GATE Center for Electric Drive Transportation at the University of Michigan - Dearborn

PI: Chris Mi

Presenter: Chris Mi

University of Michigan-Dearborn

May 15, 2013

Project ID #
TI020

Overview

Timeline

- Project start date: 9/1/2011
- Project end date: 8/31/2016
- Percent complete: 25%

Budget

- Total project funding: $1,249,977
  - DOE share: $999,981
  - Contractor share: $249,996
- Funding received in FY12: $200,524
- Funding for FY13: $209,948

Barriers

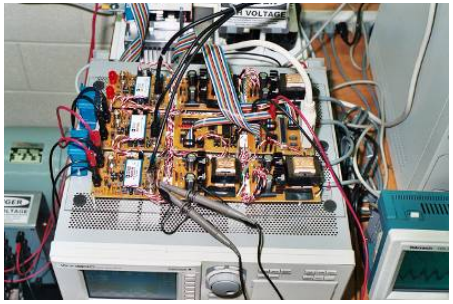
- Barriers addressed
  - Lack of trained engineers and scientists
  - Lack of advanced technology curricula
  - Automotive industry in high demand of knowledgeable and experienced workforce

Partners

- Chrysler, Ford, ANSYS, EDTA, Mathworks, DENSO, Hp Pelzer, dSPACE
- Project Lead: Univ. of Mich. Dearborn

Relevance/Objectives

- Establish concentration in electric drive transportation in MS and Ph.D programs in Automotive Systems Engineering (ASE) at UM-Dearborn
- Develop seven new courses in EDV
- Develop a series of short courses in EDV
- Offer 5 new graduate fellowships per year
- Enhance research in seven thrust areas
- Establish an Industry Consortium on EDV to support the above initiative



