Technical Training and Workforce Development: Development and Implementation of Degree Programs in Electric Drive Vehicle Technology

Building a U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities

July 26-27, 2010

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NEXTENERGY

Economic Security through Energy Diversity

Wayne State University 1868

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Ten Projects Selected in Area Of Interest 4

- *National Fire Protection Association*
- *University of Missouri*
- *Wayne State University*
- *West Virginia University*
- *University of Michigan*
- *J. Sergeant Reynolds Community College*
- *Michigan Technical University*
- *Purdue University*
- *City College of San Francisco*
- *University of Colorado*

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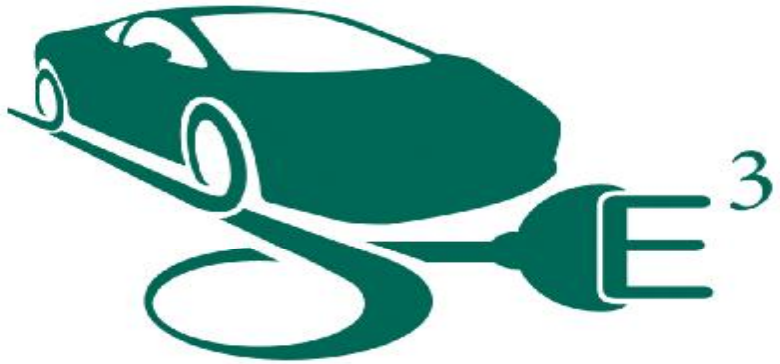
Mission

To prepare our current and future workforce with the education and skills necessary for the advancement and maintenance of electric-drive vehicles.



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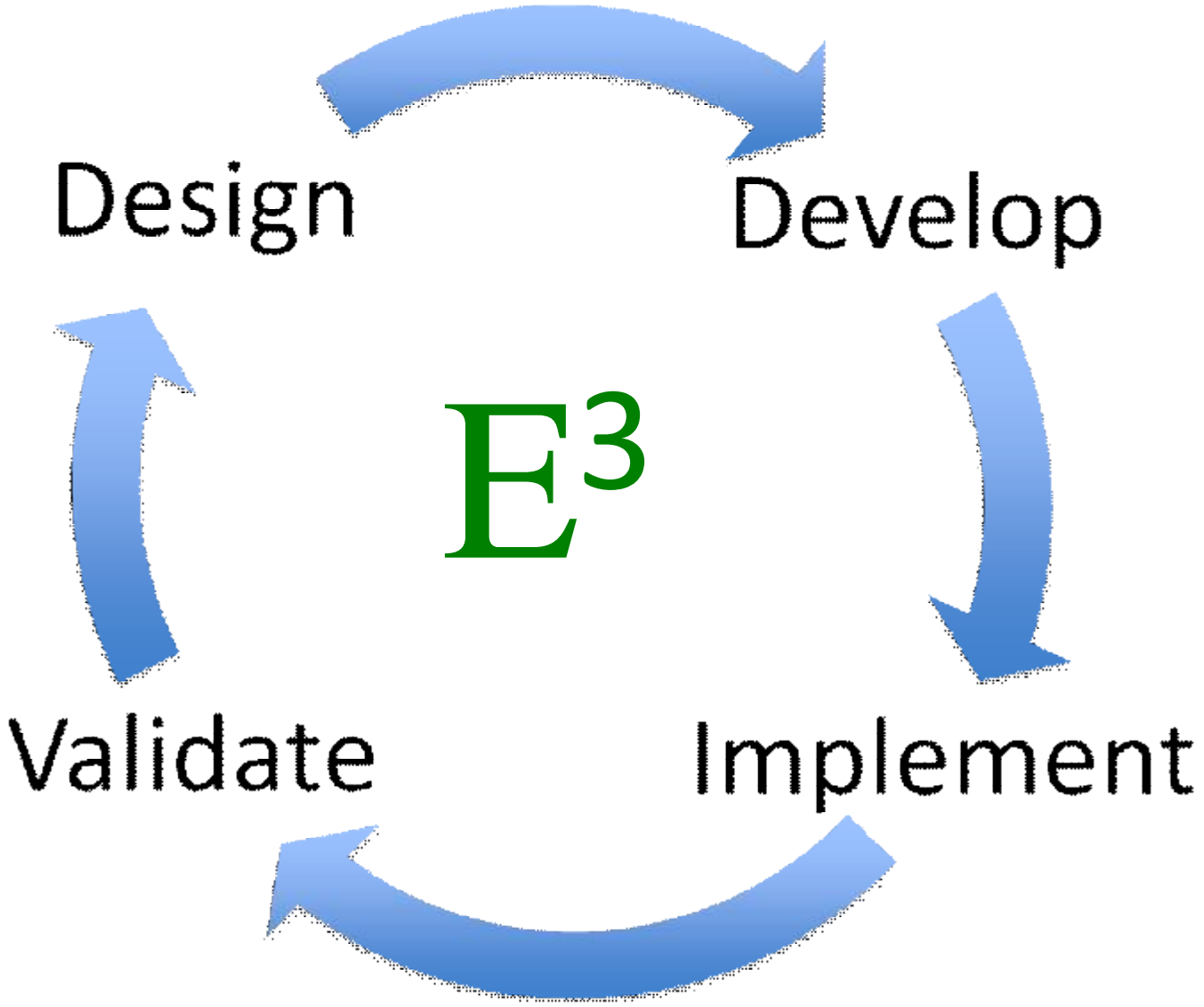
Overall Objective

