Overview

Timeline

• Project start date: 9/1/2011
• Project end date: 9/30/2016
• Percent complete: 40%

Barriers

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

Budget

• Total project funding: $1,249,977
  – DOE share: $999,981
  – Contractor share: $249,996
• Funding received in FY13: $199,423
• Funding for FY14: $209,948

Partners

• Chrysler, Ford, ANSYS, EDTA, Mathworks, DENSO, Hp Pelzer, dSPACE, PSIM, GaN Systems
• Project Lead: Univ. of Mich. Dearborn
Relevance/Objectives

- Establish concentrations in electric drive transportation in MS and Ph.D programs in Automotive Systems Engineering (ASE) at UM-Dearborn
- Develop and offer seven new courses
- Develop and offer a series of short courses
- Offer five graduate fellowships per year
- Enhance research in seven thrust areas
- Establish an Industry Consortium on EDV to support the above initiative
<table>
<thead>
<tr>
<th>Milestones</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offer three additional new courses</td>
<td>Offered 3 new courses</td>
</tr>
<tr>
<td>Recruit four to six graduate students</td>
<td>Total 8 students</td>
</tr>
<tr>
<td>Implement laboratory improvements</td>
<td>Improvement of two labs</td>
</tr>
<tr>
<td>Offer three revised existing courses</td>
<td>Offered 3 revised courses</td>
</tr>
<tr>
<td>Offer industry training programs</td>
<td>Offered 3 tutorials/short courses</td>
</tr>
<tr>
<td>Publish conference and journal papers</td>
<td>Published five papers</td>
</tr>
<tr>
<td>Approve dissertation proposals</td>
<td>One dissertation was passed</td>
</tr>
<tr>
<td>Organize Center Annual Conference</td>
<td>IAB meeting and workshops</td>
</tr>
</tbody>
</table>
# Milestones – Year 3

<table>
<thead>
<tr>
<th>Milestones</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offer the last two additional new courses</td>
<td>Offered 2 new courses</td>
</tr>
<tr>
<td>Refine and offer the new/revised course</td>
<td>Offered 5 courses</td>
</tr>
<tr>
<td>Recruit four to six graduate students</td>
<td>Total 8 students</td>
</tr>
<tr>
<td>Offer industry training programs</td>
<td>Offered 3 tutorial/short course</td>
</tr>
<tr>
<td>Publish conference and journal papers</td>
<td>Published five papers</td>
</tr>
<tr>
<td>Annual IAB Meetings</td>
<td>Two meetings per year</td>
</tr>
<tr>
<td>Organize Center Annual Conference</td>
<td>Offered WPT workshop</td>
</tr>
</tbody>
</table>
Approach - Center Management

Prof. Chris Mi
PI and Director

College Curriculum Committee

Prof. Yi Zhang
Co-PI
Coordinator, Curriculum Development, New Course Development and Existing Course Enhancement

College Ph.D Council

Prof. Dohoy Jung
Co-PI
Coordinator, Research, Dissertation, Capstone Projects, Industry Training and Seminars

Prof. Chris Mi
PI and Director

ASE Program Committee

Participating Faculty
Research Projects, Dissertation, Capstone Projects, Course Development and Offering, Student Supervision

Industry Advisory Board

Student Representative
Evaluation of Courses, Curriculum, Teaching Effectiveness

Student Fellowship, Student Recruiting, Reporting, Budget Coordination, Industry Sponsorship
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 557 Powertrain NVH Analysis
  - ISE 567 Reliability Analysis
  - ECE 5462 Hybrid Electric Vehicles
  - ECE 517 Advanced Electric Drives
  - ASE 566 Vehicle Thermal Management
  - ASE 548 Automotive Powertrains II
  - ASE 5791 Vehicle Power Management
  - ASE 515 Vehicle Electronics II
  - ECE 615 Adv. Power Electronics
  - ECE 532 Automotive Sensors & Actuators
  - ECE 646 Adv. Electric Drive Transportation
## Accomplishments:
### Development of New Courses

