  - Three-phase rectifier, inverter boards
  - DC-DC converter boards

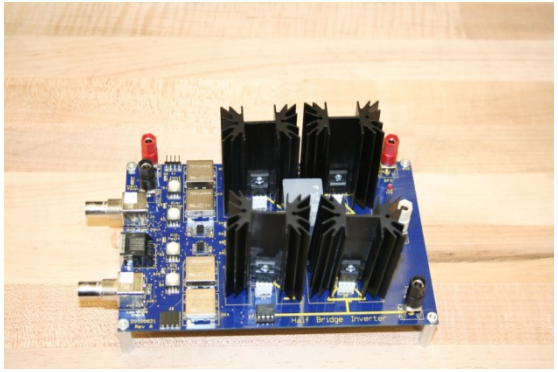
Achievements: UofM Ann Arbor EECS Power/Energy Instructional Lab



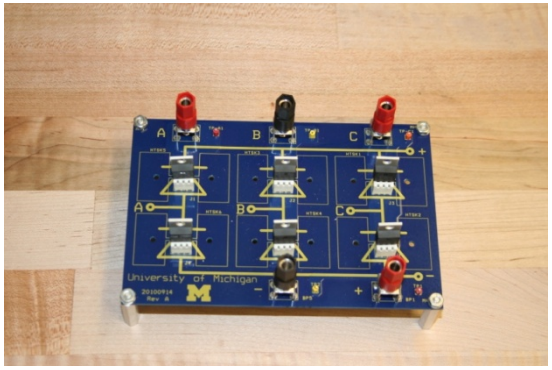
Motor/Generator Dyno



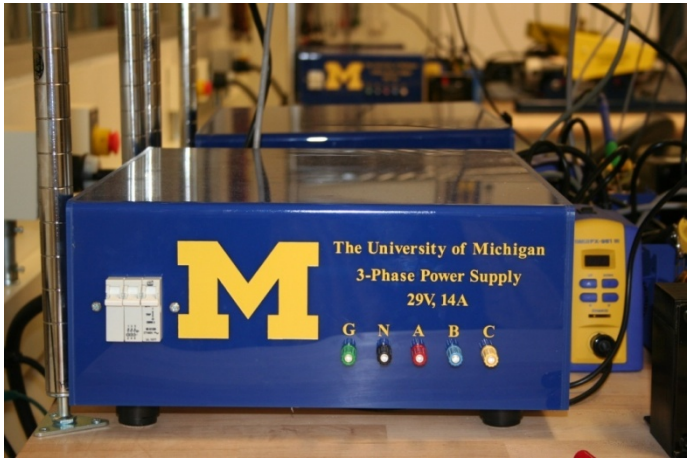
Lab station



DC-DC Converter Board



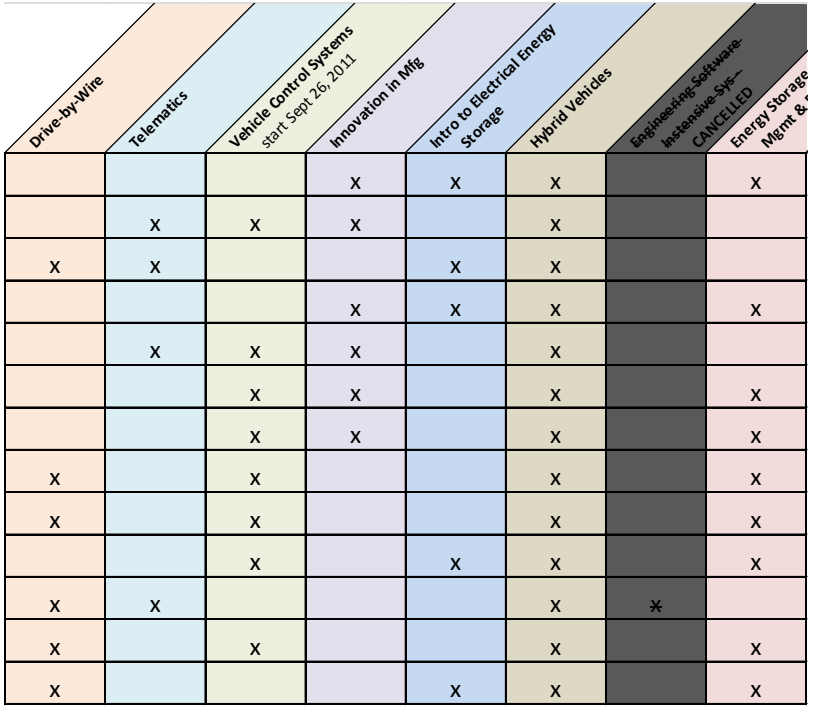
3-Phase Rectifier Board



3-Phase AC Power Supply

Achievements: Short Courses Offered

- "Battery Management Systems for EV and PHEV", an 8-hour short course, Delphi, Enrollment 50, GM, Enrolment 17
- "Energy efficient motors and power electronics for EV, HEV and PHEV" offered through SAE, enrollment 50.
- "Certificate in Emerging Automotive Technologies", 8 modules, 5-7 hours each module. Online course, 13 students in Fall 2011, 14 in Winter 2012



