

Recovery Act – An Interdisciplinary Program for Education and Outreach in Transportation Electrification

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Michigan Tech
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Overview

Timeline

- Start: Nov 2009
- Finish: Oct 2012
- Status: 15% Complete

Partners

- Project Lead
 - Michigan Technological University
- Industry
 - AVL
 - Argonne National Laboratory
 - Eaton
 - Engineering Society of Detroit
 - GM
 - Horiba
 - MathWorks
 - Michigan Green Jobs
 - Schweitzer Engineering Laboratories
 - Woodward

Technical Targets

- Graduate and Undergraduate Interdisciplinary Engineering Instruction
- Targeted to on-campus and distance learning
- Hand-on laboratories for all participants

Barriers

- Curriculum requires cooperation of four independent academic departments and University Administration
- Design of a multi-use Mobile Lab
- Course materials required input from industry

Budget

Funding	<u>Total</u>	<u>FY10</u>
DOE:	\$2.978M	\$2.978M
Industry:	\$0.750M	\$0.250M

Hybrid Electric Drive Vehicle Engineering

Primary objectives:

- Development of an **interdisciplinary curriculum** that can lead to a professional master's degree with a focus on preparing students to work in industry and train those already in industry.
- **Undergraduate and graduate certificates** in Advanced Electric Drive Vehicle Engineering; with the graduate certificate focused on **distance learning for engineers working in industry and displaced engineers**.
- Development of a **mobile laboratory** that will include subsystem learning stations, electrified vehicle software and hardware in the loop systems, a portable vehicle chassis dynamometer, and will utilize HEV's provided by GM. **This laboratory will serve as a key enhancement to the distance learning laboratories and to established university outreach activities.**

Curriculum Development and Outreach

Hybrid Electric Drive Vehicle Engineering

Program Goals:

1. Develop an Undergraduate Certificate
2. Develop an Graduate Certificate
3. Develop a Program of Study Leading to a Professional Masters with a certificate in Hybrid Electric Drive Vehicle Engineering (M.Eng.)
4. Design and Fabricate a Mobile Laboratory for Instruction and Outreach

The Interdisciplinary Curriculum Will Be Offered Both On-Campus and Through Distance Learning

Three-Year Objectives:

- Develop a master of engineering degree, and graduate and undergraduate certificate programs in Advanced Electric Drive Vehicles
- Target enrollment of **120** graduate students with an expected 50% split of on campus and distance students
- Address work force needs and competencies in emerging electric vehicle technologies for US based industries
- Promote and raise awareness for transportation sustainability through electric propulsion systems with outreach programs

This Year's Objectives:

- Curriculum Development: new course approvals, certificate approvals, course modifications
- Mobile Laboratory: design phase complete, trailer ordered, learning modules developed
- First round of courses delivered
- Modifications complete for the on-campus "Introduction to Propulsion Systems for Electric Drive Vehicles **Laboratory**"

VT ARRA Program Relevance

Relevance to VT program goals:

- Create an education program to **retrain the existing workforce and create the next generation of engineers** to:
 - Develop energy efficient and environmentally friendly technologies
 - Develop EDV to reduce dependence on fossil fuels and increase energy security,
- Conduct outreach to K-12 to attract youth to engineering and science education
- Educating the public on the technologies and benefits of vehicle electrification

Relevance to the ARRA of 2009 goals include the creation of new jobs as well as save existing ones, spur economic activity and invest in long-term economic growth:

- GRA's - 18 person years of employment (new jobs)
- Michigan Manufacturing jobs (TBD)
- Other university positions – 9 person years of employment (existing jobs saved)
+ 3 person years (new job)

This program is directly relevant to and will impact the VT ARRA program:

- Retrain displaced engineers
- Educate incumbent engineers in **Vehicle Electrification Technologies**, which will impact manufacturing jobs in transportation related industries.

