GATE Center of Excellence in

Innovative Drivetrains in Electric Automotive Technology Education (IDEATE)

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Overview

- **Timeline**
  - Start: 1 Oct 2011
  - Finish: 30 Sep 2016
  - 10% complete

- **Barriers**
  - Lack of trained engineers & scientists
  - Lack of advanced technology curricula

- **Budget**
  - Project funding
    - DOE: $954.2 K
    - Cost share: $253.4 K
  - No FY11 funds
  - Funding for FY12:
    - $303.3 K

- **Partners**
  - University of Colorado, Colorado Springs
    - Battery Modeling & Control
  - University of Colorado, Boulder
    - Vehicle Power Electronics

Objectives of *IDEATE*

- Develop a continuing-education graduate certificate in Electric Drivetrain Technology to retrain engineers
- Establish graduate MS EE degree options in Battery Controls and Vehicle Power Electronics to educate a future workforce
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- Support fundamental MSEE/PhD research in IDEATE topics
- Make IDEATE coursework accessible via on-line and extended studies means

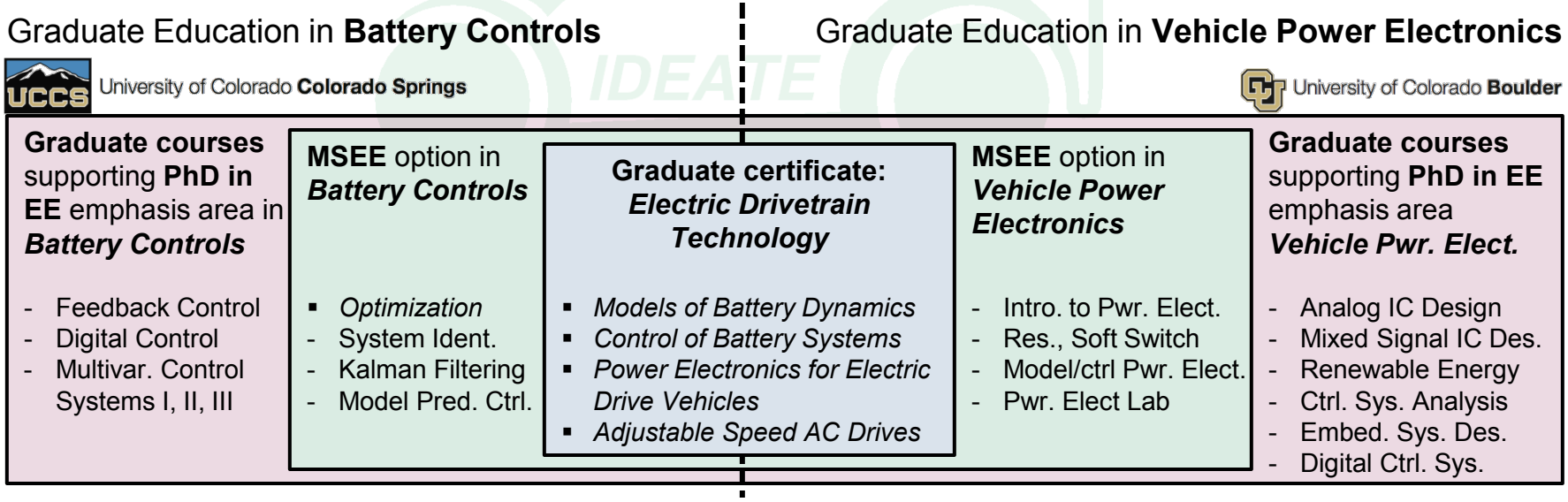
Milestones

- Key project milestones during FY12-13

	FY 12				FY 13			
Milestone	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Formalize new certificate program		■						
Develop new curriculum		▭	▭	▭	▭	▭	▭	▭
Initial offering of new courses				▭		▭		
First students complete certificate								▭
Initiate paperwork for MSEE option						▭		