Develop and implement a comprehensive set of advanced educational programs in electric drive vehicles, including:

- a Master's Degree in Electric Drive Vehicle Engineering (EVE),
- a Bachelor's Degree in Electric Transportation Technology (ETT),
- an Associate's Degrees (AAS) in Automotive Technology and Electronic Engineering Technology,
- an undergraduate concentration and a graduate certificate program (GPC) in EVE

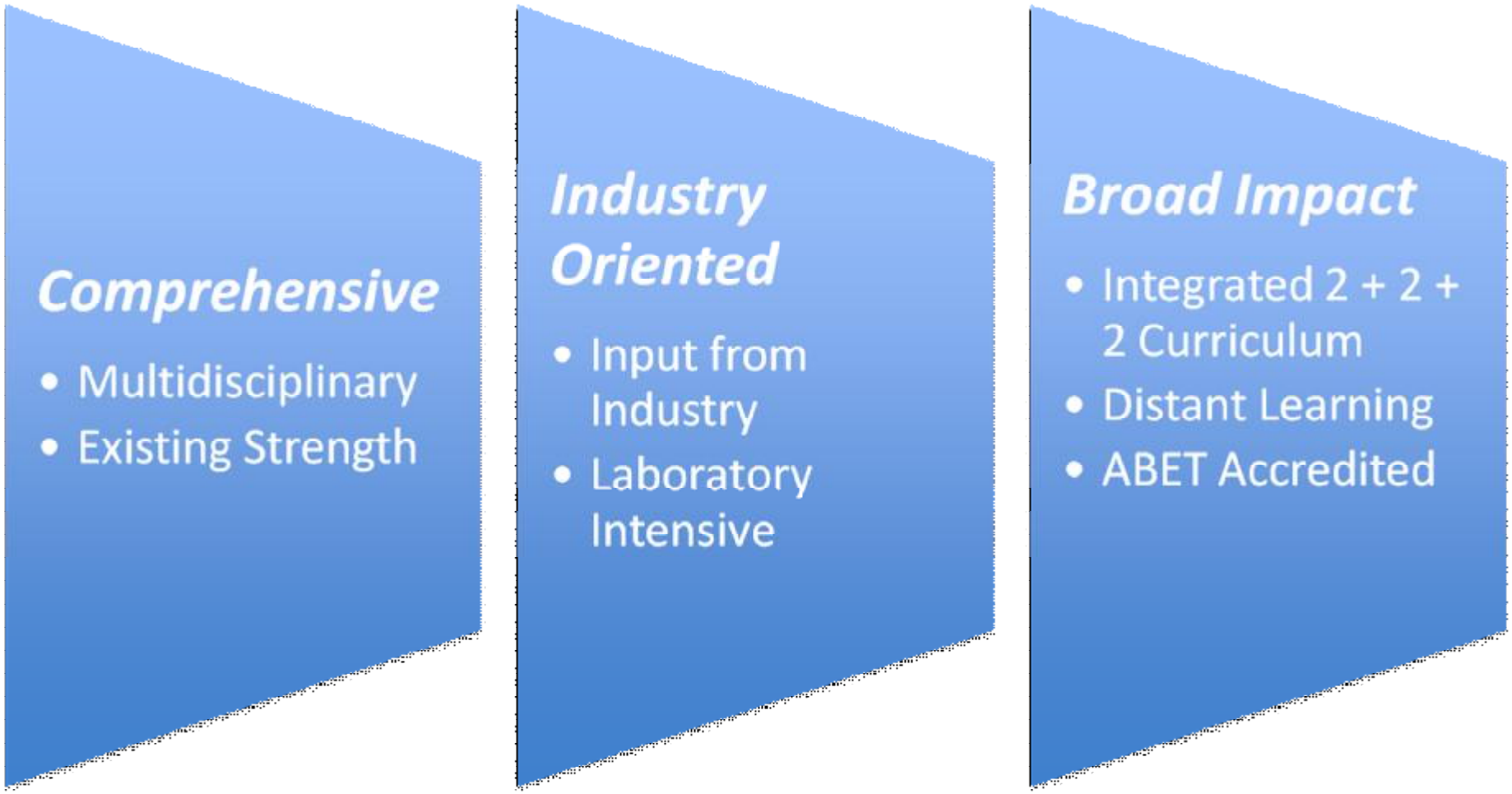
The Process



The Process

- Design a relevant curriculum based on input from the EV industry and “best practices” in EV-related curricula from around the world;
- Develop a cohesive set of graduate-level, undergraduate-level and technician-level courses and state-of-the-art interactive laboratory modules;
- Implement these degree programs strategically via synchronous and asynchronous web-based distance learning technology having a national impact;
- Validate the curriculum design and educational and training objectives leading to accreditation of the proposed degree programs.

Program Philosophy



Electric-drive Vehicle Engineering Programs

- **Master's Degree Program (MSEVE)**
  - **32 credit hours – 8 of which at 7000-level, another 8 on 2 required courses**
  - **Thesis and non-thesis tracks**
- **Graduate Certificate Program (GCP-EVE)**
  - **12 credit hours – 1 required course**