Drive-by-Wire	Telematics	Vehicle Control Systems start Sept 26, 2011	Innovation in Mfg	Intro to Electrical Energy Storage	Hybrid Vehicles	Engineering Software Intensive Sys CANCELLED	Energy Storage Mgmt &
			x	x	x		x
	x	x	x		x		
x	x			x	x		
			x	x	x		x
	x	x	x		x		
		x	x		x		x
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x	x				x	x	
x		x			x		x
x				x	x		x

Achievements: High School Summer Camp-2010

Electrified Transportation Summer Camp Day 1 Schedule
Wednesday August 11th 2010

8:30	**Report to Camp (1303 EECS)**
9:00	**Welcome & Introductions (1303 EECS)** Professor Huei Peng
9:10	**Lecture 1 Overview and Introduction to Electrified Vehicles (1303 EECS)** Professor Huei Peng
10:00	**Break**
10:10	**Lecture 2 Hybrid Vehicles (1303 EECS)** Professor Zoran Filipi
11:00	**Break**
11:10	**Lecture 3 Electric Grid (1303 EECS)** Professor Ian Hiskens
12:00	**Lunch at Commons**
13:30	**Lecture 4 Batteries (1303 EECS)** Professor Anna Stefanopoulou **Levi's Battery lab tour and hands-on experience**
15:00	**Break**
15:20	**Lecture 5 Electric Motors (2052 AL)** Professor Chris Mi
16:10	**Break**
16:20	**Lab 1 Electric Motors (2052 AL)** Professor Huei Peng, Jean Chu, Sei Jin Park, Daniel Yang
17:30	**End of day 1**

Electrified Transportation Summer Camp Day 2 Schedule
Thursday August 12th 2010

8:30	**Board Bus (in front of GGB)**
8:45	**Arrive at site 1 (UM Solar Car team,** 574 S. Mansfield, Ypsilanti**)** Rachel Kramer, Project Manager, 248.231.1234
9:30	**Leave site 1**
10:30	**Arrive at site 2 (Volt, Milford Proving Ground)** Tim Grewe, Chief Engineer and Director, GM (248) 840-2423
12:00	**Leave site 2 and lunch**
13:30	**Arrive at site 3 (ITC Transco,** 27175 Energy Way, Novi, MI 48377**)** Archisman (Archie) Gupta (734) 660-1402
14:30	**Leave site 3**
15:00	**Arrive at site 4 (Ford,** Research Innovation Center (RIC) at 2101 Village Road, Dearborn**)** Tony Phillips, 313-594-4717
16:30	**Leave site 4**
17:30	**Return to campus**

Electrified Transportation Summer Camp Day 3 Schedule
Friday August 13th 2010

8:30	**Lecture 6 Fuel Cells (1303 EECS)** Professor Anna Stefanopoulou
9:20	**Break**
9:30	**Lecture 7 Hydrogen (1303 EECS)** Professor Don Siegel
10:20	**Break**
10:30	**Tour of COE labs** in two small groups Group 1: **10:50-11:10 Anna's fuel cell lab**, **11:15-11:35 Zoran's HEV lab**, **11:40-12:00 Ian's electric lab** Group 2: **Ian's electric lab**, **Anna's fuel cell lab**, **Zoran's HEV lab**
12:00	**Lunch at Commons**
13:30	**Lecture 8 Wind power (1303 EECS)** Professor Ian Hiskens
14:15	**Break**
14:30-17:00	**Lab 2 and Electric car kit competition (2052 AL)** Professor Huei Peng, Jean Chu, Sei Jin Park, Daniel Yang
17:00 - 17:30	**Awards and close of camp** Professor Huei Peng

Achievements: High School Summer Camp-2011

Electrified Transportation Summer Camp Day 1 Schedule Wednesday August 3rd 2011	
8:30	**Report to Camp (1500 EECS)**
9:00	**Welcome & Introductions (1500 EECS)** Professor Huei Peng
9:10	**Lecture 1 Overview and Introduction to Electrified Vehicles (1500 EECS)** Professor Huei Peng
10:00	**Break**
10:10	**Lecture 2 Key components of electrified vehicles (1500 EECS)** Mike Rothenberger (PSU, education kit designer)
11:00	**Break**
11:10	**Lecture 3 Recharging the Auto Industry: The Story of the Chevy Volt (1500 EECS)** John Ferris (General Motors)
12:00	**Lunch at Commons**
13:30	**Lecture 4 Batteries (1500 EECS)** Professor Don Siegel
15:00	**Break**
15:20	**Lecture 5 Electric Motors (3437 EECS)** Professor Heath Hoffman
16:10	**Break**
16:20	**Lab 1 Electric Motors (2052 AL)** Professor Huei Peng, Mike Rothenberger
17:30	**End of day 1**

Electrified Transportation Summer Camp Day 2 Schedule Thursday August 4th 2011	
8:30	**Meet at site 1 (UM Solar Car team, Wilson Center, North Campus)**
9:30	**Board bus, leave site 1**
10:30	**Arrive at site 2 (Ford,** Research Innovation Center (RIC)
12:30	**Leave site 2 and lunch**
12:50	**Arrive at site 3 (Ford Rouge Plant Tour)** 3001 Miller Rd, Dearborn MI, 48120
14:45	**Leave site 3**
15:15	**Arrive at site 4 (CNG station, Ann Arbor)** 117 West Summit Street, Ann Arbor, 48104
15:50	**Leave site 4**
16:00	**Return to campus—Chevy Volt Demo and Drive and UM Formula Hybrid work**
17:00	**End of day 2**