Milestones

Month/Year	FY10 Milestones	April Status
Dec-2009	Pilot Course taught to 96 distance students	Complete
Aug - 2010	Modifications Complete for on-campus "Propulsion Systems for Electric Drive Vehicles Laboratory" courses	25%
Aug - 2010	Development and Modification Complete for 9 courses	35%

Month/Year	FY11 Milestones	April Status
Dec - 2010	First Round of Teaching Courses Complete	0%
Dec - 2010	Mobile Lab 2 nd Stage Simulators	20%
Dec - 2010	Senior Design Team I Completes HEDV project	50%
Apr - 2011	Mobile Laboratory Complete/Commissioned	10%
May - 2011	Outreach for 1st year Complete	0%
May - 2011	Senior Design Team II Completes HEDV project	50%
Aug -2011	Course Development Complete	15%

Curriculum Development for Advanced Electric Drive Vehicles

- Create 8 New Courses
- Modify 9 Existing Courses to integrate HEDV content
- Leverage Existing Courses
- Deliver courses both on-campus & distance learning

Mobile Laboratory

- Develop a Mobile Laboratory complete with universal educational platforms for hands-on discovery based learning.
- Develop instruction and outreach activities.

Overall Project Approach

- Development of two key **Interdisciplinary Courses in Propulsion for HEDV**: Create and implement these courses to provide students with background knowledge in propulsion systems
- Development of two associated **Laboratories**: Create and provide learning opportunities through hands-on laboratory experiences
- New Course Development: **New courses** pertaining to electro-mechanical systems, energy conservation, and battery management in electric vehicles
- Enhancing Existing Courses: **Improving current courses** in electrical, chemical, materials, and mechanical engineering to provide cross access to respective departmental students

Objective-Specific Approaches Curriculum Development

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- An **Interdisciplinary team** of faculty and staff in four engineering departments to develop and teach the courses.
- Courses are dual listed among four departments to attract a diverse student pool
- **Marketing activities** to attract new students include:
 - New web pages
www.doe.mtu.edu/hybrid_vehicle_engineering/
 - Exhibits at North American International (Detroit) Auto Show
 - Engineering Society of Detroit
 - Michigan Skills Alliance Summit



Prospective Students • Current Students • Majors • Athletics • Alumni/Friends • Parents • Faculty/Staff • Search • A22

Michigan Tech

Create the Future

College of Engineering

Departments
Graduate Programs
College of Engineering Professional Degrees
Hybrid Electric Drive Vehicle (HEDV) Engineering
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New Program of Study

Hybrid Electric Drive Vehicle (HEDV) Engineering

Download Brochure (PDF)

Highlights

- Available for on-campus and online learning students
- Interdisciplinary courses
- Mechanical, electrical, materials, and chemical engineering
- Both fundamental and applied
- More than 30 courses

Program Facts

- To be successful, online students need high-speed internet connection and a PC capable of running MS Excel and Matlab software.
- Start Dates for students: August, January or summer

Application Fee: free for online application
Student Application Deadlines: rolling admission

Three ways to take courses

Non-degree Coursework	Hybrid Electric Drive Vehicle (HEDV) Engineering for Non-degree Seeking Students Take any number of Hybrid Vehicle Engineering courses as a non-degree seeking student - click here
Certificate	Graduate Certificate in Hybrid Electric Drive Vehicle (HEDV) Engineering Earn a Graduate Certificate in Hybrid Vehicle Engineering (15 credits)
Professional Masters	Professional Master's degree (MEng) Emphasizing Hybrid Electric Drive Vehicle (HEDV) Engineering (30 credits) Earn a Master of Engineering degree in Hybrid Vehicle Engineering (30 credits) - click here

News

Michigan Tech now offers a new professional graduate program focusing on hybrid electric

Objective-Specific Approaches Curriculum Development

Schedule of new course development, modifications and delivery

Course Development / Teaching Schedule

New Courses

Name	Dept.	Number	Credits	09 Fall	10 Spng	10 Sum	10 Fall	11 Spng.	11 Sum.	11 Fall	12 Sp	12 Su	12 Fall
Intro. To Prop. Systems for EDV	EE/ME	4295	3	M/T(DL)			T(DL)			T(DL)			T(DL)
Adv. Prop. Systems for EDV	EE/ME	5295	3	M	T(DL)			T(DL)			T		
Intro. To Prop. Systems for EDV Laboratory	EE/ME	4296	1	M/T	M	M	T		T(DL)	T (2CR)		T(DL)	T (2CR)
Adv. Prop. Systems for EDV Laboratory	EE/ME	5296	1	M	T	M	M	T	T(DL)		T	T(DL)	