Approach

- IDEATE is a five-year DOE-sponsored project that will:
  - Establish a graduate certificate in electric drivetrain technology
  - **Establish graduate degree options to educate a future workforce**
  - Support fundamental research to develop new enabling technology
  - Have local appeal but national impact



Sample schedule for full-time student

Fall semester		Spring semester		Summer semester
ECE 5710: Model., Sim., Ident. Battery Dynamics	ECE 5550: Applied Kalman Filtering	ECE 5720: Control of Battery Dynamics	ECE 5560: System Identification	
ECE 5570: Optimization Methods for Systems, Ctrl	Course from elective list	ECE 5590: Model Predictive Control	Course from elective list	

Non-thesis track

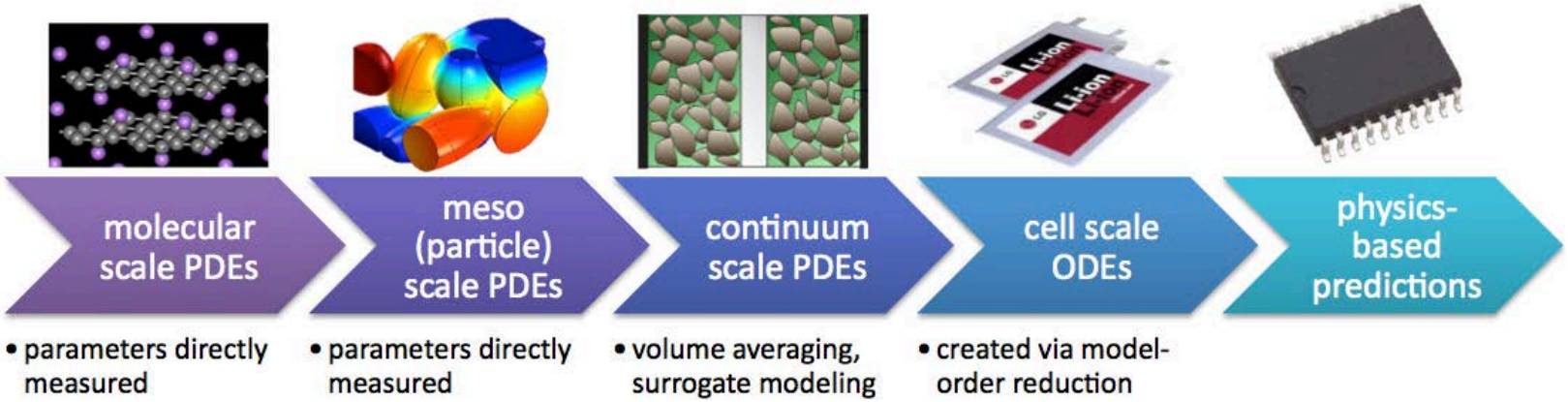
Course from elective list	Course from elective list	MSEE project plus report