  - **8 of 12 can count towards MSEVE**
- **Bachelor's Degree Program (BS ETT)**
  - **64 credit hours (3rd and 4th years)**
- **All EVE courses have home dept cross-list**

Milestone

Key Milestones	Date	Remarks
EVE Advisory Board	February 15, 2010	14 Board Members
Launch EVE Website	April 1, 2010	2,025 visits (as of July 22, 2010)
M.S. Degree Program in EVE Approved	May 5, 2010	Offered in September, 2010
Graduate Certificate Program in EVE Approved	May 5, 2010	Offered in September, 2010
B.S. Degree Program in ETT Approved	May 5, 2010	Offered in September, 2010
E3 Workshop: *Meeting the Educational Needs of the Electric Vehicle Industry*	May 25, 2010	Over 120 participants

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E3 Conference

- 120 attendees
- 12 Universities/Community Colleges, over 30 companies
- Battery Track
  - Fundamental Course in Electrochemistry
  - Battery Recycling/Manufacturing
  - System Engineering approach (Molecular, Cell, Pack, System)
- Vehicle Track
  - Some redundancy in vehicle design, system, and control
  - Business needs, skills, and competence
- Infrastructure Track
  - Public Education and Events
  - Power Engineering
  - Smart Grid and Infrastructure

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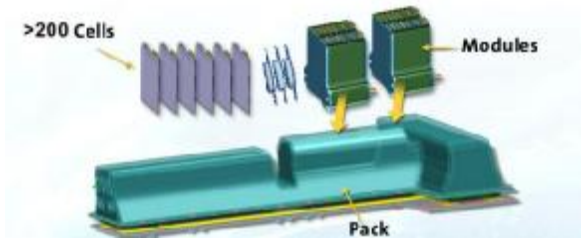
Energy Storage Laboratory