Electrified Transportation Summer Camp Day 3 Schedule Friday August 5th 2011	
8:30	**Lecture 6 Ann Arbor Clean City (1500 EECS)** Lisa Warshaw (Clean City Ann Arbor)
9:20	**Break**
9:30	**Lecture 7 Sustainable Transportation (1500 EECS)** Eli Cooper (City of Ann Arbor, Transportation Program Manager)
10:30	**Break**
10:40	**Lecture 8 Wind Energy (1500EECS)** Professor Peretz P. Friedmann
12:00	**Lunch at Commons**
13:30	**Lecture 9 Solar Energy (1500 EECS)** Professor Akram Boukai
14:20	**Break**
14:30	**Lab 2 and Electric car kit competition (2052 AL)** Professor Huei Peng, Mike Rothenberger
17:00 - 17:30	**Awards and close of camp** Professor Huei Peng

Highlights of 2011 Camp

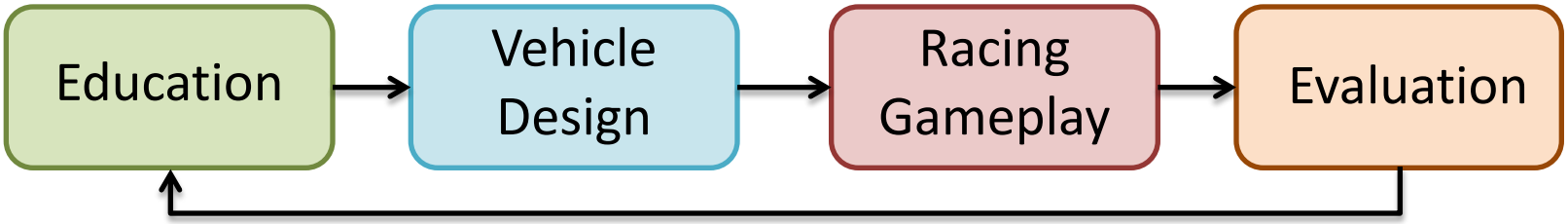
- 17 kids
- More general topics (solar, wind, CNG)
- Education kit ‘test drive’
- Site visits to
  - UM Solar Car team, Ford, Rouge plant, Ann Arbor Clean City CNG station, Volt test drive
- Motor kit competition

Achievements: Automotive Educational Activities

- Three-prong solution comprising:
  - An “Educational Videogame”
  - Information-rich “Educational Videos”
  - A Hands-on Educational “Toy Kit”

- Target 8-11 year-old kids in close cooperation with Penn State’s Women in Science and Engineering (WISE) society.