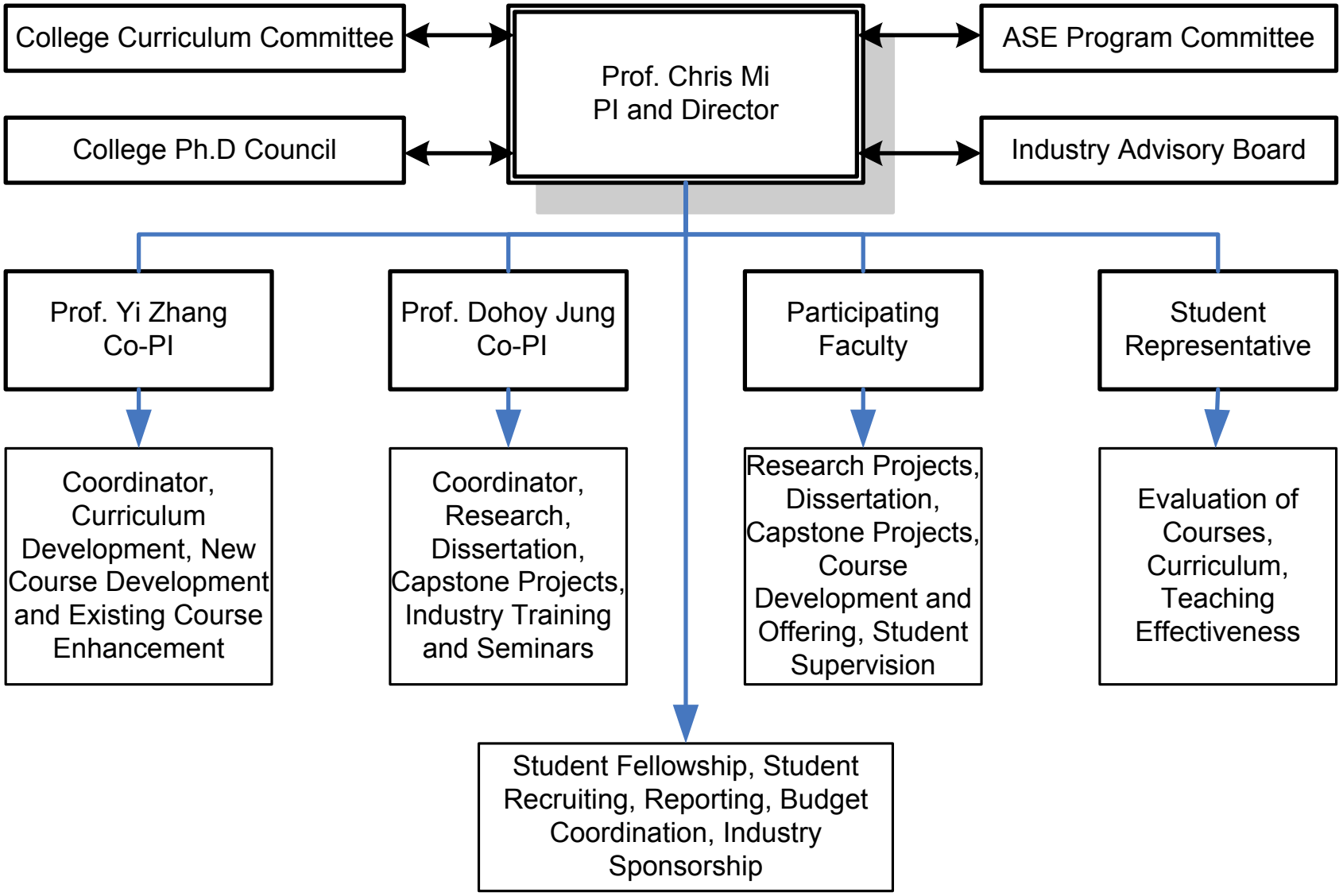
Milestones – Year 1

- **First Academic Year (09/01/2011-08/31/2012)**
  - Obtain approval of the new concentration by the College Curriculum Committee – approved by the curriculum committee
  - Develop seven new courses for the EDT concentration in the ASE program - seven new courses are developed
  - Offer two new courses - two new courses are offered
  - Revise the contents of four existing courses and offer one revised course - four courses are revised
  - Recruit two to four graduate students for the GATE program fellowships - three students were recruited
  - Receive industry support - seven companies joined the center
  - Organize Center Annual Conference - two industry advisory meetings in 2012

Milestones – Year 2

- **Second Academic Year (09/01/2012-08/31/2013)**
  - Offer three additional new courses - offered 3 new courses
  - Recruit four to six graduate students for the GATE program fellowships - recruited total 4 full time students and 4 part time in the program; 6 new applications for fall 2013
  - Implement laboratory improvements and integration of lab with course contents – improvement is underway
  - Offer three revised existing courses and implement changes - offered
  - Offer industry training programs – offered training courses
  - Publish conference and journal papers – three papers published
  - Approve dissertation proposals - underway
  - Organize Center Annual Conference – IAB meeting on 4/8/2013

Approach - Center Management



Ph.D Concentration in Electric Drive Transportation

- Required Courses
  - ASE502: Modeling of Automotive Systems
  - ENGR799: Doctoral Dissertation
  - ENGR798: Seminar
- Elective Courses: select 4 concentration courses listed below and 3 additional elective courses
  - ASE502 Energy Storage Systems
  - ECE5462 Hybrid Electric Vehicles
  - ASE566 Vehicle Thermal Management
  - ASE5791 Vehicle Power Management
  - ECE646 Adv. Electric Drive Transportation
  - ASE501 Energy Conversion Systems
  - ASE557 Powertrain NVH Analysis
  - ISE567 Reliability Analysis
  - ECE517 Advanced Electric Drives
  - ASE548 Automotive Powertrains II
  - ECE615 Adv. Power Electronics