Name	Dept.	Number	Credits	09 Fall	10 Spng	10 Sum	10 Fall	11 Spng.	11 Sum.	11 Fall	12 Sp	12 Su	12 Fall
Advanced Electric Machines	EE	5221	3			D	T(DL)			T(DL)			
Vehicle Battery Cells and Systems	MY/CM	5760	3		D	D	T(DL)			T(DL)			T(DL)
Vehicle Dynamics	ME	4450/5450	3							D	T(DL)		
Distributed Embedded Control Systems	EE/ME	4750/5750	3		T	M		T(DL)			T(DL)		

Modified Courses

Name	Dept.	Number	Credits	09 Fall	10 Spng	10 Sum	10 Fall	11 Spng.	11 Sum.	11 Fall	12 Sp	12 Su	12 Fall
Intro. to Motor Drives	EE	3221	4		T	M		T	M		T		
Power Electronics	EE	4227	3	T(DL)			T(DL)		M	T(DL)			T(DL)
Power Electronics Lab	EE	4228	1				M/T			T			T
Power System Operations	EE	5230	3						M	T(DL)			T(DL)
Power System Protection	EE	4223/5223	3				M	T(DL)					
Power System Protection Lab	EE	4224/5224	1				M	T					
Distribution Engineering	EE	4225/5250	3		T(DL)					M	T(DL)		
Intro to IC Engines	ME	4220	3	T(DL)		M		T(DL)			T(DL)		T(DL)
Internal Combustion Engines II	ME	5250	3		T				M	T(DL)			

KEY				
Status:	D = Develop	T = Teach	M = Modify	DL = Distance Learn.
Depart:	EE = Elect. Eng.	ME = Mech. Eng.	CM = Chem Eng.	MY = Mat.Sci & Eng.
Level:	3XXX = UG	4XXX = UG Tech Elect	5XXX = Grad.	ENT = Enterprise

Objective-Specific Approaches Curriculum Development

Schedule of course delivery for existing courses

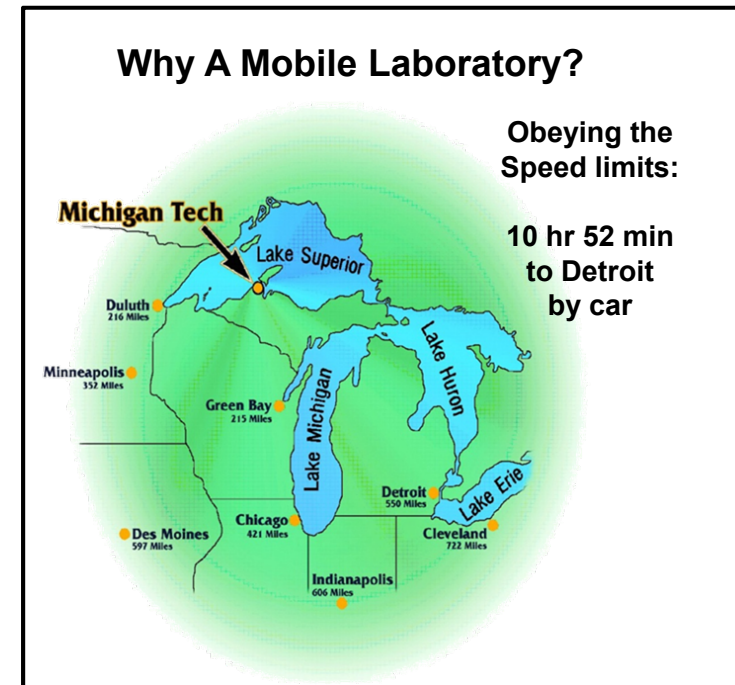
Existing Courses				09	10	10	10	11	11	11	12	12	12
Name	Dept.	Number	Credits	Fall	Spng	Sum	Fall	Spng.	Sum.	Fall	Sp	Su	Fall
Electric Energy Systems (EE/Non EE)	EE	3120	3	T(DL)	T(DL)		T	T(DL)		T(DL)	T(DL)		T(DL)
Power System Analysis 1	EE	4221	3	T(DL)			T(DL)			T(DL)			T(DL)
Power System Analysis 2	EE	4222	3		T(DL)			T(DL)			T(DL)		
Advanced Methods in Power Systems	EE	5200	3	T			T(DL)			T(DL)			T(DL)
Classical Control Systems	EE	4261	3	T			T			T			T
Thermodynamics/Fluid Mechanics (Non	ENG	3200	4	T	T		T	T		T	T		T
Principles of Energy Conversion	ME	4200	3		T		T(DL)				T		
Dynamic Systems and Controls	ME	4700	3(DL)/ 4	T(DL)	T(DL)	T	T	T	T	T(DL)	T(DL)	T	T(DL)
Advanced Thermodynamics	ME	5200	3				T(DL)						
Experimental Design in Engineering	ME	5670	3	T		T	T		T	T		T	T
Optimization	ME	5680	3	T	T			T		T	T		T
Dynamic Systems and Signal Analysis	ME	5700	4	T(DL)			T(DL)			T(DL)			T(DL)
Linear Systems	ME	5715	3		T(DL)			T(DL)			T(DL)		
Fuel Cell Technologies	ME	4260/5220	3		T		T(DL)			T(DL)			
Senior Capston Design (4 Projects, Avail	EE/ME	4900/4910	2 & 2		1		1, 2	2, 3		3, 4	4		3, 4
Fuel Cell Fundamentals	CM/ENT	3974	1				T			T			T
Fundamentals of Hydrogen as an Energy	CM/ENT	3977	1				T			T			T
Hydrogen Measurements Laboratory	CM/ENT	3978	1		T			T			T		
Enterprise Courses	FNT	29XX-49XX	1	T	T	T	T	T	T	T	T	T	T