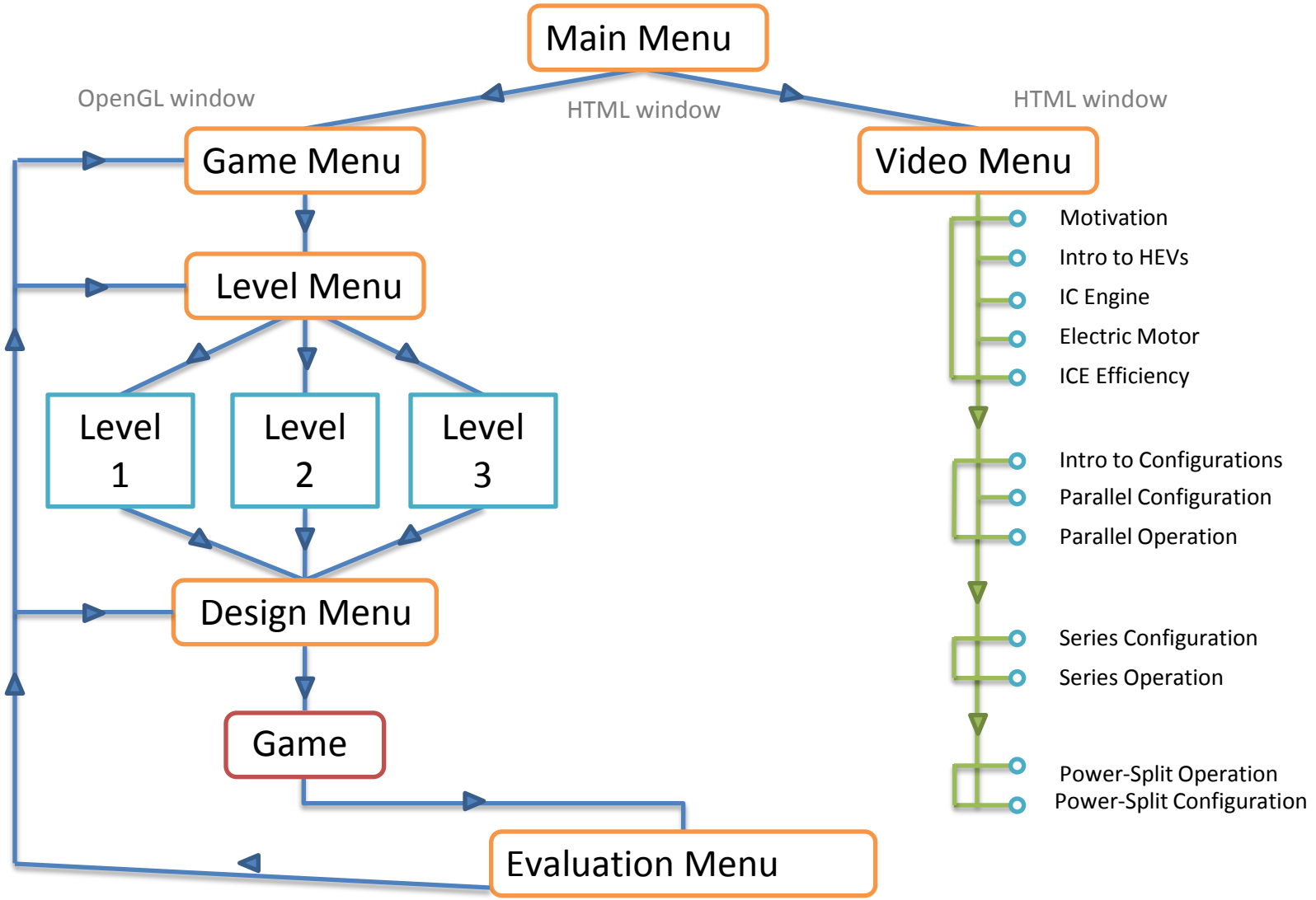
Achievements: Videogame Environment



Stages

1. Education - Videos about HEV function and design
2. Vehicle Design - Three main configurations with variable components
3. Racing Gameplay - Ambulance Driver (EMT)
4. Evaluation - Feedback to player about fuel efficiency and emissions.

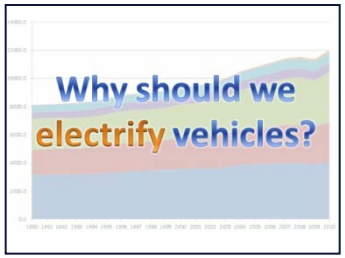
Achievements: Flow Chart of Videogame Environment

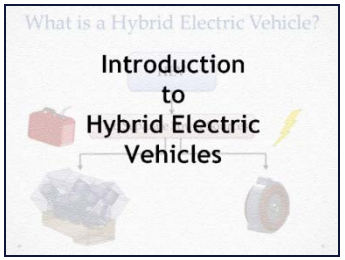


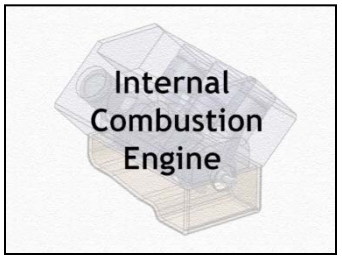
Achievements: Educational Videos

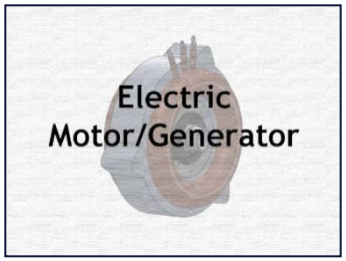
12 videos about:

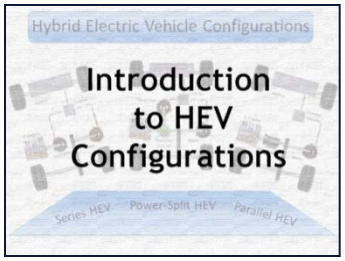
- Motivating & introducing HEVs
- Explaining main components
- Why these components can function differently in an HEV
- The 3 main configurations
- Configuration designs
- How each configuration functions