MSE Concentration in Electric Drive Transportation

- Required Courses
  - ASE 698 Capstone Project or ASE 699 Master's Thesis
  - ASE500 Automotive Systems Engineering
  - ASE587 Automotive Manufacturing Proc
- Elective Courses: select 4 concentration courses listed below and 2 additional elective courses
  - ASE 502 Energy Storage Systems
  - ECE 5462 Hybrid Electric Vehicles
  - ASE 566 Vehicle Thermal Management
  - ASE 5791 Vehicle Power Management
  - ECE 615 Adv. Power Electronics
  - ECE 646 Adv. Electric Drive Transportation
  - ASE 557 Powertrain NVH Analysis
  - ISE 567 Reliability Analysis
  - ECE 517 Advanced Electric Drives
  - ASE 548 Automotive Powertrains II
  - ASE 515 Vehicle Electronics II
  - ECE 532 Automotive Sensors & Actuators

Development of Seven New Courses

- ESE501: Energy Conversion Systems - offered
- ESE502: Energy Storage Systems - offered
- ECE615: Advanced Power Electronics – replaced with ECE517 Advanced Elec. Drives
- ECE646: Advanced Electric Transportation - offered
- ECE5791: Vehicle Power Management - planned
- ASE 557: Powertrain NVH - planned
- ASE 566: Vehicle Thermal Management - offered

Enhancement of Four Existing Courses

- ASE548: Automotive Powertrains II - offered
- ECE5462: Hybrid Electric Vehicles - offered
- ECE517: Advanced Electric Drives - offered
- ISE567: Reliability Analysis – offered
- Short courses, trainings, and seminars – offered

Industry Partners

- Chrysler Group, LLC.
- Ford Motor Company
- DENSO International
- ANSYS, Inc.
- The Mathworks
- dSPACE
- Hp Pelzer

Industry Partnership

- Non Exclusive, royalty free IP for internal use
- Access to recent, not-yet-published GATE Center research
- Access to GATE Center prepublications and presentations
- Early access to intellectual property developed by GATE Center
- Access to the GATE Center facility
- Serve on the Industry Advisory Board which helps to guide GATE Center management, curriculum, research etc.
- Attend GATE Center annual conference that includes presentations by GATE Center researchers and member companies
- Free or discounted attendance of seminar, short course, training
- Networking opportunities with faculty, students, and industry partners
- Jointly submitting proposals to federal programs, such as SBIR/STTR, that encourage university-corporate partnerships
- Priority access to students for internships and employment
- Opportunity to teach courses/subjects/seminars for the center

Industry Partnership - Structure

Member Benefits	Full Member	Affiliate Member
Seat on the IAB	X	X
Non Exclusive, royalty free IP for internal use	X	
First option to license center IP	X	
Access to center facility	X	
Priority access to students intern/employ.	X	X
SBIR/STTR collaboration	X	X
Free access to seminar/training/short courses	X	discounted
Contribution	$30,000	$2500

Industry Advisory Board (IAB) - Role

- Receives annual reports of the Center
- Reviews curriculum of the GATE Center and make recommendations for curriculum, new courses, and course contents
- Makes recommendations for research projects
- Selects projects of mutual interest to be funded from Membership fees in each Fiscal Year
- Attends the semi-annual IAB meetings (arrange an alternate if the IAB member is not available)
- Reviews industry membership structure, fee structure, and new members applications
- Elects IAB Chair who will coordinate the IAB meetings, and a vice chair to help the chair and serves acting chair if the chair is not available, and as Chair-elect
- The IAB Chair shall serve a one year term
- The IAB Vice Chair shall serve a one year term followed by a one year term as IAB Chair

The Second IAB meeting was held on June 21, 2012, with 20 companies and 25 representatives

Next IAB Meeting, GATE Annual Meeting in conjunction with a 2-day training course on April 18, 2013

Accomplishments - GATE Fellows

- One MS student graduated
- Four full time Ph.D by January 2013
  - Jinghai Xu, Ph.D Candidate
  - Chenwen You, Ph.D student
  - Xianzhi Gong, Ph.D Candidate
  - Bing Xia, Ph.D student
- Four part time Ph.D students
- Fall 2013, six applications