**Third Academic Year (09/01/2013-08/31/2014)**

<table>
<thead>
<tr>
<th>Course #</th>
<th>Course Name</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESE501:</td>
<td>Energy Conversion Systems</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td>ESE502:</td>
<td>Energy Storage Systems</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td>ECE615:</td>
<td>Advanced Power Electronics</td>
<td>Offered</td>
</tr>
<tr>
<td>ECE646:</td>
<td>Advanced Electric Transportation</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td>ECE5791:</td>
<td>Vehicle Power Management</td>
<td>Planned</td>
</tr>
<tr>
<td>ECE517</td>
<td>Advanced Elec. Drives</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td>ASE 557:</td>
<td>Powertrain NVH - Offered</td>
<td>Offered</td>
</tr>
<tr>
<td>ASE 566:</td>
<td>Vehicle Thermal Management</td>
<td>Offered multiple times</td>
</tr>
</tbody>
</table>
## Accomplishments: Enhancement of Four Existing Courses

### Third Academic Year (09/01/2013-08/31/2014)

<table>
<thead>
<tr>
<th>Course #</th>
<th>Course Name</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASE548</td>
<td>Automotive Powertrains II</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td>ECE5462</td>
<td>Hybrid Electric Vehicles</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td>ECE517</td>
<td>Advanced Electric Drives</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td>ISE567</td>
<td>Reliability Analysis</td>
<td>Offered multiple times</td>
</tr>
<tr>
<td></td>
<td>Short courses, trainings, and seminars</td>
<td>Offered multiple topics and multiple times</td>
</tr>
</tbody>
</table>
## Accomplishments: Industry Partners

<table>
<thead>
<tr>
<th>Chrysler Group, LLC.</th>
<th>Member benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Motor Company</td>
<td>Non Exclusive, royalty free IP for internal use</td>
</tr>
<tr>
<td>DENSO International</td>
<td>Access to recent, not-yet-published GATE Center research</td>
</tr>
<tr>
<td>ANSYS, Inc.</td>
<td>Access to GATE Center prepublications and presentations</td>
</tr>
<tr>
<td>The Mathworks</td>
<td>Early access to intellectual property by GATE Center</td>
</tr>
<tr>
<td>dSPACE</td>
<td>Access to the GATE Center facility</td>
</tr>
<tr>
<td>Hp Pelzer</td>
<td>Serve on the Industry Advisory Board</td>
</tr>
<tr>
<td>EDTA</td>
<td>Attend GATE Center annual conference, free or discounted attendance of seminar, short course, training</td>
</tr>
<tr>
<td>PSIM</td>
<td>Networking opportunities</td>
</tr>
<tr>
<td>GaN Systems</td>
<td>Jointly proposals to federal programs,</td>
</tr>
<tr>
<td></td>
<td>Priority access to students for internships</td>
</tr>
<tr>
<td></td>
<td>Guest lectures &amp; seminars for GATE Center</td>
</tr>
</tbody>
</table>
Accomplishments: Workshop on Wireless Power for EV Applications

- March 13, 2014 at GATE Center of Dearborn
- 100 attendees
- 8 plenary speakers
- A 6-people panel moderated by Matt Roush of CBS News
- Co-Sponsored by
  - GATE Center for Electric Transportation
  - IEEE Transportation Electrification Initiative and IEEE Future Directions Committee
  - IEEE Distinguished Lecture Program
  - ANSYS Corporation
Accomplishments: GATE Fellows

• One MS student graduated
• Eight full time Ph.D
• Three part time Ph.D students
• Three passed qualify
• One dissertation proposal exam passed
• Fall 2014, three applications
## Accomplishments: Five-year Education Plan for Course Offerings

<table>
<thead>
<tr>
<th>Course #</th>
<th>Course name</th>
<th>Faculty</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESE501</td>
<td>Energy Conversion</td>
<td>Ratts</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>ESE502</td>
<td>Energy Storage</td>
<td>Mi</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AE557</td>
<td>Powertrain NVH</td>
<td>Cherng</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ECE5791</td>
<td>Power Management</td>
<td>Murphey</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>ECE646</td>
<td>Adv. Power Elec.</td>
<td>Mi</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ECE517</td>
<td>Electric Drives</td>
<td>Kim</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ECE5462</td>
<td>Hybrid Vehicles</td>
<td>Kim</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AE548</td>
<td>Powertrain II</td>
<td>Zhang</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>ISE567</td>
<td>Reliability</td>
<td>Xi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Total courses offered per year</strong></td>
<td></td>
<td></td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>
Accomplishments: On Outreach and Professional Seminars