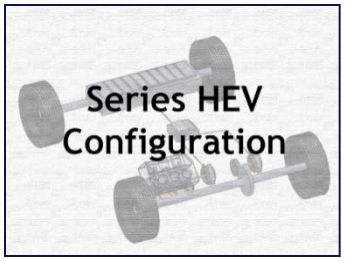


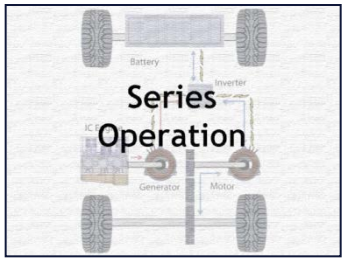


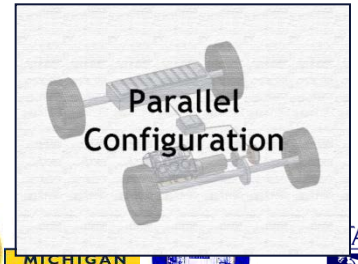


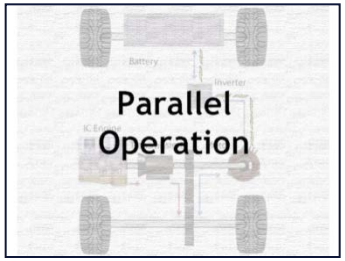


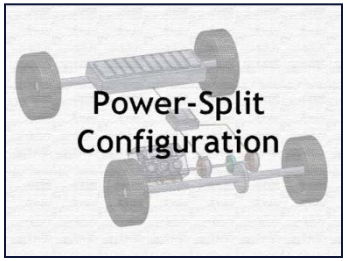


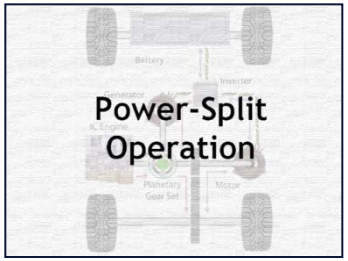










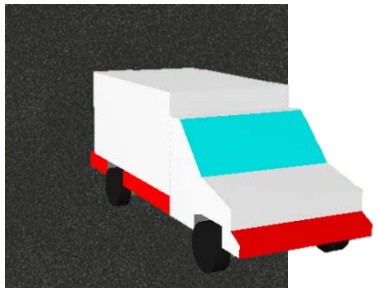


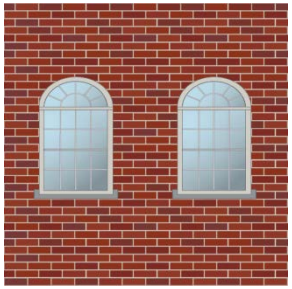
Achievements: Game Design

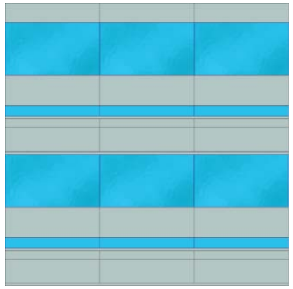
- Coding Components
  - C++ and OpenGL
  - GLUT API

```
979     glPushMatrix();
980     glTranslatef(x, y, z);
981     glColor3f(0.33f, 0.21f, 0.04f);
982     gluCylin                    5f, 0.3f, 1.0f, 30, 30);
983     glTran                      0.0f, 0.0f, 1.
984     glCo                        0.50f, 0.4
985     gluC                        r(t                    2.0f, 30, 30);
986     glTra
987     gluCyli                     Middle                 , 0.0f, 1.8f, 30, 30);
988     glTranslate                                        , 1.0f);
989     gluCylinder(treeTop, 0.7f, 0.0f, 1.6f, 30, 30);
990     glPopMatrix();
```

- Key Visual Components
  - Terrain
  - Road
  - Vehicle (ambulance)
  - Buildings
  - Trees