Five-year education plan for course offerings

Course #	Course name	Faculty	Year 1	Year 2	Year 3	Year 4	Year 5
ESE501	Energy Conversion	Ratts		X	X	X	**X**
ESE502	Energy Storage	Mi	X	X	X	X	**X**
AE557	Powertrain NVH	Cherng		X		X	
AE566	Vehicle Therm. Man.	Jung, Li		X	X	X	**X**
ECE5791	Power Management	Murphey			X		**X**
ECE615	Adv. Power Elec.	Mi		X	X		**X**
ECE517	Electric Drives	Kim		X		X	
ECE5462	Hybrid Vehicles	Kim	X	X	X	X	**X**
AE548	Powertrain II	Zhang	X	X	X	X	**X**
ISE567	Reliability	Xi		X	X		**X**
Total courses offered per year			**3**	**9**	**8**	**7**	**8**

Short Course - Fundamentals of Electric Drive Vehicles - 3/14-16, 2012

- Day 1:
  1. Chris Mi, Fundamentals of EV, HEV, and PHEV, Chris Mi, 3 hours
  2. Taehyung Kim, Power electronics and electric drives for electric drivetrain applications, 2 hours
  3. Yi Zhang, Hybrid Powertrain topology and dynamics, 2 hours
- Day 2:
  4. Yi Lu Murphey, Intelligent vehicle power management, 3 hours
  5. Dohoy Jung, Thermal management of electric drive vehicles including waste heat recovery, 2 hours
  6. John Cherng, Noise, vibration, and harshness of electric drive vehicles, 2 hours
- Day 3:
  7. Chris Mi, Battery management systems, 3 hours
  8. Zhinmin Xi, Reliability of electric drive vehicles, 2 hours
  9. Wei Guo, Application of Nanotechnology, 2 hours
  10. Ted Bohn, Codes and standards, 2 hours

Nominal Cost $99 for industry partners

Short Course - Optimal Design of Electric Machines - 4/18-19, 2013

- Fundamental Concepts for Electric Machines and Drives
- Electric Machines and Drives for State-of-the-Art and Future Generations HEV and EV
- FEA Models for Large Scale Optimization Studies
- Design Optimization – Robust Design and Differential Evolution
- Magnetic Materials and Losses
- Advanced Simulation Concepts: PM Modeling, System Modeling, Steady State Parameter Extraction
- Faults and Condition Monitoring
- Non-rare Earth Alternatives and Other Non-PM Machines
- Hands on training in the computer lab

Nominal Cost $199 for general attendee and free for partners

Out Reach - Professional Seminars

- **Prof. Chris Mi is Invited to Give Lectures at APEC, Feb 6,2012**
  - **Topic**: S.15 Control and Management of Energy Storage Systems in Electric and Plug-in Hybrid Vehicles
- **Prof. Chris Mi is invited to give lectures at IEEE ECCE, Sept 16, 2012**
  - **Topic**: Battery Management Systems for Electric Vehicle Applications
- **Prof. Dohoy Jung is Invited to Give a Seminar at BorgWarner (January, 25, 2012) and Ford Motor Co (January, 27, 2012).**
  - **Topic**: Vehicle thermal management in advanced automotive powertrain systems for improved fuel economy
- **Prof. John Cherng is Invited to Give a Seminar at Ford Motor Company, April 19, 2013**
  - **Topic**: NVH Characteristics of Electrical Vehicles
- **Prof. Offer online course for General Motors and Siemens**
  - **Topic**: Battery Management Systems

IAB Curriculum Committee

- Curriculum committee for GATE Center formed in August, 2012
- Committee Members
  - Indusrty
    - Wensi Jin (Chair, Mathworks)
    - Robert Bucciarelli (Visteon)
    - Zed Tang (Ansys)
    - Mark Zachos (DG Technologies)
  - University of Michigan-Dearborn
    - Chris Mi (Director, ECE)
    - Dohoy Jung (ME)
    - Yi Zhang (ME)