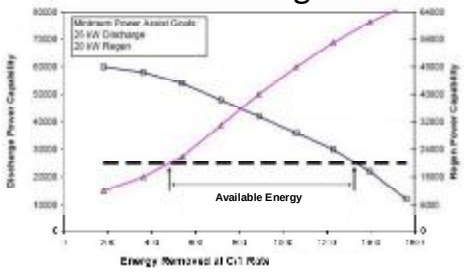
Pack and Module Characterization

ABC150

Bitrode Tester & Thermal Chamber

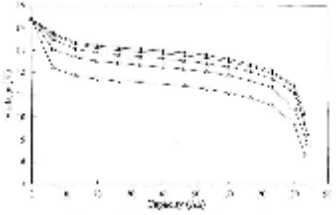


HPPC testing

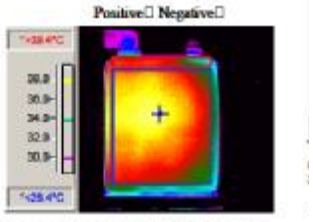


Battery Cell Characterization

Maccor and Arbin Cell Testers



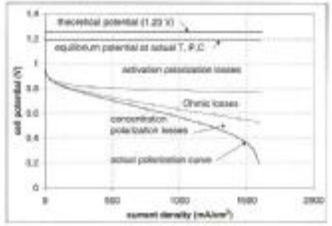
Cell performance and life tests



Thermal Imaging

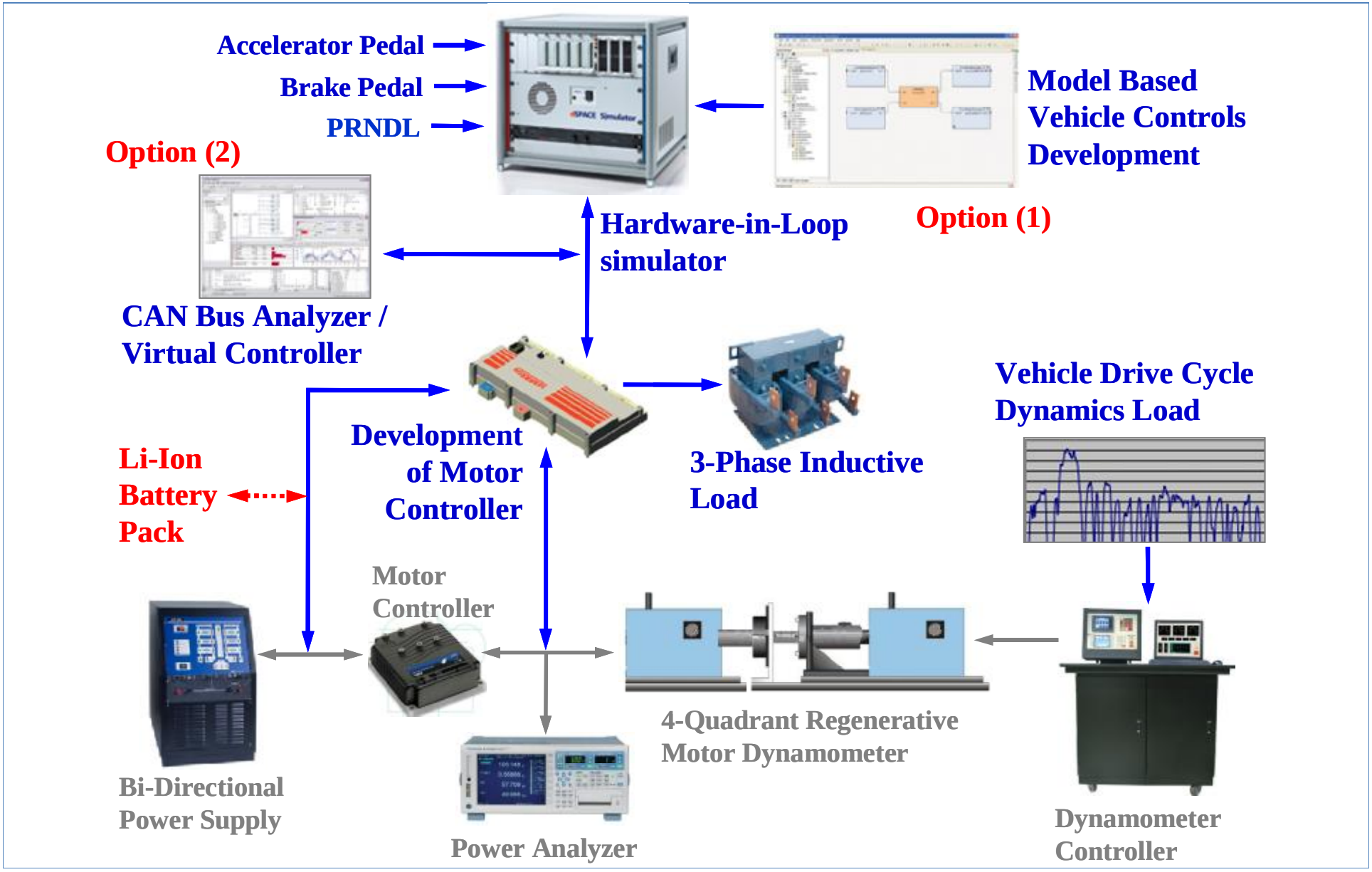
Cell Fabrication and Materials Characterization