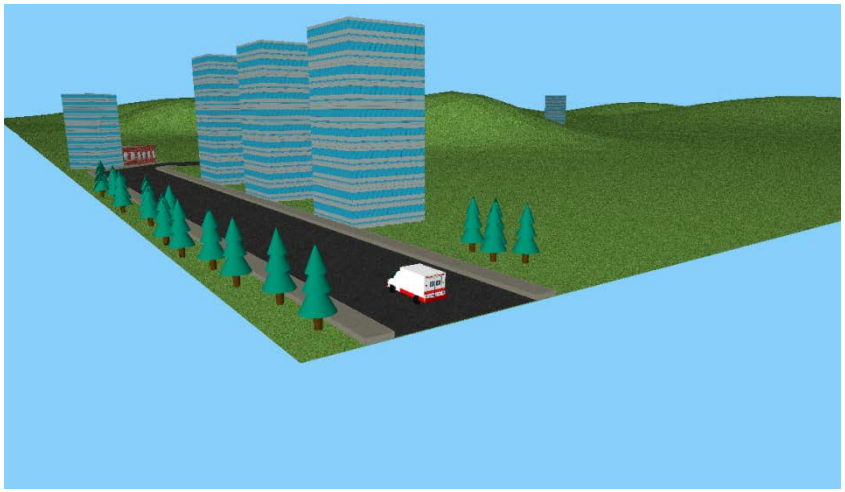


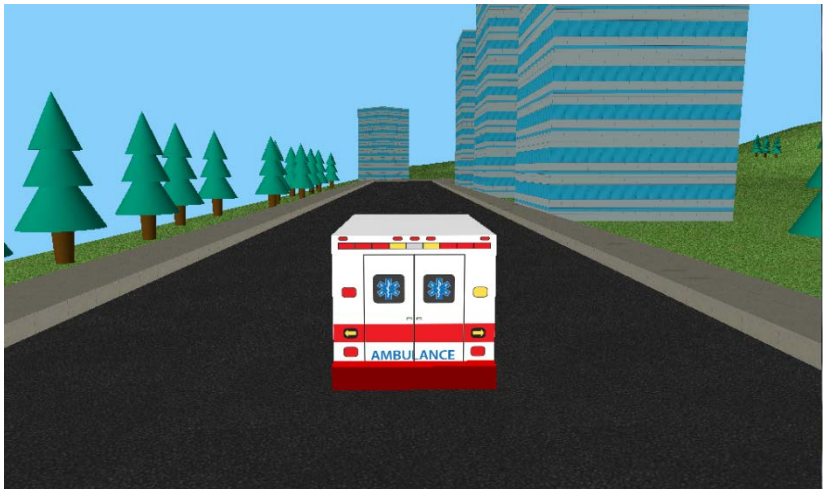


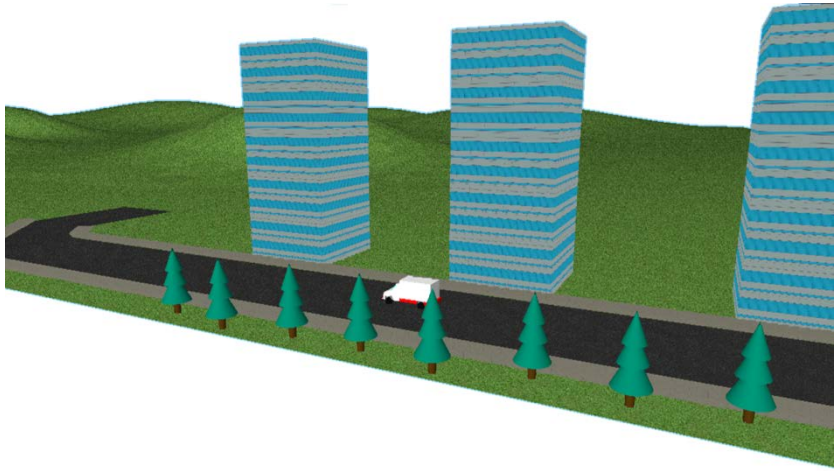


All textures designed in Adobe Illustrator and Photoshop

Achievements: Game Screenshots





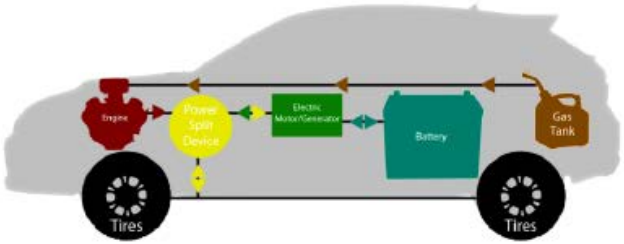


Achievements: Education Kit

Goal

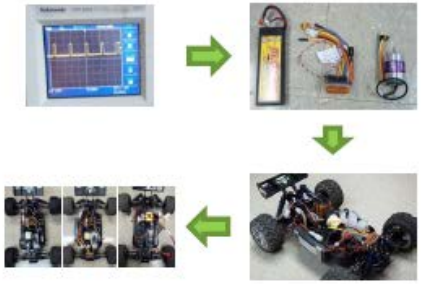
Component Selection and Analysis

Background Research

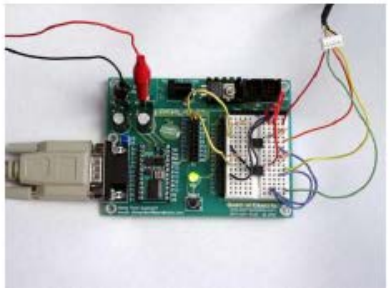


Car Conversions

Research and Development Plan

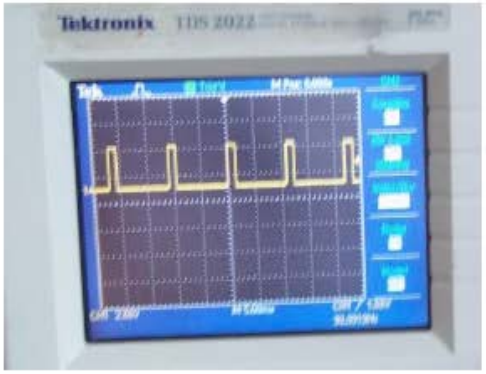


Future Work



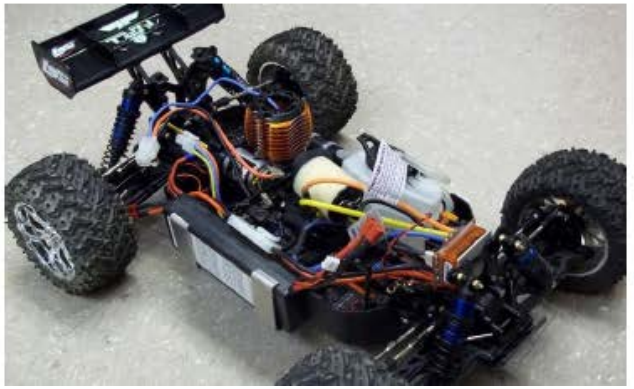
Achievements: Education Kit Project Plan