Thesis track

Determine thesis topic	Background work on thesis	MSEE thesis

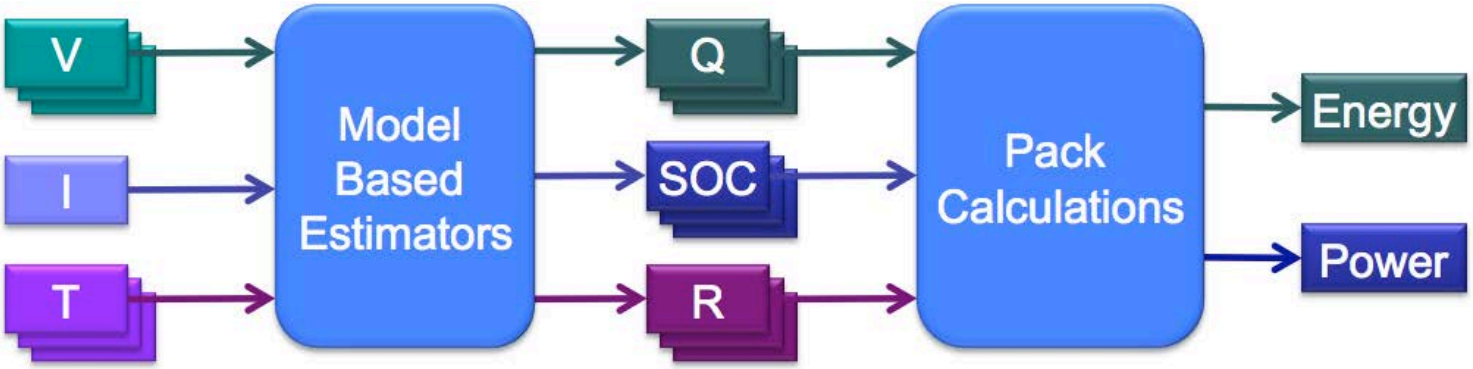
IDEATE Courses: Battery Modeling

- Multi-scale modeling of the dynamics of lithium-ion cells
- Brief introduction to microscopic models (mostly out of course scope)
- Considerable attention given to deriving meso-scale single-phase models of the solid, electrolyte, thermodynamics and kinetics of the cell.
- Volume-averaging techniques will be introduced to create continuum models via porous-electrode theory.
- Cutting edge (not yet published) methods for automatically converting continuum models to reduced-order models for controls purposes will be investigated in detail



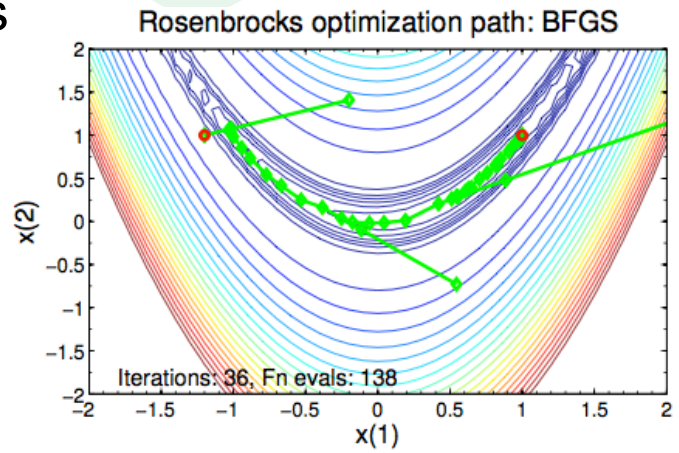
IDEATE Courses: Battery Control

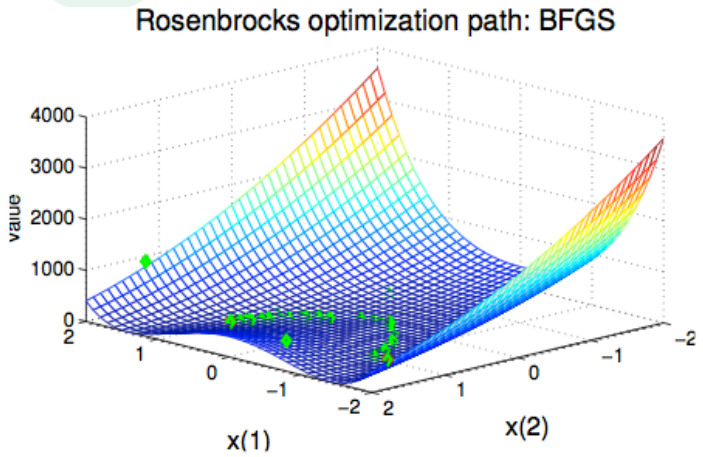
- Focus on developing model-based estimation algorithms for estimating state-of-charge, state-of-health, and state-of-life of a battery pack.
- We will emphasize methods based on nonlinear Kalman filtering
  - Figure shows the information flows: raw voltage, current, and temperature measurements are used by model-based estimators to produce estimates of cell capacity, state of charge, and resistance.
  - These estimates are then used by nonlinear optimization strategies to compute battery pack available power and energy, which are the two quantities required by a vehicle controller.