- Purpose:
  - ✓ Make the graduates' skills relevant for the industry
  - ✓ For IAB members to interact around the curriculum between the bi-annual GATE meetings
  - ✓ Make sure the curriculum covers relevant subsystems outside powertrain.
  - ✓ Make sure the curriculum reflects how software engineering and systems engineering are done in the industry
  - ✓ Help shape the curriculum as a way to influence students' directions
  - ✓ Find ways to involve industry speakers in the GATE teaching activities
  - ✓ Help identify short and long term needs and prioritize courses based on them

Curriculum Committee Activities

- UMD presented an overview of the GATE curriculum (1st Meeting)
- Committee Feedback
  - In general, the committee feels the curriculum design looks good.
  - Since the GATE student body is rather small, new courses have to cover GATE students' needs as well as the needs of other students in ASE
  - Consider EV/HEV specific NVH issues in AE 557
  - Consider inviting IAB members to recommend topics for ASE 698 capstone project

Curriculum Committee Activities

- UMD presented detailed course development plans of two new courses (2nd Meeting)
  - Vehicle Thermal Management (ME538/AE566)
  - Powertrain NVH Analysis (AE557)
- Committee Feedback
  - Vehicle Thermal Management
    - The course to be developed not only for ASE, but also EE, MM and other students.
    - The course will cover waste energy recovery.
    - Addressing climate control and battery thermal management course.
    - The focus on developing and delivering a presentation is also very good.
    - Suggestion: IAB member companies for a guest lecturer
  - Powertrain NVH Analysis
    - The course outline seems quite comprehensive. Need to balance depth and breath.
    - Question: will battery related NVH such as cooling circuit noise and contact noise be covered? Yes.

Center Website

UNIVERSITY OF MICHIGAN-DEARBORN
COLLEGE OF ENGINEERING AND COMPUTER SCIENCE

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Center for Electric Drive Transportation

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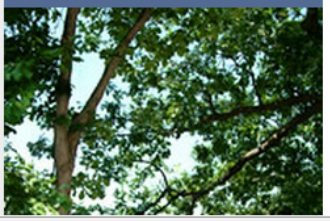


CENTER FOR ELECTRIC DRIVE TRANSPORTATION

DOE GATE Center for Electric Drive Transportation

The Center for Electric Drive Transportation (CEDT) at the University of Michigan-Dearborn is established in 2011 with a grant from the U. S. Department of Energy's Graduate Automotive Technology Education (GATE) Program.

The GATE Program was first established in 1998 with 5 centers. This year (2011), it marks the third generation of 7 GATE Centers:
- **University of Michigan - Dearborn**
- Purdue University
- The Ohio State University
- Pennsylvania State University
- Clemson University
- The University of Colorado & Colorado Springs
- University of Alabama

DOE's GATE initiative will award $6.4 million over the course of 5 years to support those 7 Centers of Excellence at American colleges, universities, and university-affiliated research institutions. The awardees will focus on 3 critical automotive technology areas: hybrid propulsion, energy storage, and lightweight materials. By funding curriculum development and expansion as well as laboratory work, GATE allows higher education institutions to develop multidisciplinary training. As a result, GATE promotes the development of a skilled workforce of engineering professionals who will overcome technical barriers and help commercialize the next generation of advanced automotive technologies.

As one of the seven university research centers that were awarded the prestigious grants, CEDT is dedicated to achieving the synergy among technological development, research and graduate education in automotive engineering, with a focus on the following thrust areas that are crucial for the development of electric drive transportation:

- Power electronics and electric machines
- Hybrid powertrain control and power management
- Battery management and control
- Thermal management of Electric Drive Vehicles (EDV)
- Vehicle to Grid (V2G), charging infrastructure, grid impact of EDV
- Reliability, diagnostics, and prognostics of EDV
- Noise, vibration and harshness (NVH) of EDV

Want More Information ?