1. Analyze RC car



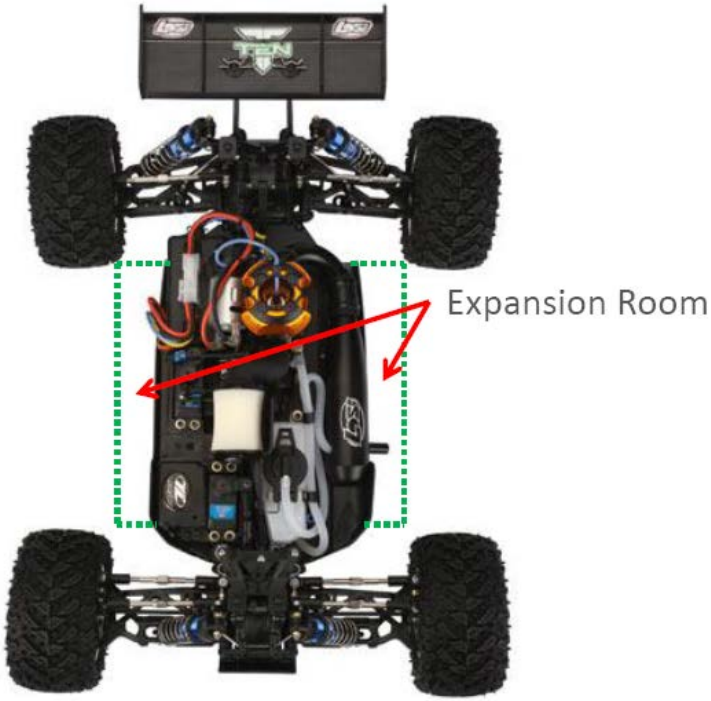
2. Convert to all electric

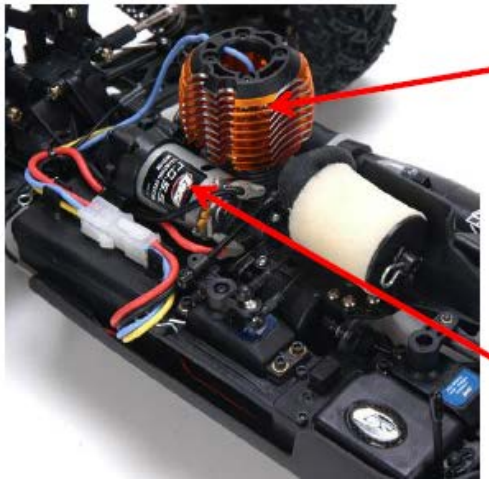
3. Develop hybrids



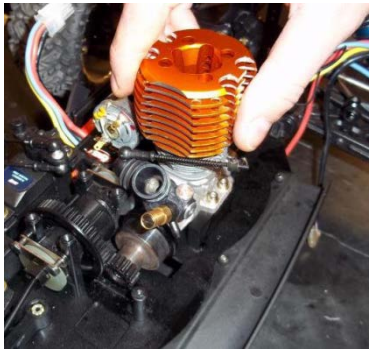
4. Develop kit

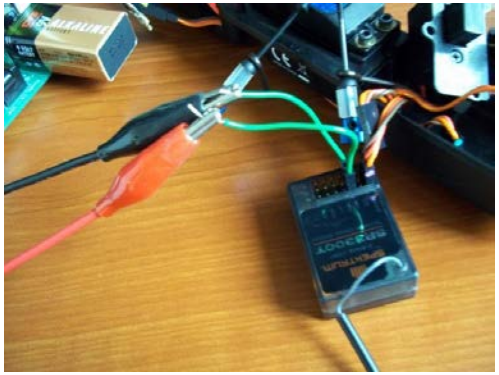
Achievements: Education Kit Hardware platform

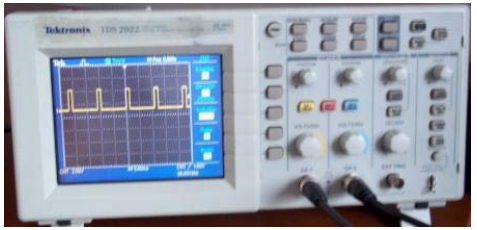


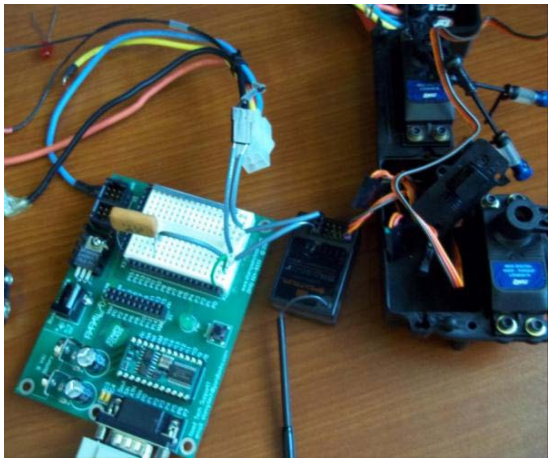


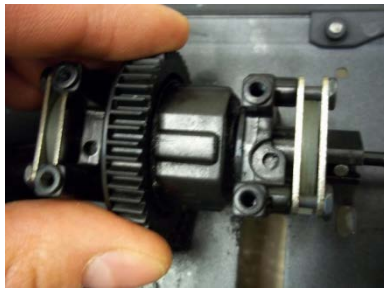
Achievements: Education Kit Mechanical and Electrical Analysis