Objective-Specific Approaches

Mobile Laboratory

Mobile Laboratory Development:

- A dedicated team of faculty and research staff meet weekly to identify and develop mobile laboratory specifications. Requirements of the mobile lab are based upon desired laboratory course content, and identified constraints it must operate within.
- Senior Design team roles: Develop configurable Hybrid Electric Learning Modules as learning stations within the mobile laboratory.
- Enterprise team roles: Develop an interactive software and game package to serve as education tools for electric vehicle technology and operation.

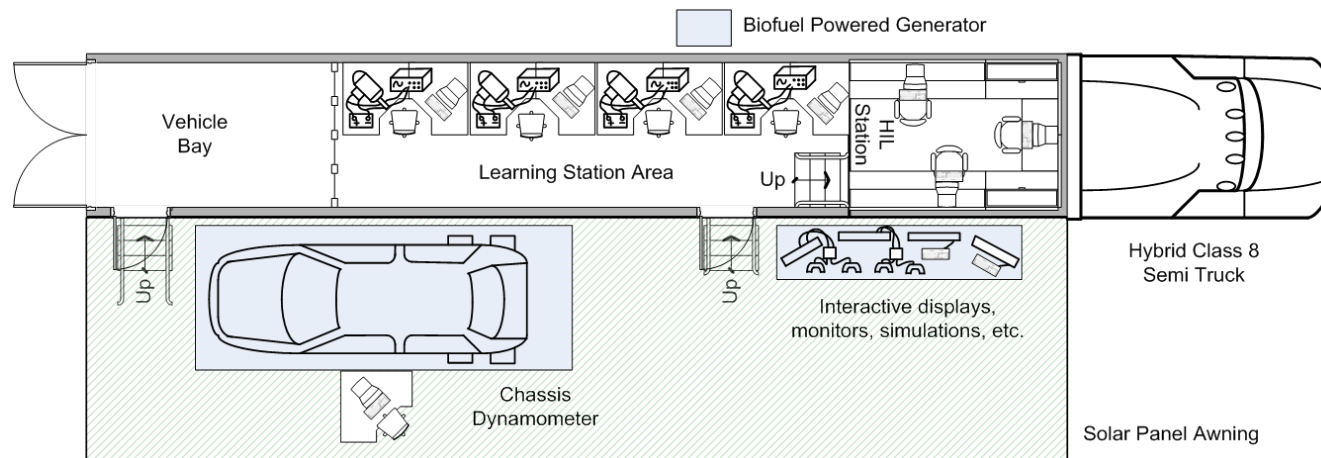


Objective-Specific Approaches

Mobile Laboratory

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Mobile Laboratory For Distance Learning Instruction & Outreach



- Universal Learning Stations
- Mobile Chassis Dynamometer
- Road legal production HEV's
- HEV Simulation Gaming
- Configurable Hybrid Electric Learning Modules
- HEV themed outreach displays & demos