Glove Box for Li-Ion Cell Fabrication

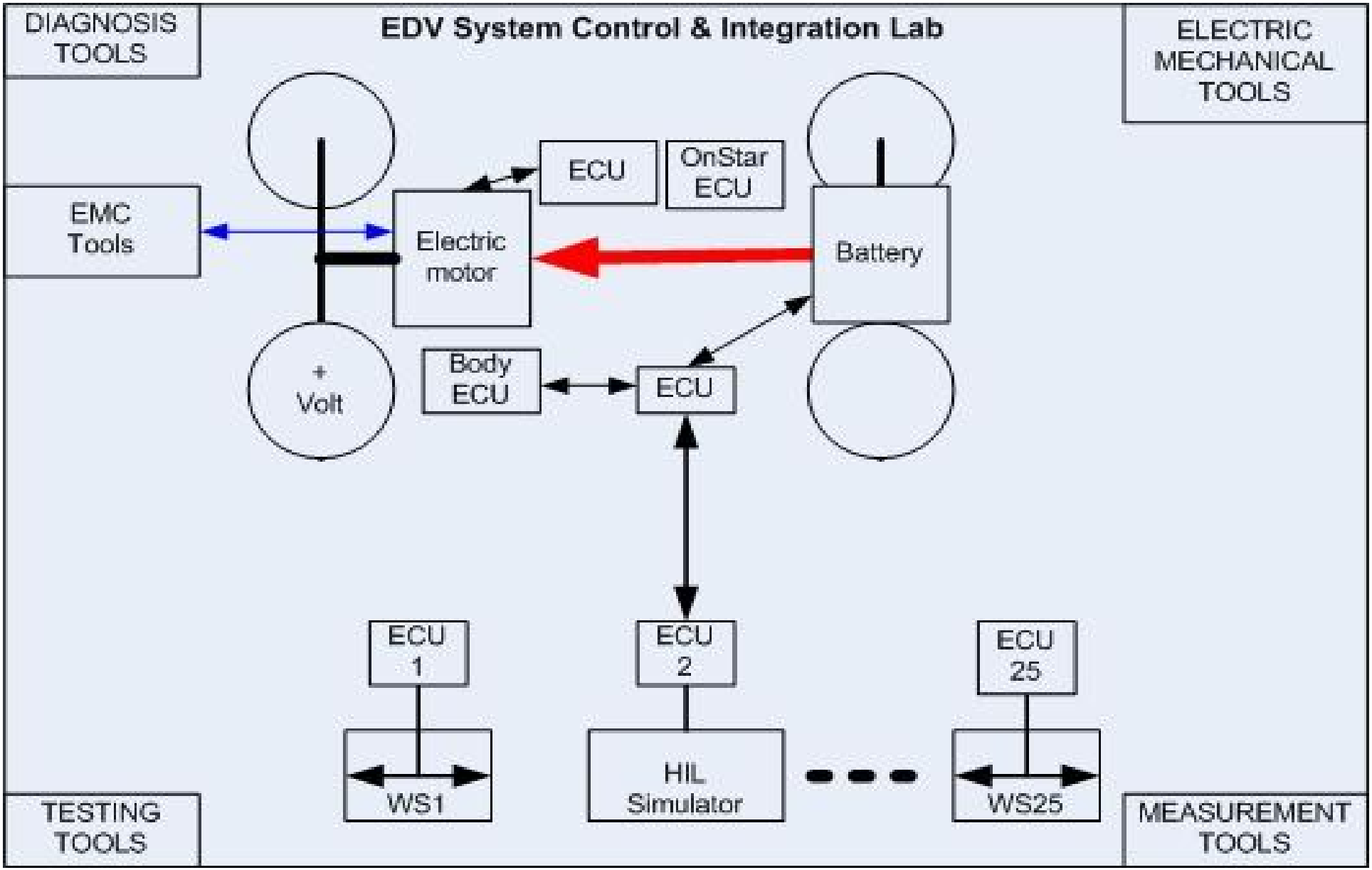


Fuel Cell Polarization Curves

Electric Propulsion Laboratory



Control and Integration Lab



Course List & Scheduling – 1/2

	Fall 2010	Winter 2011
Funda -mentals	**EVE 5110** *Fndmntls Elect-drive Vehicles* **EVE 5120** *Fndmntls Batteries*	**EVE 5130** *Fndmntls Fuel-cell-powered Sys*
Infr str		**EVE 5410** *Power Elect & Chrgng Infrstr*
Mode -ling	**EVE 5430** *Modeling Ctrl of EV Powertrain*	**EVE 5310** *EV Modeling & Simulation*

Course List & Scheduling – 2/2

	Fall (few Summer) 2010	Winter 2011
Product Design	**EVE 5600** *EV Prod & Infrstr Development*	**EVE 5620** *Energy Economics & Policy* **EVE 5700** *EV Capstone Design*
Advanced Topics	**EVE 7110** *Materials Sci of Batteries* **EVE 7430** *EV Sys Ctrl & Optimization* **EVE 7450** *Embdd Sys*	**EVE 7320** *EV Thermal Management* **EVE 7410** *Hydrogen Production and Storage*

Advisory Board

- **Ray Boeman**, Director, Advanced Transportation Systems Program and NTRC User Facility, Oakridge National Laboratory
- **Keith Cooley**, former CEO of NextEnergy
- **Sen. Hansen Clarke**, State Senator from the First District (Detroit)
- **Michael Fetcenko**, VP of Ovonic Materials (parent company: Energy Conversion Devices, Inc.)
- **Ricardo Espinosa**, Vice President of Engineering, Azure Dynamics, Inc.