DOE GATE Center for Electric Drive Transportation is featured on UM Record Update

About DOE GATE Program:
http://energy.gov/articles/graduate-automotive-technology-education-gate-initiative-awards

CEDT PI and Director:
Prof.Chris Mi
Web:http://www-personal.engin.umd.umich.edu/~chrismi/

Phone: 313-583-6434
Email: chrismi@umich.edu

A Free 3-Day Training Course on EV,HEV,and PHEV will be offered by GATE CEDT

The GATE Center for Electric Drive Transportation at the University of Michigan-Dearborn is pleased to offer a low-cost, three-day training seminar for the GATE partner companies. Participants that complete all three days of training will be awarded 2.4 CEUs (continuing education units) upon request.

Registration link:
http://www.engin.umd.umich.edu/EPD/data

Additional Funding Leveraging the GATE Program

- CECS 50% match on GSRA support
- Dr. Chris Mi, **$134,988** from Ford Motor Company "Ford-UM innovation Alliance - Electrical Safety Study of Lithium Ion Battery Packs."
- Dr. Yi Lu Murphey, **$62,500** from TRW, Inc. "Driver-Centered Intelligent Vehicle Systems"
- Dr. Zhimin Xi, **$50,000** from DENSO North America "Reliability Analysis of the Lithium-ion Battery Pack for thermal Runaway Considering Insufficient Experimental Data."
- Dr. Dohoy Jung, **$40,000** from Ford Motor Company "Control Oriented Diesel Engine Model for Developing Dual Loop EGR Control Strategy."
- Dr. Chris Mi, $200,000 from DENSO International “Wireless charging of electric vehicles”
- Dr. Chris Mi, $250,000 from DOE Funded Clean Energy Center – Clean Vehicle Center
- Dr. Chris Mi, $65,000 from Daimler, Evaulation of e-motors

Proposed Future Work

- Actively recruit GATE Fellows.
- Promote industry partners and secure additional membership fees.
- Offer scheduled courses in the curriculum.
- Organize GATE Annual meeting and IAB meeting.
- Promote GATE Center at conferences in the field of electrified vehicles, such as IEEE Electric Vehicle Conference.
- Continue to offer industry training programs
- Develop Capstone projects
- Approve dissertation proposals

Summary

- Obtained approval of the new concentration by the College Curriculum Committee
- Developed and offered 4 new courses for the EDT concentration in the ASE program
- Revised and offered the contents of 4 existing courses
- Recruited 4 graduate students for the GATE program fellowships and 4 part time students
- Signed 8 industry partner program and agreements/bylaw
- Organized the third industrial board meeting
- Offered second 3-day industry training at nominal cost and a number of seminars and short courses

Project Personnel

- Chris Mi: PI, ECE, (313) 583-6434, chrismi@umich.edu
- Yi Zhang: Co-PI, ME, (313) 593-5539, anding@umich.edu
- Dohoy Jung, CO-PI, ME
- Yi Lu Murphey, Electrical and Computer Engineering
- John Cherng, Mechanical Engineering
- Ben Q. Li, Mechanical Engineering
- Zhimin Xi, Industrial and Manufacturing Systems Engineering
- Eric Ratts, Mechanical Engineering
- Taehyung Kim, Electrical and Computer Engineering

Back Up Slides

ESE 501 Energy Conversion

- Instructor: Eric B. Ratts, Winter 2013
- Registered Students: 42
- Introduction to Energy Resources
- Nonrenewable Energy Conversion Technology
  - Steam power plants; Gas power plants; Combined cycle power plants; Fuel Cells
- Renewable Energy Conversion Technology
  - Solar thermal power; Hydraulic turbines; Wind turbines; Biomass/biofuel production; Geothermal power plants; Ocean energy conversion devices
- Direct Energy Conversion Technology
  - Thermoelectric; Photovoltaic