Objective-Specific Approaches Outreach

Mobile Laboratory is our key to outreach and educational activities:

- Secondary School Visits: Implement an outreach program with audio and visual material developed by Senior Design and Enterprise Engineering students
- Interactive Electric Drive Vehicles Software for Education and Outreach: Develop an interactive software and game package to serve as educational tool for electric vehicle technology and operation
- Summer Youth Programs: Coordinate an outreach program to supplement scholarships to ensure a diverse group of students
- Short Courses for training displaced and incumbent engineers

Mobile Laboratory will also be used for on-campus labs

Objective-Specific Approaches

Course Delivery

A interdisciplinary team of thirteen experienced educators and researchers with different but complimentary technical expertise to:

- Establish innovative, effective and engaging teaching and delivery methods for current and developing courses
- Work closely with OEMs and suppliers to ensure the program meets work force needs
- Distance Learning courses delivered with the same material and quality of instruction as traditional classroom based courses
- Deliver hands-on instruction with simulators and laboratories at the subsystem and vehicle level
- Target to concentrated locations (e.g, South East Michigan) by partnering with Engineering Society of Detroit

Objective-Specific Approaches

Course Delivery

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Course Delivery Fall 2010

New Courses

- EE/ME 4295 (DL/Campus) Intro Propulsion Systems for HEDV
- EE/ME 4296 (Campus) Intro Propulsion Systems for EDV Laboratory
- EE 5221 (DL/Campus) Advanced Electric Machines
- MY/CM 5760 (DL/Campus) Vehicle Batteries, Cells, and Systems

Modified Courses

- EE 4227 (DL/Campus) Power Electronics
- EE 4228 (Campus) Power Electronics Laboratory

Existing Courses

- Thirteen existing courses; of those six will be taught via **distance learning** in addition to on campus.

Technical Accomplishments - FY10

- **Task 1** - New course proposals developed.
- **Task 1** – Course proposals submitted to the university and approval process.
- **Task 1** – Course proposals approved.
- **Task 1 – UG and Grad Certificates Developed and approved.**
- **Task 2** – Mobile Lab requirements developed based on inputs from instructors and end users.
- **Task 2** – Request for Proposals issued, four proposal received and under review.
- **Task 3** – Four Senior Design teams developing a Configurable Hybrid Electric Learning Module
- **Task 3** – Enterprise teams developed first phase project plan for Learning Station Software development

3-Year Project Technical Tasks

1. Curriculum Development
2. Mobile Laboratory Development
3. Outreach Development & Execution
4. Course Delivery & Evaluation

Technical Accomplishments - Task 1

Curriculum Development

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- Course proposals for all 8 new courses developed, and approved by faculty, department chairs, Dean, and Provost.
- Undergraduate and Graduate Certificates developed and approved by faculty, department chairs, Dean, Graduate Faculty Council, University Senate, and Provost.
- Pilot course for Advanced Propulsion Systems
 - 64 distance and 22 on-campus students Spring semester 2010
 - 96 students all distance learning Fall 2009



Technical Accomplishments - Task 2

Mobile Laboratory Development

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- Preliminary design constraints and specifications completed.
- Mobile Lab Team has solicited bids for trailer construction, four proposals received.
- Based on response, a Michigan based trailer manufacturer has been invited to visit MTU for presentation of their proposal.
- Four Senior Design Teams engaged to develop **Configurable Hybrid Electric Learning Modules** for the Mobile Laboratory. The four teams are working in concert, resulting in a single team structure with subgroups. Teams have completed modeling, analysis, and specification requirements for major vehicle components.
- Two Hybrid Enterprise Teams engaged to develop **Interactive Electric Drive Vehicles Software** for Education and Outreach activities. Teams have created budget analysis, project timelines, deliverable agreements, and researching of and incorporating physics equations into MATLAB code

Technical Accomplishments - Task 3

Outreach

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- Student teams presented engineering design project progress to the university, community, and industry at the Undergraduate Expo and Senior Design Day April 2010.
 - Four Senior Design Teams to develop **Configurable Hybrid Electric Learning Modules** for the Mobile Laboratory.
 - Two Hybrid Enterprise Teams to develop **Interactive Electric Drive Vehicles Software** for Education and Outreach activities.