- **Nancy Gioia**, Vice President of Global Electrification, Ford Motor Company
- **David Gorsich**, Chief Scientist, U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC)
- **Denise Gray**, Former Director of Energy Storage Devices, General Motors
- **James Jacobs**, President, Macomb Community College
- **Steven Kurmas,** President and COO, DTE Energy
- **Gregory Main**, President, Michigan Economic Development Corp (MEDC)
- **Prabhakar Patil,** President and CEO, Compact Power, Inc.
- **Bob Purcell**, Purcell & Associates, LLC
- **Hilary Ratner,** WSU Vice President for Research and Chair of the Advisory Board

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Supplemental Slides

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EVE Courses 1/2

EVE 5110	**ME**	**Fundamentals of Electric-drive Vehicle Engineering**
EVE 5120	**ChE**	**Fundamentals of Battery Systems for Transportation**
EVE 5130	**ChE**	**Fundamentals of Cell-powered Systems for Transportation**
EVE 5310	**ME**	**Electric-drive Vehicle Modeling and Simulation**
EVE 5410	**ECE**	**Power Electronics and Charging Infrastructure for Electric-drive Vehicles**
EVE 5430	**ECE**	**Modeling and Control of Electric-drive Powertrains**
EVE 5450	**ECE**	**Control and Optimization for Integrated Electric-drive Vehicle Systems**
EVE 5600	**IME**	**Electric-drive Vehicle Product and Infrastructure Development**