- Prof. Chris Mi is Invited to Give Lectures at APEC, March 17, 2014
  - Topic: Wireless Power Transfer
- Prof. Chris Mi is invited to give lectures at IEEE ITEC Asia Pacific, August 31, 2014
  - Topic: Wireless Power Transfer
- Prof. John Cherng is Invited to Give a Seminar at Ford Motor Company, April 19, 2013
  - Topic: NVH Characteristics of Electrical Vehicles
- Professional online course for General Motors and Siemens, as well as APEC and ECCE
  - Topic: Battery Management Systems
- Keynote speech and industry session at ECCE, VPPC, IEVC
  - Topic: Wireless power transfer
- Special issue of IEEE TPEL and JESTPE on Wireless Power
- Workshop on wireless power by IEEE
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
IAB Curriculum Committee

- Curriculum committee formed in August, 2012
- Meet twice a year
- Committee Members
  - Industry Member
    - Wensi Jin (Chair, Mathworks)
    - Ming Kuang (Ford)
    - Zed Tang (Ansys)
    - Mark Zachos (DG Technologies)
    - Mahendra Muli (dSpace)
  - Faculty Member
    - 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

• Meeting twice in 2013 and in March 13, 2014
• 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.
Curriculum Committee Meeting  
(March 13, 2014)

  – Instructor: Prof. Eric Ratts
  – This course covers fundamental engineering principles for converting available energy sources, renewable and nonrenewable, into other energy forms of direct utility.
  – Committee Comments, Feedback and instructor responses
    • Consider including embedded systems
    • A lab component (or simulation) to help fortify the learning: Under consideration
    • Aware of other schools constructing a physical system to enhance learning (eg: McMaster U./NASA Glenn)
    • Does the course get into the math behind the various systems? Yes

- Instructor: Lecturer Gary Crosbie
- This course covers basics of energy storage systems, battery basics, other energy storage systems, hybrid energy storage concepts and integrated energy storage Systems, battery management and requirements
- Committee Comments, Feedback and instructor response
  - Exposed to different modeling approaches
  - Discussed students’ hands-on learning
  - Good content overall, 4 lectures on BMS
  - Exposure to latest trends and incidents such as the B787 battery problem
  - Cover fly wheels
  - Monte-Carlo, SPICE type laboratory componenta
Proposed Future Work

- Actively recruit GATE Fellows
- Promote industry partners and secure additional membership
- Offer scheduled courses in the curriculum.
- Organize GATE Annual meeting and IAB meeting
- Promote GATE Center at related conferences
- Continue to offer industry training programs
- Develop capstone projects
- Present at conferences and publish results in journals
- Approve additional dissertation proposals
- Overcome limitations, increase visibility, enhance resource usage, leverage internal resources and external funding
Summary

- Developed and offered all new courses for the EDT concentration in the ASE program
- Revised and offered the contents of existing courses
- Offered all classes online for distance learning
- Recruited 8 graduate students for the GATE program fellowships and 4 part time students
- Signed 8 industry partners supporting the GATE Center
- Leveraged funding from college for lab upgrades
- Leveraged funding for projects involving GATE fellows
- Organized the annual industrial advisory board meeting
- Offered second 1-day workshop on wireless power transfer for electric vehicle applications
Project Personnel

• **Chris Mi**: PI, ECE, (313) 583-6434, chrismi@umich.edu
• **Yi Zhang**: Co-PI, Mechanical Engineering, (313) 593-5539, anding@umich.edu
  – Dohoy Jung, Mechanical Engineering
  – 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
  – Wencong Su, Electrical and Computer Engineering
  – Zlex Yi, Electrical and Computer Engineering
Answers to Reviewers

1. A laboratory component to the curriculum with physical hardware could also provide an additional level of understanding of the material.
   – Response: we have upgraded EV dynamometer laboratory with leverage funding to support activities in EV motor and battery testing and experiments

2. The reviewer observed good effort on development of the academic activities, but noted that the project needed more effort on marketing.
   – We have increased our effort in offering workshops, advertizing in conferences, and through IAB members

3. The future work appeared to be business as usual; not necessarily a bad plan, but it did not seem to incorporate fine-tuning for future strategic needs
   – We have increased our effort in lab upgrades, research effort, and seek improvement of courses through IAB curriculum committee