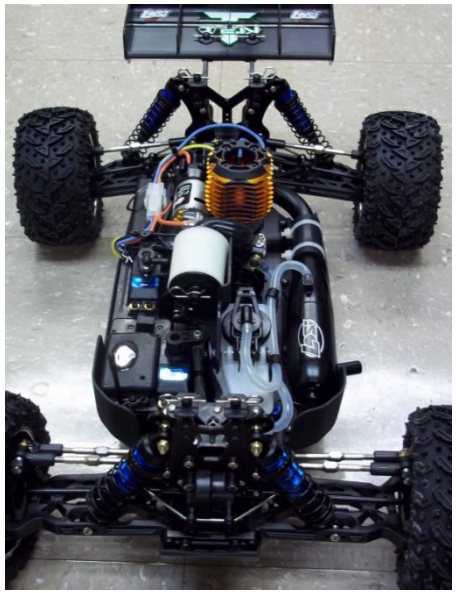




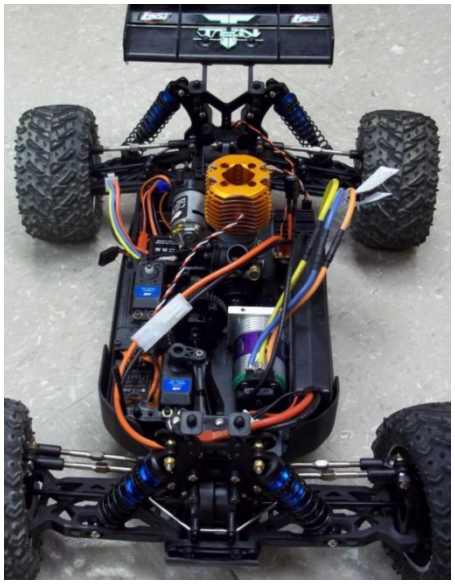


Achievements: Education Kit Two Modified Designs

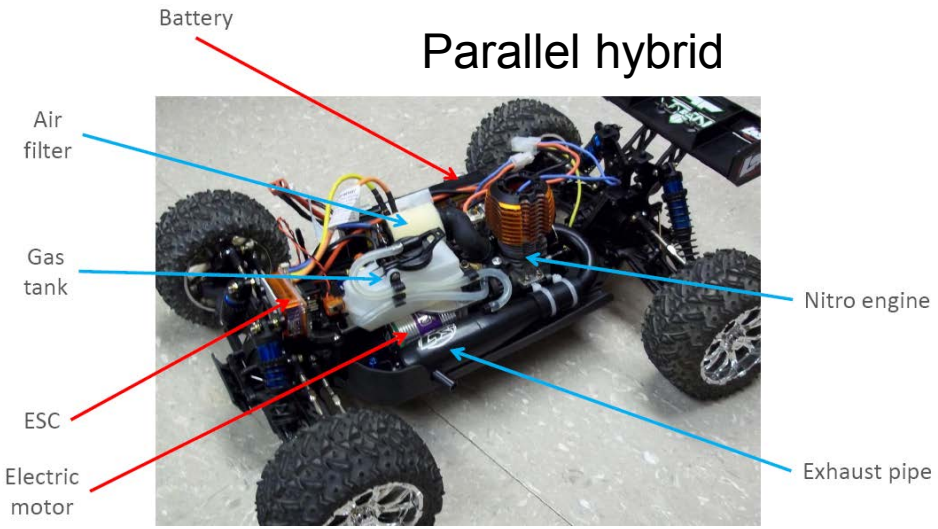
Original (gas)



All electric

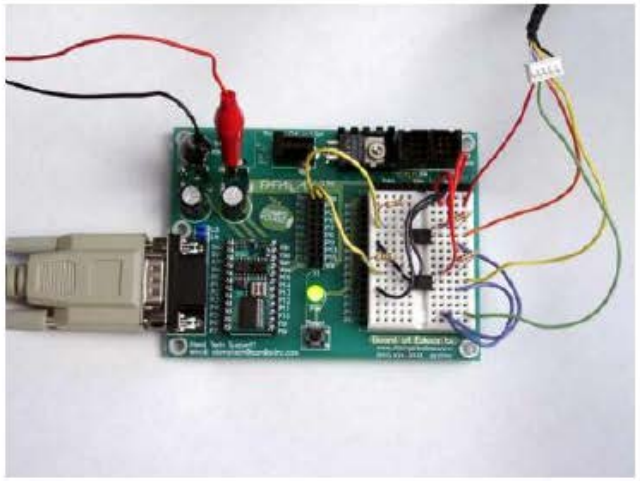


Parallel hybrid



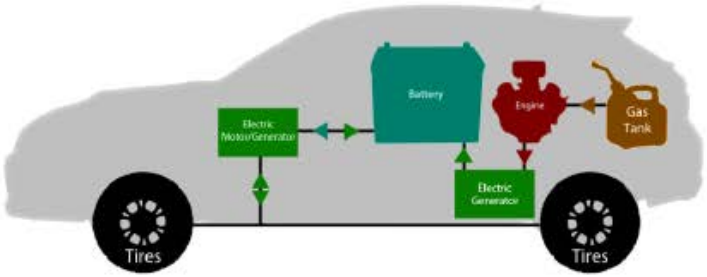
Achievements: Education Kit Work In Progress

Controls for parallel hybrid



Testing and optimization of hybrids

Development of series hybrid



Development of toy kit

Collaboration

- This project involves four partner schools:
  - UM Ann Arbor
  - UM Dearborn
  - Kettering University, and
  - Pennsylvania State University
- Industrial collaborators that have been involved in our course and lab development include
  - GM, Ford, DTE, A&D, Bosch
  - They serve the roles of equipment providers, invited lecturers, course material provider, and support our K-12 outreach activities.

Proposed Future Work

- Finish the development of the I-HES lab
  - Internal Combustion Engine lab for Fall semesters
  - Electrified Vehicle Lab for Winter semesters
  - Another lab course (powertrain control lab) contemplated

- Sustain and continue to improve all courses developed under the support of this education grant

Summary

- 9 of the 10 proposed courses have been developed and taught annually.
- All three planned laboratories will be ready by Winter 2012.
- The 10 credit courses are expected to impact 300-500 students annually.
- The short courses will impact 50-100 professional engineers annually.
- K-12 and outreach activities should impact > 100 annually.