IDEATE Courses: Methods of Optimization

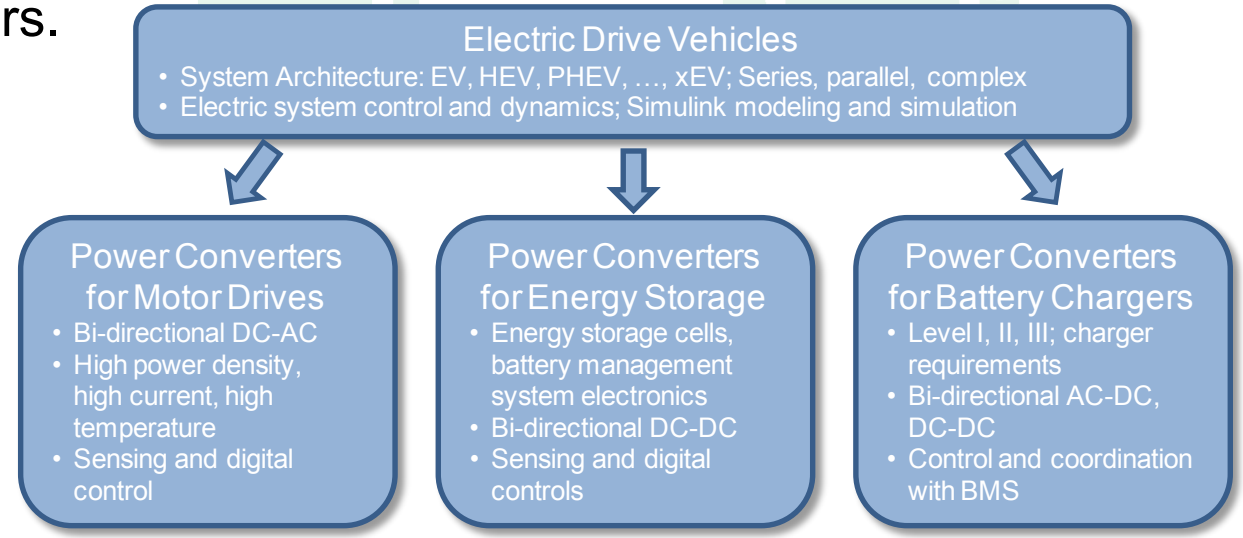
- Develop framework for solving a wide range of engineering optimization problems, integrating dynamic systems and math fundamentals
- Introduce methods of parameter optimization for both unconstrained and constrained cases; derive the numerical methods of steepest descent, including both first-order and second-order gradient approaches
- Develop optimization approaches for dynamic systems utilizing a state-space representation; treat both continuous and discrete-time representations for both single- and multi-stage processes. Include both fixed and free-time problems, with and without specified terminal constraints





IDEATE Courses: Power Electronics for EDV

- Design and control of power converters applied to the unique requirements and challenges found in electric drive vehicles.
- Course includes an overview of system architectures and covers system-level dynamic modeling and control at levels appropriate to determine requirements and validate performance of vehicle power converters
- Develops details required for practical design and control of power converters with emphasis on the unique requirements and challenges in the major applications such as motor drives, energy storage and battery chargers.