ESE 502 Energy Storage Systems

- Instructor: Gary Crosbie
- Enrollment 30; offered: Fall 2012 and 2011
- Contents:
  - Energy storage basics: Lead acid battery; Nickel metal hydride battery; Lithium ion battery; Ultracapacitors; Flywheels; super conducting magnetic, hydraulic, compressed air, integrated (hybrid) energy storage, etc.
  - Modeling of other energy storage systems
  - Battery management systems: Current, voltage, temperature monitoring ; SOC calculation and calibration; Cell balancing; Thermal management; SOH - concepts, method, impedance measurements and estimations
  - Battery chargers
  - Safety of battery systems
  - Energy storage application in EV and HEV

ME538/AE566 Vehicle Thermal Management

- Instructor: Dohoy Jung, Fall 2012
- Registered Students: 18
- Introduction to Vehicle thermal management system
  - VTMS Fundamentals; VTMS Challenges
- Fundamentals of thermo-fluid principles
  - Thermodynamics and energy conservation; Heat transfer; Fluid mechanics; Thermo-fluid devices and components
- Thermal Management Electric Drive Powertrain systems
- Battery thermal management
- Waste Energy Recovery
  - Thermal storage; Thermoelectric device; Turbo-compounding; Exhaust heat recycling

AE548 Automotive Powertarin Systems II

- Instructor: Yi Zhang, Fall 2012
- Registered Students: 20
- New Topics Covered
  - Drive trains of electrified vehicles, including system design, analysis and operation control.
- Course Renovation
  - The current technological developments in electrified vehicles are incorporated into the course, in addition to conventional vehicle powertrain systems. The new content is 6-9 lecture hours or 20% of total course lecture time.
- Results
  - The renovated course is well received by students. The enrollment of 20 students more than doubled the previous enrollment. The course will be regularly offered for the ASE/MSE programs.

ECE 517 Advanced Electric Drives

- Instructor: Taehyung Kim, Winter 2013
- Registered Students: 25
- Contents Covered
  - Introduction to Power Electronics and Motor Drives
  - Power quality (PF, THD, DPF, etc)
  - DC-AC Inverters
  - Advanced Power Electronics Circuits
  - DC Motor Drives
  - Permanent Magnet AC Motor Drives
  - Switched Reluctance Motor Drives
  - Induction Motor Drives
  - Application Examples of Motor Drives
  - Workshop Style Term Project Presentation

ME570/AENG570
Power Train NVH

- Instructor: John Cherng, Fall 2013
- Registered Students: TBD
- Contents Covered
  - Principles of mechanical Vibration
  - Principles of acoustics and Sound
  - Engine and power train induced noises/vibration
  - Technology development of EV, HEV and PHEV
  - NVH Challenges of key components
  - Power train accessories NVH
  - Principles of noise and vibration Controls
  - Case studies