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EVE Courses 2/2

EVE 5620		**Energy Economics and Policy**
EVE 5700	**ME**	**Electric-drive Vehicle Capstone Design**
EVE 7110	**ChE**	**Materials Science Aspects of Lithium Ion Batteries**
EVE 7320	**ME**	**Electric-drive Vehicle Thermal Management**
EVE 7410	**ChE**	**Hydrogen Production and Storage for Vehicles**
EVE 7450	**ECE**	**Embedded Systems for Vehicles**
EVE 7990		**Directed Studies**
EVE 7995		**Special Topics**
EVE 7996		**Directed Research**
EVE 8999		**Master's Thesis**

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EVE 5110 Fundamentals of Electric-drive Vehicle Engineering

General backgrounds of electric and hybrid electric vehicle (HEV) related technologies, including technical concepts, design factors, energy analysis, and unified modeling approach. Discussion of hybridization, hybrid powertrain architectures, IC engines for hybrid electric vehicles, associated types of transmissions used, fuel-cell vehicles (FCV), plug-in's, and on-board energy storages. Introduction to beginning-level computer tools. Introduction to control and optimization fundamentals. Key issues in future developments.

(F; 4 cr.)

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EVE 5120 Fundamentals of Battery Systems for Transportation

This course addresses the fundamental electro-chemistry and design aspects for secondary batteries for electric propulsion applications at battery cell, module, and system levels. A descriptive overview of battery technologies including lead acid, nickel metal hydride, and lithium ion batteries will be provided together with their application to hybrid and electric vehicle applications. (W; 4 cr.)

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EVE 5130 Fundamentals of Fuel-cell Powered Systems for Transportation

This course addresses the fundamental process and materials aspect of fuel cell technology, the reforming of hydrocarbon fuels to hydrogen, and the application of fuel cell for transportation. The course includes a review and discussion of various types of fuel cells, materials properties of electrodes and polymeric membranes, and electrochemical mechanisms. Reforming of various types of hydrocarbon fuel to hydrogen and the application of reforming technology to stationary and vehicle fuel cells will be discussed. (F; 4 cr.)

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EVE 5310 Electric-drive Vehicle Modeling and Simulation

Fundamentals in modeling of energy conversion, storage, utilization and optimization of complete ground vehicle systems for conventional, electric and hybrid vehicles. Modeling and simulation for a system consisting of components such as IC engine, electric machine, energy storage, and/or fuel cells, with the necessary controllers for specific power flow processes in hybrid and electric vehicles using Matlab/Simulink, Modelica/Dymola, dSPACE, GT-Drive, and/or AVL-Cruise. (W; 4 cr.)

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EVE 5410 Power Electronics for Electric-drive Vehicles

Control of electric energy using solid-state devices, diodes, thyristors, triacs; mathematical analysis of circuits containing these devices; power converters and control; solid-state drives for motor control. (S; 4 cr.)

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EVE 5430 Modeling and Control of Electric-drive Powertrains

Understand how power electronic circuits and motors are combined with battery systems, internal combustion engines to form an EDV (electric drive vehicle) power train. The course will cover dynamic modeling and control of power electronics, motors, battery systems, and power regeneration. Powertrain system components, such as motors, DC/AC converters, DC/AC inverters, battery systems, and engines, will be discussed and their basic models and component integration will be derived. Control methods will be discussed. The powertrain systems test bench in the EDV Integrated Control Laboratory will be utilized to gain hands-on knowledge in applying basic understanding and simulation experience to a real system. Models and control strategies will be evaluated by simulating an EDV powertrain in Matlab/Simulink and dSpace Hardware-in-the-Loop (HIL) Simulator. (F; 4 cr.)

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EVE 5450 Power Electronics and Charging Infrastructure for Electric-drive Vehicles

Prereq: EVE 5430. To understand how to control a system using modern control theory, how to optimize the performance of a system using various optimization technologies, and how to apply the control and optimization technologies to EDV (electric drive vehicle) systems. The course will start with system models using state equations and their connections with transfer functions. Key properties of systems, such as stability, controllability, and observability will be discussed. Controller design using pole placement will be presented. Optimal control techniques will be derived. These materials will be taught in the framework of EDV systems. Applications to EDV systems will be illustrated. Optimal controller for EDV systems will be designed and simulated using Matlab/Simulink. Performance of controlled systems will be evaluated. (W; 4 cr.)