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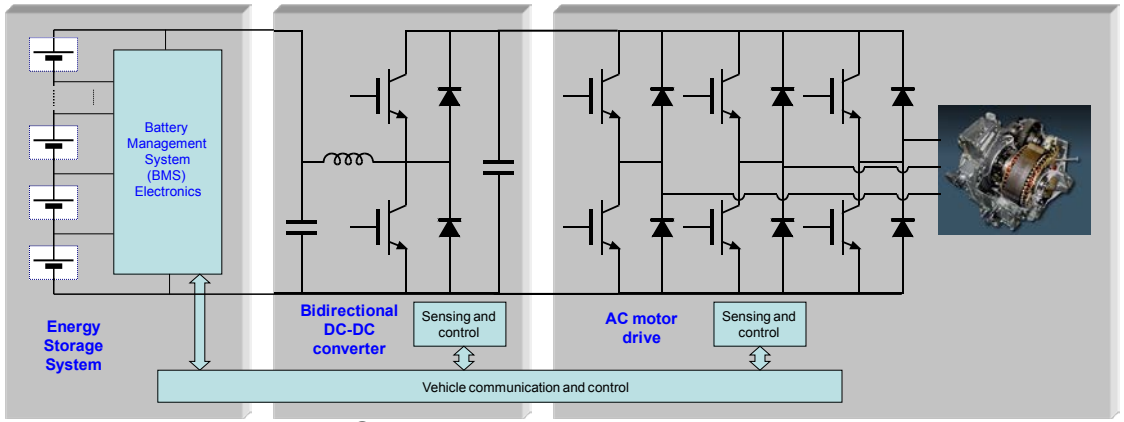
IDEATE Courses: Adjust. Speed AC Drives

- Update existing course to become a direct companion to the Power electronics for electric drive vehicles course.
- Focus on motor operation and control: Begins with basic principles for analysis of electric machines and reference frame theory, and then develops in detail the operation and control algorithms for symmetrical induction machines and permanent magnet synchronous machines.
- Updates to the course are to include an emphasis on electric drive vehicles with specific examples of practical designs and commercial solutions. Guest lecturers from industry experts and tours for hands-on experiences at local manufacturing companies

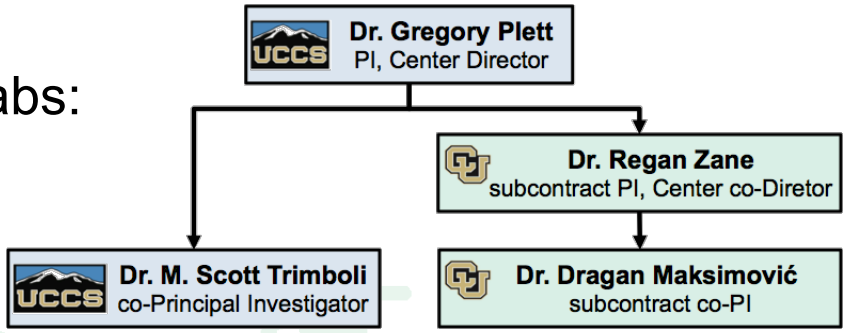


Technical Accomplishments

- FY11: New course complete:
  - ECE 5710 Modeling, Simulation, and Identification of Battery Dynamics

IDEATE Collaborations

- CU collaboration: org-chart shown
- Relationship with sixteen companies/labs:
  - Equipment manufacturers,
  - Vehicle companies,
  - Battery cell design/manufacturers,
  - Battery pack design companies,
  - Automotive semiconductor companies,
  - National Renewable Energy Lab (NREL).



- These companies alone have expressed interest in providing paid internship opportunities for students in the IDEATE program who have completed at least one semester of coursework (total of 27–46+ positions), and in hiring 10+ graduates from the program.
- Some have committed to serving on the IDEATE Industry Advisory Board (IAB), and to providing guest lecturers as well as PhD qualified personnel to sit on thesis and dissertation committees.

Activities for Next Fiscal Year

- Develop new courses:
  - ECE 5720 Battery Control
  - ECE 5570 Methods of Optimization
  - ECEN 5007 Power Electronics for EDV
- Form and implement Industry Advisory Board
- Initiate first course offerings in new Certificate Program
- Begin process for introducing new MS EE option

Summary

- IDEATE addresses a serious technology workforce shortfall
  - Necessary to propel U.S. automotive industry to the next level with the electrified drivetrain
- New certificate in *Electrified Drivetrain Technology* will begin retraining traditional automotive engineers and recruiting new entrants to the workforce
  - Emphasizes two key technologies:
    - Battery Modeling and Controls
    - Vehicle Power Electronics
- New program to kick-off in Fall 2012