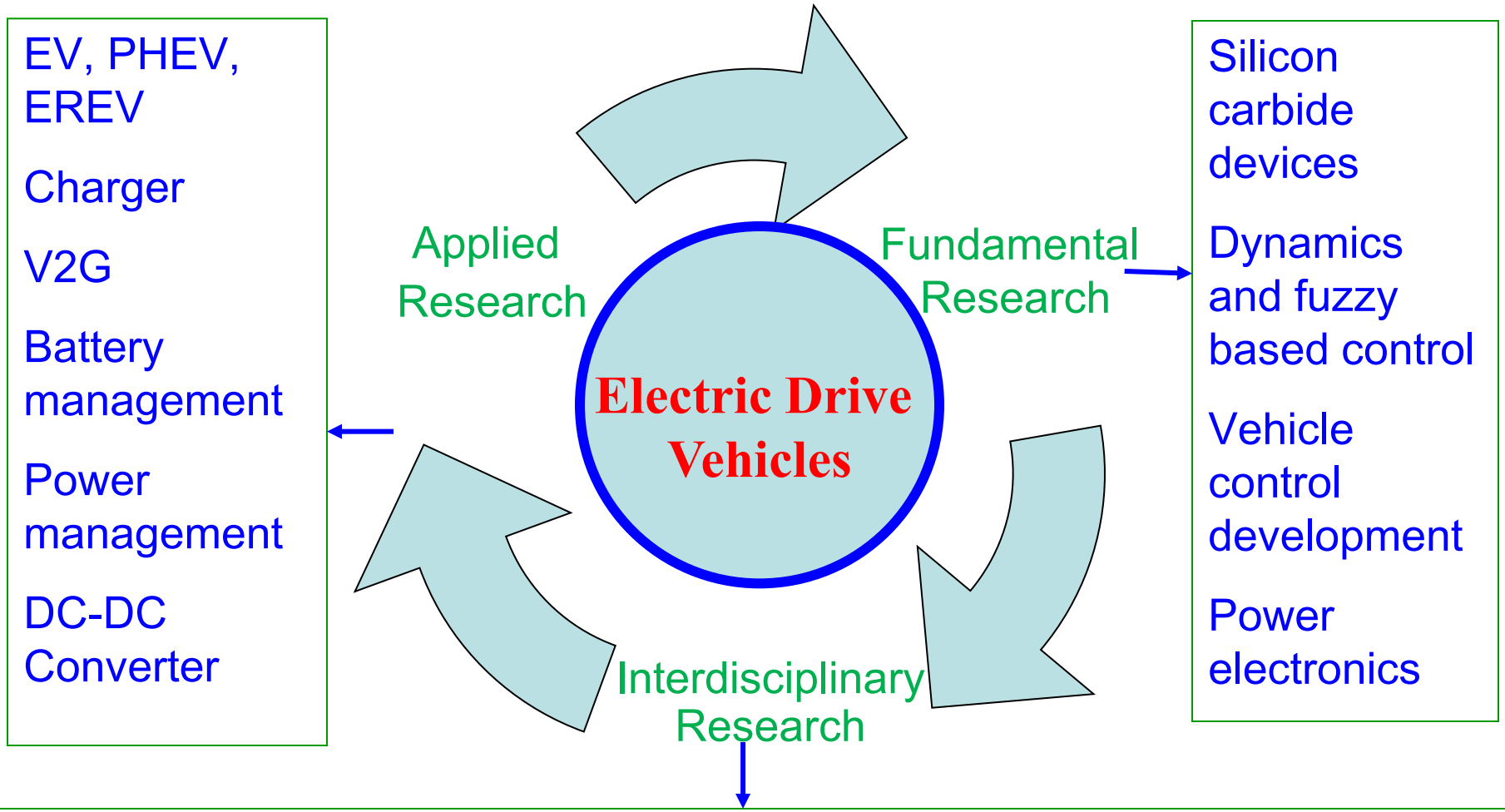
IMSE 567 Reliability Analysis

- Instructor: Zhimin Xi, Winter 2013
- Registered Students: 25
- Contents Covered
  - Failure Distribution & Constant Failure Rate Model
  - Time-Dependent Failure Models
  - Reliability of Systems; State-Dependent Systems
  - Physical Reliability Models; Design for Reliability
  - Maintainability & Design for Maintainability
  - Data Collection and Empirical Methods
  - Reliability Testing & Reliability Growth Testing
  - Identifying Failure and Repair Distributions
  - Reliability Estimation and Application

ECE646 Advanced. Electric Drive Vehicles

- Instructor: Chris Mi, Winter 2012, and Winter 2013
- Registered Students: 8
- Contents Covered
  - Advanced hybrid powertrain architectures
  - Dynamics of hybrid transmissions
  - PHEV and HEV power management – analytical approaches
  - Battery management systems
  - Battery modeling and parameter estimations
  - Battery AND high voltage safety in EV and PHEV
  - Optimization of PHEV components
  - Vehicle to grid (V2G, V2H) technology
  - Wireless power transfer for battery wireless charging

Approach – Technical Areas



Fund: DOE $1M; Automotive OEM/Supplier Consortium Membership