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EVE 5600 Electric-drive Vehicle Product and Infrastructure Development

This course will provide students the design and development experience of electric vehicle products. It will demonstrate process framework related to electric vehicle product design and concept validation methodology. Also, this course will provide an in-depth understanding of the product realization life cycle, business and process issues necessary for making appropriate business and technical decisions. The students in this class are expected to conduct team-based system realization projects to develop innovative and competitive electric vehicle product design and/or infrastructure concepts. The goal of this exercise is to learn product development principles and methods in electric vehicle product realization. (F; 4 cr.)

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EVE 5620 Energy Economics and Policy

This course explores the theoretical and empirical perspectives on individual and industrial demand for energy, energy supply, energy markets, and public policies affecting energy markets. It discusses aspects of coal, oil, natural gas, electricity, and nuclear power sectors and examines energy tax, price regulation, deregulation, energy efficiency and policies for controlling emissions. (W; 4 cr.)

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EVE 5700 Electric-drive Vehicle Capstone Design

Prereq: EVE 5110, and EVE 5310 or EVE 5430. To simulate a realistic competitive environment similar to the workplace, the class is divided into teams competing on same or similar Electric Drive Vehicle (EDV) system design project. Team score consists of half of student's final grade. Individual efforts are earned through homework, individual design exercise/project, quizzes, and peer review. The team design projects usually are on contemporary EDV issues with relevant vehicle powertrain and energy system contents. The design analyses usually include energy (thermal-fluid, electric), environmental, safety, economic and public impact/educational analyses. Each team should identify a mentor from the EDV faculty or industry expert; or the instructor will act as the mentor. The class format includes: lectures, computer lab, individual and team presentations, and weekly group discussion and interactions. (W; 4 cr.)

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EVE 7110 Materials Science Aspects of Lithium Ion Batteries

The development of advance battery materials has led to the high energy batteries now in widespread use in portable electronics applications such as laptop computers and cellular telephones. Lithium-ion batteries have improved in energy density to the point where the introduction of electric vehicles is now underway. This course provides a fundamental understanding of the role of advances in materials science and engineering to the development of these high energy batteries. Details on the novel synthesis of these new materials together with their physical and electrochemical characterization will be included. The relationship between materials structure-composition and performance will be emphasized. Promising new concepts and future trends for next generation of energy storage systems will be discussed. (S; 4 cr.)

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EVE 7320 Electric-drive Vehicle Thermal Management

Prereq: EVE 5110 and EVE 5310. To understand, model and numerically simulate thermal management scenarios for electric drive battery to ensure optimum electrochemical performance of cell charge acceptance, power and energy capability, reliability, cycle life, safety and cost. A secondary purpose of the course is to expand such thermal management analyses in an integrated approach to include other components such as electric machine, inverter, fuel cell (in FCV's) and internal combustion engines (in HEV's). Simulations are based on 2 major approaches – computational fluid dynamics (CFD) for detailed analyses at the component level, and phenomenological equivalent circuit-based modeling (ECM) for system level. (F; 4 cr.)

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EVE 7410 Hydrogen Production and Storage for Vehicles

The hydrogen economy depends on not only fuel cells but the production and storage of hydrogen fuel. This course focuses on the engineering of hydrogen production technologies including reformation of hydrocarbons, electrolysis, photoelectrochemistry, and the thermal decomposition of water. It also provides a background in hydrogen storage technologies including high pressure compressed gas, liquid hydrogen, metal hydrides, and chemical hydrides. The gravimetric and volumetric energy density are compared to goals for fuel cell hybrid vehicles. Energy efficiency and thermal issues related to hydrogen storage are also addressed. (W; 4 cr.)

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EVE 7410 Embedded Systems for Vehicles

Prereq: EVE 5430. Introduction to advanced embedded processors. Advanced processor core, power modules, auxiliary execution engine, display interface, memory controller, USB controller, DMA, I/O, initialization and configuration, programmable serial controller, serial audio interface, and video input. Embedded operating systems. Algorithm implementation on advanced embedded processors. (F; 4 cr.)

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