Portable Workstation

- Attaches to detached rear section of vehicle.
- Safe and easy way to move the detached rear section
- Will lock in place on trailer

Parallel Hybrid System

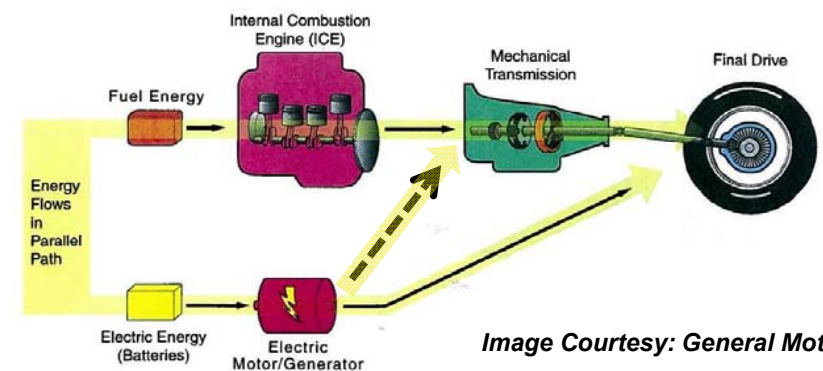


Image Courtesy: General Motors

Parallel Hybrid System Design

Technical Accomplishments - Task 4

Course Delivery and Evaluation

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- Pilot Course MEEM 5990 ‘Advanced Propulsion for Hybrid Vehicles with Concentration in Battery Engineering’ (3 cr: 2 lec/1 lab) taught Spring 2010 and Fall 2009
 - *64 Distance Learning and 22 On-Campus students*
 - *96 Distance Learning students Fall 2009*
- Distance Learning conducted with partners
 - *Engineering Society of Detroit and AVL in Southeast Michigan.*
- Course taught by interdisciplinary team of faculty
 - *Mechanical, Electrical, Material Science, and Chemical Engineering Departments.*



Technical Accomplishments - Task 4

Course Delivery and Evaluation

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- Course assessment for Pilot Course MEEM 5990 administered
 - *Fall 2009 and Spring 2010 semesters.*
- Traditional MTU survey of teacher effectiveness
- Additional surveys were given –
 - *Twenty-four question survey on prior knowledge, current knowledge, and experiences in lecture, laboratory, and teamwork*
 - *Eleven question survey on course content, time involved, pace, and course logistics including distance learning tools*
- Similar surveys to be implemented for other project courses
- Survey results will be used to define and drive future course modifications

Team Collaborations:

- Project Lead
 - Michigan Technological University –*Education Provider, Program Developer*
- Industry
 - AVL – *HEDV instrumentation, HIL components, controls expertise*
 - Argonne National Laboratory – *Graduate student internships*
 - Eaton – *power management software and controls, battery technology expertise*
 - Engineering Society of Detroit – *marketing, student recruitment, classrooms*
 - GM – *vehicles/vehicle components, student recruitment*
 - Horiba – *automotive test systems and expertise*
 - MathWorks – *software and software expertise*
 - Michigan Green Jobs – *marketing, student recruitment*
 - Schweitzer Engineering Laboratories – *electric power systems and expertise*
 - Woodward – *energy controllers, controller software and controls expertise*

Remainder of FY10

- Complete development of 6 new courses
- Finalize modifications to 5 courses
- Continue Mobile Lab design and development
- Delivery of Fall 2010 course offering
- Start modifications to 4 additional courses
- Senior Design teams continue development of HEDV lab modules
- Enterprise teams continue development of 2nd Stage Simulators

Goals for FY11

- First round of course delivery complete
- Mobile Lab 2nd Stage Simulators /Learning Station Software complete
- Senior Design completion of Phase I HEDV project
- Mobile Laboratory commissioned
- First year of Outreach developed and scheduled
- Senior Design completion of Phase II HEDV project
- Finalize Modifications to 8 courses

Summary

- **Proposed curriculum has been approved at all university levels.**
- **Proposed certificates have been approved at all university levels.**
- **Four Distance Learning courses will be offered Fall 2010.**
- **Six courses will be offered on-campus Fall 2010.**
- **Mobile Laboratory design initiated, including Configurable Hybrid Electric Learning Modules, and 2nd Stage Simulators and Software**
- **This project started November 1, 2009 with a kick-off meeting held March 2010 in Morgantown WV**